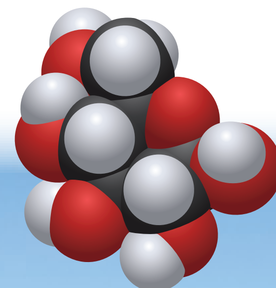
Chemical Reactions and Matter:

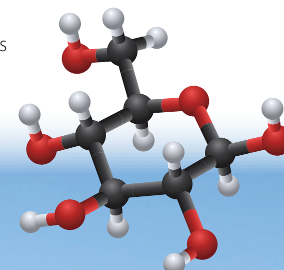
How can we make something new that was not there before?

Science Literacy

Teacher Guide

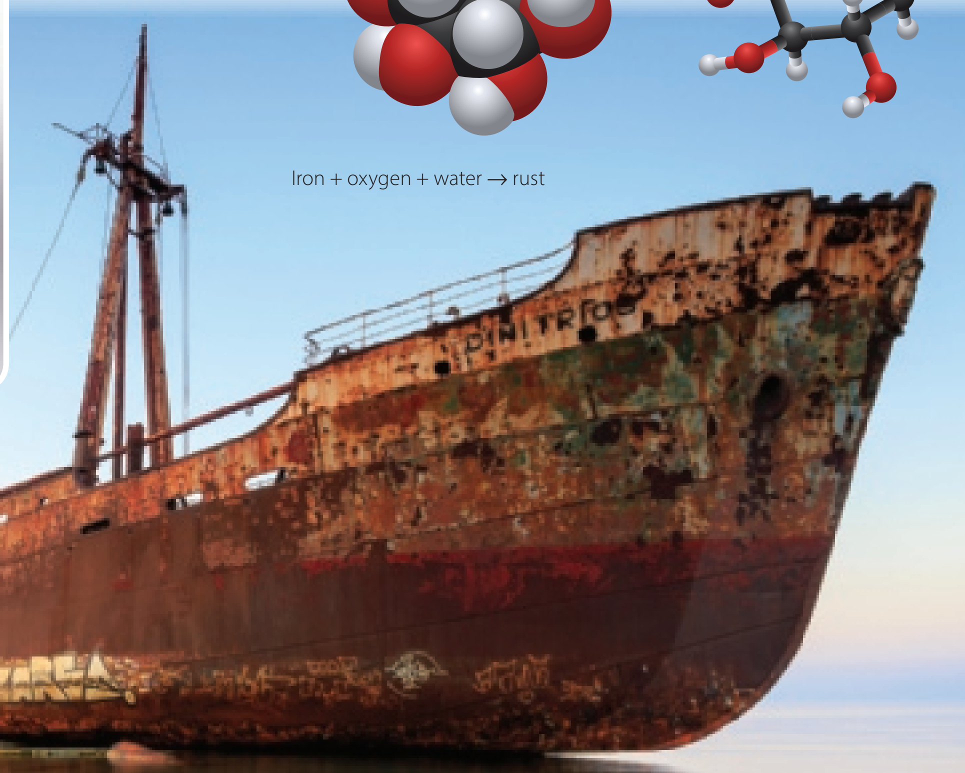
Products and reactants





Models

Iron + oxygen + water → rust



GRADE 7 Core Knowledge Science®

Core Knowledge®

This unit is a modified version of a unit that has earned the NGSS Design Badge. The sole instructional modification is the addition of Core Knowledge Science Literacy content. The modification has not been reviewed.

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Teacher Guide

Core Knowledge®

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Chemical Reactions and Matter

How can we make something new that was not there before?

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BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources	Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to: • the unit's comprehensive materials list • a full unit pacing snapshot • lesson guidance slides • all other recommended resources. **www.coreknowledge.org/cksci-online-resources**
Student Work Pages	All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.
Student Books	All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

How can we make something new that was not there before?

This unit on chemical reactions and matter transformations begins as students consider what happens to a bath bomb when it is added to water. They develop a model, at a scale smaller than they can see, to try to explain what they think happened to the matter that was in the bath bomb and what caused the gas bubbles to appear. This and related phenomena (where adding a solid to water resulted in gas bubbles appearing) leads to a broader set of students' questions around: How can we make something new that was not there before? Students analyze data about the bath bomb, including what happens to the amount of matter in the bath bomb and water before, during, and after gas bubbles appear, the properties of the substances that make up the bath bomb, the water, and the gas that is produced. Students develop models to account for how new types of particles can be appearing from old particles. They compare their models to historical models developed by Dalton and other scientists, and they conduct investigations on water to determine if it has undergone a physical change or a chemical reaction. Finally, students revisit their initial models and explanations of the bath bomb to explain what substances could have been produced in the chemical reaction, why the mass of the matter in the system wouldn't change when this happens, and conduct property tests that could be done to determine whether a particular substance was produced or not.

At two points throughout the unit, students apply what they have figured out about chemical reactions to explain related phenomena (Elephant's Toothpaste and the crumbling of the marble surface of the Taj Mahal).

Through these investigations, students:

- Plan and carry out investigations and analyze data to determine whether the matter that was in the gas bubbles produced was already part of the matter that was there beforehand.
- Analyze data to determine the properties (density, melting point, boiling point, solubility, flammability) of substances and use these properties to argue from evidence which candidate substances the gas in the bubbles from the bath bomb could be made of.
- Develop and use models to describe the atomic composition of simple molecules and extended structures.
- Analyze and interpret data on the properties of a substance (water) before and after energy is added to the substance and use these to argue from evidence for whether a chemical reaction has occurred.
- Construct an explanation to describe why the total number of atoms does not change in a chemical reaction and thus mass is conserved.
- Construct an explanation to describe possible products in a chemical reaction from a set of known reactants by considering that the type of atoms in the chemical reactions should not change.

Focal Disciplinary Core Ideas (DCIs): PS1.A; PS1.B; LS1.D

Focal Science and Engineering Practices (SEPs): Developing and Using Models; Planning and Carrying Out Investigations; Analyzing and Interpreting Data; Constructing Explanations and Design Solutions; Engaging in Argument from Evidence

Focus Crosscutting Concepts (CCCs): Patterns; Scale, Proportion, and Quantity; Systems and System Models; Energy and Matter

Building Toward NGSS Performance Expectations

MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-2: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5: Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

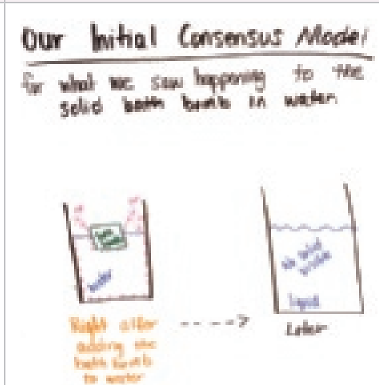
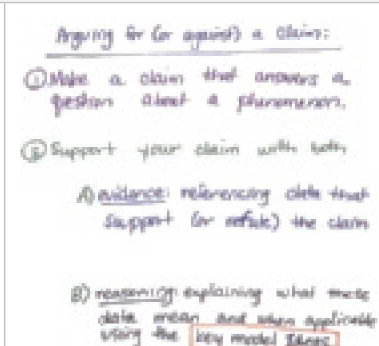
MS-LS1-8: Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

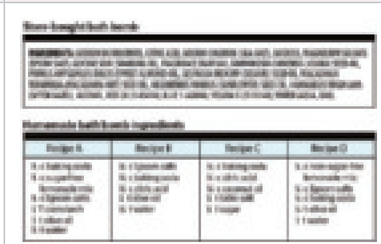
UNIT STORYLINE

How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

How can we make something new that was not there before?

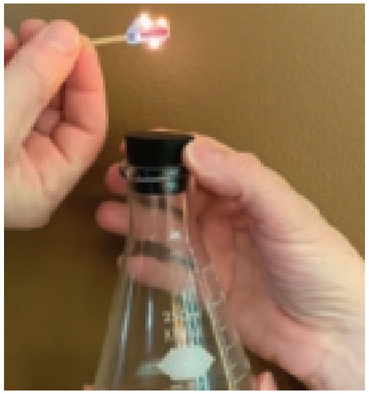
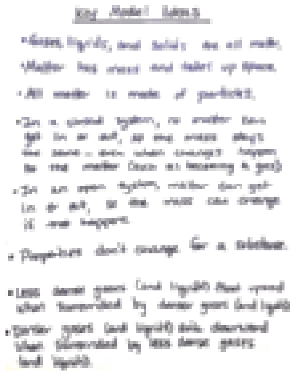
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **4 days** **What happens when a bath bomb is added to water (and what causes it to happen)?** Anchoring Phenomenon	 *When solid bath bombs are added to water, they start breaking apart, and gas bubbles appear on and around them for a few minutes, until no solid is left.*	We observe different bath bombs and what they do when added to water and then develop individual models and explanations to show what is happening at a scale smaller than we can see. We develop an initial class consensus model, brainstorm related phenomena, develop a DQB and ideas for investigations to pursue. We figure out that: • We had competing ideas for whether the matter in the solid that we started with is still there after it is added to water. Some thought that it was all still there, while others thought not all of it was still there. • We had competing ideas for where the gas came from that was in the bubbles that appeared. One was that it was there to start with (trapped inside the solid). The other was that it formed from some of the stuff we started with (e.g., in the solid and/or water).	
Navigation to Next Lesson: We want to collect some data to see whether we can find evidence for the gas being in the solid before it is added to water.			
LESSON 2 **2 days** **Where is the gas coming from?** Investigation	 *The mass of a bath bomb put in water in an airtight container does not change, but the mass decreases after the cap on the bottle is opened and gas is heard escaping.*	We investigate bath bombs, measuring their mass in a closed and open system before and after crushing them and before and after we add the bath bomb to water. We argue from evidence about where the gas came from. We figure out that: • The gas we observed from the bath bomb does *not* come from any gas that was originally trapped in the bath bomb itself. • Instead, the gas we observed when the bath bomb was placed in water comes from some change to the matter that is already there.	
Navigation to Next Lesson: Students agree to investigate common ingredients in bath bombs next and to test each ingredient one at a time in water.			

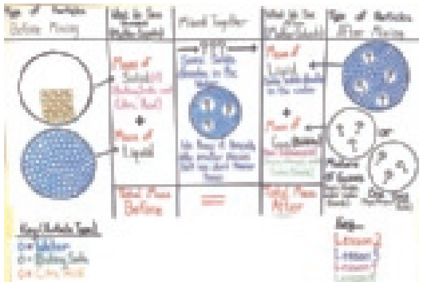
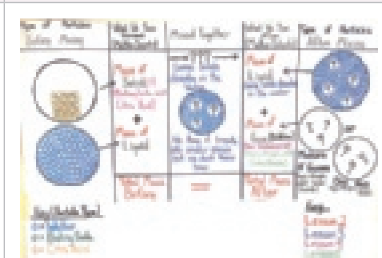
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 3 **2 days** **What's in a bath bomb that is producing the gas?** Investigation	 *Bath bombs have different ingredients and recipes. The ingredients in them interact with water in different ways, but none cause bubbles to appear when added to water on their own.*	In this lesson, we make observations and collect data on each of the main ingredients in a bath bomb, recording the properties of each. We also investigate each ingredient as it mixes with water and record our observations. However, we see that the ingredients interact with water in different ways. We figure out that: • Substances in the bath bomb have properties that can help us identify them (e.g., solubility, odor, state of matter at room temperature, melting point, density, and color). • Mixing only one substance from a bath bomb with water does not cause gas bubbles to appear.	

Navigation to Next Lesson: We figured out that a bath bomb has several ingredients, and these are called substances. These substances all have different properties. We figured out that mixing one substance with water does not make gas bubbles. We wonder if mixing two substances in water will produce gas bubbles, and if so, can we figure out which substances produce gas bubbles?

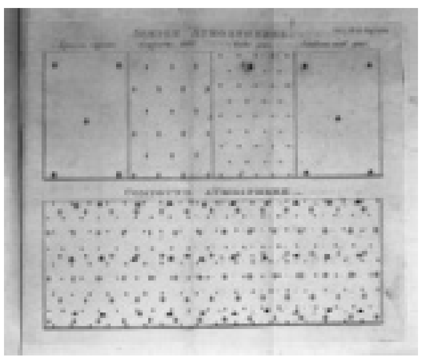
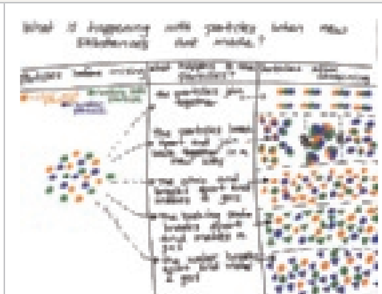
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 4 **2 days** **Which combinations of the substances in a bath bomb produce a gas?** Putting Pieces Together, Investigation	 *Combining citric acid, baking soda, and water causes bubbles to appear. Lemonade mixes (which are made of specific substances, including citric acid) also caused bubbles when combined with water and baking soda.*	We will discuss and record what we've figured out so far in the unit. We will plan and carry out an investigation to test different combinations of substances from a bath bomb, and we will use the results to argue that the gas produced must be a new substance. We figure out that: • Citric acid and baking soda combined are the only substances from the bath bomb that, when combined with water, cause gas bubbles to form. • The gas(es) in the bubbles are substance(s) that are different from any of the substances we started with.	

Navigation to Next Lesson: Since we know that the gas in those bubbles is a different substance(s) that wasn't there to start with, we want to try and figure out what substance(s) the gas is. We want to try to capture that gas and test it to figure out that.

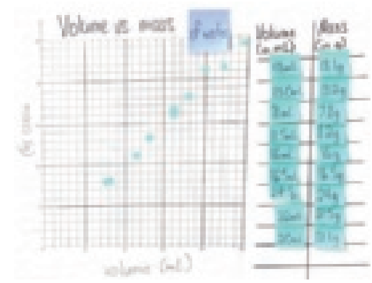
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 5 **2 days** **What gas(es) could be coming from the bath bomb?** Investigation	 *A flame goes out when put into a container of pure helium gas, gas from a bath bomb, or air mixed with helium, but does not when put in air only.*	We brainstorm phenomena related to gases and identify some different properties. We analyze the data by taking into account common gases and their known densities and flammabilities. We test the flammability of air from the room, gas from the bath bomb, and helium gas. We carry out an investigation to see if gas from the bath bomb rises or sinks. We argue from evidence (density and flammability data) that the gas from the bath bomb can be narrowed down to three candidate substances. We figure out that: • Density and flammability are properties. • In high concentrations, gases that are non-flammable will extinguish a flame. • Materials that are less dense float upward when surrounded by matter that is more dense; materials that are more dense sink downward when surrounded by matter that is less dense. • The gas from the bath bomb could be nitrogen, argon, or carbon dioxide.	
⇩ **Navigation to Next Lesson:** We want to see if we can explain a related phenomena using what we have figured out so far about property data. We want to see if we can explain a related phenomenon using what we have figured out so far about property data.			
LESSON 6 **1 day** **How can we explain another phenomenon where gas bubbles appear from combining different substances together?** Putting Pieces Together	 *When different substances are combined (potassium chloride and hydrogen peroxide), they interact and produce a gas.*	We apply what we have figured out about properties to explain a related phenomenon (elephant's toothpaste). We revisit our DQB and reflect on what other related phenomena we might explain using the same key model ideas. We figure out that: • The mass of a partially open system where potassium iodide and hydrogen peroxide are combined decreases because a gas is formed and some of it escapes the system. • The gas makes a glowing ember burst into flame and an already burning flame glow brighter. • Flammability data can help identify the types of gases that aren't being produced. • Testing the melting/freezing point, density, and/or comparing the results of the flammability test to results from controls could help identify additional gases that aren't being produced in this process.	
⇩ **Navigation to Next Lesson:** We know that the possible candidate substances that are in the gas from those bubbles are a different substance(s) that wasn't there to start with. Therefore, we wanted to try to develop a model at a particle level to explain how it is possible that a new substance that wasn't there before was produced from different substances we started with.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 **1 day** **How can we revise our model to represent the differences in the matter that goes into and comes out of the bath bomb system?** Putting Pieces Together	 *No new phenomena are introduced in this lesson. We put the pieces together for all phenomena previously explored in Lessons 1 through 5.*	We work as a class to summarize and review all of the science ideas we have figured out through the investigations we have done so far in order to put all the pieces together. We develop a new way to represent what we figured out, using an input/output table. We identify an unanswered question about where the particles that make up the substance(s) of the gas came from and individually develop a model to try to explain this. We figure out that: • The same substance is made of the same type of particles throughout. • Different substances are made of different materials throughout. • The particles that make up the substances in the gas bubbles from a bath bomb must be a different type of particle than any of those in the substances that were combined together to make it (water, baking soda, and citric acid).	

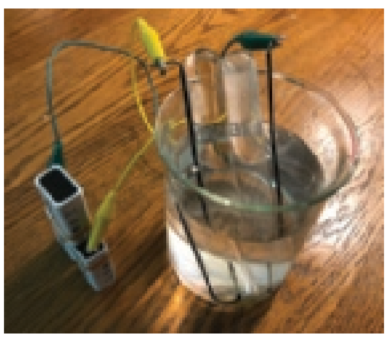
⇩ **Navigation to Next Lesson:** Since the only way there can be a new substance formed is if new particles were formed, we want to see if it is really possible to make new types of particles (and therefore new substances) out of something that we think is made of only one kind of particle.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 8 **1 day** **How can particles of a new substance be formed out of the particles of an old substance?** Problematizing	 *Alternate models can help explain how to make new particles from old particles.*	We develop alternate models for how new particles might be made from old particles using manipulatives (printed colored circles). We formulate questions we have about how we could figure out what happens when new substances are made from old. We read about what Dalton and other scientists did to see if adding energy to water could form new particles. We figure out that: • When new substances form from old substances, the particles of the old substances might break apart and/or stick together to form new combinations of particles. • We have a new line of investigations to pursue to see if new substances are formed when energy is added to a single substance (water).	

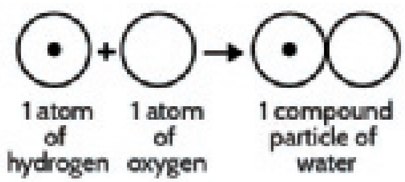
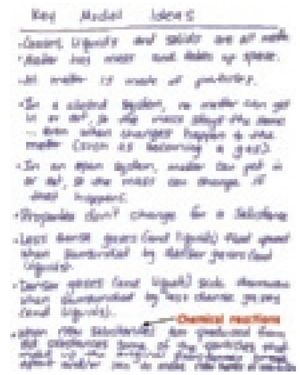
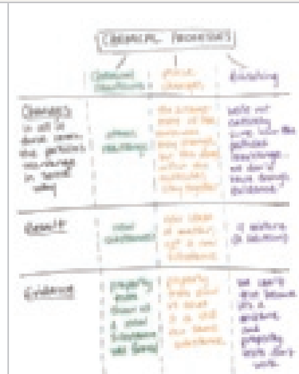
⇩ **Navigation to Next Lesson:** We came up with some initial predictions about what substances are in the gas bubbles that form when you add energy to water. We have ideas of some property tests we can try to see if our predictions are right and we want to do some of those next.

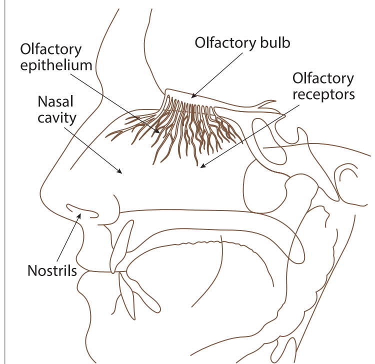
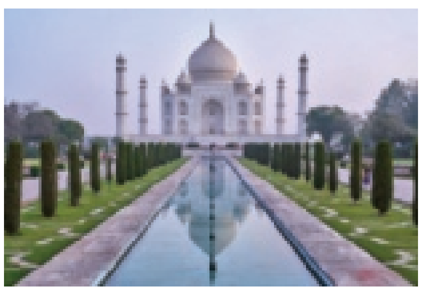
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 **2 days** **Does heating liquid water produce a new substance in the gas bubbles that appear?** Investigation	 *Gas from heated water extinguishes a flame. Clear liquid collected when gas cools has a mass to volume ratio of 1 for any size sample.*	We carry out an investigation to test the flammability of the gas produced by heating water. We collect data on the mass and volume of different samples of the water we started with and two other clear liquids and compare the mass and volume of each to the substance we collected from the gas produced by heating the water. We analyze graphs of the data and determine that the ratio of mass to volume for a substance is constant and that this is a property (density). We argue that the property data indicates that the gas we collected is made of the same particles that were in the water we started with. We figure out that: • Density is calculated as a ratio of mass to volume (a unit rate). It is constant (a property) for any sample of a substance, regardless of size. • The gas produced by the heated water is made of the same type of particles as those in the water that we started with.	

Navigation to Next Lesson: Now that we know that adding energy to water by heating it to make a gas doesn't produce any new substances, and therefore no new types of particles, we want to see if adding energy to water using electricity might create new substances.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 **1 day** **When energy from a battery was added to water, were the gases produced made of the same particles as were produced from heating the water?** Investigation	 *When energy from a battery is added to water, two streams of gas bubbles are produced. When a lit match is put into trapped gas from these two sources, one pops and the other glows brighter.*	We will carry out an investigation to test the flammability of gases produced by providing energy to water with electricity. We will construct an explanation for whether the gas(es) produced from water using energy from a battery were made of the same particles as those produced from heating the water. We figure out that: • Two different gases with different properties are produced from adding energy from a battery to water. • The particles that make up these different gases must be different from each other; they must also be different than the ones that were produced from heating water. • The matter that makes up all of the substances must come from matter that made up some of the original water particles.	

Navigation to Next Lesson: We want to return to our poster "What is happening with particles when new substances are made?" and evaluate those ideas in light of the explanations we developed.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 **2 days** **How do Dalton's models of the particles that change in a reaction compare to the ones we developed?** Investigation	 *There are many different ways (symbols, shapes, letters, numbers, and physical manipulatives) to represent the number, type, and arrangement of the atoms that make up the molecules of different substances.*	We gather and summarize information from a reading on investigations that Dalton and other scientists did and molecular models they developed for atoms, compound particles, chemical reactions, and substances. We will individually use those models to predict and explain what gas is produced in the bath bomb reaction and what is happening to the particles in the system. We figure out that: • Molecules are made of atoms and all the substances in our world are made of very few types of atoms. • A substance is made of the same type of molecules (or atoms throughout). The number, type, and arrangement of atoms in the molecules that make up a substance are unique to that substance. • In a chemical reaction, the particles that make up old substances can be broken apart and the atoms that make them up can be rearranged to form new molecules to make new substances.	
⇩ **Navigation to Next Lesson:** We are ready to take stock of all that we have learned, revise our final model, and use it to explain the chemical reaction that takes place when a bath bomb is placed in water.			
LESSON 12 **2 days** **How can a new substance (a gas) be produced and the total mass of the closed system not change?** Putting Pieces Together	 *The mass of water captured in a container after a bath bomb reacts in it is greater than was initially in the container before the bath bomb was put in it. A white substance, with a different density and different solubility than any of the substances in the bath bomb is found in this container after the water is boiled off.*	We revise our consensus model with the molecules of the reactants and the gas produced from the bath bomb. We explain why it could be possible that water is also a product in this chemical reaction. Using property data and molecular models, we argue whether one the solids found in the container after the water has been boiled off is a new substance. We develop a model to represent what is happening to particles in three different chemical processes. We revisit the DQB and identify which questions we have made progress on. We figure out that: • In a chemical reaction, the amount of matter at the beginning (in the reactants) is the same amount of matter at the end of the reaction (in the products). This is because all of the atoms we started with are still there. No new atoms can appear that weren't there to start with. • Chemical reactions, phase changes, and dissolving are all chemical processes that involve rearrangement of the particles that make up the matter in the system.	
⇩ **Navigation to Next Lesson:** We identified one line of questions that we made only a small bit of progress on related to odors. We have some ideas about how we might investigate this line of questions further.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 13 **1 day** **Why do different substances have different odors and how do we detect them?** Putting Pieces Together	 *Some substances can be identified by their odor and each substance has a unique molecular structure. These odors are received by the receptors in our nose and signals are sent to our brain so we can recognize what the substance is.*	We carry out an investigation about the scents of different substances to see if we can identify these substances by their odors. We gather information from a reading about how sensory receptors in our nose work. We use what we figure out from the odor lab and the reading to write an explanation about why different substances have different odors and how we detect them. We figure out that: • Odor is a property of a substance that is determined by the number, type, and arrangement of atoms that make up that substance. • Molecules of substances must travel into our nose for us to detect an odor. • Our nose has many different cells that each have different structures (sensory receptors for odor) that different shaped molecules can fit into, which will cause that cell to send a signal to other nerve cells that relay that signal to our brain. • The perception of different scents is the result of a combination of signals that the brain receives from different nerve cells.	
⇩ **Navigation to Next Lesson:** We want to apply everything we figure out to another phenomenon in the world.			
LESSON 14 **2 days** **What is happening to the Taj Mahal?** Putting Pieces Together	 *The marble of the Taj Mahal is crumbling and falling apart.*	We apply what we have figured out about properties to explain a related phenomena (pollution and erosion on marble). We carry out an investigation to collect data about what happens when different substances in the air interact with marble. We identify what other evidence we would want to collect in terms of property data to be able to argue whether a chemical reaction occurs. We figure out: • Two pollutants in the air around the Taj Mahal are interacting with the surface causing a chemical reaction to occur and change the surface to a new substance. • Algae that is on the surface of the Taj Mahal secretes different acids that cause a chemical reaction to occur with the (calcium carbonate) marble surface. • The algae and pollutants in the air around the Taj Mahal are causing it to crumble due to chemical reactions that are occurring.	
LESSON 1–14 **25 days total**			

TEACHER BACKGROUND KNOWLEDGE

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstration, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g. wearing safety goggles, non latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the units include teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as taking down, disposing, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgement form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle school activities through the **Online Resources Guide. www.coreknowledge.org/cksci-online-resources**

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non latex apron, and non latex gloves during the set-up, hands-on investigation, and take down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip and fall hazard.
3. Follow your teacher guide for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.

Specific safety precautions are called out within the lesson using this icon and a call-out box.

Where does this unit fall in the Scope and Sequence?

This is the first unit in the 7th grade scope and sequence. There are six total units designed for 7th grade. This unit directly builds off the Disciplinary Core Ideas (DCIs), Crosscutting Concepts (CCCs), and Science and Engineering Practices (SEPs) developed in two of the 6th grade units that preceded this one. Those two units are:

- *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*
- *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*

There are three units that follow this unit in 7th grade, that will build off the DCIs, CCCs, and SEPs developed in this unit. Those units are:

- *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit)*
- *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)*
- *Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*

What phenomena are the context for this unit?

This unit begins with an exploration of observing what happens when a store bought bath bomb is added to water. Students make observations of the bath bomb multiple times: 1) before adding it to water by passing it around the class, 2) right after the bath bomb has been added to water, and 3) after the bath bomb has been in the water for 10 minutes. They notice that when the bath bomb is added to water it immediately begins to behave differently—it bubbles (forming a gas), breaks apart (dissolves and reacts), changes the color of the water, and has an odor that wasn't as evident before adding to the water. After observing a store bought bath bomb as a class, each student is given one of four different homemade bath bomb samples to investigate before and after adding to water. These investigations lead to students having many questions about bath bombs and ideas for how to investigate what is causing the different bath bombs to behave the way they do.

This unit is broken into two lesson sets, focusing on properties of substances, chemical reactions, and conservation of mass. In the first lesson set, students investigate bath bombs and the ingredients that make up bath bombs to identify different substances in gas form using property data. In the second lesson set, students use property data and conservation of mass to argue whether a chemical reaction has occurred resulting in a new substance.

In the first half of the unit, students investigate where the gas that forms when the bath bomb is added to water comes from. Initially they look at the solid bath bomb to figure out if the gas is part of the bath bomb to begin with. Then they read about the ingredients that make up the homemade bath bombs and conduct investigations to see if any of the individual ingredients create bubbles and a gas when added to water on their own. When a gas doesn't result in any of these investigations of the homemade bath bombs, they conduct an investigation trying more than one ingredient in water and find baking soda and citric acid, when combined with water, to be the ingredients causing the gas to form. Students work with property data to determine what gas could have been formed from the bath bomb's interaction with water. As a culminating assessment task, students apply what they have figured out about properties to argue whether a new substance is made in a related phenomenon, elephant's toothpaste. Students work with property and mass data and determine what gases could not have been formed during this reaction. Then they explain what further evidence they would need to determine which gas(es) were produced during this reaction.

In the second half of the unit students problematize where the gas comes from when the bath bomb is added to water and hypothesize the gas must be a new substance. They conduct investigations to see what happens when heat is added to water and when electricity is added to water. They conclude adding heat to water results in phase changes to the water, but it is still water, while adding electricity to the water results in a chemical reaction change to the water resulting in two different gases that students identify using property data. From these investigations and while using manipulatives, students figure out that when substances are combined and a chemical reaction occurs, the atoms of the original substances break apart or separate and rearrange into different molecules resulting in a new substance that can be identified by its properties. Students test this in both open and closed systems and find that the mass does not change in a closed system, which further supports what they have figured out that the atoms of the original substances in a chemical reaction rearrange to make a new substance using the same atoms. Using the evidence and key model ideas they have figured out over the course of the unit students construct an explanation about what gas is produced when a bath bomb is added to water. At this point in the unit, most questions have been answered from the Driving Question Board, but usually there are some left about odor. In order to answer these questions and further convince ourselves that odor is a property, students investigate the odor of different substances and read about how we detect these odors. This concludes the unit. As a transfer task, students apply what they have figured out to a phenomenon occurring out in the world on a larger scale. They are given a scenario around what is happening to the marble of the Taj Mahal. In this transfer task, they plan and carry out an investigation, analyze the data they collect, and construct an explanation about the chemical reaction(s) happening to the substances that make up the Taj Mahal.

What NGSS Performance Expectations does this unit target?

This unit builds toward the following NGSS Performance Expectations (PEs):

- **MS-PS1-1:** Develop models to describe the atomic composition of simple molecules and extended structures. [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.]

- **MS-PS1-2:** Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.]
- **MS-PS1-5:** Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms, that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.]

The following PE will be developed over three units; *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*, *Unit 7.1: How can we make something new that was not there before? (Bath Bombs Unit)*, and *Unit 8.2: How can a sound make something move? (Sound Unit)*. This unit will address only the chemical inputs that transmit signals to the brain through smell. The other units will address electromagnetic and mechanical inputs, as well as the connection to signals processing in the brain, resulting in immediate behaviors or memories.

- **MS-LS1-8.** Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain ~~for immediate behavior or storage as memories~~. *[Assessment boundary: Assessment does not include mechanisms for transmission of this information]*
- LS1.D: Information Processing: Each sense receptor responds to different inputs (~~electromagnetic, mechanical~~, **chemical**), transmitting them as signals that travel along nerve cells to the brain. ~~The signals are then processed in the brain, resulting in immediate behaviors or memories~~.

What should my students know from earlier grades or units?

Related Disciplinary Core Ideas (DCIs) that students should know from earlier grades and experience in *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*:

DCIs from 5th grade:

- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects. (5-PS1-1)
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. (5-PS1-2)
- Measurements of a variety of properties can be used to identify materials. (5-PS1-3)

Before this unit, students should understand the following ideas from their experiences in *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*:

- The same substance is made of the same type of ingredient throughout.
- The type of particle that water is made of throughout is a molecule.
- When the state of a substance changes, the speed of the molecules and their spacing change, but the type of molecules making up that substance do not.
- Particles of matter can get in and out of an open system, but cannot in a closed system.
- Matter takes up space and has mass.

Before this unit, students should understand the following ideas from their experiences in *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)* and in Unit 6.6: *Cells and Growth*:

- Eyes work with the brain to process information from light inputs. The brain pieces together the information to tell us what we "see."
- Large groups of cells work together to form tissues or organs that work together to perform particular body functions.

What are the Disciplinary Core Ideas (DCIs) in the context of the phenomenon?

Disciplinary Core Ideas are reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K-12 Science Education Standards. National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

PS1.A: Structure and Properties of Matter

- Substances are made from different types of atoms, which combine with one another in various ways.
- Atoms form molecules that range in size from two to thousands of atoms.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved, and thus the mass does not change.

LS1-D:

- Each sense receptor responds to different inputs (~~electromagnetic, mechanical~~, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

What are the Focal Science and Engineering Practices (SEPs) for this unit?

While this unit engages students in multiple SEPs across the lesson level performance expectations for all the lessons in the unit, there are three focal practices that this unit targets to support students' development in a learning progression across the 7th grade year for the SEPs. These are:

- Constructing Explanations and Designing Solutions
- Analyzing and Interpreting Data
- Engaging in Argument from Evidence

In addition there are two supporting practices that students will utilize over the course of the unit. These practices are two that students have developed over the course of 6th grade in the sequence and will be used as supporting practices in this unit:

- Developing and Using Models
- Planning and Carrying Out Investigations

The sections below describe the learning progressions for each of these practices leading to this unit and through this unit.

1) The learning progression for Developing and Using Models

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	In Unit 6.2 and Unit 6.3, students have already had these experiences with the middle school elements of this practice:
• Identify limitations of models. • Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. • Develop and/or use models to describe and/or predict phenomena. • Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. • Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	• Develop or modify a model—based on evidence—to match what happens if a variable or component of a system is changed. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms.

Develop and Use Models: Over the course of the unit, students develop many models, but two of these models are revisited and refined over and over again (the initial consensus model and a particle based model that is first introduced mid-unit). One nature of science component of this practice is that scientists revise their prior models to help them make sense of a phenomenon as they collect new evidence. This nature of science connection is made explicit in the readings about Dalton's work in Lesson 8 and

Lesson 10. Here are key places that students revise and refine their particulate models of matter in this unit:

- **Lesson 1** - Students develop both a macroscopic and microscopic model of what they think is happening when a bath bomb is placed in water. From students' initial models, the class develops a class consensus model. At this point, these models represent particles of matter without any distinction between molecules and atoms.
- **Lesson 7** - The class revisits and refines their consensus model to include what students have figured out—that mass is conserved, there are only two substances (baking soda and citric acid combined in water) in the bath bomb that create the gas, some of the substances dissolve, and a gas is formed. This model necessitates the development and use of a new idea—that particles that make up substances must be able to be broken apart into smaller pieces and those pieces may be able to be combined into new kinds of particles.
- **Lesson 8** - The class develops a particle based model to represent what we think is happening to the substances in the bath bomb that create the gas. This model includes all initial thinking and predictions of how the particles may come apart, join together, come apart, and rejoin together in different ways.
- **Lesson 10** - Students revisit their particle-based model and add to it to include what they think happens to water during electrolysis.
- **Lesson 11** - After figuring out that the makeup of the particles that they have been modeling are called "molecules" and the pieces that make them up are called "atoms," students analyze molecular models of substances in the bath bomb and use these to argue what molecules could (and could not) be produced in the gas from the bath bomb.
- **Lesson 12** - Students revisit the class consensus model of the bath bomb to add the molecular models of the different substances. They use this to argue what additional two products (a liquid and a solid) are produced in the bath bomb reaction.

2) The learning progression for Planning and Carrying Out Investigations

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	In Unit 6.2 and Unit 6.3, students have already had these experiences with the middle school elements of this practice:
• Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. • Evaluate appropriate methods and/or tools for collecting data. • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution. • Make predictions about what would happen if a variable changes. • Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.	• Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to support a claim. • Evaluate the accuracy of various methods for collecting data. • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. • Collect data about the performance of a proposed object, tool, process, or system under a range of conditions.

In this unit, students will build upon these prior experiences with planning and carrying out investigations by engaging in these elements again, but will also engage in a new element:

- Collect data to produce data to serve as the basis for evidence to answer scientific questions ~~or test design solutions under a range of conditions~~.

Students will engage in this element in Lessons 3, 4, and 14. This marks a shift in progression toward setting a purpose for carrying out investigations that will provide data (evidence) that can be used in conjunction with the practice of argumentation to support or refute a claim than in prior units.

Plan and Carry Out Investigations: Students develop this practice starting in Lesson 2 when they co-design 2 investigations to determine where the gas is coming from when a bath bomb is placed in water. Again in Lesson 3 students plan out an investigation to determine how each of the ingredients of the bath bomb behave when added to water. In Lesson 4, students co-plan and carry out an investigation to determine what combinations of bath bomb ingredients leads to a gas forming. In Lesson 5 students test properties of known gases as controls in an investigation to ensure their tests are reliable before carrying out these same tests on the unknown bath bomb gas. Students continue to engage with this practice through the second half of the unit so that by the end, a component of their assessment asks them to plan and carry out an investigation on pieces of marble (calcium carbonate) to determine what could be happening to the surface of the marble on the Taj Mahal that is making it crumble. A second part of this assessment asks students to propose what other investigations they would plan in order to collect more evidence to help them explain what is happening to the Taj Mahal.

3) The learning progression for Analyzing and Interpreting Data

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	In Unit 6.1, 6.2, 6.3, and 6.4, students have already had these experiences with the middle school elements of this practice:
• Represent data in tables and/or various graphical displays (bar graphs, pictographs, and/or pie charts) to reveal patterns that indicate relationships. • Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. • Analyze data to refine a problem statement or the design of a proposed object, tool, or process. • Use data to evaluate and refine design solutions.	• Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). • Analyze and interpret data to provide evidence for phenomena. • Analyze and interpret data to determine similarities and differences in findings. • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.

In this unit, students will engage in the third and fourth middle school level element listed above on the right again. These two elements of this practice students will use when developing arguments around comparing different substances based on property data (aligned with the fourth bullet point) **and** constructing explanations about whether a chemical reaction has occurred or not (aligned with the third bullet point).

Analyze and Interpret Data: In this version of the unit, students begin developing this practice starting in Lesson 2 when they argue as a class, and sometimes in their small group, for what data should be collected and how this data should be recorded, and in Lesson 3 when they analyze their first property data table. As the unit progresses, students analyze data tables that look similar to the ones they had made earlier in the unit to help them figure out different parts of the story of what is happening when the bath bomb is placed in water. A few examples of where students are engaging in this practice are in Lesson 4 (collecting data to determine the substances in the bath bomb that cause the gas), Lesson 5 (recording data from flammability and density tests of gases and using a property data table to determine what gas could be produced), and Lesson 7 (students argue for what additional data they would want to analyze). By the end of the unit, students will be analyzing data to determine whether a chemical reaction has occurred in a couple different scenarios and will argue for what additional data they would need to be more confident in their explanation.

4) The learning progression for Constructing Explanations and Designing Solutions

This unit assumes students have had experience with the following elements of this practice from the 3–5 grade band:	In Units 6.1, 6.2, 6.3, and 6.4, students have already had these experiences with the middle school elements of this practice:
• Construct an explanation of observed relationships (e.g., the distribution of plants in the backyard). • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. • Identify the evidence that supports particular points in an explanation. • Apply scientific ideas to solve design problems.	• Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. • Construct an explanation using models or representations. • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. • Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process, or system.

Though students have had experience with different elements of this practice prior to this unit, they engage with the first four bullet points above in almost every lesson of this unit. At each juncture in the unit where students have collected new data, information, or evidence, they pause to record new key model ideas (scientific principles) that they then use to construct arguments and explanations about what is occurring with the phenomenon (bath bombs, elephant's toothpaste, electrolysis, or crumbling marble on the Taj Mahal).

Construct Explanations and Design Solutions and Engage in Argument from Evidence: These two practices complement each other well in this unit. Students' experience and engagement with both practices evolve over the course of the unit. In the first half of the unit students engage in argumentation to explain **what is happening** when the bath bomb is placed in water (a new substance—a gas) is produced. The second half of the unit builds on this initial work done in the first half of the unit. But in the second half, students shift to explaining what is happening at the molecular level. Some examples are included below to show these practices are developed:

- **Lesson 1 -** Students construct an initial explanation for what is causing the gas bubbles to form when a bath bomb is placed in water. They will return to making a revised explanation of this phenomenon toward the end of the unit in Lesson 11.
- **Lesson 2** - Students engage in argumentation to explain whether the gas from the bath bomb is trapped in the bath bomb or whether it came from the matter that was in the system to start with. They use the data (mass, bag inflation) collected from crushing a dry bath bomb in a closed system to argue the gas is not in the solid bath bomb. Then they place a bath bomb in water in a closed system and use the same data (mass, inflation of the bottle) to argue that the gas is made from the initial substances in the system when the bath bomb is placed in water.
- **Lesson 4** - After trying different combinations of the ingredients of the bath bomb together in water, students determine that baking soda and citric acid are the two substances that cause gas bubbles to form. They use this data to construct an oral and then written argument that only certain combinations of the ingredients in a bath bomb cause a gas to form. Then, using this data and the key model ideas around properties, students co-construct an argument that this gas that is formed must be a new substance that wasn't there before the bath bomb was added to water.
- **Lesson 5** - In this lesson, students collect property data about different known gases and then use the data to try to determine what the gas from the bath bomb is. The two known gases students look at are air and helium. Using the observations of testing these two known gases, students construct predictive explanations around what evidence they would look for to help them determine what the gas of the bath bomb is. Using density and flammability data from the bath bomb gas and comparing it to a table of common gas properties, students construct an argument about which gas(es) could be the bath bomb gas.
- **Lesson 6** - This lesson is a transfer task designed to support students in applying what they figured out to explain a new related phenomenon. As part of this task, students construct three short written pieces (one explanation and two arguments). Using data they analyze and watch through a video clip, they write one explanation about why the mass of a system decreases when substances are mixed together. They write an argument about which substance(s) could or could not be produced in that process. And lastly, because there is not enough data to be able to narrow down to the one single substance that is formed during this task, they argue what additional tests could be done on the gas (or gases) to help identify additional substances that aren't being produced in this process.
- **Lesson 9** - Students heat water and figure out that the gas bubbles that form when this happens is still water through the property data they collect. They analyze two different arguments supporting the claim: "The gas in the bubbles is made of water particles." In their analysis of these two arguments, students are given an organizer to use to record evidence and key model ideas that they use to develop an argument to explain how they know the gas in the bubbles is made of water particles. They use what they have recorded on their organizer to construct stronger arguments to support the original claim.
- **Lesson 10** - Prior to Lesson 8, students have constructed arguments for various claims, but not yet developed particle-based explanations for how/why various aspects of the bath bomb phenomena occur. We made this distinction between "mechanistic explanations" vs. "arguing from evidence" to help students see that the arguments they develop in this lesson and the last one could now be considered explanations, because they are trying to explain how/why something happens (through a particle level model). Students investigate electrolysis and figure out with evidence

that water can go through a process that causes it to split into two different substances. Using this evidence, students construct an argument about whether the gas produced here is the same as the gas produced from heating the water in the prior lesson.

- **Lesson 11** -After analyzing molecular models of the different substances that make up the bath bomb, and figuring out that the atoms that are part of the reactants are also part of the products, students revisit their initial explanation from Lesson 1. Using evidence from the course of the unit, students construct an explanation about how molecules of the original reactants interact to produce molecules of a new substance.
- **Lesson 12** - Students construct two explanations in this lesson. The first explanation explains why mass is conserved in a chemical reaction and the second explanation students use molecular models to explain whether and how more than one type of substance can be produced in a chemical reaction. These explanations serve as summative pieces for what is happening when the bath bomb is added to water and closes out the anchoring phenomenon.
- **Lesson 13** - Students investigate odors and related molecular models. After collecting evidence from this odor lab and through an informational reading, they construct an explanation to answer the question "Why do different substances have different odors and how do we detect them?" in their science notebook.
- **Lesson 14** - This lesson is a transfer task to a related real-world phenomenon. Students construct multiple explanations about what is occurring to the surface of the marble that the Taj Mahal is made of and about what additional data and/or investigations they would like to collect to more confidently determine the cause of the crumbling of the marble. An optional part 2b extends these explanations to include accounting for changes happening to the iron clamps and rods in the Taj Mahal.

What are the Focal Crosscutting Concepts (CCCs) for this unit?

While this unit engages students in multiple CCCs across the lesson level performance expectations for all the lessons in the unit, there are three focal CCCs that this unit targets to help support students' development in a learning progression across the 7th grade year in CCCs. These are:

1. Patterns
2. Scale, Proportion, and Quantity
3. Energy and Matter

The sections below describe the learning progressions for each of these CCCs leading to this unit and through this unit.

1) The learning progression for Patterns

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	In Units 6.1, 6.2, and 6.3, students have already had these experiences with the middle school elements of this CCC:
• Similarities and differences in patterns can be used to sort, classify, communicate, and analyze simple rates of change for natural phenomena and designed products. • Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.	• Macroscopic patterns are related to the nature of microscopic and atomic-level structure. • Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. • Patterns can be used to identify cause and effect relationships. • Graphs, charts, and images can be used to identify patterns in data.

In this unit, students will engage in the middle school level elements listed above again. But the first bulleted element involving the relationship between what can be seen (macroscopic) happening and what is occurring at a molecular level (microscopic) is an underlying question throughout the unit. In addition, in the first half of the unit, students use patterns to help them determine that different substances are made of different, unique particles, but it isn't until the second half of the unit that students develop the idea that these particles must be made of different parts (atoms) and that the way these parts are put together is unique to different substances. Students will engage in this CCC element at a greater extent and in new ways as they continually revise their model of what is occurring to a bath bomb when added to water. In this unit, students will use this element in the following lessons to help them refine and revise their understanding of the reaction between the substances of the bath bomb when placed in water: 1, 3, 7, 8, 9, 10, 11, 12, and 13.

Students' engagement in finding and making sense of patterns is generally more complex than their work in prior units. In prior units, students' work looking for patterns in the relationship between the macroscopic and microscopic properties did dive into the molecular or atomic structure of different substances. In this unit, students will figure this out through doing an electrolysis lab in which they add electrical energy to water (a substance made of one kind of particle) and produce two different substances (oxygen gas and hydrogen gas). This leads students to argue that the particles we have been modeling must be made up of more than one type of particle and they revise their particle model to include pieces of particles, or atoms.

Students develop the skill of looking for patterns over the course of the unit. Initially in the unit they are looking for patterns of macroscopic occurrences in the bath bomb phenomenon. Then they analyze some property data of different substances and use this crosscutting concept to argue which substances cause a gas to form from the bath bomb. Eventually, students are looking for patterns at the macroscopic level to explain what is happening at the microscopic level.

- **Lesson 1** - Students use the crosscutting concept of patterns for describing how macroscopic patterns can often be accounted for through changes occurring at the microscopic or atomic level. In an initial model that students develop, they are asked to “Show what you think is happening at a scale you can’t see. Use the circles to show zoomed in views at different points in time. Annotate these to explain what you think is happening to the matter in each of the five zoomed-in circles.” The goal of the modeling task is to elicit particle representations of different states of matter and different substances at a molecular level without relying on prior knowledge that molecules are made of atom(s).
- **Lesson 2** - Students engage in the practice “Analyze and Interpret Data” and use the crosscutting concept of Patterns to make sense of this data.
- **Lesson 3** - Students observe similarities and differences in the ingredients found in different recipes of bath bombs and they record observations of their characteristic properties including what they do when individually added to water and they share the patterns in their observations in large group discussions.
- **Lesson 5** - Students use patterns in the property data of gases to identify instances when the reported density of the gas and/or the flammability of the gas cause certain observable behaviors that are the same as the gas trapped from a bath bomb. Students use the property data in tables and charts to identify patterns they can investigate. In this lesson there is an assessment and guidance for the teacher on how to look for students using this crosscutting concept in their assessment.
- **Lesson 6** - Students use the property data in tables and charts to identify patterns they can investigate. In this lesson there is an assessment and guidance for the teacher on how to look for students using this crosscutting concept in their assessment.
- **Lesson 9** - Students develop and use the idea that macroscopic patterns are related to the nature of microscopic and atomic-level structure when they use property data to develop an argument that the gas inside the bubbles is made of water particles. Students develop and use the idea that patterns in rates of change and other numerical relationships can provide information about natural systems when they plot mass vs. volume measurements for three different substances and discover a directly proportional relationship for each—with a different unit rate for each substance—based on the steepness of the graphs and the patterns in the data tables.
- **Lesson 12** - Students build on the concept that the macroscopic patterns of chemical reactions are related to both the nature of microscopic patterns, as well as the atomic-level structure of the substances involved in those reactions, working with multiple examples of molecular models throughout the lesson.

2) The learning progression for Scale, Proportion, and Quantity

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	In Units 6.1, 6.2, and 6.3, students have already had these experiences with the middle school elements of this CCC:
• Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods. • Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.	• Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. • Phenomena that can be observed at one scale may not be observable at another scale.

Students begin the unit by developing an initial model to represent what is happening to the bath bomb when it is added to water and a gas is produced. This initial model includes what students can see and what they think is happening on a smaller scale that they can’t see. This model gets revised and refined by students as they collect more evidence. By the end of the unit, students are explaining what is happening at a molecular scale that results in the occurrences at the macroscale. One example of this can be found in Lesson 9 where students use ideas related to proportional relationships among different types of quantities to provide information about the magnitude of properties. They do this by calculating the density of a substance for a variety of combinations of measurements of mass and volume at the start of day 2 of this lesson. Students develop and use the idea that scientific relationships can be represented through the use of algebraic expressions and equations, by expressing density as a unit rate that can be calculated with the expression mass /volume at the start of day 2 of this lesson.

3) The learning progression for Energy and Matter

This unit assumes students have had experience with the following elements of this CCC from the 3–5 grade band:	In Units 6.1 and 6.2, students have already had these experiences with the middle school elements of this CCC:
• Matter is made of particles. • Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. • Energy can be transferred in various ways and between objects.	• Matter is conserved because atoms are conserved in physical and chemical processes. • Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. • Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). • The transfer of energy can be tracked as energy flows through a designed or natural system.

In this unit, students figure out what is happening to the substances of the bath bomb when it reacts in water, through multiple investigations including collecting evidence of the mass of the system before and after reacting. Therefore the first bullet point is paramount for students in figuring out by the end of the unit, that molecules of substances can come apart and rearrange to make new substances and when this happens, the matter is conserved. They engage with this crosscutting concept multiple times over the course of the unit in Lessons 1, 2, 3, 4, 6, 7, 10, and 12.

Students develop and use the idea of conservation of matter in this unit to explain what happens to matter during a chemical reaction. The energy component of this crosscutting concept in relation to a chemical reaction is not explored or explained in this unit as it will be a focus of the unit that directly follows this one, *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit)*. In this version of the unit, students have many opportunities to engage with and use this crosscutting concept to develop their model of what happens to the atoms of molecules that make up reactants in a chemical reaction and compare this to the atoms in the molecules of the products. By the end of the unit, students will have figured out that matter is conserved and cannot appear or disappear. This will help them in constructing a full explanation about what products are made from the bath bomb reaction. Some examples where students have practice with and progress in their use of matter include:

- **Lesson 1** - This lesson foregrounds thinking that students have done numerous times in two prior units in 6th grade, *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*. They use this to develop models and trace what they think happens to the matter of the bath bomb when it is placed in water. During the consensus model building discussion, students share potential ideas for what causes the changes to the matter of the bath bomb and whether this matter is still there in the water. This leads to the idea of needing to record the mass of the system before and after this matter transformation in order to answer that question. This becomes a recurring theme in future investigation protocols that the class starts developing and refining in Lesson 2 and beyond.
- **Lesson 2 -** Students begin to develop and use the idea of conservation of matter in physical and chemical processes by figuring out that the gas (a type of matter) is not created but must come from something that is there at the beginning. They also determine that the gas cannot be originally trapped inside of the bath bomb.
- **Lesson 6 -** On their assessment, students use the idea of conservation of matter in chemical processes and that it couldn't have just disappeared.
- **Lesson 12 -** Students use the idea that matter is conserved because atoms are conserved in chemical processes in multiple arguments they make throughout the lesson.

How do the focus of the SEPs and CCCs work together and shift over the course of the entire unit?

Over the course of this unit, students use Patterns and Matter and Energy to first develop the practice of engaging in argumentation and by the end of the unit students are able to construct explanations. In the first lesson set of this unit students are figuring out *what* is happening when a bath bomb reacts with water. And in the second lesson set they figure out *how* this reaction occurs. Until students have the key model ideas (scientific principles) and evidence to support these from investigations in the unit, they are not able to construct explanations that include the mechanism (or how and why) behind a phenomenon. In the first part of the unit, students have enough evidence to be able to argue for what is happening between the water and bath bomb. They engage in this practice or argumentation orally and through writing by stating a claim and supporting it with evidence. As the class develops key model ideas (sometimes called scientific principles), students begin to use some of these in their writing to begin explaining the why or how behind the reaction of the bath bomb. By the end of the unit, students will have written many arguments and three full explanations.

Patterns and Matter and Energy are focal CCCs throughout the unit. Students are continually using the crosscutting concept of Patterns to make sense of data and evidence they collect to revise their models and arguments. A central focus of this unit is on developing a microscopic model of what is happening to the matter that makes up different substances when they are combined. So in addition to using patterns to make sense of things, the elements of Matter and Energy having to do with conservation of matter is a key crosscutting concept students engage with to figure out the atoms of molecules can come apart and rearrange in new ways to produce different substances.

What are prerequisite math concepts necessary for the unit?

The **bolded** sections of the related common core math standards are ones that students engage in.

Density is a property that students measure, graph, and calculate from mass and volume data in Lesson 8. They will be using the following two math concepts in that lesson:

- **CCSS.MATH.CONTENT.7.RP.A.2.A** Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.
- **CCSS.MATH.CONTENT.7.RP.A.2.B** Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.

What are some common ideas that students might have?

Students may think that the gas bubbles that appear from the bath bomb added to water is a substance that is already present before the water and bath bomb are combined together. They may think the substances in the gas either are already trapped in cavities in the bath bomb or it is one of the substances initially present that is turning into a gas. Students will eliminate these competing explanations in Lessons 2–5, through different lines of evidence they collect.

Based on 5th grade DCIs, some students may have an idea that new substances can be made from mixing old substances and may call such transformations a chemical reaction, but they are unlikely to have a particle level model to explain how this is possible and what is happening to the matter in the system.

- Prior conceptions students may have on atoms, properties and conservation of mass are detailed via links in the **Online Resources Guide. www.coreknowledge.org/cksci-online-resources**

What modifications will I need to make if this unit is taught out of sequence?

Because this unit is taught using a conceptual approach to developing a model of matter that requires the existence of compound particles and smaller continuent parts (atoms), pre-teaching the idea that atoms exist and that they make up molecules is counterproductive to the trajectory of this unit. Students may have heard of the words “atoms” and “molecules” in other contexts and should be encouraged to try to apply any ideas about the particulate nature of matter they may bring to the table in the first part of the unit. But, since units in 6th grade develop a particulate model of matter that doesn’t distinguish between molecules and atoms, the middle of this unit will be the first time that students will find the need for such distinction based on something they can’t explain about the anchoring phenomena. Many subsequent units in 7th grade will use the ideas developed in this unit, to explain other phenomena, and will rely on the development of the following ideas developed in this unit. The unit that requires each idea listed here is identified in parentheses.

- Every substance has characteristic properties that can be used to identify it (e.g., solubility, odor, melting point, boiling point, flammability, density, color). These do not change regardless of the amount of the substance. (7.2, 7.3)
- Substances are made from different types of atoms, which combine with one another in various ways. The number, type, and arrangement of atoms in the molecules that make up a substance are unique to that substance. (7.2)
- Atoms form molecules. (7.2, 7.3, 7.4)
- In a chemical reaction, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (7.2, 7.3, 7.4)

- In a chemical reaction, the total number of each type of atom is conserved, and thus the mass does not change. (7.2, 7.3, 7.4)
- There are two ways to break apart matter—physical processes and chemical processes. (7.3, 7.4)
- Chemical processes involve the rearrangement of particles that make up the matter; this includes chemical reactions, phase changes, and dissolving. (7.2)

GUIDANCE FOR DEVELOPING YOUR WORD WALL

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have "earned" that word and can add the specific term to the class Word Wall. These "words we earn" should be recorded on the Word Wall using the students' own definition whenever possible. On the other hand, "words we encounter" are "given" to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, words we encounter are helpful just in that lesson and need not be recorded on the Word Wall. However, if a word we encounter will be frequently referred to throughout the unit, it should be added to the Word Wall. As such, the Word Wall becomes an ongoing collection of words we will continue to use, including all the words we earn in the unit and possibly a few key words we encounter.

It is best for students if you create cards for the Word Wall in the moment, using definitions and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the posted meaning of the word, students "own" the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support.

Sometimes creating Word Wall cards in the moment is a challenge. The teacher guide provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate. If you keep one Word Wall in your classroom for several sections of students, you might choose to record each class's definition separately, and then propose an "official" definition to post the next day that captures the collected meaning. The words we earn and words we encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

Lesson	Words we earn	Words we encounter
L1		
L2		citric acid, baking soda, epsom salt
L3	property, substance, soluble, state of matter	dissolve, mixture, viscosity, insoluble, solubility
L4		
L5	density, flammability	nitrogen, oxygen, argon, carbon dioxide, neon, helium, methane, hydrogen, propane
L6		
L7		
L8		
L9		meniscus
L10	atom, molecule	sulfur
L11	chemical reaction, phase change, chemical process	
L12	product, reactant	
L13	odor	
L14		acid rain, pollutants, algae, sulphuric acid, nitric acid, iron, calcium carbonate, marble, malic acid

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy routine integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things; and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading collection. The products are varied in form and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and well-constructed paragraph.

Put Yourself in This Scene

Literacy Objectives

✓ Initiate thinking about the need to evaluate information in text and images.

Literacy Exercises

- Read a brief scenario to pique interest, launch discussion, and begin to frame expectations.

Instructional Resources

Student Reader

Preface

Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigation

The reading of the Preface is appropriate during the first week of unit instruction. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS

Disciplinary Core Idea PS1.A: Structure and Properties of Matter Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2) (Note: This Disciplinary Core Idea is also addressed by MS-PS1-3.)

Science and Engineering Practice: Asking Questions and Defining Problems

Crosscutting Concepts: Cause and Effect; Stability and Change

CCSS

English Language Arts

RST.6-8.6: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Math

7.RPA.2: Recognize and represent proportional relationships between quantities.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. No Core Vocabulary terms are highlighted in the Preface.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

chemical	**chlorine**	**concentration**
dehydration	**dilute**	**scientific literacy**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the reading.

2. Preview the assignment and set expectations. (Monday)

- Let students know that for the Science Literacy routine, they will read independently and then complete short writing assignments. The reading selections relate to topics they will be exploring in their Chemical Reactions and Matter unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have available class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface about the baby carrots and chlorine scenario is written at approximately Lexile 1100–1200, which leans toward the high end of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion. (Friday)

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Pages 2–3 **Suggested prompts**	**Sample student responses**
How would you summarize the "scene" referred to in the title?	*It begins with a social media post with one person commenting about the possible dangers of eating baby carrots. It ends with an excerpt from a website that refutes and corrects the social media claim made by that one person.*
What impression do you get about the word chemicals *in the context of this social media post?*	*that it is a bad word, meaning something that is dangerous*
What are bacteria, and why are food sellers concerned about them?	*Bacteria are living things too small to be seen without a microscope.* *Some bacteria can make people who eat them sick.* *Food sellers don't want anyone who buys their food to get sick because they don't want to hurt people and because if the people get sick, they will not want to buy from them again.*
What did the fact-checking site mean by the "concentration" of chlorine?	*They meant the proportion of chlorine particles to water particles in the solution.*
What does dehydration *mean, and what are some other examples?*	*Dehydration happens when something loses water.* *I've eaten dehydrated apples for snacks.* *My family keeps dehydrated (powdered) milk in the kitchen and uses it when we run low on fresh milk.*

Student Reader

Preface

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

CHALLENGE—Challenge students to do a web search to find reputable fact-checking websites and to search the sites to see if the mock fact-checker site's explanation is accurate.

Pages 2–3 Suggested prompts	Sample student responses
	My parents put evaporated milk in their coffee. It's partially dehydrated. *Raisins are dehydrated grapes.* *Our family takes dehydrated foods on camping trips.*
How could you test the explanation that the white stuff on baby carrots is due to dehydration?	*We could plan an investigation. First, we could buy two bags of baby carrots at the same time and place. Next, we could open both and reseal one bag immediately. Then we could put some clean, dry paper towels in the other bag and reseal it. If we replace the towels when they soak up water, the inside of the bag will dry out. We can check the carrots in the two bags after a few days and look for the white stuff.*
What other questions do you have about baby carrots that can be answered by carrying out a science investigation?	*Do baby carrots in a bag taste different from carrots that are cut up at home?* *Do baby carrots stay fresh in the refrigerator longer or less time than uncut large carrots?* *How much water is in baby carrots?*
What questions do you have about chlorine?	*Does the drinking water in our town contain chlorine?* *How does the concentration of chlorine in a swimming pool compare to that used on baby carrots or in our drinking water?* *How does chlorine kill bacteria?* *How much chlorine is too much for people and will make us sick?* *Is chlorine something found in nature, or is it made in a science lab?* *What other foods that I eat are rinsed in chlorine solutions to kill bacteria?*
Why is it a good idea to be skeptical about what you read on social media?	*People can post anything they want on social media without anyone fact-checking it.* *Lots of people copy and share posts they have seen elsewhere without checking the sources.* *There is a lot of false information on social media.*

KEY IDEA—Without fact-checking the claims made by the writer of a social media post, there isn't a reasonable way to make an informed decision about its accuracy. While "Chexafax" is a mock website, there are several actual websites where students can fact-check rumors and other claims they find online. Using reputable websites supported by empirical science is an important aspect of science literacy and digital literacy. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more scientific knowledge to apply to the scenario, and they can more effectively argue a position on the topic of baby carrots processed in chlorine solutions at the end of the unit.

LESSON 1

What happens when a bath bomb is added to water (and what causes it to happen)?

This Lesson

Anchoring Phenomenon

4 DAYS

We observe different kinds of bath bombs and what they do when added to water. We establish shared norms. We model, at a scale smaller than we can see, what we think happened to the matter that was in the bath bomb and what caused the gas bubbles to appear. We brainstorm related phenomena where adding a solid to water resulted in gas bubbles appearing. This leads us to a broader set of questions that we use to form our Driving Question Board (DQB). We brainstorm possible investigations we could do and additional data sources that could help answer our questions.

Next Lesson

We will investigate bath bombs, measuring their mass in a closed and open system before and after crushing them and before and after we add the bath bomb to water. We will argue from evidence for whether the gas was trapped inside the bath bomb to start with or whether some of the solid or liquid matter that was there to start with changed into a gas.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

1.A Develop a model showing what is happening at a scale smaller than we can see (patterns) to help explain what happened to the matter in the solid bath bombs (matter) and what caused the gas bubbles to appear (matter).

1.B Ask questions that arise from our observations of different bath bombs before and after they were added to water in order to seek additional information about what caused the changes (effects) we saw occurring. This includes what happened to the matter in the solid bath bombs and what caused the gas bubbles to appear as well as what kind of changes are happening to the matter in examples of other related phenomena we raised.

What Students Will Figure Out

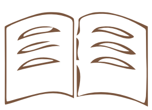
- We have competing ideas for whether the matter in the solid that we started with is still there after it is added to water. Some thought that it was all still there, while others thought not all of it was still there.
- We have competing ideas for where the gas came from that was in the bubbles that appeared. One was that it was there to start with (trapped inside the solid). The other was that it formed from some of the stuff we started with (e.g., in the solid and/or water).

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**INTRODUCE BATH BOMBS AND PREPARE FOR STORE-BOUGHT BATH BOMB INVESTIGATION** Introduce the context of how you got a bath bomb. Help students set up their notebooks and discuss observations they want to record.	A-B	chart paper, markers, Store-bought bath bomb investigation
2	10 min	**CARRY OUT OUR STORE-BOUGHT BATH BOMB INVESTIGATION** Students make observations of the bath bomb before adding it to water and after. Record the noticings and wonderings they share on a piece of poster paper.	C	chart paper, markers, Store-bought bath bomb investigation
3	10 min	**OBSERVE HOMEMADE BATH BOMB INVESTIGATIONS** Introduce the context about making homemade bath bombs and carry out a brief investigation with them.	D-E	tape, Homemade bath bomb investigation
4	18 min	**REPORT PATTERNS IN THE PHENOMENA AND DEVELOP INITIAL MODELS AND EXPLANATIONS** Share out patterns that students noticed between the homemade and store-bought bath bombs. Introduce the goal of developing an initial model and explanation, and have students develop those.	F-I	*What Happens to a Bath Bomb When Put in Water?*, *Initial Model-based Explanation*, 1 piece of notebook paper, chart paper, markers, tape
				End of day 1
5	13 min	**COMPARE INDIVIDUAL MODEL-BASED EXPLANATIONS** Explain the purpose of comparing initial models and explanations, and have students do that in small groups.	J	tape
6	12 min	**DEVELOP SHARED NORMS FOR THE CLASSROOM COMMUNITY** Develop explicit, shared norms for the learning community before students develop their first classroom consensus model.	K-M	*Science Classroom Norms*, chart paper, markers, tape
7	20 min	**DEVELOP AN INITIAL CONSENSUS MODEL FOR THE BATH BOMB PHENOMENON** Stay in a Scientists Circle as students practice norms when they share similarities and differences. Facilitate a consensus-building discussion among students to develop the first classroom consensus model.	N-O	class norms poster, two partially filled out consensus model posters with titles, circles, labels and keys on them (see materials preparation), chart paper, markers
				End of day 2

Part	Duration	Summary	Slide	Materials
8	5 min	**CHOOSE A FOCAL NORM** Ask students to review the norms again and select a norm to focus on for class today.	P	class norms poster
9	10 min	**SHARE RELATED PHENOMENA THAT COULD HELP US EXPLAIN** Record students' ideas of related phenomena and experiences they have had, such as what they saw happen with the bath bombs and also any other phenomena that they think might happen due to similar causes.	Q	chart paper, markers
10	5 min	**DEVELOP INITIAL QUESTIONS** Students develop questions for the Driving Question Board (DQB) individually.	R	3+ sticky notes, 1 marker
11	25 min	**DEVELOP A DRIVING QUESTION BOARD AND REFLECT ON NORMS** Gather students in a Scientists Circle to construct a Driving Question Board (DQB) about what is causing the phenomena students have been thinking about over the previous days.	S-T	extra sticky notes, tape, chart paper, markers
				End of day 3
12	15 min	**CHOOSE A FOCAL NORM AND DEVELOP INITIAL IDEAS FOR FUTURE INVESTIGATIONS** Develop ideas for future investigations or sources of data that could help us figure out our questions. Make a public record of them as they are shared with the whole class.	U-W	printout of the DQB questions, chart paper, markers
13	20 min	**START PROGRESS TRACKER, UPDATE THE TABLE OF CONTENTS, AND REFLECT ON NORMS** Have students reflect on their norms. Provide an example of how to fill out the table of contents in their notebooks to reference each piece of work they developed so far.	X-Y	*Science Classroom Norms*, chart paper, markers
14	10 min	**EXIT TICKET** Fill out an exit ticket about engagement during the discussion about initial ideas for future investigations.	Z	notecard (index card)
				End of day 4

Lesson 1 • Materials List

	per student	per group	per class
Store-bought bath bomb investigation materials			• clear bowl with fresh water • 4 store-bought bath bombs (reuse between classes) • 1 additional bath bomb per class • 1 digital scale • 1 digital thermometer • clear bowl or container such as a plastic shoebox bin with fresh water
Homemade bath bomb investigation materials	• 1 chemical splash goggle	• 3 different homemade bath bombs • 3 clear plastic cups • 3 toothpicks • 1 eye dropper or pipette • 1 digital scale (only if requested by the group) • 1 digital thermometer (only if requested by the group)	• access to water
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *What Happens to a Bath Bomb When Put in Water?* • *Initial Model-based Explanation* • 1 piece of notebook paper • *Science Classroom Norms* • 3+ sticky notes • 1 marker • notecard (index card)	• printout of the DQB questions	• chart paper • markers • tape • class norms poster • two partially filled out consensus model posters with titles • circles • labels and keys on them (see materials preparation) • extra sticky notes

Online Resources

Materials preparation (120, plus 60+ (drying time) minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Gather chart paper, notecards, tape, and markers.

Download *Communicating in Scientific Ways* from the website and post in your classroom and/or add to students' notebooks. It can be used as a poster or a handout.

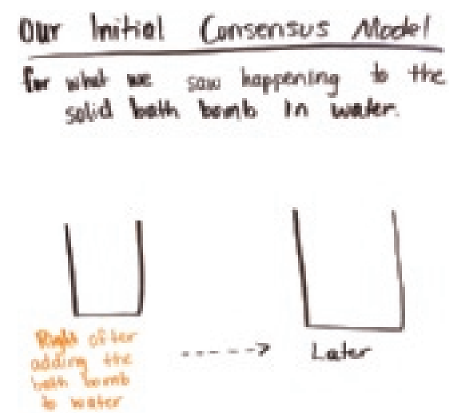
Determine where to set up the Driving Question Board so that students can gather around it.

Print out this copy of all the Driving Question Board questions for all your classes, 1 per group of 2 students.

Trim all handouts to fit in science notebooks.

Prepare two pieces of poster paper for each class for the initial consensus models that you will co-construct. One poster is of the macroscopic view (the side view of the cups) and the other poster is of the microscopic view (with the five circles). You will create the two consensus models for each class. Note that the corresponding colors in both posters match the same parts of the system.

On day 2, for the Initial Consensus model: The colors chosen for the example poster included in the teacher guide for this class model were intentional in order to support students who are color blind to be able to differentiate between the different particles. Since we are working together to figure out what is happening at the particle level and what is different between the particles, it is important that all students can tell the difference between the different particles.



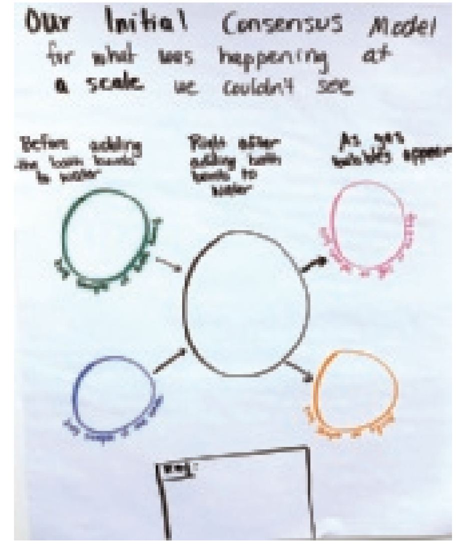
After your last class on day 3: Merge all the questions together on your Driving Question Board into categories that emerge across all your classes. After (or as) you do that reorganization of the board after this lesson, make a record of all the questions that are on the board so that you can print them out for students to reference in groups of three during class the next day. One way to do this is to take a high resolution photo of the board, and another way is to transcribe the questions on the board.

Day 1: Store-bought bath bomb investigation

- **Group size:** Whole class
  - **Setup**
  - For each class, place a clear bowl or container with fresh water in the middle of the Scientists Circle.
  - Have 4 store-bought bath bombs to pass around (reused between classes).
  - Have 1 additional bath bomb ready to be used up per class. (The most total bath bombs you will need are 4 + the number of class sections)
  - Set up this equipment off to the side (in case it is requested): digital scale, digital thermometer
- **Safety:** Consider using an unscented bath bomb if any students have a scent sensitivity.
- **Disposal**: All materials can be washed down the drain with cold or warm water.
- **Storage:** Store unused bath bombs in sealed or closed containers.

Day 1: Homemade bath bomb investigation

- **Group size:** Arrange students into 6 groups of 3–5 students
  - **Setup**
  - Make each of the recipes (A, B, C, and D) for the homemade bath bombs one day prior to this investigation. Watch the video for instructions on how to make one of the bath bomb recipes. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) In addition, see *Recipes for Homemade Bath Bombs* for complete instructions for preparing these. Each recipe will just fill a mini ice cube tray. This will produce 160 bath bombs from each recipe, for a total of 640 bath bombs. For the investigations in this lesson, you will need enough for one bath bomb per student. The extras that you have left over after Lesson 1, can be stored in ziplock baggies or a sealed container for use in later lessons.
  - Make four batches of recipe B. Save three batches for Lessons 2 and 5.
  - Make sure students have access to the following items placed in a common area for this investigation:
    - trays or paper plates with different bath bomb samples on them
    - water
    - 1 splash goggle per student
    - paper towels
  - Make sure you have supplies available so that every student gets at least one of the following:
    - clear plastic cups (wash and reuse between classes)
    - disposable pipettes (can be washed and reused between classes)
    - toothpicks
    - paper plates
  - Set up this equipment off to the side, one per group, in case groups request them:
    - digital scale and digital thermometer
- **Safety:** There are no safety concerns.
- **Disposal:** All materials can be washed down the drain with cold or warm water.
- **Storage:** Store unused bath bombs in sealed or closed containers.



Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

This lesson is meant to draw out students' prior experiences where they have seen solids dissolving in water (relatively common), and more specifically, where that coincides with the appearance of gas bubbles, which is less common (e.g., Alka Seltzer, dental retainer cleaning tablets). Competing explanations will come up for what happened to the solid and why the gas appeared. We hope to foreground all of these competing explanations in this lesson to provide motivation for ideas to pursue that are largely parallel to the ones that are part of what is planned for lessons in the first learning set of the unit.

Competing explanations include:

1. What happened to the solid: Some students will likely claim that the solid melted. Other students will claim the solid is dissolved. Assuming that students have developed the 5th grade DCIs related to both melting and dissolving, students should know that mass is conserved in both processes, and that particles of solids can break apart in both cases. They should also know that you have to warm something up (increase its temperature) to get it to melt (change from a solid to liquid). Therefore, you can leverage this line of reasoning to help students argue that we could determine if the solid melted or dissolved in the water by simply tracking the temperature of the stuff in the system before and after we mix them together. That argument can help motivate taking the measurement of temperature of everything in the system, either in Lesson 2 or in Lesson 4, if that didn't already emerge in Lesson 1. The corresponding slight temperature drop that occurs after adding the solid bath bomb to the water should help provide evidence that nothing is melting in the system.
2. Where the gas came from: Students will identify the bubbles as an interesting aspect of the phenomenon, but don't initially tend to think of those as being filled with gas. It is anticipated that a small amount of additional facilitation and questioning will be needed to help them make that connection (see the learning plan). One possible source students will suggest from their initial models is that those types of particles were there to start with (e.g., they were inside pockets/cavities within the solid bath bomb before it touched the water and were released when it dissolved). A second possible source other students will suggest is that those types of particles formed when the bath bomb (inter)acted with the water, but were not there to start with, and that some of the substances in the system reacted to form something new. This is an idea that the class will develop, and they will uncover additional evidence over the course of this unit after they eliminate other possibilities. A third possible source that students may raise (but is less commonly suggested) is that the gas is the result of the boiling of a substance that was in the system (the bath bomb in the water). There is no need to resolve whether this is happening until Lesson 5, even if your class has the temperature change data (from this lesson or Lesson 2) to refute this explanation. Boiling is a relatively new phenomenon that is not connected to any DCIs students will have developed around particulate models of matter in 5th grade. Understanding that boiling point is a property of a substance is a middle school DCI. In Lesson 5 of this unit, students will narrow in on potential candidates for the type of substances that the gas in the bubbles could be using. Property data will lead them to determine that it is not the result of any of the original substances boiling.

Students should be ready to make connections to what they figured out about the particulate nature of gases from their work in the *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*. We want to use this initial consensus modeling activity to establish what students know about gases (that they are made of particles with lots of space between them). From this, we also want to further elicit what students should know about solids and liquids (particularly water) from a particle perspective. This will help build on what they figured out in the *Cup Design Unit* and *Storms Unit*. In particular, we want to help them recall that in those prior units, they figured out that solids and liquids are made of particles closely packed together. We also want to help them recall the idea that it can be helpful to represent different types of substances (e.g., water vs. plastic vs. other gases in the air) by representing them with different types of particles (e.g., different shapes or colors). This is something they did in the *Cup Design Unit*. We want to help them recall that we can keep track of the same substances (e.g., liquid water and water vapor) by representing the same type of particles (which we often call molecules, as in the case of water) as we did in the *Storms Unit*. Students should be reminded that these are important connections when developing the consensus model. All of this will culminate in helping students articulate two possible sources for the particles that make up the gas in the bubbles.

Where We Are NOT Going

It is not important in this unit that students understand whether dissolving is a physical change or a chemical reaction. It is not important that they figure out what happens to the particles that make up the solid bath bomb as the solid dissolves, beyond the idea that the solid is breaking into little pieces too small to see. It is, however, productive to represent dissolving in the consensus models as "breaking into pieces of matter too small to see and mixing into the water." Do not try to label those as a specific kind of particle.

In the later part of the unit, students will figure out that the substances that made up the bath bombs were made of smaller particles that are atoms. If that idea is introduced by some students, you can, of course, record it, but don't offer any more feedback regarding this possibility versus other ideas that are raised. Do not introduce the idea of atoms making up matter in this lesson, as this is the idea that is new in the middle school grade band. This unit is where that idea is developed for the first time and later lessons will support students in constructing propositions for the idea of atoms making up substances according to the line of evidence they accumulate up to that point in the unit. In addition, though students will be modeling what happens when substances go through a chemical reaction (that the molecules break apart and the atoms rearrange to form a new molecule), the mechanisms underlying how this happens with bonds between atoms breaking apart and the different parts of the atom are above grade band.

1. Introduce bath bombs and prepare for store-bought bath bomb investigation.

7 MIN

Materials: Store-bought bath bomb investigation, science notebook, chart paper, markers

Introduce the context of how you got some "store-bought" bath bombs. If someone ordered bath bombs for you and you test one before class, then you can say something like this to introduce the bath bombs you are about to show them, *I recently got something from the store called a bath bomb. I tried it at home (or school) and found it did something pretty interesting. Have you heard of these? What do you know about them? What are your experiences with bath bombs?*

Display **slide A**. Allow a couple of minutes for students to turn and talk with a partner about the questions on the slide.

- Have you heard of bath bombs before? What is your experience with bath bombs?
- What do you predict will happen when the bath bomb from the store is placed in a bowl of water?

Help students prepare for the first investigation. Bring the class back together. Hold up a sample bath bomb and introduce what we plan to do with it next, saying, *The directions on the package suggest that they are fun to add to water. Let's get ready to take some observations of the bath bombs I got from the store before and after we add one to some water.*

Prepare science notebooks to record noticings and wonderings. Display **slide B.** Have students title a new page in their notebooks and make a T-chart below the title to record what they notice and wonder about the bath bomb.

Science Notebook

If this is the first unit of your 7th grade course and you have not yet set up and organized their science notebooks, you need to include additional time to do so now. Have students organize their notebooks using a format that will be easy for them and you to maintain across the year. Helpful tips for keeping the notebooks organized include the following:

- Number pages so that students can easily refer to their work (e.g., models, data sets) during collaborative discussions.
- Maintain a table of contents and update this table of contents throughout the unit. Plan to reserve at least 2 pages (4 pages front-to-back) for the table of contents for a single unit. The table of contents can be at the front of the notebook for all units within, or at the beginning of each new unit within the notebook.
- Title each page with a recognizable title that can be added to the table of contents, after those artifacts are added to the notebook (students will do this at the end of this lesson).
- After the table of contents, reserve the next 10 pages (20 pages front-to-back) for their Progress Tracker for the unit. This is the place where students will individually reflect on their progress and also add key consensus modeling work completed by the class.

For more information on *Science Notebook Management*, refer to this section of the *Teacher Handbook*.

Then have students bring their science notebooks and sit in a circle on the floor, around a bowl of water in the middle of it that everyone can see. The students should be about 6–8 feet from the bowl of water.

Hold up a store-bought bath bomb and ask students to share what kinds of observations they would like to make of the bath bomb before, during, and after adding it to water. Have students share these ideas with the group.

2. Carry out our store-bought bath bomb investigation.

10 MIN

Materials: Store-bought bath bomb investigation, science notebook, chart paper, markers

Pass some bath bombs around the circle. Hand out four store-bought bath bombs, starting them at different parts of the circle, and have students pass them around in the same direction (e.g., to their right). Tell students to take no more than 20 seconds for each bath bomb before passing it on, and then record anything they notice and wonder about it.

When one of the bath bombs gets back to you, say that you are going to collect all the bath bombs in a minute and then will put one of them in the bowl of water for everyone to watch together, so that each person can add to their noticings and wonderings. To confirm that everyone has examined the bath bombs first-hand, take a show of hands of who has examined them before collecting them.

Prepare to add the bath bomb to water. Say, *Think for a minute about whether there is any additional data you want us to collect before I put the bath bomb in the water.*

Ask for any additional suggestions. Have a thermometer available or scale at a table some distance away from the circle, in case students ask for it. Only use these devices if students suggest the idea of using them now, but don't suggest either of these devices yet if they don't.

As the class is making observations of the bath bomb in the water, ask questions to encourage students to make detailed observations. Some suggested prompts to push students to make multiple observations:

- What are some things you see happening to the bath bomb?
- What are some things you see happening to the water?
- What kinds of observations do you hear?
- For those of you closer to the bowl, do you notice any odors?
- Would a volunteer nearer to the bowl be willing to feel the liquid and tell us what they observe?

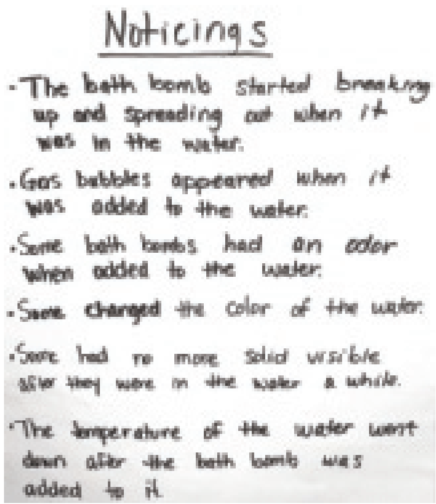
If other students wish to make observations about whether they can smell anything but they aren't close enough, encourage the closer students to move around so others can have a chance, or if the surface the bowl is on is smooth enough maybe carefully push the bowl around the circle so more than one student can make these close up observations (like smell, what it looks like, what it feels like).

Additional Guidance

Encouraging some students to make observations about what the bowl feels like before, during, and after the bath bomb is put in water will help collect some qualitative observations that the liquid gets slightly cooler. Noticing the small temperature drop that happens here is helpful for two reasons. First, if any students suggest that the bath bomb is "melting" in the water, this temperature drop can be used as evidence that it can't be melting. Second, students will be investigating other reactions that release or absorb energy in the next unit, *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit)* and they will recall the bath bombs as another example of reactions that absorb energy. So, if students have other questions about the temperature drop that they notice here, have them add those questions to the DQB so you can come back to them in that subsequent unit.

Measuring the mass of the whole system for the store-bought bath bombs is rather challenging for most science classroom scales since the mass is usually greater than the upper limits of what the scale can measure. But students may wish to measure the weight of the bath bomb before putting it in the water and then they may suggest measuring the weight after adding it to the water. They will realize afterwards that this isn't possible, but it is okay for them to suggest this now.

Facilitate a whole-class Initial Ideas Discussion. After about three minutes, have students report what they noticed. Display **slide C.** List their noticings on a poster titled, "What we noticed about what happened to the store-bought bath bomb." A sample poster is shown to the right.



Key Ideas

Purpose of this discussion: This discussion should be a fluid moment for students to share their observations and consider their initial explanations and questions. The discussion should be grounded in what students notice and find interesting rather than focused on a set question to frame the discussion. Consequently, the emphasis should be on eliciting and recording students' noticings.

Listen for these ideas:

- The solid we started with breaks apart into smaller pieces when it is added to water.
- After a while, the solid we started with is no longer visible (or there is less of it visible).
- Fizzing (gas bubbles) appear around or on the bath bomb when it is added to water.
- Any other observations (such as there is a smell or scent after bubbles appear, a film appears on the water, or the water becomes cloudy).

You might need to introduce the idea of "gas bubbles" when noticings of fizzing or bubbles appearing are first raised by students. If this idea that the bubbles are "gas bubbles" isn't raised, ask students what the bubbles are made of. If they do not suggest bubbles are filled with a gas, suggest the idea that the bubbles must be filled with some kind of gas. For example, you could say, *So we put the solid bath bomb in water, which is a liquid. But after that, a gas appeared in the form of little bubbles.*

Add the addendum phrase "gas bubbles" to the list of noticings if students are in agreement with that idea.

3. Observe homemade bath bomb investigations. 10 MIN

Materials: Homemade bath bomb investigation, science notebook, tape

Preparing for our observations. Introduce the homemade bath bomb context by saying something like, *I have just a few store-bought bath bombs. I realized it would be kind of pricey to buy enough samples from the store for every group to have and experiment with, so I looked up how to make homemade ones. I found multiple recipes with different ingredients and made a large batch of each of those for you to work with. Let's head back to our seats so your group can discuss how you want to work with the materials we have available and what data you will want to collect.*

Have students return to their regular seats.

Display **slide D** describing the materials they will have to work with. Say, *I made bath bombs from four different recipes (A, B, C, and D). I will assign one sample to each person in your group, giving your group a total of at least three of the four possible different bath bombs to test. This will give you a chance to get close to each of these to inspect them before adding them to water and see what is happening when they are in water too.**

Safety Precautions

Review any safety guidelines and have students wear goggles during this and all future investigations in this unit. Emphasize that as we shift to working with stuff that we make ourselves or get up close to investigate, we want to prevent any of it from getting into our eyes because it may irritate or damage them. Review any cleanup procedures and materials you want them to wash out to reuse between classes (e.g., cups).

Some students may have skin sensitivity issues. If this is the case, having non-latex gloves on hand for these students will be necessary and helpful.

Display **slide E.** Share with students all the supplies and tools you have available that they can use to make their observations (i.e., toothpicks, pipettes, thermometers, paper plates, a scale). Give students a couple of minutes to title their observation page and discuss with their groups a plan for what data they will collect. Then each person should be in charge of inspecting the homemade bath bomb they were given and recording data for it.*

Observing the homemade bath bombs. Allocate the remaining time for students to conduct their investigations. This should be relatively quick at this point. Set a timer and tell students the amount of time they have for this (e.g., 7 minutes).

Additional Guidance

There are four different homemade bath bomb recipes so students can see differences in how they behave. When making Recipes A, B, and D you will notice the recipes are similar, with similar consistencies and drying time. Recipe C, with the coconut oil, will feel a little softer than the other three recipes. This is okay. They will still dry and do something when interacting with the water. In addition, students will probably notice that Recipes A, B, and D will behave more similarly to each other when added to water and Recipe C will behave less bubbly and more like it is "melting" into the water. This is okay for them to notice and exactly what should happen when this bath bomb is added to water. The melting point of coconut oil is very low, only a few degrees above room temperature. So when added to warm water, it does tend to melt. Later in the unit, students will figure out that melting point is a property and one way to identify different substances. At this point in the unit, they do not need to know this; they only need to make observations. If you hear them saying out loud that it looks like it is melting, encourage them to be sure to record it in their Notice and Wonder chart.

After this step, make sure to leave 18 minutes after students have cleaned up to go back to their seats for an individual modeling task at the end of the period on the first day.

*** Attending to Equity**
Using four different recipes gives students a chance to compare and discuss their observations with classmates, and allows the class to investigate a wide variety of substances when considering properties of matter.

*** Attending to Equity**
Offering students supplies to *choose* from in planning what data they wish to collect and what observations they wish to make provides them the opportunity to decide what they think will be the most important data to collect. Though the lesson is written for small groups to decide together how to set up a data table for the bath bomb investigation, an alternative to this could be to allow each student to individually decide what data they want to collect based on the materials available to them. Not all students need to do the same observations since multiple students across the class will be investigating the same bath bombs and as a result the class should have a wide range of data for each of the four homemade bath bombs.

4. Report patterns in the phenomena and develop initial models and explanations. 18 MIN

Materials: *What Happens to a Bath Bomb When Put in Water?*, *Initial Model-based Explanation*, science notebook, 1 piece of notebook paper, chart paper, markers, tape

Reporting patterns in the whole-group discussion. Display **slide F.** Take three minutes *or less* to have student volunteers share how the homemade bath bombs compared to the store-bought ones.

Suggested prompts	Sample student responses
What things were the same as compared to the store-bought ones?	• *They all were solids to start with.* • *They all broke apart in water.* • *Gas bubbles appeared in both.*
What things were different between them or between them and the store-bought ones?	• *They had different smells.* • *They had different colors.* • *Some broke apart easier than others.* • *Some felt smoother or oilier.* • *Some left a film in the water and some did not.*

Foreground two aspects of the phenomena that were common. Say, *It seems like there were two things we noticed that were common across all the experiences that we should try and explain:*

- *The solid was no longer there after it was in the water, and*
- *Gas bubbles appeared around it for a bit after it was added to the water.*

Represent what happens at the macro level.* Ask students to represent these changes that occured to the matter over time when the bath bombs were added to the cup. Display **slide G.** Pass out a copy of *What Happens to a Bath Bomb When Put in Water?* Give students 3 minutes to do this.

Develop an initial model. Pause student work. Display **slide H.** Orchestrate the labeling of their drawing on *What Happens to a Bath Bomb When Put in Water?*, in concert as a class, as outlined on slide H. Ask all students to point to the part of their model where each of these are represented. When you see each student doing that, ask them to draw an arrow pointing to that location and label the arrow with the corresponding letter (A through D):

A. Pointing to a spot in the bath bomb before adding it to the water.

B. Pointing to a spot in the water right before adding the bath bomb to it.

*** Supporting Students in Three-Dimensional Learning**

This is an opportunity to pre-assess students' engagement in all three dimensions of NGSS to explain a phenomenon. There are prompts in this task that ask students to engage in two elements of the modeling practice related to representing descriptive aspects of the phenomena as well as unobservable mechanisms. Students are prompted to explain the mechanisms that caused the observable changes, which will provide an opportunity to bring related DCIs from grade 5 and the middle school grade band to the explanation (such as melting, dissolving, or reacting/interacting with other materials). There are phrases in the prompts that ask students to consider related elements of CCCs, particularly patterns (at a particulate scale), matter, energy, systems, and system models.

*** Supporting Students in Developing and Using Energy and Matter**

The prompt on **slide I** foregrounds thinking that students have done numerous times in two prior units in 6th grade, *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times*

C. Pointing to a spot in the liquid remaining in the cup a few minutes after adding the bath bomb to the water.

D. Pointing to a spot inside of a gas bubble a couple seconds after adding the bath bomb to the water.

As students are labeling these, hand out a copy of *Initial Model-based Explanation* to each student. Don't have students put this handout in their notebooks yet. You will be collecting them at the end of the period.

Read through **slide I** with the students.* Have students point to where A, B, C, and D are shown in *Initial Model-based Explanation*. Tell students that in each of the circles in Part 1, they should model what they picture they would see happening if they could zoom in to that part of the system. Give students five minutes to develop this model.

Use the model to develop a written explanation. Then pause students again and direct them to Part 2 of *Initial Model-based Explanation*. Instruct students to use their model to help them develop an explanation to answer these two questions on the bottom of the slide:

1. What happened to the solid bath bomb?
2. What caused the gas bubbles to appear?

Let students know they will have an extra five minutes in the next class to add to their explanations and models. Collect *Initial Model-based Explanation* before the end of the class.*

Assessment Opportunity

Building towards: 1.A Develop a model showing what is happening at a scale smaller than we can see (patterns) to help explain what happened to the matter in the solid bath bombs (matter) and what caused the gas bubbles to appear (matter).

What to look for: This first model students develop on *What Happens to a Bath Bomb When Put in Water?* is more representative of what they see happening with the bath bomb at a macrosopic level. Therefore the particle level representations may not be included at all, or may be minimally included. They will develop a second model of this at a microscopic, or particle level next in *Initial Model-based Explanation*. Look for the following elements across their models and explanations to see if they bring these ideas to the table with the prompts for the task as written:

- **Particle-level representations:** Different types of particles in different parts of the system or at different points in time. Students may use other words to describe changes happening at the particle level as well, includings particles speeding up, spreading apart or coming together, colliding, breaking apart from other particles, and mixing in between other particles.
- **Unobservable mechanisms** labeled/referenced for two aspects of the phenomenon: Changes in the solid: through a process such as melting, dissolving, or reacting/interacting with other materials. Appearance of a gas: through a process such as the "release of a gas" from pockets in the solid, evaporation, boiling, or a new substance being produced that wasn't there before from some of the matter that we started with.

and not others? (Storms Unit). If students ask for clarification about this prompt, remind them that they have used this sort of thinking about systems and matter at a scale too small to see in *Cup Design Unit* and *Storms Unit*. One unit was about trying to figure out how to keep a drink cold or warm in a container, and the other was about trying to figure out why it hails, rains, or snows sometimes but not others. If this is the first unit for your students, you may need to explain that the system consists of all the stuff in the bowl of water before the solid bath bomb is added to it, right after it is added, and a few minutes later.

* Supporting Students In Developing and Using Systems and System Models

Students use their models in *What Happens to a Bath Bomb When Put in Water?* and *Initial Model-based Explanation* to represent systems and their interactions. In these two models students represent the matter inputs and outputs in an open system (a bowl of water) in their initial models. The two models students develop are designed to foreground accounting for where the matter in the system went to and open up the possibility that maybe the matter in the system wasn't conserved (even though it was). At the end of this model

What do to: Make a copy of these explanatory models and compare them with what students show in their individual model and explanation at the end of Lesson Set 2. You may also want to have students compare their growth by comparing these artifacts as well, related to the elements mentioned above.

development, the processes we are trying to track—what we started with (inputs) and what we ended with (outputs)—as well as what happened in between, help lay the groundwork for a representation of reactants vs. products in chemical reactions that students will uncover in the later half of the unit.

End of day 1

5. Compare individual model-based explanations.

13 MIN

Materials: science notebook, tape

Reorient students to the initial models and explanations they developed. If you have collected students' initial model-based explanations, return them to the students and have them secure them to pages in their notebooks (e.g., with glue or tape).

Students review and revise their initial models and explanations from the previous class. Display **slide J**. Give students 5 minutes to review their models and explanations and add any further details or ideas.

Prepare to compare individual model-based explanations. Take a moment to have a short conversation about why we want to look at each other's models and explanations. Ask students:

- *What can we learn from looking at each other's initial ideas in their models and explanations?*
- *What if someone has different ideas than yours?*

Reinforce students' ideas by saying, *We want to use our time to see what other people in the class are thinking and how they are thinking about the cause of the changes we saw in the bath bombs last time. We don't need to have the same ideas because we all think differently. But we can learn from one another by closely looking at our classmates' work.* * *We are going to use this time to study their work closely and see if it helps our own thinking.*

Compare models and explanations in pairs. Tell students that the purpose of the next activity is to compare models and explanations, and use them to note similarities and differences in the way each person is thinking about what happened to the solid bath bomb. This includes why the bubbles appeared, paying particular attention to any changes to the matter in the system that were happening at a scale that is too small to see.

Share examples and non-examples of productive comparisons (e.g., a non-productive example would be focusing on the artistry of the drawing or diagram; a productive example would be noting how other students talked about why the bubbles appeared where they did).

Students, working in pairs, will take turns sharing their work. As the group notes similarities between the diagrams, they can make a small check mark on their diagram noting that it is similar to a diagram by another member in their group. If they have a different thing, or the group is confused about part of the system, they can mark those parts of the diagram with a question mark. The groups do not need to achieve consensus at this time.

*** Attending to Equity**
This is an important opportunity to emphasize that each individual has contributions to make to their community of learners. It is through differences in thinking that the class will grow their knowledge together. Throughout this unit, students will be asked to be open to sharing knowledge products that depict their current thinking and to be open to learning from classmates who share their knowledge too.

6. Develop shared norms for the classroom community.

12 MIN

Materials: *Science Classroom Norms*, science notebook, chart paper, markers, tape

Form a Scientists Circle. Ask students to assemble their chairs in a circle and to bring their science notebooks and something to write with. They will be in this circle for most of the class session. Ideally, they will need to be able to see the slides and have access to a whiteboard, but if that is not possible, the whiteboard (or chart paper) will be more critical for the rest of the class.

Scientists Circle

Scientists Circle

You will form a Scientists Circle in many future lessons as well. Setting up the norms and logistics for forming, equitably participating in, and breaking down that space is important to do if this is your first time forming such a space. Having students sit in a circle so they can see and face one another can help build a sense of shared mission and a community of learners working together. Returning to this Scientists Circle throughout the course of the unit to take stock of what the class has figured out and where they need to go next will be an important tool in helping the class take on greater agency in steering the direction of their learning. This circle will also help build a sense of pride in their work. You may want to inform students that professional scientists collaborate with one another to brainstorm, discuss, and review their work also.

Additional Guidance

Setting norms is an important part of supporting a collaborative and safe learning culture. We wait to set these norms until the second day of the lesson though so students will have had time to interact with the phenomenon and have some observations and questions to share. Here on day 2 of the lesson, we start class in our first Scientists Circle to share out what we have observed, but before taking turns to share with each other, we need to set the expectations so we will all be listening to each other. If you feel setting norms should come before engaging with the anchoring phenomenon, you are encouraged to begin your school year with a norms discussion, then begin the anchoring phenomenon.

Introduce the task to develop an initial class consensus model. Tell students that next, we'll try to identify areas of agreement and areas of uncertainty across all of our models and explanations. The purpose of introducing the consensus task before talking about classroom norms is to get students thinking about how difficult it will be to get all members of the learning community to agree. It is also important to think about how we want to make sure everyone is included and everyone's voice is heard.

Introduce science classroom norms. Tell students that before the class moves on to this next step in our work, it is time for the class to set up some norms for how the class wants to work together and learn together in science class. You may want to reiterate productive behaviors you witnessed on the first day of this lesson (Lesson 1) as a way of communicating to students that they were already operating using some positive norms, but they had not yet talked about them.*

*** Attending to Equity**
It is important to use this norm building time to begin to cultivate an equitable learning community that promotes trusting and caring relationships. The norms should reinforce the value of diversity of the classroom community members, and equity in the sense-making work they will do together this school year. It is critical that the norms support safe and fair participation and interrupt cultural norms or stereotypes that could make science experiences feel uncomfortable to students (e.g., as being someone who is not intelligent enough to think like a scientist, who has trouble putting their thinking into writing, who cannot do the relevant math, or who cannot share their thinking).

Alternate Activity

When setting up community norms, it should be explained to the students how norms help everyone in the community understand what is expected of them. Two approaches to setting up norms include:

- Give students a set of norms as a starting point (the default approach written in the learning plan below). Share a set of community norms with students and provide space for students to edit or add to the norms if students believe something is missing and to share what each can look and sound like.
- Co-construct norms with students (the alternate approach). Explain what norms are and why we need them for productive science talk and classroom culture. Have students co-construct norms, first sharing ideas in small groups, and then sharing with the whole class. Compile a list of agreed-upon community norms. As the teacher, you can add norms that may be missing from the list. Make sure to explain to students how you think the norm you added is helpful, so that they are clear about why you are adding it to the list.

In selecting which approach to use, consider the following questions that can help you determine which approach is best for your situation:

- Do you want students to participate in co-constructing the norms?
- Do you want the same set of norms for every section of science you teach?
- Do you want to work with your team teachers to establish a shared set of norms for students across all their classes?
- What kinds of consequences will you enforce if students do not follow the norms?

Display **slide K** and pass out *Science Classroom Norms*. (Note: Edit the handout as desired.) Many students may not know what a "norm" is, so tell students that norms are something that we all agree to try and work on so that we have a productive and respectful learning environment. They are similar to rules, but are intended to ensure that all students have a positive learning experience in science class. These are things that we collectively decide upon as a community about how learning will happen best and what we want and need to hold each other responsible for upholding.

On the slide are a set of norms that are a starting point for the class. It is important to talk through each one with students and ask them to provide an example of the norm or paraphrase it. The purpose of this is to develop a shared understanding of each norm. Also, provide opportunities for students to clarify a norm, ask for a modification, or develop a new norm. Allow students to write on their handout if the class decides to change something. Norms are intended to be shared by the students and teacher, so even though a set has been provided, it is just a starting point for students. Making the norms public and visible in the classroom is encouraged. This can be done on a poster.

Choose a norm to work on for the rest of class. Display **slide L**. Ask students to read through the norms one more time and nominate one norm that may be particularly challenging to follow if we are out of practice and require that we must work at it intentionally to get good at it. Discuss a strategy or two that could help everyone adhere to it. Then, before the students end their conversation, ask them to look at the sheet and pick one norm that they personally will work on for the rest of class. They should share the norm with a partner and tell the partner why that norm is important for them.

Display **slide M**. Before moving on to the next step, let students take a moment to cut and paste the *Science Classroom Norms* into their notebook (or you can wait until they break from the Scientists Circle and return to their desk).

Additional Guidance

If there are many edits, you may choose to modify the document and reprint it for students before they paste it into their notebooks. It will be important for the norms to appear early in their notebook. Consider pasting it to the inside cover of the notebook so that it is easily and often seen by students. Also, be sure to have a public place where the norms are posted on the wall so that students can easily refer to it.

7. Develop an Initial Consensus Model for the bath bomb phenomenon.

20 MIN

Materials: science notebook, class norms poster, two partially filled out consensus model posters with titles, circles, labels and keys on them (see materials preparation), chart paper, markers

Display **slide N**. Let students know that the class is now ready to have a consensus-building discussion.* Tell students, *Remember that the goal of this discussion is to figure out areas of agreement and disagreement in the initial models. Knowing where we agree and disagree will help us to figure out what is happening in the bath bomb phenomenon. We also want to use this time to practice our norms with one another.*

Key Ideas

Purpose:

- Develop an initial class consensus model to capture the ideas we agree and disagree on or are more uncertain about to explain what happened to the solid bath bomb and why the gas bubbles appeared.
- Reflect on what we know about matter from previous units (i.e., liquid water is made up of many water molecules, water as liquid and gas, mixtures—like air—are made of different types of gases, different states of matter, spacing between particles).
- These questions are setting us up for the practice of argumentation in Lesson 2. Identifying possible areas of disagreement or controversy is what motivates finding evidence for or against these ideas.

Listen For:

- Areas of agreement for what we think is happening to the matter at a scale too small to see (zoomed-in views)
    - **There are small pieces (particles)** that make all the matter in the system, including: (1) the solid bath bomb, (2) the water we start with, (3) the liquid we end with, and (4) the gas in the bubble.
- Possible areas of disagreement/controversy
    - **Types of particles:** How many different kinds are in the solid? Are the particles in the gas the same kind of particles that we started with (e.g., water vapor)?
    - **Changes occurring in the solid**: Is it melting, dissolving, or reacting/interacting with other matter in the system?
    - **Appearance of the gas:** Was the gas released from pockets in the solid vs. evaporation or boiling vs. a new kind of material that wasn't there before?
    - **Spacing, speed, or particle interactions:** Are the particles changing speed or spacing, colliding, sticking, or breaking apart from other particles and mixing in between other particles?

*** Strategies for This Consensus Discussion**

Since this is our initial consensus model, we want to capture our competing ideas. For example, in the zoom-in circle for the solid bath bomb you might draw particles close together and particles close together with something in between the particles. Use question marks to help show that this is where we have some different ideas. Be careful not to favorably respond to any one idea over others so as not to give away what might be going on in the phenomenon. The class can return to the model and evaluate their initial competing ideas as they gather more evidence throughout the unit.

*** Attending to Equity**

The colors chosen for the example consensus poster included here in the teacher guide (and in subsequent lessons in this unit) are color blind friendly meaning that students who are color blind should still be able to distinguish between the different shades of

Ask about areas of agreement. Ask students about what they put in their zoomed-in views that were similar to what other students provided. You should be able to establish agreement around the first item above in the "Listen For's".

Suggested prompts	Sample student responses
What did you notice was common in how other people represented the different kinds of matter in the system in the zoomed-in circles?	*We used particles to represent these different kinds of matter.*
Is this something everyone showed?	*The gas particles were spread apart further than the solid and liquid particles.*
Do we agree that it makes sense to include this based on what we know about the nature of matter in solids, liquids, and gases?	*We used a different kind of particle to show that water was different than what was in the solid or the gas.*

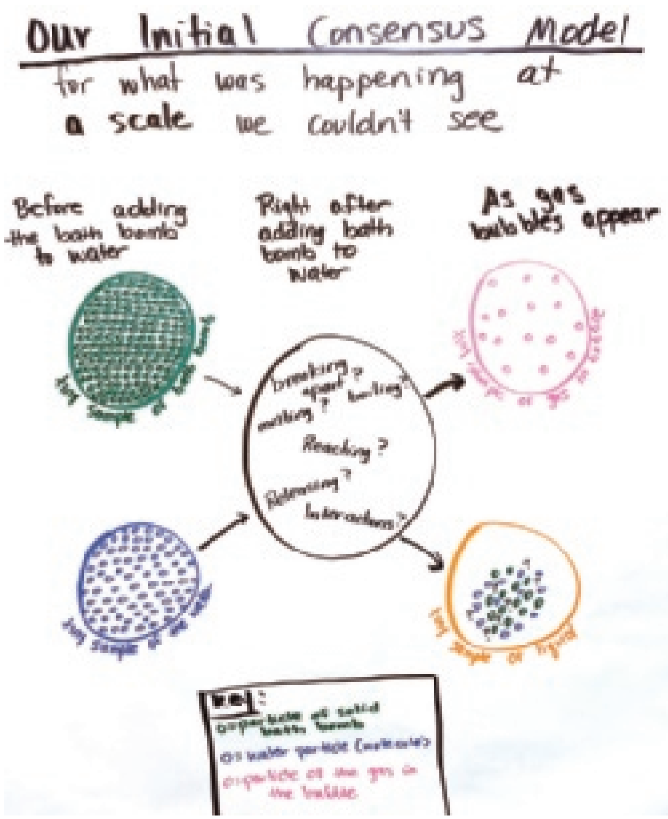
Work through the locations in the model in this strategic order:

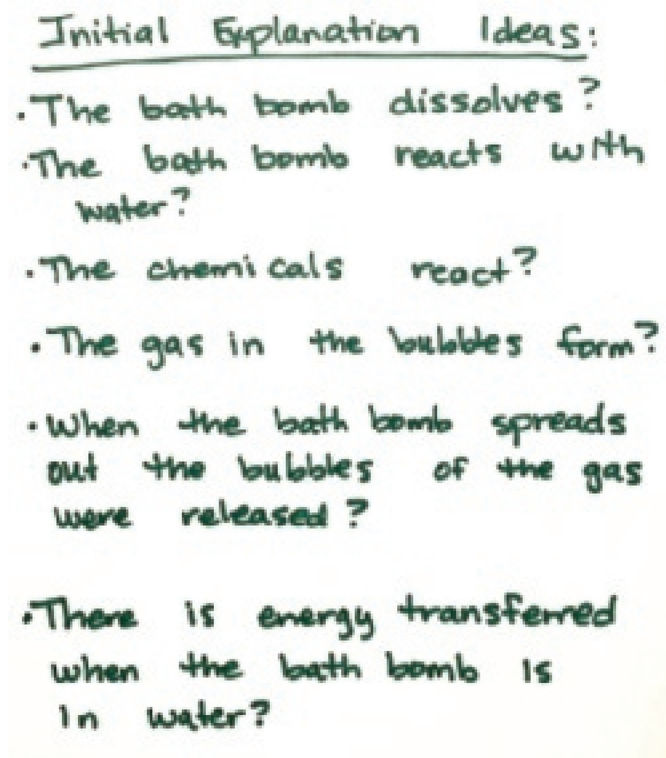
- Start with the zoom in of the bath bomb, in circle A on the top left. Students will likely say that we should model the particles of the solid as being closely packed together. This is how they have modeled solids in *Cup Design Unit* and *Storms Unit*. But, there may be multiple areas of disagreement about the homogeneity of the solid that will be productive to capture such as:
  - Is it made of the same type of particle throughout or different types (based on observations they made of the solid bath bomb)?
  - Is it solid throughout or are there cavities of trapped gas?
- Move to circle B next, bottom left. This zoom-in is likely to have the least controversy around a particle model, due to students' prior experiences with modeling liquid water particles as circles in *Cup Design Unit* and *Storms Unit*.
- Move to circle C next, bottom right. Students will likely say that some of the water is still part of the liquid and that something else is in the liquid that wasn't before (that makes it cloudy or oily). This should help establish that this liquid is probably a mixture of water and something else. Representing mixtures is something students have done in *Storms Unit*. This will allow you to establish that there is at least a second type of particle mixed in between the water particles.
- Move to circle D next, top right. Students will likely say that there are particles spread far apart in the gas. They have modeled air this way in *Cup Design Unit* and *Storms Unit*. Where there is likely to be some controversy is what type of particles is the gas made of. Air particles? Bath bomb particles? Something else?
- End in the middle circle. This is where you will want to capture competing mechanisms for what is happening at a particle level to cause these outcomes. In the diagram below, notice how the competing mechanisms are listed both in the center circle and in a larger poster, so they can be read more easily.*

colors. If you know you have color blind students, using similar colors and/or using different shapes for each particle will be helpful so they can differentiate between them. There are many websites that have information about what colors are useful for different color blindness. Marker sets that have more color choices will have enough different shades of color that can be used so students who are color blind can still distinguish between the different colors.

*** Supporting Students in Engaging in Developing and Using Models**

Emphasize to students that they will develop and use models for a purpose in science. Scientific models are dynamic and change as new information is learned, and models need to be "applied" to explain phenomena or design solutions to be considered useful. We develop and use models not just to be able to describe something that happened, but also to be able to come up with a way to explain how and why it happened or to accurately predict what will happen or to engineer a way to make it happen differently. Avoid asking students to simply repeat back an element of a model or even an entire model as an inert fact.





Frame what we accomplished.* Once these ideas are captured in these posters, step back and introduce students to the idea that they just developed an initial consensus model. Explain to students that scientists develop and use models to understand and explain phenomena and to clarify areas of uncertainty and limitations in their current understanding. They then try to refine that model by doing additional investigations and collecting additional evidence. Over time, they try to test the model to see how many other related phenomena it can also explain.

Debrief how we did with our focal norm. Display **slide O.** Have students talk and share how they did with the norm they selected. Ask students, *How did the norms help us talk together and come up with some ideas of what we think is happening*? Allow a few students to share, and tell students they will continue to work on the norm.

End of day 2

8. Choose a focal norm.

5 MIN

Materials: science notebook, class norms poster

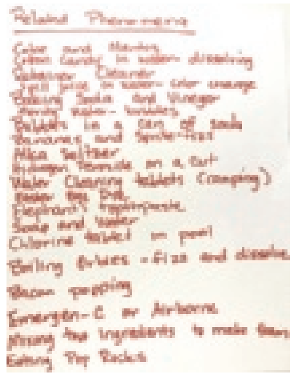
Choose a norm to work on today. Display **slide P.** Direct students to look over the norms chart once more. Ask them to silently choose a norm to intentionally work at and monitor for themselves in class today to help our learning community grow stronger and more productive for everyone.

Connect to the work students did yesterday. Say, *Look back at the initial consensus model we developed. When we did that, we were trying to explain why certain things happened with the bath bomb. But scientific models are most powerful when they can help explain a wide range of phenomena. Let's start thinking about whether the items we have shown are applicable for trying to explain other things we have observed in the world.*

9. Share related phenomena that could help us explain.

10 MIN

Materials: science notebook, chart paper, markers



Reflect on related phenomena. Display **slide Q**. The purpose is to have students think of experiences that they have had that reminds them of what they saw happen with the bath bombs and to also brainstorm any other phenomena that they think might happen due to the same sorts of things that caused the bath bomb to behave how it did.

Share related phenomena and experiences. Start the conversation by having students share with the whole group. Encourage students to snap their fingers if someone mentions a phenomenon that they also have observed.

- What other experiences have you had that the bath bomb reminds you of?
- What other phenomena might happen due to the same sorts of things that caused the bath bomb to do what it did?

Record a bulleted list of what students share on chart paper like the one shown to the right. After making this list, link it back to the classroom consensus model. Say, *As we revise and refine our model to try to explain what is happening with the bath bomb in future investigations, let's keep in mind these other phenomena too, so that we can see if the model we develop can be used to explain any of these as well.*

10. Develop initial questions.

5 MIN

Materials: 3+ sticky notes, 1 marker, science notebook

Introduce the goal of building a Driving Question Board (DQB). Tell students that we are going to capture all of our questions today. The purpose of this work is to use all of our individual questions to determine what it is we want to figure out as a class. To do that, we need to prepare to get all of our questions shared and represented on a single board, which will be called our Driving Question Board.

Write individual questions. Display **slide R**. Pass out 3 sticky notes and a marker to each student and encourage them to take time to review their Notice and Wonder charts from the bath bomb investigations, their initial models, the class consensus model, and the list of related phenomena. In addition, suggest that students think about questions they have that might help address some of the areas of disagreement in making the consensus model. Tell students that their questions can be related to any of these things as well as any new related phenomena that come to mind. Remind students that it will be part of our class mission to try to answer these questions.

Give students the next few minutes to write their questions. Remind them to use a pencil to put their initials on the backs of the cards. If they have time to write additional questions and wish to do so, pass out additional sticky notes.

Assessment Opportunity

Building towards: 1.B Ask questions that arise from our observations of different bath bombs before and after they were added to water in order to seek additional information about what caused the changes (effects) we saw occurring. This includes what happened to the matter in the solid bath bombs and what caused the gas bubbles to appear as well as what kind of changes are happening to the matter in examples of other related phenomena we raised.

What to listen for: Listen for questions that are open (how/why) and testable versus closed (yes/no) in the classroom. Also listen for questions that are specific to the bath bomb and questions that are about related phenomena when solids are added to liquids.

What to do: Since students will put their initials on the backs of these sticky notes, you will have a few opportunities to take stock of the kinds of questions students ask in this initial lesson after they are posted on the DQB, as well as now when they write them. When students share these questions for the DQB, they will likely only have time to share one. Collect the remaining questions that don't get posted after the development of the DQB is complete. This record of questions they form today will help you formatively assess their fluency in the practice at the start of this year. If your students are asking mostly closed questions, you can provide a copy of a photo of the questions on the Driving Question Board, and ask them to work on refining three or more of these questions so that they become "how" and "why" questions that can help answer the original question posted as well the original yes/no question. This could be an in-class or home-learning assignment. For practice (e.g., exit/entrance ticket) the following two questions can be answered at the end or start of any future lessons:

- What questions were raised for us (now or from the end of the last lesson)?
- How might we investigate one or more of those questions using equipment in our classroom to collect our own data or using data that other people have collected in other places?

11. Develop a Driving Question Board and reflect on norms. 25 MIN

Materials: extra sticky notes, tape, chart paper, markers

Gather in a Scientists Circle around the DQB. Display **slide S.** Instruct students that when they have their questions ready, they need to bring them along with chairs to meet in a Scientists Circle around the DQB. Remember that the posters for the initial consensus model and the related phenomena poster should be near where the DQB is built.

Explain to students how you will create the DQB.* Use **slide T** if needed.

- The first student comes up to the DQB with his or her sticky note, faces the class, and remains standing.
- The student reads his or her question off of the note and then posts it on the DQB near the section of the model it is most related to.

*** Attending to Equity**
A Driving Question Board (DQB) provides a public representation of the joint mission of the class. Students can share their questions and wonderings with one another, and the visual representation offers another modality for students to access science in the classroom.

- The student selects the next student.
- The second student reads his or her question and posts it on the DQB near the section of the model it is most related to. The student also says what other question on the board it relates to and why or how. The student selects the next student.
- This process continues until everyone has had a chance to post a question.

Additional Guidance

Helpful teacher notes

- If a student forgets to explain why or how their question is linked to someone else's question, press that student to try to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off each other's ideas and to help scaffold student thinking.
- Don't worry if some questions are raised that are not part of topics in this unit. Over time, students will get better and better at forming testable questions in the scope of the driving question. This type of activity gives them practice at doing that.
- If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.
- If a question is similar to (or the same as) another one, have the student place it on top of the question that is similar so other students can visually see how many of the questions are the same or related. Emphasize that this provides us with evidence of where many people are thinking about similar things.

Organize questions into categories. As students share, clustering of questions with similar themes will naturally start. Once students have finished their sharing, ask them to consider, *What are some categories or themes we see in the clusters of questions?*

Five to six themes or categories will probably emerge. Use the categorization that the class suggests to put up a temporary half sheet of colored paper that has that category written on it in that space. If you have a single space for a DQB that will be shared across multiple classes, it is suggested that you will keep these up temporarily for each individual class and then try to merge the categories that other classes suggest too. The example board shown above is from an early pilot of the unit. It is recommended that you create the category of "Gas bubbles" rather than "Fizzy" as shown above. Temperature emerged as a category for these classes, because a few students felt the liquid cooling as the bath bomb dissolved, and some measured its temperature. That category may not emerge in every class.

Propose a suggested driving question for the entire board, starting with this one: "**Can we make something new that was not there before?**" Suggest the question of whether the gas that appeared in the bubbles was something that was there or not to start with. Share that this question seems central to lots of our related questions, which is why you are suggesting this question. Point out that although this is not a how or why question, maybe we can revise it within a few lessons to become one, after we make some progress on this question first.

Additional Guidance

You will suggest revising the driving question to include the word "How" at the front of this question at the beginning of Lesson 3 in light of what students figure out. At that point, the driving question will change to, "How can we make something new that was not there before?"

Before the next group of students comes in, make a record of these categories and erase them as well as the driving question, or hide the entire board and start with a fresh one for the next group of students you teach this lesson to.

After your last class on day 3, merge all the questions together on your DQB into categories that emerge across all your classes. After (or as) you do that reorganization of the board after this lesson, make a record of all the questions that are on the board that you can print out for students to reference in groups of three the next day. One way to do this is to take a high-resolution photo of the board, and another way is to transcribe the questions on the board.

Print out this copy of all your classes' DQB questions, 1 per group of three students. Save this as a digital file as you will need to print copies of it in future lessons.

End of day 3

12. Choose a focal norm and develop initial ideas for future investigations. 15 MIN

Materials: science notebook, printout of the DQB questions, chart paper, markers

Choose a norm to work on today. Display **slide U**. Direct students to look over the norms chart once more. Ask them again to silently choose a norm to intentionally work at and monitor for themselves in class today to help our learning community grow stronger and more productive for everyone.

Connect to the work students did yesterday. Say, *Let's get ready to look again at the Driving Question Board we developed. It represents our joint mission. We now need to think about how we can make progress on the questions we developed last time. I merged the other classes' questions together with ours and tried to show the common clusters of categories of questions across all the classes. I made a printout of these for you and your partner to refer to.* Pass out copies of the printout of the DQB questions you made.

Display **slide V**. Have students work on developing their own ideas for investigations for a couple of minutes first and record these in their notebooks, and then have the students talk to a partner about ideas for future investigations that address their partner's question(s) and other questions on the Driving Question Board.

Share ideas for investigations. Display **slide W.** Reconvene in a Scientists Circle, having each person sit next to their partner. Ask students to share their ideas with the whole group, recording a list of ideas for investigations that will remain public throughout the unit.

*** Attending to Equity**
Using the marker strategy or other object for passing around from student to student allows for equitable sharing among all students and gives them an opportunity to piggyback on another student's idea. Try to provide time for a second pass through the class because students may have additional ideas as they are listening to other students. If time is short, revisit this activity at the start of Lesson 2.

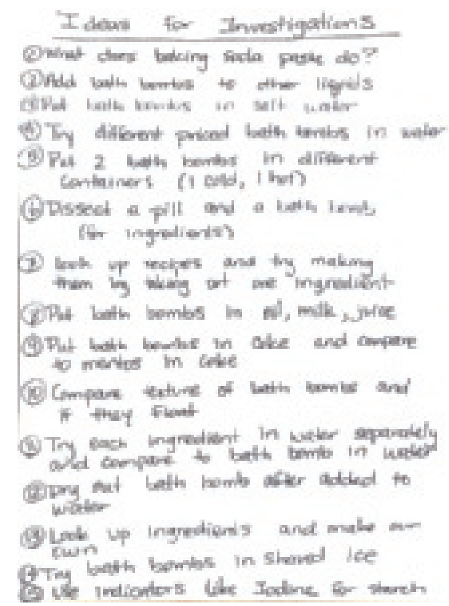
To ensure that all students share ideas, say, *To make sure we have everyone's ideas up here, I will pass a marker to the first person on the edge of the circle. The student with the marker should share one idea they have. I will write it up and number it. That student should pass the marker to the student next to them. The second student then shares an idea. If the idea is on the poster already, the student should identify which idea is similar and how it is similar. I will then put another tally mark next to that idea.** In this way, the marker is passed all around the circle, and all students have a chance to have their thinking represented on this poster. Offer to students that if they have additional ideas that don't end up on the poster, they can raise their hand after we have heard once from everyone in the class (after the marker makes it all the way around the circle). Emphasize to students that the Ideas for Investigation poster can change throughout the unit as they learn more. If students think of new ideas along the way, ask them to jot them down to add to the poster.

Additional Guidance

Help to elicit student ideas for investigations by doing the following:

- Put up the Ideas for Investigation poster next to the DQB to jot down these new ideas. As students are sharing their ideas, add tally marks next to any ideas that are repeated to keep track of common ideas among students.
- Encourage students to think about their questions and see if they have an idea to investigate a specific question or group of questions.
- Emphasize that the list is our draft set of ideas for what we want/need to do that we think might help us answer our questions. We may not do all these things, but we will try to do similar-type investigations. We can add to this list and our DQB throughout the unit as we go.
- Also, encourage students to think about things that could be investigated to help address some areas of disagreement we have as a class.

A sample poster is shown here.



Notice that in both posters, the ideas that were common to both classes of students are the ones that map closely to the work they will be doing in Lessons 2 through 4, which include the following:

- Look up the ingredients used to make the bath bombs.
- Test the ingredients separately.
- Try bath bombs (or the ingredients in them) in different liquids (e.g., the olive oil or baby oil that is an ingredient in the homemade recipes for some of the bath bombs).

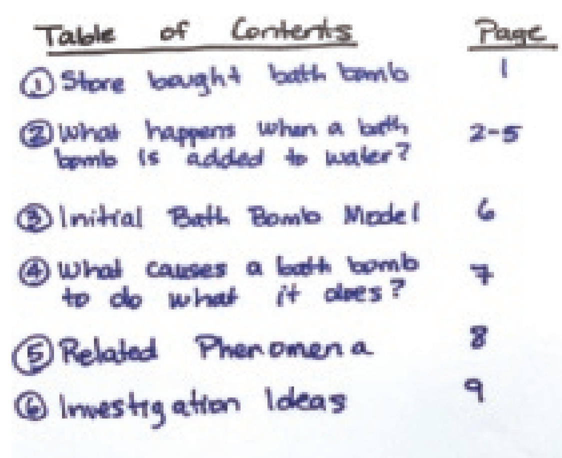
Additional Guidance

Keep in mind that this list is simply a set of "initial draft ideas." Given more time and additional learning experiences, you will see students' ideas shift. They will think of new things to investigate that will become targeted at answering the most pressing and relevant questions emerging from their work at that point in the unit. Knowing that you will be able to deliver on a few of their initial suggestions right off the bat can provide a powerful sense of shared enterprise and agency for students. But you will need to remind students that these were their ideas in order for them to recognize it when you get to the start of Lessons 2, 3, and 4. A way to foreground this is to post a public record or revisit this Investigation Ideas poster any time the thing you are about to do is going to deliver on any of these ideas in subsequent investigations when you get to them. You can do this by putting up a sticky note with a check mark near the idea they listed on the poster when they start work on that sort of investigation, and then remind them that this was an idea that they came up with.

Once this poster is built, help students realize and get excited about the fact that they created a joint mission and proposed action plan to guide the work of their learning community for weeks to come. You may want to say something like this to emphasize that message, *Wow. We have accomplished so much. We now have a mission to accomplish as a class, thanks to all the questions you shared and how you connected them. These questions represent what we hope to be able to figure out. And we have a lot of ideas for investigations and sources of data we can work with to try to figure this all out. I am very excited for us to get started investigating all of this. I have a lot of additional data, materials, and equipment for us to use that is well matched to many of the things you identified we need. Let's plan to start working with some of those next.*

13. Start Progress Tracker, update the table of contents, and reflect on norms. 20 MIN

Materials: *Science Classroom Norms*, science notebook, chart paper, markers



Update the table of contents with students. Say, *But before we start on our investigation ideas, let's organize the work we have done so far.*

Display **slide X.** Remind students that we reserved at least 2 pages (4 pages front-to-back) for the table of contents for this unit. After the table of contents, they should have reserved the next 10 pages (20 pages front-to-back) for their Progress Tracker for this unit. This is the place where students will individually reflect on their progress and also add key consensus modeling work completed by the class.

Organize the table of contents. Have students update their table of contents and page numbering to include references to all the work they have done so far. Develop a sample table of contents with students on a poster to show one way to name the work they have in their notebooks and reference the related pages it is on. Remember to have students start the page numbering after the 10 pages reserved for their Progress Tracker section and to only make a table of contents for the work after the Progress Tracker section.

Have students finish numbering the rest of the pages of their notebook.

Science Notebook

If this is the first unit of your 7th grade course, you may also want to remind students to update their notebook on days when you have some extra time available. It is recommended that you make time to have students update the table of contents whenever they are adding to their Progress Tracker for the unit. This will happen individually at the end of most lessons, and collectively at other key points in the unit. This periodic time for organization helps students look back on the trajectory of their learning journey. For many students, this is a helpful way to support coherence.

For more information on *Science Notebook Management*, refer to this section of the *Teacher Handbook*.

Reflect on the classroom norms. Display **slide Y.** Take a couple minutes to ask students to check in how they did individually on the norms and how the class did as a learning community. Students can think silently on their own norm, and if time allows, a few students could share both what the class did well and what the class could improve.

14. Exit Ticket

10 MIN

Materials: notecard (index card)

Pass out a notecard to each student. Display **slide Z.** Tell them to put their name on one side of the notecard. Then on the other side they should answer the questions on the slide. Ask students to think about the norm "Equitable". Then they should answer the following questions on their notecard:

- Why is it important that we hear what other people say?
- How did this norm help us with hearing each other?
- What did we do that helped you feel your ideas were heard?

Give students the remainder of the time to finish the exit ticket and finish getting their notebook organized.

Read through the students' ideas from the exit tickets. It can be useful to share a summary of what students wrote at the beginning of the next day as a reflection of what students thought about the usefulness of the marker protocol in the Scientists Circle. There are many different strategies to use to support students in feeling safe and comfortable enough to share their ideas in the whole group. By beginning the unit (and year if you are following the scope and sequence) with this protocol where everyone's voice is heard, you are setting the foundation to support the norms that everyone's voice and ideas are important. This is in addition to the DQB protocol where everyone shares their question by linking into the question that was shared before theirs supports a collaborative learning environment.

ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.7.1.C Pose questions that elicit elaboration and respond to others' questions and comments with relevant observations and ideas that bring the discussion back on topic as needed.

When the class is building the DQB, if a student forgets to explain why or how their question is linked to someone else's question, press that student to try to talk through his or her own thinking. This is a key way to emphasize the importance of listening to and building off each other's ideas and to help scaffold student thinking.

Don't worry if some questions are raised that are not part of topics in this unit. Over time, students will get better and better at forming testable questions in the scope of the driving question. This type of activity gives them practice at doing that.

If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

LESSON 2

Where is the gas coming from?

Previous Lesson

We observed what bath bombs do when added to water. We established shared norms. We modeled what happened to the matter that was in the bath bomb and what caused the gas bubbles to appear. We brainstormed related phenomena. We developed a Driving Question Board (DQB), a list of possible investigations we could do, and additional data sources that could help answer our questions.

This Lesson

Anchoring Phenomenon

2 DAYS

We investigate bath bombs and take careful mass measurements to determine where the gas bubbles that we observe come from. We measure the mass in a closed and open system before and after crushing the bath bombs and before and after adding them to water. We argue from evidence for whether the gas was trapped inside the bath bomb to start with or whether some of the solid or liquid matter that was there to start with changed into a gas.

Next Lesson

We will analyze an ingredient list and recipes of bath bombs and make observations on each of the main ingredients in these, recording the properties of each. We will investigate what each ingredient does as it is added to water and will conclude that the ingredients interact with water in different ways, but none cause gas bubbles to appear.

Building Toward NGSS

RMS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

2.A Collaboratively plan and carry out an investigation in a closed system to answer the question, "*Where does the gas produced by the bath bomb come from?*"

2.B Construct and present an oral and written argument supported by empirical evidence and scientific reasoning to support the claim that gas is not trapped in the bath bomb to start with but must come from some change to the matter that was already in the system to begin with.

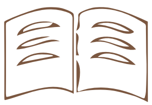
What Students Will Figure Out

- The gas we observed from the bath bomb does *not* come from any gas that was originally trapped in the bath bomb itself.
- Instead, the gas we observed when the bath bomb was placed in water comes from some change to the matter that was already there to begin with.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Students meet at the Driving Question Board (DQB) to consider their investigation ideas and where to go next.	A-B	DQB
2	5 min	**LOOKING CLOSELY AT A BATH BOMB** Student pairs use a hand lens to observe a bath bomb, noting the air spaces and wondering if the gas comes from inside the bath bomb.	C-I	hand lens, mini bath bomb cube, digital microscope (optional upon student request)
3	7 min	**RECALL WHAT WE KNOW ABOUT GASES** List key model ideas we have from previous units that will be helpful as we try to make sense of the bath bomb gas.	J	chart paper
4	12 min	**PLAN AND CARRY OUT "CRUSHING BATH BOMBS" INVESTIGATION** The class works together to plan and carry out an investigation to figure out if the gas is trapped in the bath bomb.	K-N	chart paper, Crushing Bath Bombs
5	18 min	**PLAN AND CARRY OUT BATH BOMBS IN A BOTTLE INVESTIGATION** Plan a short investigation to determine if the gas produced by bath bombs comes from the original materials or not. Carry out the investigation in small groups, taking careful mass measurements of the closed and open systems.	O-S	chart paper, Investigating Gas from Bath Bombs in a Bottle
				End of day 1
6	15 min	**BUILDING UNDERSTANDING ABOUT THE GAS FROM BATH BOMBS** Students discuss the meanings of their data to identify key science ideas.	T	chart paper, chart for class-wide data, Key Model Ideas chart
7	15 min	**SCAFFOLD AN ARGUMENT ABOUT WHERE THE GAS COMES FROM** Using evidence from their investigation and reasoning based on key model ideas, students argue that the gas bubbles from the bath bomb must come from substances that are present to start with.	U-V	chart paper, highlighter, premade "Arguing for (or Against) a Claim" poster, Key Model Ideas chart, evidence charts you made after both investigations
8	15 min	**WRITE AN ARGUMENT ABOUT WHERE THE GAS COMES FROM** Students individually write their response to the lesson question "Where is the gas coming from?" by making a claim, supporting it with evidence, and providing reasoning that includes key model ideas.	W	notebook paper
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 2, students are ready to read Student Reader Collection 1 and then respond to the writing exercise.		Student Reader Collection 1: *Noticing the Chemical World*

Lesson 2 • Materials List

	per student	per group	per class
Crushing Bath Bombs materials			• quart-sized ziplock bag • 8 mini bath bomb cubes from Recipe B • digital scale • book or other flat heavy object for crushing
Investigating Gas from Bath Bombs in a Bottle materials		• 8 mini bath bomb cubes from Recipe B • 16 or 20 oz plastic soda bottle with screw-on cap • small plastic test tube • water • digital scale	
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • hand lens • notebook paper	• mini bath bomb cube	• DQB • digital microscope (optional upon student request) • chart paper • chart for class-wide data • Key Model Ideas chart • highlighter • premade "Arguing for (or Against) a Claim" poster • evidence charts you made after both investigations

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Each pair of students will need one mini bath bomb cube or a broken piece of a bath bomb to observe closely in part 2 of this lesson. Any recipe (or a variety of them) will work for this exploration, and it is a good opportunity to use pieces of bath bombs that may have started to crumble already.

Note: To complete the labs in this lesson, each class will need 56 total bath bombs from Recipe B. (If you did not already prepare these when making others for Lesson 1, see the directions in *Recipes for Homemade Bath Bombs* to make them now. They will need several hours to dry before use.)

To save time during the lesson, you may choose to premake the poster "Arguing for (or Against) a Claim" to support the discussion for "Scaffold an argument about where the gas comes from" (Step 8).

Online Resources

Day 1: Crushing Bath Bombs

- **Group size:** Whole class
- **Setup:** You will need 8 mini bath bomb cubes from Recipe B (see the directions in *Recipes for Homemade Bath Bombs*). If you have some available, students may also want to test a sample of the store-bought bath bombs.
- **Notes for during the lab:** Use a book or other heavy flat object to crush the bath bombs inside the bag, being careful not to puncture the bag.
- **Safety:** There are no safety concerns.
- **Disposal:** All materials may be safely disposed of in the wastebasket.
- **Storage:** Store bath bombs in a sealed container or bag.

Day 1: Investigating Gas from Bath Bombs in a Bottle

- An example video of this lab is available for your reference. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)
- **Group size:** Form 6 groups of 3 to 5 students each
- **Setup:** Each group will need 8 mini bath bomb cubes from Recipe B, so for 6 groups you will need 48 total. If you need to make additional mini bath bombs, the recipes and directions are in *Recipes for Homemade Bath Bombs*. Also, gather an empty 16.9 or 20 ounce soda or pop bottle with a screw-top lid for each group.
- **Notes for during the lab:** Groups will need access to water. It is recommended that students rinse their bottles after the lab for reuse in future classes.
- **Safety:** There are no safety concerns.
- **Disposal:** All products may be safely poured down the drain with water. Solids may be disposed of in the wastebasket.
- **Storage:** Store bath bombs in a sealed container or bag.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students came up with many questions about the phenomenon of gas bubbles appearing when a bath bomb is placed in water. Students will naturally wonder where the gas bubbles came from. Two competing initial explanations came out of the previous lesson for this phenomenon. One was that the gas was already in the solid bath bomb to start with. The other was that the gas is the result of some sort of matter transformation (e.g., reaction) of the stuff that was there to start with. Generating evidence to support or refute the first candidate explanation is the focus of Lesson 2.

In this lesson, the class begins recording key model ideas on a poster. Students should know from previous work in *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* and in learning connected with PS1.A DCIs from grade 5 that:

- Gases, liquids, and solids are all matter.
- Matter has mass and takes up space.
- All matter is made of particles.

This connection to prior knowledge is intentional so we can help students build a foundation on those key model ideas about particles, matter, and mass conservation at the beginning of this unit. Then, as the unit progresses, we can help students extend that thinking to develop evidence for a different kind of particle (the atom), which is a fundamental building block of larger particles (molecules) that make up matter. This reuse and extension of ideas is a key feature of developing a coherent learning progression for students over multiple years in NGSS.

Students will figure out that there is a new substance in the system; this substance is a gas and must come from some sort of matter transformation from some of the materials they started with. They also discover that the gas is not trapped in the bath bomb. By taking mass measurements in a closed system, students figure out that the gas comes from the substances in the system. Therefore, the matter loss that happens when the gas is released from an airtight container shows that the matter in the gas was all part of the matter that was there to start with.

Where We Are NOT Going

Although the previous lesson elicited student ideas about the particulate nature of gases, that is not the focus of this lesson. That understanding will be revisited and refined further in later lessons.

In the second investigation you are using a rigid airtight container to mass the system, rather than a baggie to ensure that the overall volume of the system doesn’t change measurably when the bathbomb mixes with the water. This volume change happens when using a baggy, and this would add a confounding variable when weighing the baggy, as it leads to an additional amount of upward buoyancy force on the system. This reduces the overall weight registered on the scale. Such a result would take time to reason out, and would not be a productive avenue of investigation at this point in the unit. This is why additional guidance is provided in the lesson to motivate using a rigid airtight container for recording the mass of the system.

LEARNING PLAN FOR LESSON 2

1. Navigation

3 MIN

Materials: science notebook, DQB

Gather at the DQB and within view of the initial class consensus model. As students arrive in class, have **slide A** displayed. Have students bring their science notebooks with them and gather at the DQB. Ask students to review their questions and suggestions for investigations as the class arrives.

Once everyone is gathered at the DQB, display **slide B** and say, *We had a lot of questions and ideas about where the gas came from.* Invite students to help you point out the gas and bubbles-related questions on the DQB. Refer to the initial class consensus model while students recap their competing claims about where those gas bubbles came from. Remind students that we have modeled the bath bomb differently than the gas in our model and we are now trying to figure out where this gas comes from.

Suggested prompt	Sample student responses
What were some of the competing claims we had about where the gas in the bath bomb comes from?	*Some of us said the gas was part of the bath bomb already.* *Some of us said the gas is something new made from the bath bomb.*

Record these two competing claims on the board for reference throughout this lesson. As we plan investigations for them, we will refine and clarify these claims, but we want to recall where our thinking started based on the initial class consensus model we have at this time.

Alternate Activity

Students should be familiar with claims from their previous science experiences (in 6th grade or before). But if you need to introduce or reteach this term to your class, you may remind them that the question we are trying to answer is, "Where did the gas come from?" The brief statement we would give that answers this question is our claim.

Call attention to DQB questions about what is in a bath bomb, and/or to the investigation ideas about looking more closely at a bath bomb. Say, *Okay, we have these two different claims for where the gas might be coming from. Let's do some investigations based on some of your ideas to see what data we can collect that would help us find evidence for our claims. Let's begin by looking inside a bath bomb and seeing what is there.*

Additional Guidance

Returning often to students' initial ideas from the DQB and their suggestions for investigations is an effective way to support coherence for them and honor their contributions. You might use a sticky note with a star or checkmark on it to point out the question we are investigating or the investigation we will do next. Emphasize to students that these ideas came from them.

2. Looking Closely at a Bath Bomb

5 MIN

Materials: science notebook, hand lens, mini bath bomb cube, digital microscope (optional upon student request)

Display **slide C** to show the question "What is inside a bath bomb?" and the instructions for examining the bath bomb. Say, *When you get your bath bomb, use your hand lens to observe it carefully and talk with a partner about what you notice. Work on top of your notebook or a piece of paper so it's easy to clean up if your bath bomb crumbles.*

Additional Guidance

It's okay if the kids squish or break up the bath bomb while exploring it.

Allow students about 2 minutes to gather materials, go back to their desks to examine their bath bomb, and talk about their observations.

Alternate Activity

Your students might ask to use a microscope to observe the bath bomb more closely than they can with a hand lens. This is an extension that you may encourage if you have the time and available microscope(s). If you are not able to allow the students to explore with microscopes in your classroom but you would like to offer this enrichment opportunity, optional **slides D-H** are provided with images of homemade and store-bought bath bombs taken through a digital microscope.

Share observations. Give instructions for quickly putting away materials. Display **slide I** and discuss briefly. Students may or may not notice that there are air spaces in the bath bomb (maybe they are just too small to see). Students will continue to wonder if the gas bubbles from the bath bomb come from air trapped inside it.

3. Recall what we know about gases.

7 MIN

Materials: chart paper

Recall prior learning about gases. Say, *Some of you described small spaces that you saw in the bath bomb when you looked closely and wondered if a gas could be trapped there. Not everyone saw these spaces, but we know from earlier units that the particles that make up matter are smaller than we can see, so maybe we just can't see the gas particles! If we look back at our initial class consensus model for the gas in the bubbles, we decided to include particles there (as well as for the other forms of matter in the system, such as the bath bomb and the water).*

Say, *Let's take a minute to remember some of the key ideas that we figured out about gases from earlier units. We are going to label these key model ideas because these are ideas we have figured out and can reuse in the new models we develop in this unit to explain what is going on with the bath bombs.* What do we already know about gases?*

Display **slide J**. Pose questions to help students recall what they have figured out about gases in previous units. Use prompts such as:

- *What sort of things did you figure out about gases in the Cup Design Unit or the Storms Unit?*
- *What sort of evidence did you collect to determine whether gas was escaping from a system like the cup?*

*** Supporting Students in Engaging in Developing and Using Models**
In science, a model is a set of ideas that can help us explain a range of phenomena. Models need not include drawings, although drawings are frequently helpful, especially when developing models with students. Recalling the relevant key model ideas about particles, states of matter, and open and closed systems that students

- *What sort of thing did you do in the Storms Unit to see what air does in a closed system when you heat it or cool it?*

As students share, be sure to ask them to describe the evidence they used to figure out that idea.

Based on their prior experiences with the *Cup Design Unit* and *Storms Unit* in 6th grade, students should suggest the following ideas:

- Gases (and other matter) are made of particles.
- Gases take up space.
- Gases have mass.
- Gases are a state of matter (as are liquids and solids).

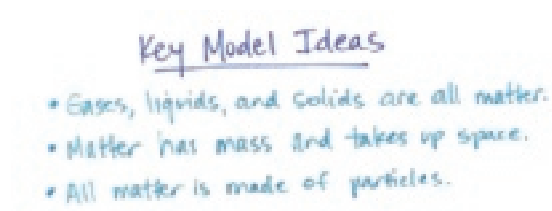
Students may also add ideas such as gases float, or that particles in gases are far apart. Accept these ideas and others as you see fit, but be sure to continue the discussion at least until students have mentioned the four ideas in the bulleted list above. They will be used to support arguments in this lesson and later in the unit.

already have from prior units will support them as they build their model for what is happening in chemical reactions in this unit.

Additional Guidance

In the *Cup Design Unit*, students will have had experiences measuring the mass of different cups and containers filled with warmed water. In cases where those systems were open, the container lost matter via evaporation to the air outside of it, and its mass decreased over time. In the *Storms Unit*, students warmed and cooled air in a soda bottle with a film of soap over it to uncover evidence that the air expanded in volume when heated and contracted when it was cooled. They also warmed a balloon partially filled with gas that was just a bit more dense than the air in the room before it warmed. It expanded in volume and became less dense than the air in the room when warmed, causing it to rise to the top of the ceiling. It then fell back to the ground after it cooled for a minute.

Record Key Model Ideas. Title a new piece of chart paper “Key Model Ideas.” Be sure that your list includes the four ideas bulleted above, although the way you phrase them should use language that you agree upon as a class. An example Key Model Ideas chart is shown here.



Say, *Great! Starting our Key Model Ideas chart with these important ideas you already know will help us figure out what’s going on with this bath bomb gas. Then, as we identify more key model ideas throughout this unit, we will add them to this list, too.*

Additional Guidance

The wording of the statements on your list may be slightly different from the ones listed here, because they are based on ideas the students have shared or offered in the previous discussions, although this should be a condensed version of them. These are not something new you give students to memorize. The class will return to this list, add to it, and reference these ideas throughout the unit.

4. Plan and carry out crushing bath bombs investigation. 12 MIN

Materials: Crushing Bath Bombs, chart paper

Plan an investigation to crush dry bath bombs. Display **slide K.**

Say, *One of the claims we made at the beginning of our lesson today was that the gas may be part of the bath bomb already, that it's coming from inside the bath bomb itself. Some of us saw those little spaces in the bath bombs just now, or wondered if there were spaces too small to see that could be holding the gas until it gets released. How can we investigate whether or not the gas is trapped inside the bath bombs?*

Facilitate a brief discussion about what the class could do to figure out if the gas bubbles are trapped inside the bath bombs. Ask the class questions such as those that follow.

Key Ideas

Purpose of this discussion: Plan an investigation to figure out if gas is trapped inside the dry bath bombs, and consider how the possible outcomes of that investigation could support or refute the claim that the gas is already part of the bath bomb, trapped inside it.

Listen for these ideas:

- We should crush the bath bombs inside a ziplock bag so no gas escapes.
- We should find the mass of the bag (with bath bombs inside) before and after we crush them.
- We can add "In a closed system, no matter can get in or out, so the mass stays the same" to our Key Model Ideas chart.
- We can add "In an open system where matter can get in or out, if the mass changes, it's because something got out" to our Key Model Ideas chart.
- Evidence in support of our claim that the gas is trapped in the bath bomb would be:
  - The bag inflates.
  - The mass of the open system decreases.
- Evidence against the claim would be:
  - The bag does not inflate.
  - The mass of the closed system stays the same.
  - The mass of the open system stays the same.

Assessment Opportunity

Building towards: 2.A.1 Collaboratively plan and carry out an investigation in a closed system to answer the question, "*Where does the gas produced by the bath bomb come from?*"

*** Supporting Students in Engaging in Analyzing and Interpreting Data**
A grades 3-5 element of this practice is for students to enter data in tables and other displays to reveal patterns. Although this is an earlier grade level element for this practice, some learners may need additional practice with the thinking routines required to organize data collection in a table, particularly at the start of the year. This is an opportunity for you to support their developing mastery of this element so that they are prepared to meet the middle school elements for this practice. Including students in this process is essential to scaffolding student understanding of what data is important to collect and how to organize it.

*** Supporting Students in Engaging in Argument from Evidence**
Argumentation is the practice of finding evidence to decide between two competing ideas, such as two possible claims or two competing models. We will often design an experiment to collect some data that can help us decide between two competing ideas. When we use the data to support one idea or rebut another, we talk about using that data as evidence to support or refute a claim.

What to look for/listen for: There are three discussions in this part of the lesson that scaffold students in collaboratively planning investigations to figure out where the bath bomb gas comes from. During these discussions, pay attention to which of your students are able to contribute meaningfully to identify the data, tools, and measurements needed to answer the lesson question. Throughout the lesson, try to elicit responses from everyone in the class so that you can formatively assess which students may need more support and guidance when planning future investigations. See the Key Ideas box for additional guidance.

What to do: If students are not raising the idea of trapping the gas during the initial discussion, ask them to think back to their experiences from prior units. There is guidance in the Teacher Guide about specific experiences students had in *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* that could help them generate ideas for this investigation.

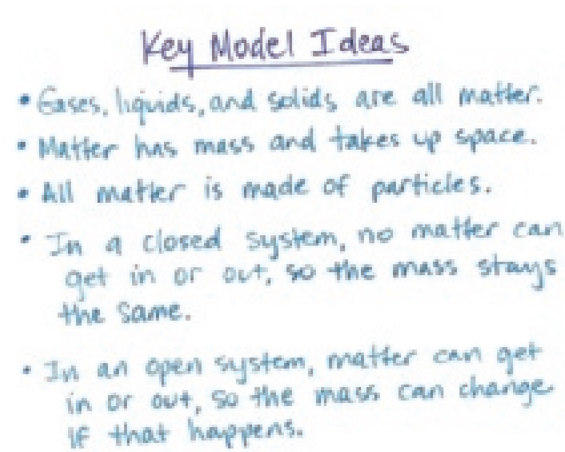
Suggested prompts	Sample student responses
One claim we're considering is whether the gas is already part of the bath bomb, trapped inside it. How can we investigate whether the gas from the bath bomb is coming from inside the bath bomb itself?	*We should crush the bath bomb (without adding any water) to see if the gas comes out.*
How will we know if gas comes out from inside of the bath bomb when we crush it?	*We need to trap the gas.* *We should crush the bath bomb in a closed container like a ziplock bag.*
If our claim that the gas is trapped in the bath bomb is correct, then what would we observe? What would be our evidence for this claim?	*We will see the bag inflate because gas takes up space.*
What evidence would go against (or refute) the claim that the gas is trapped in the dry bath bombs?	*If the bag does not inflate, no gas was released when we crushed them.*
What other data should we collect during this investigation that would provide evidence for the claim that the gas is already in the bath bomb, trapped inside?	*We should weigh the bag.* *We need to find the mass of the whole system (bag and bath bombs).*
(If needed) How could we use our key model idea that gases have mass to help answer our question?	*We would need to compare the mass before and after we crush it.*
How would measuring the mass of the bag before and after we crush the bath bombs give us evidence to support or refute our claim?	*When we keep the bag closed, the mass should be the same before and after we crush it because nothing left the system or got added to it.*

Suggested prompts	Sample student responses
That thinking about a closed system sounds like a key model idea we already know. What do you already know about closed systems from the Cup Unit? *Let's add that to our list of key model ideas.*	*In a closed system, no matter can get in or out, so the mass stays the same.*
What if we opened the bag after crushing the bath bombs? What evidence might that give us to support or refute our claim?	*If the bag has less mass when we open it after crushing, we know something got out of the system. That evidence would support the idea that gas was trapped in the bath bombs, because it would leave the system when we open the bag.*
Okay, on our Key Model Ideas chart, we have an idea about closed systems. What can we add about what happens in an open system from what we remember from the Cup Unit?	*In an open system, matter can get in or out, so the mass can change if that happens.*

Additional Guidance

At this point in their learning, students are not expected to differentiate between weight and mass. The distinction was introduced in *Storms Unit* and they will revisit that distinction in *Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)*, two contexts where the role of forces is important to explaining the phenomena. That is not the case here. The teacher guides and other materials in this unit will refer to mass, but if your students talk about weight instead, you do not need to take time now to explore the difference between them.

Add to our Key Model Ideas chart. Update the list of key model ideas to include what we know about closed and open systems. See the example shown here.



Create a data table. Work with students to plan a way to organize the data they will collect.* Display **slide L.** Create a data table on the board, chart paper, or the slide as the class directs. Students should suggest collecting mass before and after crushing the bath bomb. They should also suggest obtaining the mass for an open system. Students should include a space for recording other observations, such as how the bag looks. If your students still have questions about the temperature of the bath bomb and water, they may choose to record that here, too.

Alternate Activity

If time is running short, you may choose to give students the pre-constructed data table on optional **slide M**.

If you have students construct their own data table, it should be similar to the one shown below (also on optional **slide M**).

Investigation	Starting mass in closed system (g)	Ending mass in closed system (g)	Change in mass (g)	Ending mass in open system (g)	Change in mass (g)	Observations
Crushing the bath bomb						

Lead the class through the investigation together. Say, *I would like to suggest that we crush 8 mini bath bomb cubes in our bag. If they do release a gas when we crush all of them, that should provide enough gas for us to see the bag inflate. Who can summarize the steps we should take to carry out this investigation?*

Listen for a student(s) to summarize procedure steps such as these:

1. Put 8 mini bath bomb cubes in a ziplock bag.
2. Squeeze out as much of the air as possible and seal the bag.
3. Record the mass of the bag and its contents. (You may need to fold the bag in half to let it fit well onto the scale.)
4. Off the scale, use a book or other flat object to carefully crush the bath bomb. You want to avoid puncturing the bag so materials do not escape the system.
5. Record observation about the inflation of the bag.
6. Record the mass of the bag again.
7. Open the bag and record the mass again.

Carry out these procedures as a whole class.

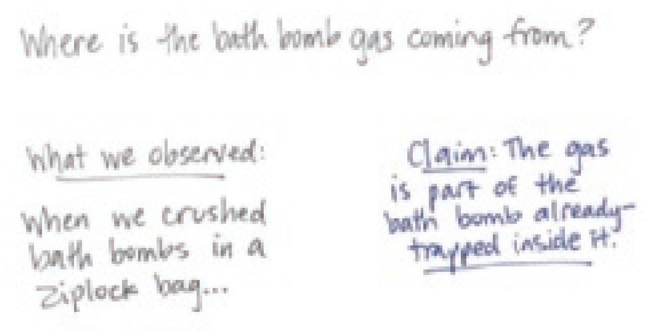
Additional Guidance

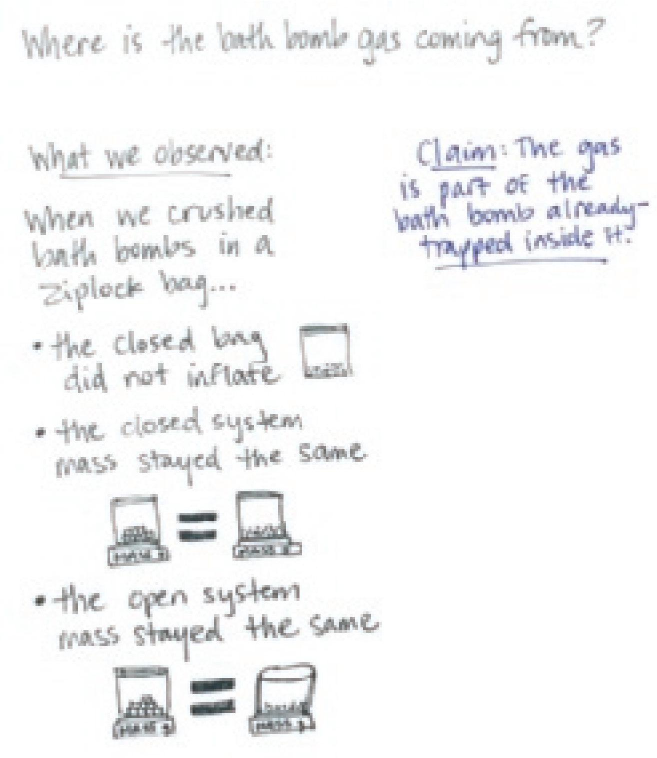
It can be helpful to share with students that digital scales have an accuracy limitation (usually noted on the scale or its package). For example, some scales are accurate within a range of +0.1 g and -0.1 g of the mass of the object. A measurement may fluctuate within that range without the actual mass changing that much. Discussing the limitations of scientific tools can help students realize that sometimes tools may not work correctly and will encourage them to be more critical about making sense of the data they collect.

In addition, it may be helpful to allow your students to witness a scale's sensitivity firsthand. You may have a volunteer blow on the scale (directing their breath away from others) while someone else watches the reading. This demonstration can help explain the fluctuations students may notice when moving materials nearby the scale and illustrate the need to be careful when taking measurements (such as waiting for the numbers to stop changing before recording a mass).

Discuss and record thinking about the crushed bath bombs. Display **slide N**. Begin by setting up a chart to record our observations from this investigation, such as the example shown here. Ask, *What did we observe about these crushed bath bombs and the bag they're in?* As students respond, list their observations in the chart you've created, such as the example here.

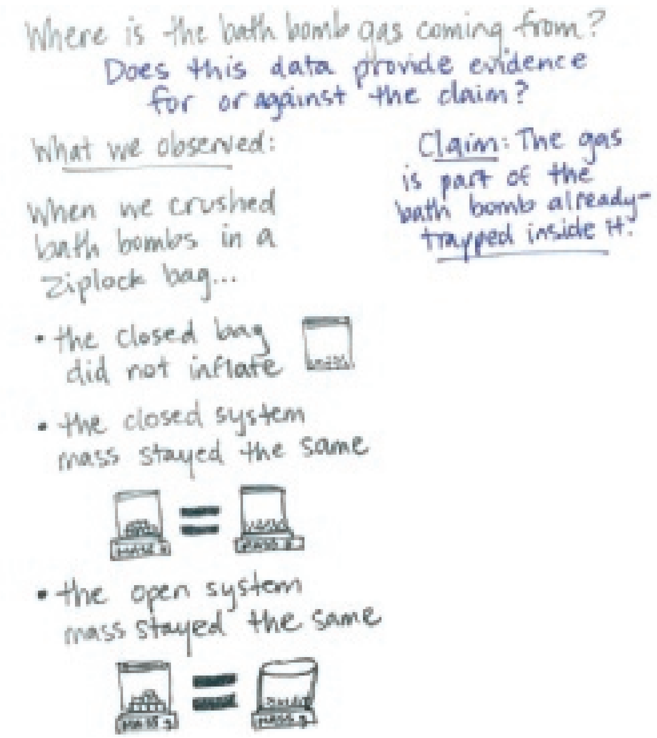
Say, *Okay, so this is all the data we collected from our investigation. Let's see if we can use any of this data as evidence in support of or against our claim that the gas is trapped inside the bath bomb.**

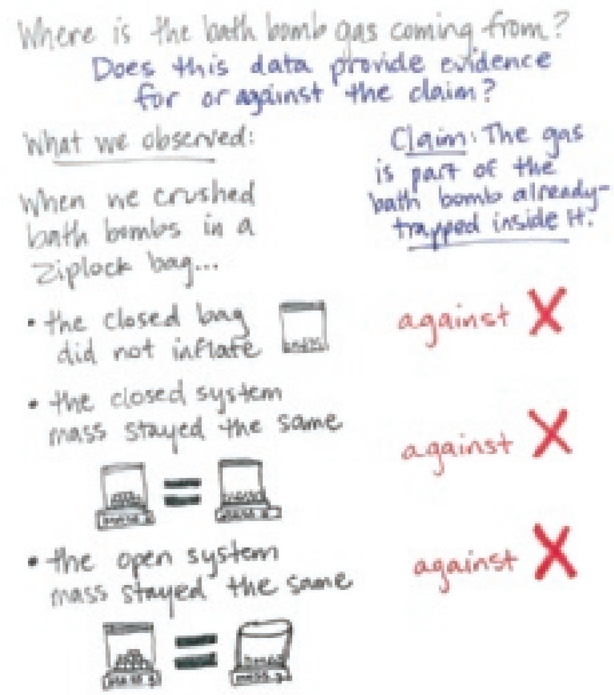




Add this question to the title of your chart: *Does this data provide evidence for or against the claim?* See the example shown on left. Then, as you point to each row of data, ask, *Is this evidence in support of or against this claim?*

Mark the chart to reflect these responses, as shown in the example on right. Say, *We did not find evidence in support of our claim about the gas being part of the bath bomb to begin with… it is not trapped inside it. So, where is it coming from? It looks like we are going to need to plan another investigation to figure that out.*





5. Plan and carry out bath bombs in a bottle investigation.

18 MIN

Materials: Investigating Gas from Bath Bombs in a Bottle, science notebook, chart paper

Additional Guidance

It is important that groups use bottles that previously held carbonated drinks because the screw-top caps are designed to withstand the pressure of the gas inside them. Using other drink bottles (from water, tea, or sports drinks, for instance) may allow some of the bath bomb gas to escape during the investigation and result in inaccurate data.

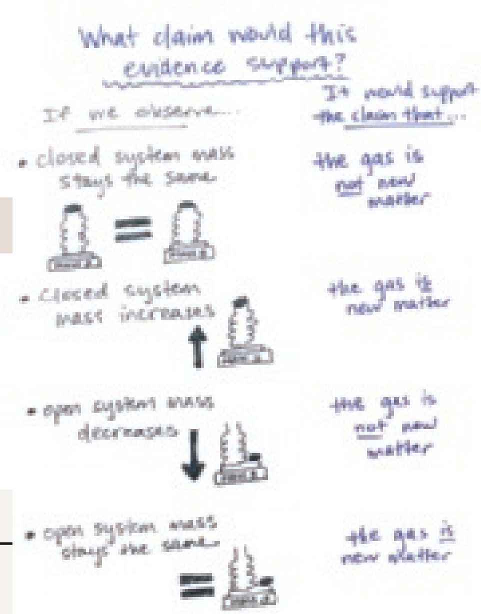
Refine the claims for which we're trying to find evidence. *Okay, so we collected some evidence that helped us figure out the gas was not trapped in the bath bomb to start with. But we also had another claim we wanted to investigate. We thought maybe the gas is something new—like new matter—that is made when the bath bomb is combined with water. How could we design an investigation to collect evidence that would support or refute this claim?*

Begin planning the investigation of bath bombs in a bottle. Display **slide O.** Ask, *What are some of your ideas for how we could investigate whether the gas is new matter or not?*

*** Attending to Equity**
Investigating Gas from Bath Bombs in a Bottle includes a step-by-step guide to these procedures with photos for use by students who may have been absent during this lesson or who could otherwise use that support. *Teacher Reference for Investigating Gas from Bath Bombs in a Bottle* includes the same information and an example video of this lab is available for your reference through the **Online Resources Guide**.

Show students the supplies you have available that might be useful for this investigation. These supplies include plastic soda bottles with screw-on caps, small plastic test tubes, and scales.

Begin planning by considering how measuring the mass of open and closed systems could support either of our claims. Use prompts such as the ones below and record students' ideas on a piece of chart paper or on the board. An example chart is shown here.



Alternate Activity

Students may suggest using a baggie for this investigation since they just used one with the crushing investigation. To honor this idea, you could insert a brief demonstration here where you add bath bombs to a baggie with water. Students will notice that the baggie does inflate. However, when they try to record the mass they will notice that depending on how the bag is positioned, the water may be hanging off one side of the scale or the other. Use this noticing to help motivate the need for some kind of rigid, sealable container that will stay on the scale to be accurately measured.

Suggested prompts	Sample student responses
How could these materials help us test whether the gas from the bath bombs is new matter or not? Should we just put bath bombs in the bottles?	*Not just the bath bombs, but water too. We just figured out that bath bombs alone don't cause a gas to form—we only saw bubbles when we added the bath bombs to water.*
OK. How would putting the bath bombs and water into a bottle help us find evidence to support our claims of whether or not the gas is new matter?	*When we cap the bottle, it's a closed system and nothing can come in or out.* *We should record the mass of the whole system before and after we combine the bath bombs and water so we can see if the mass changes.*
How would the mass change (or not) of the closed system support either of our claims? If the mass stays the same, what would that tell us about the gas?	*If the mass stays the same, no new matter was created. The gas must have come from what was already there, because it's a closed system.*
If the mass of our closed system were to increase, what would this tell us about the gas?	*If that happened, somehow some new matter must have been added to the system. I don't think that's likely, but if it did it would support the claim that the gas is new matter.*
What about an open system? How would it support either of our claims if we measured the mass of an open system before and after combining the bath bombs with water?	*If the mass of the open system goes down, it means that matter left the system. So that would support the claim that the gas was made from the matter we started with (since there's less of it at the end).* *If the mass of the open system stays the same, that would support the idea that the gas is new matter, since the mass of the solid and liquid we started with would still be there—they didn't leave the open system.*

Co-construct the investigation procedure. Work together as a class to plan the procedure students will follow in their small groups when they carry out this investigation. Write, *Is the gas new matter or not?* on the board, chart paper, or use **slide P** to list the steps as you discuss them (see example procedure steps listed here).

1. Measure 100 mL (100 g) of water into the bottle.
2. Put 8 mini bath bombs (from recipe B) into a small plastic test tube.
3. Carefully slide the test tube of bath bombs into the bottle so they don't spill into the water.
4. Tighten the cap onto the bottle.
5. Obtain and record the mass of the whole system.
6. Turn the bottle over to mix the bath bombs into the water.
7. Wait for the bubbles to stop fizzing.
8. Obtain and record the mass of the whole system again.
9. Slowly remove the cap.
10. Obtain and record the mass of the whole system (including the bottle cap on the scale).
11. Rinse out the bottle for other students to use, and put away materials as directed.

Use prompts such as these to guide the planning of this investigation.

Suggested prompts	Sample student responses
OK, we agree we want to find the mass of the closed system before and after we combine the bath bombs with the water. We don't want any gas to have a chance to escape the closed system. We have to figure out a way to keep the water separate from the bath bombs until we can close the bottle. How could these little plastic tubes help us do that?	*The tubes will fit inside the bottle, so if we put the water into the bottle first, then add the bath bombs in a tube, they will stay separate while we cap the bottle and record the mass. Then we can turn it over and mix it after we have the mass.*
OK, sounds good. How could we use this same setup to see what happens in an open system? Is there a way we could change something about the setup we already have with the closed system to make it an open system?	*Opening the bottle's cap would make it an open system, like we did with the bag after we crushed the bath bombs before.* *The open system would have started with the same mass as the closed system, so we could measure the mass of the closed system after we mix the bath bombs and water, then open the cap and record the mass again.*
Right. How can we make sure that we're only measuring the mass of whatever gas might escape the open system? If we open the system by removing the cap, how can we be sure we are accurately recording the mass of the open system? *(If needed) What should we do with the cap after removing it?*	*We should put the cap on the scale, too, since it was included in the first mass we found.* *We only want to track the change in mass of the matter from the bath bomb, not the change in mass because we removed the cap.*

Suggested prompts	Sample student responses
I want to make sure we have enough gas in the bottles to be measurable, so let's use 8 mini bath bomb cubes per group and 100 mL of water. Remember, our scales only measure accurately within one tenth of a gram, so what mass change will we consider significant?	*If the mass changes more than 0.1 gram, that would be significant.*

Plan how to collect and organize our data. Decide if any modifications are needed to the same data table the class used earlier when crushing the bath bombs in a bag. It is likely that students will suggest we could simply reuse the old data table and add a new row to it to keep track of the results for this investigation. As students discuss, construct or refer to an example data table on the board, or display **slide Q** if time is short. Instruct students to turn their science notebooks to landscape orientation and copy the table for use during the investigation. You will then create a larger class data table to collect data from each of the small groups.

Additional Guidance

Since you already have a digital scale out, you may choose to record the mass of 100 g of water rather than get out graduated cylinders to measure out 100 mL of water. If using the scale, place the cup on the scale and then use the tare button to zero it, then pour in water to 100 g. It is recommended that you demonstrate here with the whole class whatever method (scale or graduated cylinders) you want the students to use in groups for the testing in bottles that comes next.

Briefly reflect on these steps. * Ask, *How will these steps provide us the evidence we need to support or refute our claims about the gas being new matter?* Elicit responses from a few students you didn't hear from while listing steps so you can formatively assess their proficiency with planning an investigation.

Carry out the investigation in small groups. Display **slide R.** Direct students to get into groups, gather materials, and follow the procedure you've listed on the board (switch back to **slide P**, if needed). They should record their data in the table they created in their science notebooks.

Assessment Opportunity

Building towards: 2.A.2 Collaboratively plan and carry out an investigation in a closed system to answer the question, "*Where does the gas produced by the bath bomb come from?*"

What to look for/listen for: As students carry out the bottle investigation, look for students to include measuring the mass of the entire contents of the bottle system before and after tilting the bottle over to mix the contents together. Check to see that students are remembering to seal the cap tight on the bottle before taking both measurements.

What to do: If you notice a group that has skipped measuring the mass beforehand, and time permits, encourage them to start over and run a new trial, asking them first why they need to measure both the mass before and after mixing in order to answer the lesson question.

Collect data from each group. Display **slide S**. As groups finish their investigations and clean up their materials, have them enter their group's data on class-wide data tables you've made on the board (if you can save it there for day 2) or chart paper. See the example tables below.

Group	Change in mass (g) in the closed system	Change in mass (g) after opening the system
1		
2		
3		
4		
5		
6		

Students should have observed no significant change in mass in the closed system. They should have also noticed that there was a significant mass loss when the closed bottle system was opened. Remind your students that many scales are only accurate to within 0.1 gram of the true mass being measured, so changes of plus or minus 0.1 gram are not significant. If your students see an unexpected mass change greater than the possible error range for your scales, ask them what could account for the change. Measurement error, failure to tighten the lid well, changing to a different scale, or failing to zero the scale could explain significant differences in measurements.

Additional Guidance

Your students may observe that the bottle is harder to squeeze after mixing the bath bombs and water. If so, ask them why they think that happened. They should respond that gas takes up space differently than solids or liquids, and now that there's gas in the bottle, those gas particles are spreading out and filling the space. You could also ask if this observation could be used as evidence to support either of our claims about where the gas came from, but students should point out that the gas is taking up space in the bottle regardless of where it came from, so this observation does not provide evidence to support or refute either claim.

Close today's work. Say, *Thank you all for working together to gather this data. I know some of you have already been noticing some patterns. Next time we have class, we will make sense of these results.*

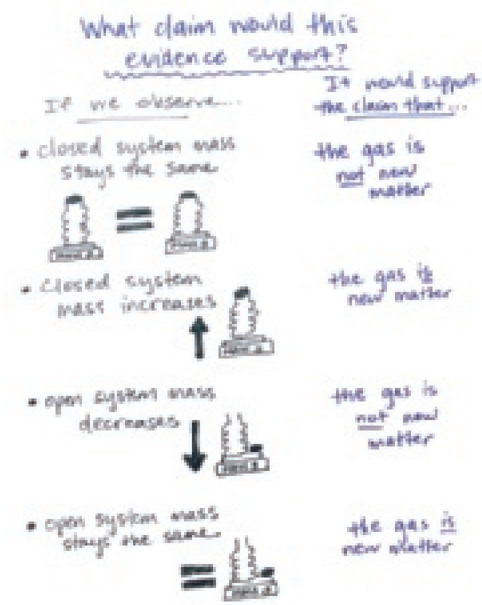
End of day 1

6. Building Understanding About the Gas from Bath Bombs

15 MIN

Materials: science notebook, chart paper, chart for class-wide data, Key Model Ideas chart

Build understanding and make sense of the data. Display **slide T**. As students come into the classroom, have them form a Scientists Circle in view of the board or chart showing the class-wide data. An example of a class-wide data chart is shown below, but bear in mind that your class values may be quite different depending on the type of bottle you used, etc.



Group	Change in mass (g) in the closed system	Change in mass (g) after opening the system
1	0.0	-0.6
2	-0.1	-0.7
3	0.0	-0.4
4	0.0	-0.4
5	+0.1	-0.4
6	-0.1	-0.9

Say, *Last time we were together, we did some investigations to try to determine where the gas from the bath bombs comes from. So now we have a chance to make sense of the data each group collected.*

Lead the class in a Building Understandings Discussion about the data and observations the class collected. Reference the ideas students shared before the investigation about the evidence they expected (such as the example shown here).

Key Ideas

Purpose of this discussion: Prepare to develop an argument to decide between our two competing claims.

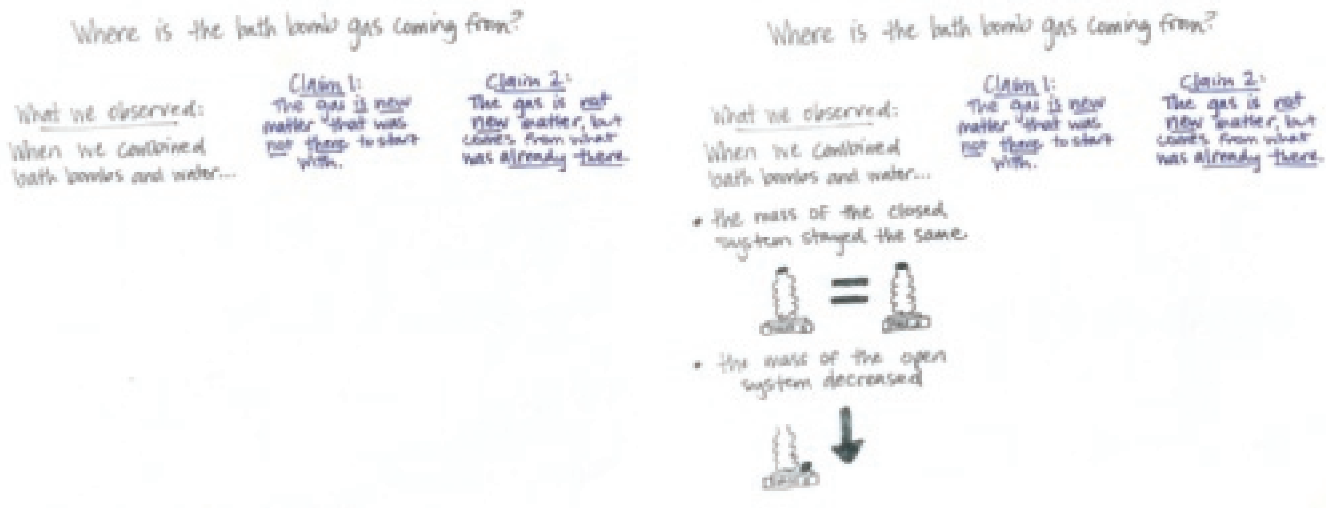
Listen for these ideas:

- The gas must have come from some matter that was already there beforehand—it is not new matter.
- We know the matter that makes up the gas came from what was already there because the mass did not change in the closed system.
- When we removed the cap to open the system, we heard gas escape and the mass decreased.

Make a record of the discussion. Guide the discussion using questions such as the ones that follow, and use a new piece of chart paper to track the discussion of which data can be used as evidence to support each claim. Begin by setting up a chart to record our observations from this investigation, such as the one shown left. Ask, *Who can summarize our observations from this investigation?*

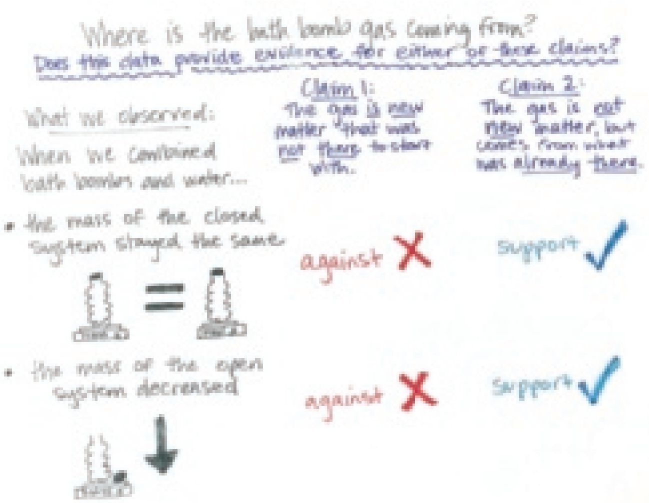
As students respond, list their observations in the chart you've created, such as in this example. Say, *Okay, so this is all the data we collected from our investigation. Let's see if we can use any of this data as evidence in support of either of these claims about whether the gas is new matter or not.*

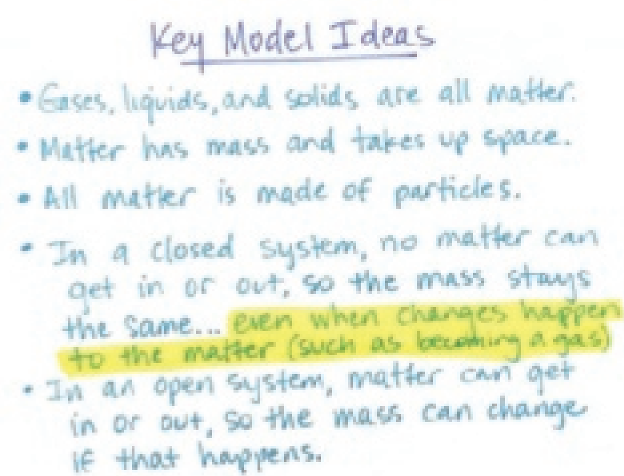
Add this question to the title of your chart: "Does this data provide evidence for either of these claims?" Discuss each row of data using questions such as those that follow.



Suggested prompts	Sample student responses
We found that the mass of the closed system stayed the same. Can we use that data as evidence to support either of these claims?	*The gas is not new matter. It came from what was already there.*
Really? The gas isn't new matter? But the bath bomb was only made of solids and the water was a liquid. . .	*The gas was a new state of matter that was different from what we started with, but that matter had to come from something we started with.*
Can you talk through how you came up with that idea?	*Well, the mass did not change before and after in a closed system. Nothing got in or out. So the matter had to be there to start with.*
We also found that the mass went down in the open system. What caused the mass to decrease? Why was there a mass loss when you opened the system?	*The gas got out. It left the system. It escaped.* *We know gas is a type of matter and has mass. So if it left, then the mass would go down.*

Suggested prompts	Sample student responses
So can we use this data about the open system's mass decrease as evidence to support either of these claims?	*It supports the claim that the gas is not new matter, but comes from what was already there.*
Why do you think so?	*Some of the original matter left the system when the gas escaped—the mass went down—so it must have come from what we started with.* *If the gas was new matter, the mass of the open system would have stayed the same because the matter in the solid bath bomb and liquid water would have still been there when the gas left the system.*
Hmmm… interesting. We have our list here of key model ideas that we know from previous units. We said that gases have mass. Do we now have additional evidence to support this idea?	*Yes, because when we opened the cap and heard the gas escape the system, the mass went down.*
We also have on our Key Model Ideas chart that "In a closed system, no matter can get in or out, so the mass stays the same." I propose that we add a note here based on today's investigation. What did we figure out about the mass of a closed system, even when we were combining a solid with a liquid and seeing bubbles?	*The mass of the closed system still didn't change, even when changes happened to the matter (such as becoming a gas).*





Mark the claims chart to reflect these responses, as shown here. Say, *Let's add the idea we just mentioned to our Key Model Ideas chart, too.*

Add the note to the Key Model Ideas chart so the line about the mass of matter not changing in a closed system now also includes "even when changes happen to the matter (such as becoming a gas)." An example of the updated list is shown here with the new addition highlighted.

7. Scaffold an argument about where the gas comes from. 15 MIN

Materials: science notebook, chart paper, highlighter, premade "Arguing for (or Against) a Claim" poster, Key Model Ideas chart, evidence charts you made after both investigations

Discuss claims with a partner. Be sure the Key Model Ideas chart and evidence charts from both investigations are visible. Display **slide U** to show our two possible claims:*

- Claim 1: The gas is new matter that was not there to start with.
- Claim 2: The gas is not new matter, but comes from what was already there.

Say, *We've made sense of our data, but having evidence to support or refute a claim is only one part of a strong and convincing argument. We're going to work together as a class to build a well-supported argument, which does require evidence. So, let's start by talking with a partner. Discuss with your partner how the evidence from our investigations supports one claim. Then, discuss how our evidence refutes the other claim.*

Share ideas with the whole group. After 3 minutes of partner talk, have students use a dialog like the one below to share the claim they chose and why. Since this unit is designed to start the year, there are specific teacher moves included that will help students develop the process critical to forming strong and convincing arguments supported by evidence and key model ideas. If students have already learned how to build strong arguments in prior units, this dialog can serve as a review and reinforcement of this process.

Say, *While you share your ideas, I will record them, and you'll see me marking them up a bit. I want us to have these ideas here to refer back to as we practice how to make strong and convincing arguments in support of (or against) a claim. So you'll also hear me pushing you to tell us more than just which claim you think is best supported by our evidence. We are going to work on putting together arguments that are also supported by key model ideas. I'll want you to tell us what happened to the matter, step by step, and how you know each step.*

Prompt	Response	Follow-Up Questions *Student Response*	Teacher Moves
Which claim is best supported by our evidence?	Claim 2: The gas is not new matter because we saw that the mass of the closed system did not change.	What did the mass not changing tell you and why? *The mass didn't change even though I saw the gas bubbles. Gas has mass, so since the mass didn't go up, the stuff that makes up the gas was already in there.*	As students respond, record their responses on the board, chart paper, or a blank slide. Underline evidence. Highlight key model ideas.

*** Supporting Students in Engaging in Argument from Evidence**

The scaffolding provided in this lesson will support students as they learn to argue from evidence to support or refute a claim. Over the course of this unit, we will continue to provide students with more opportunities to further develop the practice of argumentation. By the end of the unit, students will also have had opportunities to practice arguing for more complex explanations of what is happening in the bath bomb when added to water.

Prompt	Response	Follow-Up Questions *Student Response*	Teacher Moves
Was there any other evidence shared that would support Claim 2?	We also saw that the mass went down when we opened the bottle.	What did the mass going down in the open system tell you? *The mass going down after we opened the bottle, shows that some matter left the system. Gas is matter that has mass, so the gas escaping (we heard a hiss) made the mass of the system decrease. That means the gas came from what we had to start with, because we didn't have as much mass there after it left.*	Record student ideas. Underline evidence. Highlight key model ideas.
Did anyone think we have evidence to support Claim 1?	Yes. I can see the spaces in the bath bomb, and gas must be in there, so I think it's already there to start with.	What do others think? Why might you disagree with Claim 1? *I think there are spaces—I saw them too. But when we crushed the bath bomb in the sealed bag, the bag did not inflate.* And what did that tell you? *Well, we know that gas is matter that takes up space, so even though there may be a little gas in the spaces that came out when we crushed it, there wasn't the large amount of gas we saw when the bath bomb was put in water because the bag would blow up like a balloon!*	Record student ideas. Underline evidence. Highlight key model ideas. Continue gathering and recording student responses until you have several pieces of evidence from the lesson's investigations. You may also ask students why our evidence refutes Claim 1 in order to gather several examples of evidence and key model ideas from the students.

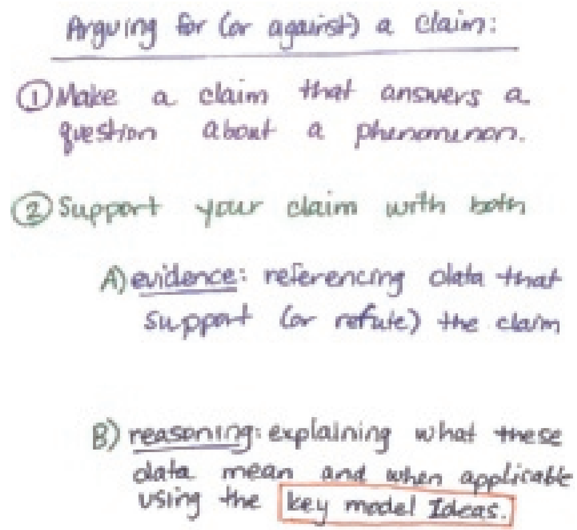
Additional Guidance

In the Teacher Moves column of the previous table, instructions say to highlight phrases once you have recorded them. There are many options for how you highlight these phrases, but be consistent throughout in the method you choose. Options you may consider are

- using a broad-tipped highlighter in a color you will continue using,
- drawing a box around the word or phrase, or
- using a different color for these words or phrases.

Whichever way you choose, be consistent in the method and in the color that you use, and always use the same method or color when highlighting the key model ideas.

Be sure key pieces of evidence and model ideas have surfaced. If the following ideas have not yet come up in the discussion, continue to probe for student thinking until they do. These statements are coded in the same way you are coding student responses during the discussion by underlining evidence and highlighting pieces of key model ideas. These lists are summary statements; the exact wording from your students' discussion may differ slightly.



Crushing Bath Bombs

- The mass did not change before and after crushing.
- The bag did not inflate.
- When we opened the bag, the mass did not change.
- Gases are matter that have mass.

Investigating Gas from Bath Bombs in a Bottle

- The gas must come from something that is already there—it is not brand-new matter.
- We know that it came from something already there because the mass did not change in the closed system.
- When we opened the closed system, the mass went down.
- Gases are matter that have mass.

Support strong and convincing arguments. Pause the discussion. Using the examples students have shared, say, *You notice that I have underlined several words that you mentioned, and I also highlighted different words. Why do you think I did that? What is the pattern?*

Students should notice that the underlined words or phrases are things we saw or witnessed during the labs. They may also use the word *evidence*. Reinforce this label by writing the word evidence near these statements and underlining the word. Students should also note that the highlighted words and phrases are key model ideas that we recorded on our Key Model Ideas chart. Write the words *key model ideas* near a statement and highlight them.

Display **slide V.** Point out to students that they are now using a combination of two key features that are necessary in constructing a strong argument: (A) referencing specific data to use as evidence and (B) explaining what these data mean by connecting them to key model ideas. Emphasize that these are two key features of a strong argument that we want to practice in all future arguments.

Display a poster for the elements of a strong and convincing argument. If you made this poster before class, display it now. If not, use a new sheet of chart paper to create a poster like the example shown here. Post it in a highly visible space in your classroom. Emphasize to students that a convincing scientific argument connects these two main parts, evidence and reasoning, in a way that helps support the claim.

8. Write an argument about where the gas comes from. 15 MIN

Materials: notebook paper

Students write an answer to the lesson question. Display **slide W**.

Say, *Like you did last year in science, we are going to be working a little at a time to figure out this gas from the bath bombs. What we've figured out today is just our initial answer. We are going to keep investigating and working to build more* *complete models and explanations. So, let's keep track of our arguments for these important ideas that we have decided need to be in our model.*

Assessment Opportunity

Building towards: 2.B Construct and present an oral and written argument supported by empirical evidence and scientific reasoning to support the claim that gas is not trapped in the bath bomb to start with but must come from some change to the matter that was already in the system to begin with.

What to look for/listen for: Look for the use of key model ideas, for example that gas is matter so it has mass and takes up space. Look for the use of observations as evidence, such as:

- the mass of the bath bomb and water did not change in the closed system,
- the mass did not change before and after crushing, and
- the bag did not inflate after crushing.

Making connections between the evidence and relevant key model ideas is the challenging part of providing coherent reasoning, so look for that logic as well. For example, "The gas must come from something that is already there—it is not new matter. We know that it came from something already there because…" *Sample Student Response for Written Argument* is also available for your reference.

What to do: Collect the written arguments and identify where students are using evidence (underline it) and key model ideas (highlight them). Students will benefit from seeing multiple examples of where this support is being used in their own writing or in the writing of their peers.

Direct students to work individually to write an answer to the lesson question in the form of a well-supported argument.* Have them use a new page of looseleaf notebook paper so you can collect their work as a formative assessment. They will make a claim, support their claim with evidence, and provide reasoning to connect their claim with any relevant key model ideas to show why their evidence supports their claim.* Allow students the rest of the class time to write their arguments, and complete the exit ticket that follows (on **slide Y**).

Exit Ticket

Since this is students' first chance this year to write a strong and convincing argument, take a moment to ask them how confident they feel about this practice. Use **slide Y** to present the question, *On a scale of 4 (totally independent) to 1 (need lots of help with this), how are you feeling right now about writing a well-supported argument? Briefly explain what makes you feel that way and what help you could use as you develop this practice.* Direct students to respond on the bottom or back of the page where they wrote their argument. Students will have another chance to reflect on their confidence with argumentation in Lesson 5 so you and they can consider their progress with this practice.

* Attending to Equity
Universal Design for Learning:

If you would like to offer sentence starters to support your students as they *engage* in writing, here are some examples, which are also provided on optional **slide X**.

Sentence starters for referencing specific data could include:

- When we did the investigation ____ (name or description) ______, we found that the data showed that _ (description of the data) __.
- We saw _ (description of the data) __ in our investigation.

For using key model ideas, you could offer

- This means ___________ because we know ___ (key model idea) ____.

* Supporting Students in Engaging in Constructing Explanations and Designing Solutions

Students often struggle with reasoning. If you need to support students with reasoning, ask them to look at the Key Model Ideas chart to see if there is an idea there they could use to explain why their evidence supports their claim. Students should recognize that "gas is matter that has mass" is a strong reason why their evidence supports their claim.

Home Learning Opportunity

If more time is needed, you may choose to have students complete their written arguments and/or the exit ticket reflection as home learning.

Close today's lesson. As students turn in their written arguments, thank them for their work today and remind them that we will continue figuring out these bath bombs next time.

ADDITIONAL LESSON 2 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.7.1: Write arguments to support claims with clear reasons and relevant evidence.

In this lesson, students write an argument based on evidence and supported by reasoning with key model ideas. At this point in their development, this written argument was scaffolded by class discussion and resources in the room, but as the unit and school year progress, students will develop more independence with this skill.

CCSS.ELA-LITERACY.SL.7.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.

CCSS.ELA-LITERACY.SL.7.1: Come to discussions prepared, having read or researched material under study; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

In this lesson, students are expected to gather data by observing whole-class demonstrations and then by working with a small group. Those data serve as evidence to support claims students discuss with partners and the whole class at the conclusion of the lesson. Students are expected to participate fully in these discussions, referencing the evidence they've gathered, listening to their classmates, and working together to build strong arguments.

SCIENCE LITERACY: READING COLLECTION 1

Noticing the Chemical World

1 **Variety of Bubbles**

2 **Sensing States of Matter**

3 **Chemicals in Nature**

4 **Chemicals: Matter and Energy in Systems**

Literacy Objectives

- ✓ Summarize key points related to readings about matter.
- ✓ Distinguish causes and effects related to bubble formation and human senses.
- ✓ Organize related details about states of matter.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Activities

- Read varied text selections related to the topics explored in Lessons 1 and 2.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a concept map in response to the reading.

Instructional Resources

Student Reader

Collection 1

Science Literacy Student Reader, Collection 1
"Noticing the Chemical World"

Exercise Page

EP 1

Science Literacy Exercise Page
EP 1

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: What happens when a bath bomb is added to water (and what causes it to happen)?
- Lesson 2: Where is the gas coming from?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS1.A: Structure and Properties of Matter Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Systems and System Models

CCSS

English Language Arts

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

WHST.6-8.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Core Vocabulary

Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

viscous

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

cohesion	**dissolve**	**ecosystem**
molecules	**nutrient**	**plasma**
pressure	**state of matter**	**substance**
thermoreceptor	**viscosity**	

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

Exercise Page

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2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Chemical Reactions and Matter unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read a photo-and-caption selection about how bubbles form in your home and in nature.*
    - *Next, you'll consider the different ways your body can sense the presence of, or differences in, solids, liquids, and gases.*
    - *Then, you'll interpret a mock comic strip and read about the different meanings of the word "chemical."*
    - *Finally, you'll read a selection about open systems using familiar examples of how matter and energy move into and out of ecosystems.*

- Distribute Exercise Page 1. Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate a concept map about states of matter with examples from all four readings in Collection 1.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What state of matter is inside the pocket of a bubble?	*a gas*
Why wouldn't you want to touch matter in the plasma state?	*because it is extremely hot*
What is the difference between a chemical and a substance?	*Nothing, except that people think chemicals can be bad. They mean the same thing.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompt	Sample student response
How does the reading selection about bubbles support your observations of the bath bomb?	*It reinforces that there is a gas inside the bubble pockets that we observed and that the gas could be oxygen or carbon dioxide, and it explains that the outside of the bubble is a liquid, though we don't know what kind.*

Suggested prompt	Sample student response
Why do you have to be aware of pressure when investigating bubbles?	*You need to watch that too much pressure does not build up in a closed container and burst.*
How does the scale of systems on Earth and in our investigations vary?	*Systems can be very large in scale, such as an ocean ecosystem, but also small in scale, such as when we sealed the bath bomb in a bottle of water.* *We can also talk about the bath bomb system at the scale of molecules and atoms, which is too small to see.*

- Refer students to the Exercise Page 1. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to draw a concept map to show examples of states of matter related to Collection 1.*
    - *That means thinking about classifying matter using examples from all four readings.*
    - *When you draw the map using all the terms listed on Exercise Page 1, leave plenty of space on the page to add the examples.*
    - *As you read each selection, look for interesting examples to add to your map.*
    - *The important criterion for your work is that your map shows main ideas and details clearly.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 1

4. Facilitate discussion.

(Friday)

Facilitate class discussion about the reading collection and writing exercise. Students begin the reading activity by learning that bubbles are usually pockets of gases surrounded by liquids and that there are many natural and human-designed systems in which bubbles form, often involving changes in pressure.

Student Reader

Collection 1

Pages 4–7 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Variety of Bubbles"?	*It explains what bubble are and describes some ways that they form at home and in nature.*
When you read a photo-with-caption article, how do you decide what to look at first? How do you make sure you see everything?	*I try to start with the photo closest to the top left. Then I go left to right and top to bottom, like reading a paragraph.* *I start with the photos I find the most interesting. Then I circle back to the rest.*

Pages 4–7 Suggested prompts	Sample student responses
What examples from this selection were you able to include in your concept map?	*Gases: the insides of a soap bubble, the foam on ocean waves, oxygen gas released by plants, carbon dioxide bubbles dissolved in a carbonated beverage, sulfurous gases from a volcano, nitrogen bubbles dissolved in the blood* *Liquids: the outside surface of a soap bubble, the rest of the carbonated beverage, lava, blood [sort of]* *Solids: the bottle that holds a carbonated beverage, pumice*

The next selection focuses on how the human body detects solids, liquids, and gases by using sensory receptors.

Pages 8–9 Suggested prompts	Sample student responses
What is the general purpose of the second selection, "Sensing States of Matter"?	*It explains how we use body parts, experience, and prior knowledge to sense solids, liquids, and gases.* *It also explains that there is a fourth state of matter called plasma that we can sense with our eyes.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals that the gas bubbles dissolved in a liquid are due to the gas being added at a high pressure. The second article details how the human body can sense changes in pressure in many situations.*
Which human senses are involved in detecting the four states of matter described in the reading?	*Thermoreceptors in the skin detect changes in temperature.* *Pressure receptors detect solids and if liquids and gases are in motion.* *The sense of sight can sometimes detect all four states of matter.* *The sense of smell detects gases, solids, and liquids in the air.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—For reinforcement that gases are matter and therefore take up space, have students watch a video demonstrating evidence of this concept. Then provide students with bubble solutions, straws, and a spray bottle filled with water, and allow them to replicate the activities shown in the video.

Online Resources

CHALLENGE—Challenge students who are intrigued by the idea of a fourth state of matter to find out how plasma compares with solids, liquids, and gases. Have them do online research to find out how the particles of plasma differ from the particles in other states, whether plasmas have a fixed shape and volume, and how common they are in the universe. Then have students display the most interesting facts on an infographic to share with the class.

The third selection begins with a comic strip that succinctly previews the essay that follows. Finally, proceed with discussion of the last selection in this collection, a look at ecosystems as open systems.

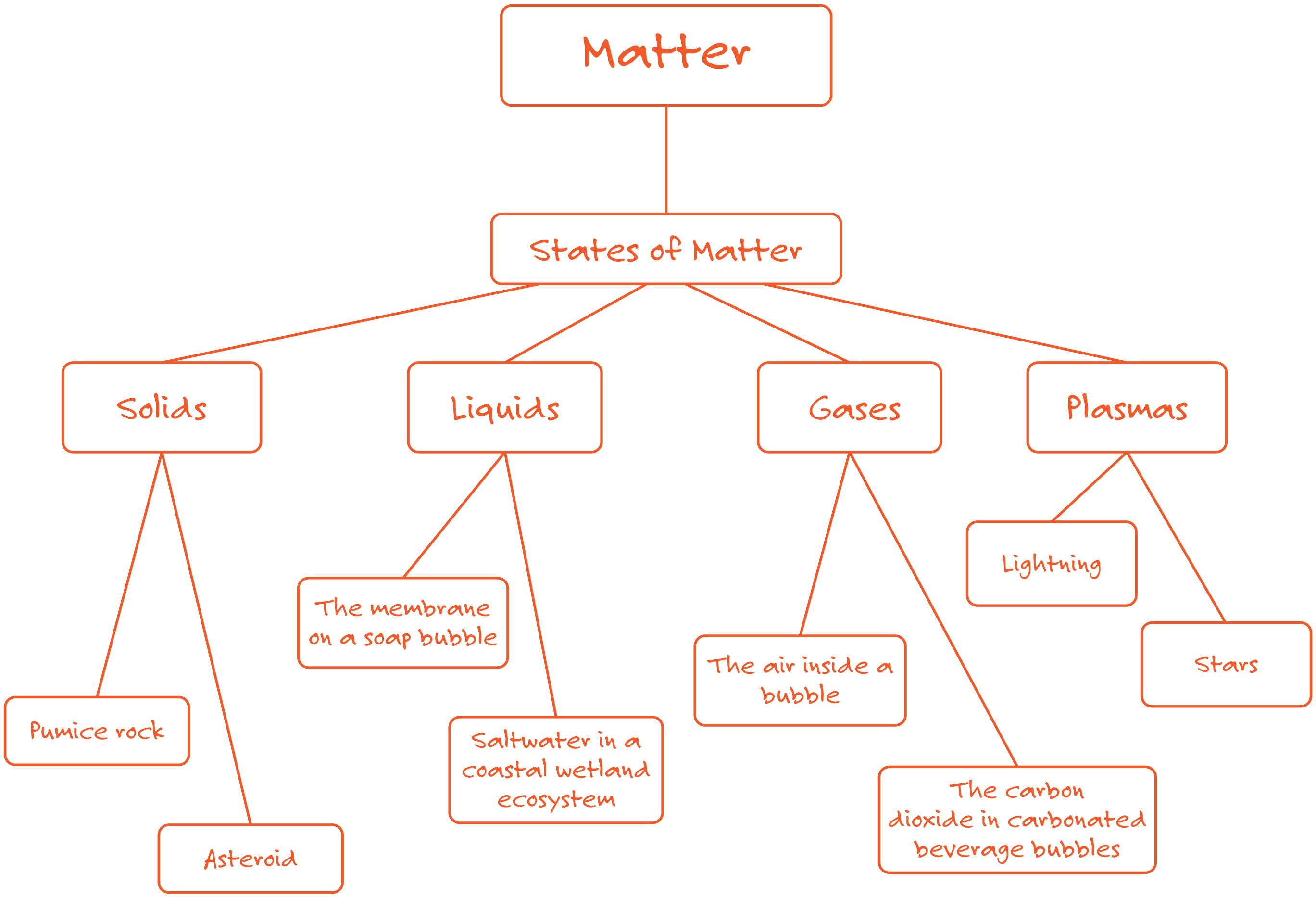
Pages 10–13 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article, "Chemicals in Nature"?	*It compares and contrasts the common and scientific meanings of the word* chemical.
What are some advantages of including a comic strip in a serious science essay?	*It grabs the reader's attention.* *It's more fun to read than straight text.* *It gets the main idea across quickly and easily.*
Let's say you are the chief editor for a large science website. To reduce confusion among readers, when would you allow writers to use chemical versus substance*?*	*I would only allow* chemical *to be used as an adjective, not as a noun. All references to kinds of matter would use the word* substance. *I would only allow use of* chemical *for matter made by humans. Any matter found in nature would be called a* substance.
What is the general purpose of the fourth article, "Chemicals: Matter and Energy in Systems"?	*It explains that ecosystems are open systems because matter and energy flow into and out of them.*
How do closed systems contrast with open systems, like the ones you are trying to investigate with the bath bomb?	*Closed systems do not allow matter to escape.*
Why do plankton need nutrients?	*Plankton are living things. All living things need to take in nutrients that they use for life processes.*

SUPPORT—Have students create simple semantic maps that reflect the usage of *chemical* that the class agrees upon. For example, if the class agrees to use the word only for human-made matter, write the word in the middle of a sheet of paper and words that fit that meeting around it. Then they can create another semantic map for the word *substance*.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 1, students should draw a concept map using the six terms provided on their Exercise Page and then add examples of the four states of matter from each of the four readings in Collection 1. Look for a clear hierarchy in the concepts on the map and accurate examples of solids, liquids, gases, and plasmas. A sample student solution is shown below. Use the rubric provided on the Exercise Page to supply feedback to each student.



Online Resources

EXTEND—For students who want to stretch their minds, point out that scientists also discuss a fifth state of matter, called "Bose-Einstein condensates." Point students to websites that explain B-E condensates, and invite students to report back to classmates how matter in this fifth state differs from the other four states.

LESSON 3

What's in a bath bomb that is producing the gas?

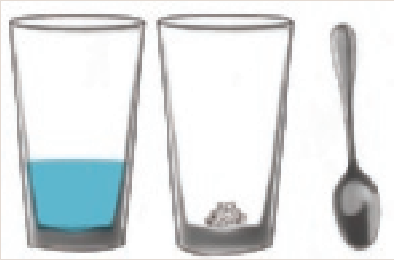
Previous Lesson

We investigated bath bombs, measuring their mass in a closed and open system before and after crushing them and before and after adding them to water. We argued from evidence for whether the gas was trapped inside the bath bomb to start with or whether some of the solid or liquid matter that was there to start with changed into a gas.

This Lesson

Investigation

2 DAYS



We analyze an ingredient list for a store-bought bath bomb and recipes for homemade bath bombs and make observations on each of the main ingredients in these, recording the properties of each. We investigate what each ingredient does as it is added to water and use the results to conclude that the ingredients interact with water in different ways, but none cause gas bubbles to appear.

Next Lesson

We will synthesize what we figured out in the unit so far. We will test different combinations of substances from a bath bomb and use the results to support an argument that the gas is a different substance than those we started with and this substance must come from the matter that makes up baking soda, citric acid, and water.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

3.A Analyze and interpret data to identify patterns in the characteristic properties of substances.

3.B Plan and carry out an investigation to collect data to identify patterns in the characteristic properties of substances from a bath bomb when they are individually added to water.

What Students Will Figure Out

- Substances in the bath bomb have properties that can help us to identify them (e.g., solubility, odor, state of matter at room temperature, melting point, density, and color).
- Adding only one substance in a bath bomb to water does not cause gas bubbles to appear.

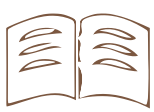
Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Students will revise the unit question to a "how" question, and then decide that to continue their figuring out they need to know the ingredients in a bath bomb.	A-B	
2	10 min	**OBSERVING BATH BOMB INGREDIENTS** Students examine the ingredient list for a store-bought bath bomb as well as the recipes for homemade bath bombs. They look for patterns across all of the bath bomb ingredients.	C-D	*Bath Bomb Recipes*, tape
3	25 min	**OBSERVING THE INGREDIENTS IN BATH BOMBS** Students decide what data to collect and make observations of each ingredient in a bath bomb. They record their observations in a data table they have drawn in their notebooks.	E-F	1 pack of 3" x 5" sticky notes, Ingredients in Bath Bombs
4	5 min	**NAVIGATION** The class reviews what they have figured out and what they still need to know. Students write their ideas on an exit ticket to turn in before they leave class.	G	notecard or scrap paper
				End of day 1
5	3 min	**NAVIGATION** Students review what they learned in the last class and share their ideas from the exit ticket. The teacher sets up the next activity.	H	
6	18 min	**TEST ONE INGREDIENT WITH WATER** Pairs of students investigate bath bomb ingredients by adding them to water and recording observations.	I-L	Investigating Ingredients Mixed in Water
7	10 min	**INTERPRETING OUR DATA** Students relate their data to scientific vocabulary such as "dissolve," "soluble," "insoluble," "substance," and "property" as they analyze and add to a table of data for the ingredients in a bath bomb. They will continue to add to this table in future lessons.	M-S	*Bath Bomb Ingredient Data*, tape
8	10 min	**ADDING TO OUR PROGRESS TRACKER** Students record what they figured out in the Progress Tracker.	T	

Part	Duration	Summary	Slide	Materials
9	4 min	**NAVIGATION** Students reflect on their entries in the Progress Tracker and consider how the information they figured out today helps them find out what is causing the gas bubbles to be released from the bath bomb. Students complete an exit ticket, answering three questions to turn in before they leave class.	U	notecard or scrap paper

End of day 2

Lesson 3 • Materials List

	per student	per group	per class
Ingredients in Bath Bombs materials		• 10 samples of each of the ingredients in labeled cups • plastic spoon • hand lens • 2-3 paper towels	
Investigating Ingredients Mixed in Water materials		• 2 different bath bomb ingredients in labeled cups • 2 large clear cups • plastic spoon • water	• electronic balances • thermometers
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Bath Bomb Recipes* • notecard or scrap paper • *Bath Bomb Ingredient Data*		• tape • 1 pack of 3" x 5" sticky notes

Materials preparation

Review teacher guide, slides, and teacher references or keys (if applicable).

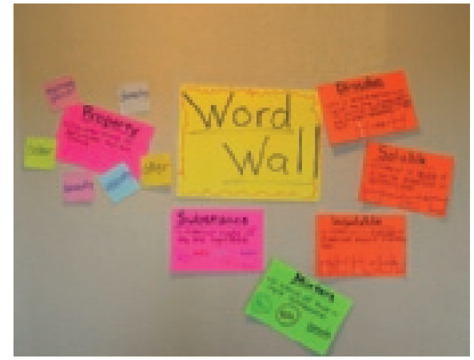
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

- Cut an 8.5” x 11” piece of paper in half for words on the Word Wall.
- The words and definitions are:
  - **property**—a characteristic of a substance that doesn’t change
  - **substance**—made of one type of material throughout
  - **dissolve**—when a solid dissolves in a liquid, the solid breaks apart into particles too small to see and it mixes completely in the liquid
  - **soluble**—describes a material that can dissolve in a particular substance
  - **insoluble**—describes a material that does not dissolve in something else
  - **mixture**—a blend of two or more substances
- Also make a “Word Wall” sign.
- Your completed Word Wall at the end of this lesson will look something like the image to the right.

Day 1: Ingredients in Bath Bombs

- **Groups:** Form 10 groups of 2-3 students each
- **Setup**
  - For each of your 10 groups, 10 small cups will be needed. Label each cup with one ingredient and its corresponding letter from the list below. You will save these cups for use in Lesson 4, as well. The following list of ingredients is common to many bath bombs. Ingredients that are not used or contaminated in this lesson will be saved and reused for lesson 4.
    - A. coconut oil
    - B. olive oil
    - C. baking soda
    - D. Epsom salts
    - E. table salt
    - F. sugar-free lemonade mix
    - G. citric acid
    - H. sugar-based lemonade mix
    - I. sugar
    - J. corn starch
  - Place approximately 1 teaspoon of each of these ingredients into the small cups. Place a set in a small bin, and make 10 sets for easy transport.

Online Resources



    - Each group of 3 students should have a complete set. Decide if you want to make a set per class or have students share a set with the next class. You have enough supplies for doing either.
    - After this lab, keep these labeled cups and the ingredients for the next lab (Lesson 4). Replenish as necessary.
- **Notes for during the lab:** Monitor the groups and encourage them to avoid cross-contamination. If this happens, discard the cup and its contents into the trash.
- **Safety:** No safety concerns.
- **Disposal:** Any mixed or contaminated ingredients can be disposed of in the trash. Collect the uncontaminated ingredients and save the labeled cups to use Lesson 4.
- **Storage:** Store ingredients in their corresponding cups until Lesson 4.

Day 2: Investigating the Ingredients Mixed in Water

- **Group size:** Your class should work in groups of 2.
- **Setup**
    - Rearrange the cups from the previous day so that pairs of students get two different ingredients. There is a pairing in the lesson that is suggested so that students do not get two ingredients that will make bubbles when mixed with water if accidentally combined. We don't want that to happen until Lesson 4.
    - Students will need two larger clear cups and access to water.
    - Notes for during the lab: Have paper towels available for accidental spills.
- **Safety:** There are no safety concerns.
- **Disposal:** All materials can be disposed in the trash or washed down the drain with cold water. Rinse the larger clear cups to use in the next class.
- **Storage:** Store ingredients separately in sealed or closed containers.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In this lesson students begin to explore what is in the bath bomb that could be creating the gas by examining the ingredients individually both before and after adding to water. Students will test substances for their properties and will examine data that list one of its properties (melting point). Students will acquire scientific vocabulary such as solubility, viscosity, etc., to describe characteristic properties of substances that can be used to identify them. They find that individually adding the substances to water does not produce a gas, which motivates them to combine ingredients in the next lesson.

Where We Are NOT Going

Students will not measure the boiling point or melting point of substances. They also will not measure or calculate density at this time. In this unit we will not be exploring pressures' relationship to boiling of a substance. We will assume boiling points are constant.

LEARNING PLAN FOR LESSON 3

1. Navigation

5 MIN

Materials: None

Revise our driving question. Display **slide A.** Say, *We started off with the question, "Can we make something new that wasn't there before?"* Use the following dialog to consider revising this question.

Suggested prompts	Sample student responses	Follow-up questions
Have we answered this question already?	*Yes! We measured the mass in a closed system and found out that it could not be something new.*	*Why do you think it couldn't be something new?*
Are there other ideas?	*I think we did make something new. We made a gas, and we know it was not there to start with.*	*How do you know it was not there to start with? What is your evidence?*

Say, *It sounds like the answer to our question right now is both "yes" and "no." So maybe we need to tweak the question a bit. Many of you wrote how and why questions for the Driving Question Board (DQB). Why don't we make this question into a how or why question? How could we change it?* Your classes should converge on something similar to: How can we make something new that was not there before?

Say, *Several of you said that we didn't make brand new matter, but I think we all agree that the gas was not something that was there to start with—it was produced when we put the bath bomb in water. How did that happen? How do you get gas bubbles from a solid bath bomb and water? Let's try to figure this out!*

Reflect on Lesson 2. Display **slide B**. Ask students if they know where the gas came from. They know it came from the starting materials, but do they know what those materials are?

Suggested prompts	Sample student responses
Do we know where the gas came from?	*No, we just know the gas had to come from something we started with.*
Okay, so if we want to know how these gas bubbles are appearing, what else do you think we need to know?	*We need to know what is in a bath bomb! Like what a bath bomb is made up of.*
How could we figure out what a bath bomb is made of?	*We could look at an ingredients list for bath bombs.*

Students may share several different ideas, but establish that our next step will be to investigate the ingredients in bath bombs.

2. Observing Bath Bomb Ingredients

10 MIN

Materials: science notebook, *Bath Bomb Recipes*, tape

Distribute the ingredient lists for homemade bath bombs. Also display **slide C,** which shows the ingredients for a store-bought bath bomb along with the list of ingredients for several homemade bath bombs. Ask students to tape *Bath Bomb Recipes* into their notebooks and make a two-column chart to record their noticings and wonderings about these.

Assessment Opportunity

Building towards: 3.A.1 Analyze and interpret data to identify patterns in the characteristic properties of substances.

What to look for/listen for: Look for students to observe and mention what ingredients were similar among the different recipes and connect this to the idea that these ingredients might be responsible for the bath bombs bubbling.

What to do: Guide students to note patterns in the data, and categorize these using words/phrases that scientists also use to describe similarities and differences around different kinds of characteristics. Have students state the purpose of looking at the ingredients to help them to connect these activities to the original phenomena. Some students might struggle with providing enough detail when describing the physical characteristics of each substance. Ask students, *What properties make these substances differ from each other and what properties make them similar? How might you write your descriptions differently to show these differences?* Engaging in this type of dialog will help push students to dig deeper into their observations allowing them to make stronger connections to data and potential evidence for explaining what is causing bubbles in bath bombs.

Additional Guidance

Students may notice that the store-bought bath bombs do not list baking soda. They will likely list sodium bicarbonate or sodium hydrogen carbonate—both are scientific names for baking soda. It is helpful to let students know that they are the same thing and that some substances have both scientific names as well as common names.

Students record observations. Ask students to make some observations about the ingredients. This should be a quick scan of the lists to see what they have in common. One thing they should notice is that the store-bought bath bomb has ingredients that are similar to the homemade bath bombs. Moving forward, we will focus on the recipes of the homemade bath bombs.

Once students have had a few minutes to look over the recipes, ask students to share some of their observations.

Suggested prompt	Sample student responses
Do you notice any patterns in the ingredient lists?	*We see that baking soda is in all of the recipes.* *Citric acid and Epsom salts are in most of the recipes.* *They all have some type of oil in them.*

Suggested prompt	Sample student responses
What can you learn from these patterns?	*We think that baking soda is important for gas bubbles because it is in all the recipes and citric acid and/or Epsom salts must also be important for gas bubbles because they are in most of the recipes.*

Ask students what we should do with this information. Display **slide D**. Now that the class knows the names of the ingredients, refer students to the questions on the slides to figure out what additional information they want to know about these ingredients to help figure out how bath bombs form bubbles.

- *Now that we know the names of these ingredients, what do we want to know about them?*
- *How can we use the ingredients to help us figure out how the bath bomb makes gas bubbles?*
- *What could we eventually investigate using these ingredients?*

Allow students to discuss this with a partner, and then ask for a few responses from the class. Students should suggest looking at each ingredient separately. Students may also suggest putting all of these ingredients by themselves in water to see if any gas bubbles form.

3. Observing the Ingredients in Bath Bombs

25 MIN

Materials: Ingredients in Bath Bombs, science notebook, 1 pack of 3” x 5” sticky notes

Decide what data to collect. Work with students to decide what data to collect as they observe each of the ingredients. Work together to create a data table. Prompt them by saying, *If we look at the different ingredients by themselves, what kind of data do we want to collect? We should decide as a class what kind of data we want, and then let’s set up a data table to use.* Display **slide E**.

As a class, agree to collect data such as the color, smell, how it feels, how it moves in the cup, etc. Some students may suggest weighing the sample and recording the volume or how much they have of each. Students should set up a table in their notebooks to record these data. Their data table can be as simple as the one below.

Ingredient	Observations (color, smell, how it feels, how it moves, etc.)

Distribute materials to student groups. Each group of students should have a small sample of each of these ingredients:

- baking soda
- table salt
- citric acid

*** Supporting Students in Engaging in Analyzing and Interpreting Data**
Students often do not include enough details when recording data and observations. You can encourage them to do so by asking questions that include, *I noticed you have white as a color for more than one substance. Can you be more descriptive? We want to try to be able to tell these apart based on their characteristics.* Or you can say, *Do they all feel the same? I notice you have powdery listed for more than one. Are all of these powdery to the touch?* By doing this, you will help all students understand how being specific in descriptions and observations will make it easier

- powdered lemonade mix (sugar-free)
- powdered lemonade mix (non-sugar-free)
- Epsom salts
- olive oil
- coconut oil
- sugar
- corn starch

Students record observations of each ingredient. Encourage students to record observations that will help them tell the ingredients apart later. This will encourage students to be detailed in their observations and to focus on accurately recording the characteristics and properties of the ingredients. Students will learn what a property is later in day 2 of this lesson.

Monitor groups as they make observations. As students are making observations, visit each group and encourage students to be detailed in their observations.* When needed, prompt students to add more detail so they can tell the ingredients apart.

when they analyze and interpret the data to find similarities and differences, and will result in the collected data serving as stronger evidence.

Bring the class back together as one group. When the students are finished with their observations, display **slide F**. Say, *What were some of your observations—what did you notice? Did you find any evidence that would help us figure out how the bath bomb produces gas bubbles?*

Assessment Opportunity

Building towards: 3.A.2 Analyze and interpret data to identify patterns in the characteristic properties of substances.

What to look for/listen for: As students report out their observations with the rest of the class in the whole class discussion, listen for these ideas:

- None of the substances made bubbles when added to water.
- Some of the substances dissolved when added to water—these were soluble in water.
- Some of the substances didn't change in water. They just clumped up or formed a layer—these were insoluble in water.
- A couple of the substances made the water turn murky or cloudy—these were partially soluble in water.

What to do: If students are hesitant to share or there are not enough students sharing the patterns they found when they tested the different substances in water, pause the discussion and ask them to turn and talk with someone that was not in their small group and compare what they found in the investigation so they can compare and see if they have similar results.

Share patterns. Guide students to note patterns and categorize these using words/phrases that scientists also use to describe similarities and differences around different kinds of characteristics.

Suggested prompts	Sample student responses	Follow-up questions
What are some of your observations—what did you notice?	*There are several of these that are white powdery or crystal stuff.*	*What do all of these have in common? How are they different?*
The coconut oil seems to melt when I hold it in my hand.	*What does it mean to melt?*	
When making observations, what patterns do you notice?	*Lots of them are white but others have a different color.*	*So color is one of your observations?*
	When I poured the water and the olive oil, they seemed to pour (flow) out of the cup differently.	*Are you saying the liquids flowed differently?*
You have different amounts and masses of each. Are you recording this in your observations?	*Not really—that is not going to help me tell the ingredients apart.*	*Why not? Are there some observations that will?*

Students should note these observations as they collect their data. The ingredients in the bath bomb (that we had to start with) have characteristics that we can use to tell them apart (and also to determine what each one is). Say, *Let's add examples of all the characteristics we could use to help identify our ingredients. We will write each characteristic on a separate sticky note and stick them on the Word Wall. Are there examples we can add now?*

Let students suggest, write, and post the examples. Listen for these characteristics students bring up after observing the ingredients:

- Some have different colors **(color).**
- **Texture** (whether it is granular or powdery).
- Some have a noticeable scent/smell, but others do not **(odor).**
- One turned to liquid when touched (it went above its **melting point of** 76 degrees), while others didn't change phase.
- They are liquid or solid at room temperature **(**different **states of matter at room temperature).**
- The liquids flow differently **(viscosity).**
- **Mass.**
- How much space it takes up **(volume).**

You may notice that students add characteristics that are not properties such as mass, volume, and/or texture. At this point allow these words to be added to the Word Wall. We will sort through all of these words to see which of these characteristics are properties on day 2.

Additional Guidance

To help facilitate this discussion and to keep it moving, it might be helpful to have some of these characteristics and definitions pre-written on sticky notes. When students in the discussion bring up some of these pre-written characteristics the class can then quickly add them to the Word Wall.

4. Navigation

5 MIN

Materials: notecard or scrap paper

Navigate from this activity and set up the learning for the next day. Once several students have shared their data, say, *We now know a lot about each individual ingredient. None of those ingredients are gases, and we know we got a gas when we put the bath bomb in water.* (Display **slide G**.) *What else should we do to try to figure this out?* Ask students to write their ideas on a notecard as an exit ticket. Collect these from students as they leave class.

End of day 1

5. Navigation

3 MIN

Materials: None

Navigate to test each ingredient individually in water. Display **slide H**. Prior to the start of class, review students' exit ticket responses. There are likely to be some that say that they need to test each individual ingredient in water. They may wonder if mixing the ingredients with water causes the gas bubbles. Say, *Many of you wanted to test each ingredient in water. Why do you think that is important to do?* Students should comment that the bath bomb didn't make gas bubbles until it was put in water. *Why is it important to test each one individually rather than just putting a bunch of ingredients at the same time?**

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**
Asking students questions such as this will help students think about how to limit variables in their investigation in order to obtain more reliable data that will support them in their development of understanding over time as they engage in the practice of planning an investigation.

6. Test one ingredient with water.

18 MIN

Materials: Investigating Ingredients Mixed in Water, science notebook

Divide the ingredients from the list among teams. Display **slide I**. The table below illustrates one way to divide the ingredients so that each group gets a variety of properties to observe. This is the same grouping as shown on the slide. Duplicate small group assignments as necessary. Have students label the large cup with the name of the substance that they are going to add to the water. Display **slide J.** Have students record which substance they are assigned in their science notebooks. Adjust this slide if you are using different groupings.

*** Attending to Equity**
Extension: Some students might want to keep track of mass in their investigation. For those that suggest they want to collect this data, encourage them to reason out why

Group #	Ingredients to test in water (one at a time!)
1	baking soda
	coconut oil
2	Epsom salts
	olive oil
3	sugary powdered lemonade mix
	citric acid
4	sugar-free powdered lemonade mix
	sugar
5	salt
	corn starch

Additional Guidance

Do not give a group of students both of the ingredients that will react—baking soda and citric acid (or either lemonade mix). With unreactive sets, if they accidentally mix the two before putting them in water, no reaction will occur. Students will investigate mixing two substances together in the next lesson.

Solicit ideas for data to collect. Help students identify data that we should collect with the following prompts:

- *What types of data in this investigation are important for us to keep track of?*
- *What are some different ways we could keep track of this data?*
- *What kinds of things have we kept track of in our other investigations? Are those also important to keep track of here?*

Assessment Opportunity

Building towards: 3.B Plan and carry out an investigation to collect data to identify patterns in the characteristic properties of substances from a bath bomb when they are individually added to water.

What to look for/listen for:

- Looking for evidence of bubbles coming from the ingredients when they are placed in water.
- The physical observation of what happened to each ingredient when it was added to water.
- Testing only one ingredient at a time so that they know what ingredient is potentially responsible for producing the bubbles.

keeping track of mass might be useful. Then have students plan how and when they would incorporate taking mass measurements in their investigations. The following questions can be used to help facilitate this conversation with these students.

- *In Lesson 2 we measured mass in our experiment. Why was measuring mass important in that experiment? How do you see mass being an important measurement in this experiment?*
- *When should you measure mass in this experiment?*
- *What materials will be on the scale during each measurement and why?*

Allowing space for some students to reason through why they would want to collect this data and then actually collecting the data supports high interest students in going deeper with SEP3 (Planning and Carrying Out Investigations).

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**

Asking students questions such as these will support them in figuring out what evidence they need to collect, and how to accurately collect it when setting up their investigation. This will help students in their development of an understanding of this practice over time as they engage in planning an investigation.

What to do: If you see groups rushing from one test to the next, without first writing down their observations for the previous one, remind those groups that detailed observations are important for providing evidence for future arguments. If you notice some students not participating, or not being included, remind the small group of the class norms and ask them how they could alter what they are doing so that all of them are contributing members of the investigation.

Students may offer several ideas. Accept all and discuss as a class how to keep track of them in a data table. Some suggestions students may make might include, temperature, mass, color change, thickness change, etc.*

Solicit ideas for recording data. Work together as a class to determine a way to organize their data, keeping in mind that they will add the rest of the ingredients when groups share their data with the class. Draw their suggested data table on the board. Tell students they should make a data table in their notebooks also to keep track of the data they collect for the ingredients they test.*

Carry out the investigation. Display **slide K**. Give each team *Lab Procedure for Mixing the Ingredients in the Water* and their set of assigned ingredients to test in water using the visual procedure on the slide. This student investigation should take no more than 10 minutes.

Report the results. Display **slide L**. Ask a few students to report what they saw happen to each ingredient when it was added to water. They can bring their labeled cups up to the front of the room and line them up on the front table as they report their results for other groups to see, if you wish. Ask students to also compare how this was the same or different from bath bombs interacting with water. Encourage students to add ingredients that they did not test to their data table. Each student should have data for each ingredient after everyone has shared.

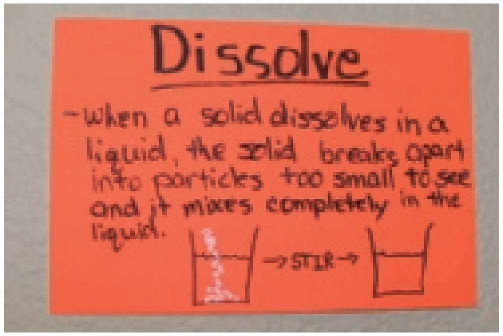
Suggested prompts	Sample student responses	Follow-up questions
Okay, so we are trying to figure out what causes the gas bubbles in the bath bomb. Looking at our class data, can we come to any conclusion about what causes the gas bubbles?	*Not really…because none of the ingredients resulted in gas bubbles.* *None of these ingredients bubbled when we put them in water.*	*What other patterns in the data do you notice?* *What does that information tell you?*
Was there anything all the ingredients had in common?	*There wasn't a gas made for any of the ingredients when mixed with water.*	*What did this data tell you?*
Was there anything in the data that was different between the ingredients after being mixed with water?	*Some of the ingredients looked as if they didn't mix with the water—they just floated on top of the water.*	*Which ingredients were those?*
	Some ingredients dissolved in the water and the liquid looked clear. But others looked cloudy or milky.	*Do you think the ones that looked milky dissolved like the ones that looked clear? Why or why not?* *You said some ingredients "dissolved." Do you have ideas about how that happens? What does it mean to dissolve?*

Additional Guidance

Students will likely not know the terms "soluble" or "insoluble" yet but will learn them in the next activity. Make sure to emphasize these ideas and their connection with things dissolving so that when students learn the vocabulary associated with the ideas later, they can reference these experiences.

7. Interpreting Our Data

10 MIN



Materials: science notebook, *Bath Bomb Ingredient Data*, tape

Make sense of the data. Students will bring up that some of the ingredients dissolved in water. Ask students what it means to dissolve.

Students should agree from what they learned in previous years that when something dissolves in water, the water can be evaporated off and the original substance will still be there. (This should be something that was learned in 5th grade. However, if your students haven't learned it yet, you may wish to take the time to ask how to collect evidence supporting the concept that when something dissolves in water, we can let the water evaporate and get the original substance back.) An example dialog is shown below.

Suggested prompts	Sample student responses
When we add something to water—like salt—does it totally disappear?	*Yes—we cannot see it again.* *No—we cannot see it, but it is still there.*
How could you figure out if it is still there?	*We could weigh it before and after we dissolve it in water. Then let the water evaporate. If it really didn't disappear, then we would see it again.*

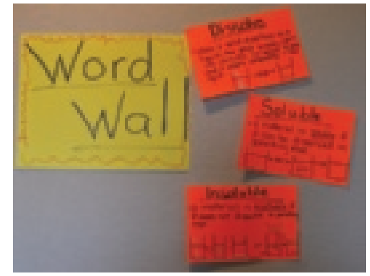
Add the word "dissolve" to the Word Wall with the definition: when a solid dissolves in a liquid, the solid breaks apart into particles too small to see and it completely mixes with the liquid. While dissolving in liquids is not the only example, it fits our purposes here. You can return and add details to this definition as students perform additional experiments.

Additional Guidance

Using a Word Wall to display important vocabulary is an effective strategy to support all students. Call attention to words that students use that are on the Word Wall, and if students struggle to find the right word to use, ask them to look at the Word Wall to see if there are words there that will help them.

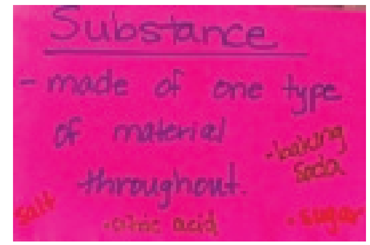
If your wall space is limited, use smaller pieces of paper to put words up, but make sure that the text is readable from all parts of your classroom. It might be helpful to have some of these properties and definitions pre-written on sticky notes. When students bring up some of these pre-written properties and definitions in a discussion, the class can then quickly add them to the Word Wall.

*** Attending to Equity**
This is an opportunity to build literacy skills and also to provide support for emerging multilingual learners or struggling readers. Ask students, *What do the words "dissolve" and "soluble" have in common?* Focus students on just the word, and not what each means. After students have had a chance to respond, either support their ideas if they emerge or say, *Both words have "sol" in them. One meaning of "sol" is to loosen. This makes sense because we loosen little parts of the solids away from each other until they are so small we cannot see them.*



Introduce or reinforce scientific vocabulary. Say to students, *We have learned that some of the bath bomb ingredients dissolve and some do not. Does anyone know the word we use to describe if something dissolves when added to a particular liquid? If something has the ability to dissolve, it is **soluble**, and if it does not dissolve and is not soluble, then it can be described as **insoluble**. If something only partially dissolves and looks cloudy or murky we can describe it as partially soluble.** Ask students to name some things that were soluble, insoluble, and partially soluble in water. Add these terms to the Word Wall.

Say, ***Solubility in water** is what we have been talking about, and that is another characteristic. Can someone write this on a sticky note and put it on our Word Wall?*



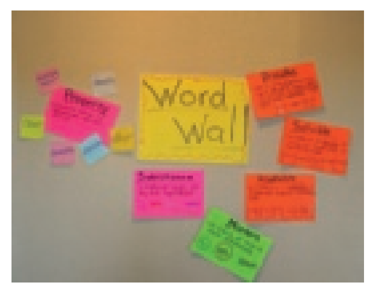
Record data for bath bomb ingredients. Display **slide M** and distribute *Bath Bomb Ingredient Data*. Tell students not to tape it in their notebooks yet because we will be adding to it first.

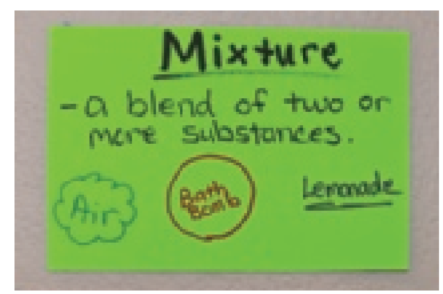
Say, *Let's make sense of this data table.* Display **slide N.** *Each ingredient's name is in the first column. We have been calling all these things ingredients, but in science, they are identified as substances because they are all made up of the same type of material throughout. So all these ingredients that are recorded in the first column are considered substances.* Display **slide O**. Have students in column 1 and 2 of their table cross out the word "ingredient" with one line and relabel it with the word "substance." Then say, *Let's add that to our Word Wall. **Substances** are made of one type of material throughout. The second column is the scientific name of the different substances.* At this point, it may be helpful to encourage your students to write the word "substance" under Ingredient on their table. Continue using a dialog similar to the prompts below.

Suggested prompts	Sample student responses
So what would the bath bomb be? Would it be a substance?	*No, because it is made of several different substances all mixed together.*
Can you think of a word that we can use to call things like bath bombs that are made of different substances and that are, like you said, all mixed together?	*How about a mix?* *Or a mixture?*

Add the word "mixture**"** to the Word Wall with the definition: a blend of two or more substances. Ask students to give you some examples of mixtures that they have worked with before. Add examples to the mixture card.

The last two ingredients on the table (lemonade mix and sugar-free lemonade mix) are not substances. Students will most likely notice the word "mix" after the lemonades. When this comes up, suggest that we should keep track of this. **Display slide P** to provide an example of how to note this, if needed.





Enter the state of matter data. Show students that the next column on the data table gives the melting point for everything that is not a mixture. Display **slide Q**. You will talk more about the melting point later. Students may notice that many of the substances are solids at room temperature and have extremely high melting points. That characteristic is not easy to measure for all of these substances in a school setting.

Additional Guidance

Students may ask why the last two ingredients don't have a melting point listed. If so, you can point out that the different substances that make up the mixture might have different melting points, so one can't list a single melting point for a mixture. You can give an example of a mixture of sugar and table salt using the melting point data for these provided in the table, to encourage students to think about how part of the mixture (the sugar) would melt at a lower temperature than the other part of the mixture (the table salt).

Display **slide R**. Tell students to enter the state of matter of each ingredient in the column labeled "State of Matter." Ask students why it is important that the room temperature be included in their data. Record the room temperature on the column heading. Tell students they only need to enter "solid," "liquid," or "gas" in the column.

Students may have noticed that the coconut oil melted in their hands. Encourage them to reason about this and compare their body temperature to the melting point.

Suggested prompts	Sample student responses	Follow-up questions
You may have noticed that when we record the state of matter, it says "at room temperature." Why is that important?	*The temperature is different on different days.* *Things change state at different temperatures, so it is important that you say what temperature it is when you record the state.*	*Why would that matter?*
What did you notice that happened to the coconut oil when you put it in your hand?	*It melted!*	*Why do you think that happened?*
What is your body temperature?	*98.6°F*	*Do you know what that is in Celsius? (37°C)*
How does the melting point for coconut oil compare to the room's temperature?	*The melting point is higher than room temperature.*	*Knowing this about coconut oil, can you estimate what its melting point is?*

Other connections to the data for states of matter can be brought out by asking questions similar to the ones below. Students may want to put "state of matter at room temperature" and "melting point" on sticky notes and add them to the Word Wall.

Suggested prompts	Sample student responses
Why is noting the state of matter important to what we are doing with bath bombs?	*We know that there aren't any ingredients in the bath bomb that are gases, but when we put them in water, we got a gas.*
Why is it important that the state of matter says "at room temperature"?	*It means that these ingredients are at the temperature of our room. This would be important because we are comparing them all at room temperature and we don't yet know if temperature is important. Also, we said bath bombs are usually used in warm bath water, so maybe these act differently in warmer water.*

Add solubility data to the table. Display **slide S**. Tell students to use their data and observations from the *Observing the Ingredients of Bath Bombs* activity to complete a new column in *Bath Bomb Ingredient Data*. Have them label the first blank column "Soluble in Water?" Give them 2-3 minutes to add their data. Encourage them to enter "yes," "no," or "partially" in the column for each ingredient.

Have students share what they recorded to ensure that everyone in the class agrees upon which substances were water soluble and which ones were not.

Additional Guidance

Students may question why "in water" follows "solubility." Students may not have thought about dissolving the solid substances in liquids other than water, but a substance's solubility depends on the liquid it is dissolved in. It also depends on the temperature of the liquid. Discuss this with your students if they bring it up. If students have not thought of or tried dissolving some of the solid substances in oil yet, you may want to give them the opportunity to do so now. The solubility of the substance in other substances, besides water, that are also liquids at room temperature is also a property.

Sort the characteristics of bath bombs that are properties on the Word Wall. Bring students' attention to the Word Wall. Say, *We have added a lot of different characteristics for the different substances in our bath bomb. We are trying to figure out where these gas bubbles come from when the bath bomb is added to water. I heard some of you suggest that something in the bath bomb turns into the gas bubbles. In order to figure this out we will need to really keep track of when something changes and what it was like before and after that change. We can use these characteristics to tell whether the baking soda is still baking soda, and the coconut oil is still coconut oil or it has changed. If a substance, or ingredient, changes then its characteristics will change. But for us to be able to tell if a substance changes, we need to figure out which characteristics are always true for a substance. For example, some characteristics like "it weighs 5 grams" or "it is spread across the table" are not always true. But others like the color of baking soda are always true. Let's call these characteristics that are always true for a substance "properties." Let's take a few minutes to reflect on them and think about which ones would be more helpful in identifying a substance and which ones would be less helpful. Take a look at all the characteristics. Can we sort this list into things that we think are always true for a substance?* Have students as a class sort the characteristics on the Word Wall into two groupings.

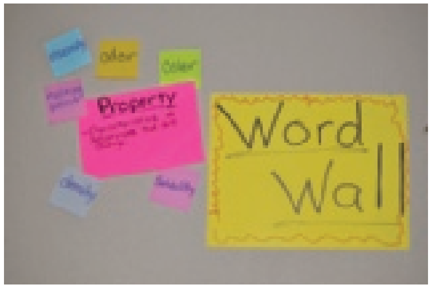
Group 1: Characteristics that are always the same for that substance. Those shown in bold are considered properties:

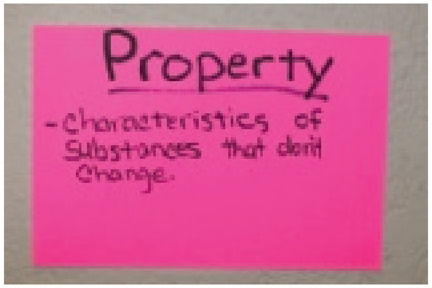
- Some have different colors **(color).**
- Some have a noticeable scent/smell, but others do not **(odor).**
- One turned to liquid when touched (it went above its **melting point of** 76 degrees), while others didn't change phase.
- They are liquid or solid at room temperature **(**different **states of matter at room temperature).**
- **If it can dissolve in water (solubility in water).**
- The liquids flow differently **(viscosity).**

Group 2: Characteristics of a substance that are only sometimes true:

- mass
- volume
- shape
- texture

Additional Guidance





If the class attempts to place a characteristic into the wrong grouping then push on students' thinking by asking questions or having students attempt to change some of the bath bomb properties. For example, if students think that texture is a property that can't be changed, have students attempt to grind Epsom salt (a coarse solid) into a powder.

Introduce the term "property." Say, *These ways of describing characteristics of matter that don't change are helpful for identifying what a substance is because they are constant for any sample of that substance, no matter the size of the sample. In scientific communities these characteristics are called "properties."* Add, "**Properties:** characteristics of a substance that do not change" on the Word Wall.

Additional Guidance

If you are planning to teach *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit)* directly following this unit, plan to keep up your Word Wall in a place as you transition to that unit so it can still be referred to and used. Students will refer to many of the words from this unit during that one, and it will be helpful to have them posted.

Prepare your notebook for the data table. Have students attach *Bath Bomb Ingredient Data* to their notebooks by taping along the left edge. They should fold the page if their notebook will not close flat. Have them title this data table and page "Bath Bomb Ingredient Property Data."

8. Adding to Our Progress Tracker

10 MIN

Materials: science notebook

Add to the Progress Tracker. Display **slide T**. Individually, have the students add a row to their Progress Tracker to note what they have figured out and how this will help them figure out what causes bath bombs to behave the way they do. Encourage them to add what they have learned about solubility.* Do not score this version of the Progress Tracker, but rather, use it as a way to formatively assess what your students have figured out to this point. Sample ideas that students may list as to what they figured out are:

Question	What I figured out
What's in a bath bomb that is producing the gas?	• *None of the substances made bubbles when added to water.* • *Some of the substances dissolved when added to water—these were soluble.* • *Some of the substances didn't change in water, they just clumped up or formed a layer—these were insoluble.* • *A couple of the substances made the water turn murky or cloudy—these were partially soluble.*

* Attending to Equity

This example Progress Tracker serves as teacher guidance for what students might say at various points throughout the unit. However, some students may say more and others may say less. It is important that what the students write in the two-column tracker reflects their own thinking at that particular moment in time. This is an opportunity for students to express their understanding and reasoning in their own way. Encourage students to express what they've learned using a mode that makes sense for them. For some Emerging Multilingual Learners, encourage them to use space to make sense in the language that they feel most comfortable using. The individual Progress Tracker is a space for students to be creative and to synthesize learning in their own words. It is not supposed to follow a prescriptive plan or structure and should be a low-stakes opportunity for students to make sense of what they are learning without the worry and anxiety that comes with knowing their work will be graded. Use the Progress Tracker for formative assessment only.

9. Navigation

4 MIN

Materials: notecard or scrap paper

Wrapping up day 2. Display **slide U**. Ask students, *You just listed some things you figured out on your Progress Tracker. How do these things help you figure out what is (or is not) producing the gas bubbles from the bath bomb?* Students should respond with something like, "We know that there must be more than one ingredient that makes the gas bubbles because when we put each one on their own in the water, there were no gas bubbles. But, we don't know which of the ingredients make the gas bubbles."

Key Ideas

The observation that each of the ingredients by themselves did not produce bubbles in the water is an important idea that needs to be emphasized by the class and remembered by students through the end of the unit. Students will later model what particles are reacting by breaking apart and rearranging into new particles. Although this reaction takes place in water, the ingredients did not react with the water to produce bubbles.

Complete an exit ticket. Say to students, *Use a notecard or scrap of paper to answer the questions on the slide before you leave.* The questions for students are:

1. What else should we investigate about these substances or try to do using these substances?
2. What is one new question you have based on the investigation we did today?
3. What was one new idea you heard from a classmate?

Assessment Opportunity

This exit ticket structure is one you should use often, even if we do not specifically call out this structure. The student responses to these questions will allow you to assess students' sense of coherence in the science content storyline, their curiosity, and how they are working with other classmates' ideas in their learning community. Since this is an individual task, it will give you a good measure of this from each student. Additionally, this structure will communicate to your students that you value what they think and wonder about related to the science ideas you are focusing on in the unit.

LESSON 4

Which combinations of the substances in a bath bomb produce a gas?

Previous Lesson

We analyzed an ingredient list and recipes for bath bombs and made observations on each of the main ingredients in these, recording the properties of each. We investigated what each ingredient did as it was added to water and concluded that the ingredients interacted with water in different ways, but none caused gas bubbles to appear.

This Lesson

Putting Pieces Together, Investigation

2 DAYS

We synthesize what we've figured out so far in the unit, and use this to help us update our list of key model ideas. We plan and carry out an investigation to test different combinations of substances from a bath bomb. We use these results and what we know about the state of matter being a property at room temperature to support an argument that the gas is a different substance than those we started with and this substance must come from the matter that makes up baking soda, citric acid, and water.

Next Lesson

We will analyze the density and flammability data for common gases. We will test the flammability of the gas from the bath bomb. We will carry out an investigation to see if the gas from the bath bomb rises or sinks. We will argue from evidence that the gas from the bath bomb can be narrowed down to three candidate gases.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

4.A Conduct an investigation to produce data to serve as the basis for evidence to determine which combinations (patterns) of substances in a bath bomb cause bubbles of gas to appear (effect).

4.B Construct and present a written and oral argument supported by citing empirical evidence and scientific reasoning that only certain combinations (patterns) of substances (water, baking soda, and citric acid) result (cause) in the formation of a gas (effect).

4.C Apply scientific ideas and evidence (patterns in properties) to co-construct an explanation that the substance(s) in the gas bubbles must be a different substance(s) than the water, baking soda, or citric acid.

What Students Will Figure Out

- Citric acid and baking soda are the only substances from the bath bomb that, when combined with water, cause gas bubbles to form.
- The gas(es) in the bubbles are substance(s) that are different from any of the substances we started with.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**CHOOSE A FOCAL NORM** Students select a norm to work on in this lesson.	A	Norms poster
2	20 min	**ADDING TO OUR PROGRESS TRACKER**	B–C	highlighter, chart paper, Key Model Ideas chart (started in Lesson 2)
3	15 min	**PLANNING FOR OUR INVESTIGATION**	D–G	*Combinations of Ingredients to Test*, sticky notes, chart paper
4	5 min	**REFLECTING ON NORMS**	H	index card, Norms poster
				End of day 1
5	15 min	**CARRYING OUT OUR INVESTIGATION**	I–J	sticky notes, Norms poster, Combinations of Ingredients Lab
6	5 min	**ANALYZE OUR LAB DATA**	J	computer, projector
7	5 min	**EXAMINE LEMONADE MIX AND ADD TO PROGRESS TRACKER** Make predictions about what substances are in lemonade mix, and then analyze lemonade mix ingredient lists. Individually update Progress Trackers.	K–M	*Lemonade Mix Labels* (optional)
8	15 min	**ARGUE WHICH SUBSTANCES IN A BATH BOMB PRODUCE A GAS AND EXPLAIN IF THE GAS IS A DIFFERENT SUBSTANCE** In a whole-class discussion, use evidence and reasoning to argue in support of a claim that answers our lesson question: Was the gas one of the substances we started with?	N	chart paper, Arguing for (or Against) a Claim poster (from Lesson 2)
9	5 min	**NAVIGATION** Reflect on progress made in the practice of developing an argument.	O	notecards, chart paper
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 4, students are ready to read Student Reader Collection 2 and then respond to the writing exercise.		Student Reader Collection 2: *Chemistry Concepts*

Lesson 4 • Materials List

	per student	per group	per class
Combinations of Ingredients Lab materials	• splash goggles	• ice cube tray (standard size)	• 90 small cups • 10 large cups • 10 bins • 10 wooden stirrers • 100 disposable pipettes • water • olive oil • coconut oil • baking soda • Epsom salts • table salt • sugar-free lemonade mix • citric acid • sugar-based lemonade mix • sugar • corn starch
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • highlighter • *Combinations of Ingredients to Test* • *Lemonade Mix Labels* (optional) • notecards	• index card • sticky notes	• Norms poster • chart paper • Key Model Ideas chart (started in Lesson 2) • sticky notes • computer • projector • Arguing for (or Against) a Claim poster (from Lesson 2)

Materials preparation (35 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Trim handouts to fit science notebooks.

Online Resources

An optional material to copy for students is *Lemonade Mix Labels*, which shows the ingredient lists for both lemonade mixes. These lists are also displayed on **slide N**, but you may choose to provide this copy to your students and reuse it across classes.

Day 2: Combinations of Ingredients lab

- **Group size:** form 10 groups of 2–3 students each
- **Setup:**
  - A video of the setup for this lab is available via the **Online Resources Guide**. **www.coreknowledge.org/cksci-online-resources**.
  - Make a solution of each of the following substances by stirring 2 T of each ingredient into 250 mL of water. If you were able to collect uncontaminated leftovers of these ingredients after Lesson 3, use those to make these solutions. Ingredients are labeled here by the letter of the cup in which they'll be distributed.
    - C. baking soda
    - D. Epsom salts
    - E. table salt
    - F. sugar-free lemonade mix
    - G. citric acid
    - H. sugar-based lemonade mix
    - I. sugar
    - J. corn starch
    - (Ingredients A and B are coconut and olive oils; they are not mixed into solution.)
  - Obtain 9 sets of 10 small (3 oz) plastic cups, for a total of 90 cups, and label each set A through J. You should already have sets of small cups labeled like this saved from Lesson 3.
  - Obtain 10 large (5 oz) plastic cups and label them A through J (a single cup for each letter). Since each group will test a single ingredient in combination with all the others, each group will have a larger amount of the single ingredient that they will test repeatedly.
  - Pour 100 mL of each solution into its corresponding large cup (labeled C through J).
  - Pour about 10 mL of each solution into the corresponding small cups (labeled C through J).
  - Pour about 100 mL of olive oil into the large cup labeled B. Pour about 10 mL of olive oil into each small cup labeled B.
  - Scoop out about 3 tablespoons of coconut oil into the large cup labeled A and 1 teaspoon of coconut oil into each small cup labeled A.
  - Label a different bin for each group, numbered 1–10.
  - You are now ready to prepare bins of cups for each group to use for testing. Put a different large cup in each bin and add smaller cups for the other solutions as follows:
    - Bin 1: large cup of A (coconut oil) and small cups B-J
    - Bin 2: large cup of B (olive oil) and small cups A and C–J

    - Bin 3: large cup of C (baking soda solution) and small cups A–B and D–J
    - Bin 4: large cup of D (Epsom salts solution) and small cups A–C and E–J
    - Bin 5: large cup of E (table salt solution) and small cups A–D and F–J
    - Bin 6: large cup of F (sugar-free lemonade solution) and small cups A–E and G–J
    - Bin 7: large cup of G (citric acid solution) and small cups A–F and H–J
    - Bin 8: large cup of H (sugar-based lemonade solution) and small cups A–G and I–J
    - Bin 9: large cup of I (sugar solution) and small cups A–H and J
    - Bin 10: large cup of J (corn starch solution) and small cups A–I
  - Add a disposable wooden coffee stirrer to each of the cups labeled A (large and small) for scooping and spreading coconut oil.
  - Label 90 disposable pipettes, 10 each with each letter B–J. To avoid rubbing off the labels during use, write in permanent marker below the bulb, or make flags of tape with the letters on them. Add a set of labeled pipettes (one of each letter) to each bin. When you prepare for classes to follow, keep these pipettes with their corresponding cups and bins. The goal is not to cross-contaminate the pipettes.
  - Reuse the bins for transport of materials to the next class.
- **Safety:** Be sure students wear splash goggles during this investigation.
- **Disposal:** All materials can be washed down the drain with cold or warm water. Cups can be saved and reused for next year.
- **Storage:** Unused solutions F, H, I, and J may be stored in a closed container in a refrigerator for up to one week. The other solutions you prepared may be stored on a shelf for the duration of the unit if they are in a closed container.

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

This lesson begins with identifying a new key model idea that was discovered in the previous lesson.

- Properties don't change for a substance.

After this lesson, you can start referring to this phenomenon as something that "produces" a gas, rather than simply saying it causes a gas to appear. This is because we now know that the gas wasn't something that was there before. We know the combination of substances that caused it to form, and we know that matter is conserved in this process.

Lesson 5 will help students narrow down a list of candidate gases that could be in the bubbles based on their property data.

Where We Are NOT Going

It is not yet important that students determine that this is a chemical reaction. At this point, they only have a partial understanding of this idea: that certain combinations of substances, when mixed together, may cause a new substance to form. But they will need some additional data to support their new understandings about this idea.

It is not important that students understand the role of water in this process. Students already know that water causes baking soda to dissolve (break into smaller pieces), and that it does the same for citric acid. It could be reasonable to assume that one or both substances must be broken down into smaller pieces in order for the gas to appear.

LEARNING PLAN FOR LESSON 4

1. Choose a focal norm. 5 MIN

Materials: science notebook, Norms poster

Choose a norm to work on during this lesson. Display **slide A.** Point students' attention to the class norms poster or the copy in their notebooks. Direct students to silently choose a norm they will intentionally work at and monitor today to help our learning community grow stronger and more productive for everyone. After a moment of silent thinking, tell the class that we'll take time at the end of class today to reflect on how well they did working toward the norm they each chose.

Additional Guidance

The first day of this lesson is a strategic point to have students revisit their class norms. The beginning of this lesson requires students to participate in an extended whole-class discussion in the Scientists Circle, and the second half of the lesson requires negotiation and coordination with classmates in a small group. It is helpful to begin and end by focusing on norms during days that involve lots of whole-class and/or small-group talk, even if it isn't written into the teacher guide. It is recommended that you continue to revisit classroom norms at such strategic places (and debrief as a class, as time permits) about once a week during your first unit of the year, and as needed after that.

2. Adding to Our Progress Tracker 20 MIN

Materials: science notebook, highlighter, chart paper, Key Model Ideas chart (started in Lesson 2)

Introduce the 3-box Progress Tracker. Display **slide B.** Gather in a Scientists Circle with science notebooks. Say, *We have been making a lot of progress on our lesson question. However, we haven't taken time yet to summarize all of the things we've figured out, or the sources of data we have explored to do that figuring out. It's important for us to reflect and organize our thinking so we can celebrate our work and plan our next steps. To do that, we're going to use a Progress Tracker that looks a little different than what we've set up already in this unit.*

Set up notebooks with a 3-box Progress Tracker. Display **slide C.** Direct students to create this chart in their science notebooks following the two-column entry they had from Lesson 3.

Lead a Consensus Discussion about what we've figured out so far. Say, *We will use the boxes on this tracker to guide our discussion, and we'll pause to let you record your thinking as we go.*

Key Ideas

Purpose of this discussion:

- Identify and record a new key model idea we uncovered in Lesson 3.

Listen for these ideas:

Key model idea from Lesson 3:

- A substance has properties that can help us identify it.

Other ideas about specific properties that you might discuss and add to the tracker as time permits:

- Solubility is a measure of how much a substance breaks apart and mixes in the liquid it is added to.
- Mixing only one substance in a bath bomb with water does not cause gas bubbles to appear.
- The composition of matter is the same throughout a substance.

Identify the question we've been working on most recently. Ask students to look back at their individual Progress Tracker from yesterday and identify the question we were working on. Students should respond with, *What is in a bath bomb that is producing the gas?* (Students may say, *What do each of those things do when added to water?* If so, you can follow up with, *Why did we combine each ingredient with water? What were we trying to figure out?*)

Direct students to write this question in the question box of their 3-box Progress Tracker: *What is in a bath bomb that is producing the gas?*

Identify the sources of evidence. Ask, *How did we investigate this question? What evidence did we gather to help us try to answer it?*

Students may want to look back through recent pages of their notebook to find this evidence. They should identify the following:

- Ingredients lists from store-bought and homemade bath bombs
- Observations of individual bath bomb ingredients
- Observations of each individual ingredient added to water

Co-develop the "What we figured out" section from our work with these sources of evidence. Invite students to contribute ideas to the discussion using prompts such as the ones below, and encourage students to take note of, build on, and clarify each other's ideas. Use follow-up prompts such as *Do you agree?* and *Did anyone say the same idea in a different way?* to encourage students to find consensus.

Suggested prompts	Sample student responses
What did we figure out using these sources of evidence?	*The bath bombs were made of lots of different ingredients.* *None of the substances produced a gas when mixed alone with water.*
What evidence did we have that none of the substances alone mixed with water produced a gas?	*They didn't make bubbles.*

Additional Guidance

This Scientists Circle discussion includes time to record key model ideas in our Progress Trackers because as students develop the practice of argumentation, it will be critical that they understand and are able use the key model ideas the class agrees upon in their oral and written argumentation. You will see prompts and suggested responses, then pauses for students to interact with these ideas with a partner. The class will come back together and share before students record these key model ideas in their Progress Trackers using their own wording. This activity should not be seen as note-taking. Instead, it is intentional time to discuss and make sense of the key model ideas we have agreed upon as a class and an opportunity for students to personally grapple with and assimilate these ideas to evidence they have collected before they record them individually.

Suggested prompts	Sample student responses
Did any of them make gas bubbles when combined with water on their own?	*None of them made gas bubbles when combined with water.*
OK, so if none of them produced gas bubbles when combined with water. Then what did we see them do when combined with water? Can someone remind us of what we saw?	*Some of the substances dissolved in the water—we couldn't see them any more after mixing.* *Some substances didn't mix into the water at all.* *Some of the substances mixed partially with the water and made the water look cloudy.*
Would we expect the way each substance interacted with water to be the same, any time we tested them?	*Yes.*
Why would we expect this?	*Well . . . more than one group tested the same substances in water and had the same results.* *And we figured out that this is a property of a substance, how it interacts or dissolves in water.*
Can someone remind us what we figured out a property of a substance is?	*A property is something about a substance that will always be the same.* *Yeah, it is like a characteristic of the substance that doesn't change.*

Say, *OK, let's recognize that we are using another key model idea here. We are saying properties don't change for a substance. Let's add that to our Key Model Ideas chart.* (Add this idea to the chart):

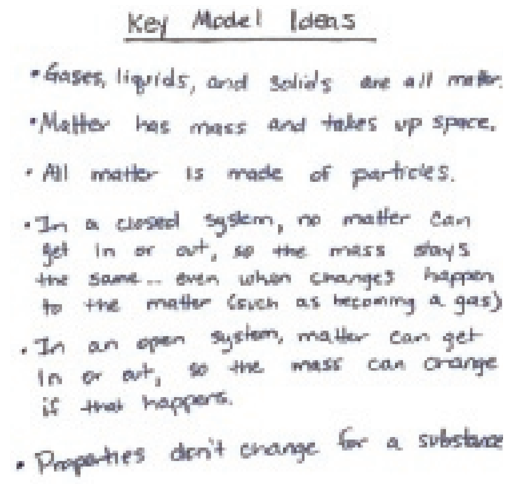
- Properties don't change for a substance.

Say, *So up until now, we've kept track of our key model ideas on this chart only. And all of the key ideas we've listed here are ones that you all developed in previous units like Cup Design Unit and Storms Unit. But this idea about properties is a new key model idea that we just developed in our last lesson. Going forward let's make sure to keep a record of these new Key Models Ideas in your Progress Trackers as we figure them out. That may end up being a useful reference for you as you develop future arguments, explanations, and models.*

Tell students to record this new key model idea in their Progress Trackers in the *What we figured out* box. Tell them they can use the exact wording on the poster or their own words for the same idea.

Say, *Just to make sure each new key model idea is easy to find when we need them, let's highlight each one that we add to our Progress Trackers so they stand out. Let's highlight this first one now.*

See the example Key Model Ideas chart shown here, updated from this discussion.



Alternate Activity

You may choose to have students keep a list of key model ideas in a separate space in their science notebooks. Some teachers may choose to take a photo of their classroom key model ideas poster or keep a digital list of key model ideas and print these for students to tape into their science notebooks.

An example of a 3-box tracker with possible responses is shown here with key model ideas highlighted. The exact wording you and your class have chosen to use might vary from this example.

Question	Sources of evidence
What is in the bath bomb that is producing the gas?	• Ingredient list from store bought bath bomb • Observations of individual bath bomb ingredients • Observations of individual ingredients added to water
What we figured out in words/pictures	
• Bath bombs are made of many different ingredients. • None of the individual substances produced a gas when mixed with water alone. • Properties don't change for a substance.	

Help students summarize what we can conclude and what our next steps should be using the prompts below.

Suggested prompts	Sample student responses
We've agreed that the solubility of the substances in the bath bomb won't change. We've tested what happens when we add each to water. Based on our observations, what can we claim about "What is in a bath bomb that is producing a gas?"	*We don't know what is producing the gas yet, but we know that none of the substances combined with water on their own is producing a gas.*
So what could be producing the gas then?	*The bath bomb is made of many substances and when they are all together, a gas is produced.*
What might we do next to help us figure this out?	*Since we know that there isn't one substance that makes the gas, then maybe we should try two substances together in water to see which, if any, combination of substances produces a gas.* *And if none of those produce a gas, then we should try combinations of three substances with water, etc.*

Emphasize that this sounds like a great suggestion for a new investigation we should plan to carry out.

3. Planning for Our Investigation

15 MIN

Materials: *Combinations of Ingredients to Test*, science notebook, sticky notes, chart paper

Discuss the investigation in small groups. Display **slide D**. Say, *In a moment you will talk with your group about the questions on the slide. But before you do, can someone remind us again what question we are trying to answer through this investigation?*

Students should say we are trying to figure out what combinations of substances in a bath bomb are the ones that are producing a gas.

Assessment Opportunity

Building towards: 4.A.1 Conduct an investigation to produce data to serve as the basis for evidence to determine which combinations (patterns) of substances in a bath bomb cause bubbles of gas to appear (effect).

What to look/listen for: On day 1, listen for discussions about how data are needed to support a claim:

- all the possible combinations of substances that need to be tested [9 x 9 = 81]
- possible redundancies with some combinations
- making predictions about the patterns of causes (combinations) and effects (bubbles) they expect to see

What to do: If students are struggling to consider the number of combinations or redundancies, you may want to talk through creating a chart with them rather than jumping to the one you already have prepared.

*** Attending to Equity**

Supporting Universal Design for Learning: You may choose to type Xs into the table on the slide you're projecting, or if you have a smart board, write Xs directly onto the slide from there. Another option is to project a copy of *Combinations of Ingredients to Test* using a document camera. In any case, provide visual *representation* support for students to see the pattern in the table and mark their own handouts accurately.

Give students about 3–4 minutes to get into small groups and discuss the following questions on **slide D**:

- What are we hoping to figure out by testing combinations of these different ingredients?
- What evidence are we looking for to help figure that out?
- How many different possible combinations will we have if we combine them two at a time with water?

Prepare for the investigation. Say, *I have a chart listing each of these 10 ingredients in each row and in each column. Let's see if we can use it to reason out how many unique combinations there are for us to try.*

Distribute a copy of *Combinations of Ingredients to Test* to each student. Display **slide E**. Say, *I was thinking we could have 10 groups, and each group could test all the combinations for a row in this table. For example, group 1 could test coconut oil, which is listed at the start of their row, with each of the ingredients listed at the tops of the 10 columns.*

Ask, *Does anyone see any combinations in this row that it wouldn't make sense for this group to do?* Students will say, *Coconut oil with coconut oil.*

Point out that this sort of redundancy might be in other rows too. Mark Xs in these boxes together as you identify them as a class, as shown at right.*

Ingredients		A	B	C	D	E	F	G	H	I	J	Team
		Coconut oil	Olive oil	Baking soda	Epsom salt	Table salt	Sugar-free lemonade mix	Citric acid	Sugar-based lemonade mix	Sugar	Corn starch	
A	Coconut oil	X										1
B	Olive oil		X									2
C	Baking soda			X								3
D	Epsom salt				X							4
E	Table salt					X						5
F	Sugar-free lemonade mix						X					6
G	Citric acid							X				7
H	Sugar-based lemonade mix								X			8
I	Sugar									X		9
J	Corn starch										X	10

Say, *This leaves 9 combinations for each group to try. I will give each group an ice cube tray like this one, which has 12 spots in it.* Hold up an ice cube tray to show the class.

Say, *This will allow each group to test the 9 combinations they are assigned from their row. So, let's assign the groups now.*

Alternate Activity

Extension Opportunity

In the current layout, every combination will be tested twice. Students may not notice that. If they don't bring this up, then move on.

If they do notice it, ask for a student to point out an example or two. If the class seems interested in this sort of math problem, you could give them a minute to calculate how many unique combinations there are. (There are 45 unique combinations.) Then say, *If we were pressed for supplies, we might skip the duplicate combinations that groups would test. But we are more pressed for time, and having every group test their row is a quick and easy way to plan and would give us two data points for each combination. Because more data makes us more certain, let's go ahead with the plan of having your group do your assigned row.*

Assign group numbers to lab groups. Continue to display **slide E**. Have students highlight the row that shows the combinations that their group has been assigned to test.

Set up a key for the ice cube trays. Display **slide F.** Instruct students to work with their group to use the bottom of the handout and set up a key. They should indicate which combination will go in each cell of their tray.

Prepare space to record observations. Display **slide G**. Direct students to attach the handout onto the left side of their next blank set of notebook pages, then list the numbers 1–9 on the right side of their notebook (opposite the handout they've attached) so they have space to record their observations and can easily cross-reference them with what was tested in that cell of the ice cube tray. See the slide for an example of this.

4. Reflecting on Norms — 5 MIN

Materials: science notebook, index card, Norms poster

Assign exit tickets. Display **slide H**. Ask students to answer the following questions on an index card or separate sheet of paper. Collect the responses before students leave class.

- How did you do with practicing the norm you selected to work on?
- How did the class do as a learning community today?
    - What did we do well?
    - What could we improve on?

End of day 1

5. Carrying Out Our Investigation — 15 MIN

Materials: Combinations of Ingredients Lab, science notebook, sticky notes, Norms poster

Reflect on the exit slips from yesterday. Celebrate what's going well, and draw attention to any norm the class feels they could work on based on the note cards they filled out at the end of last class. Suggest to the class that today we focus on one of the norms we as a class feel we need to work on. Connect that norm to today's investigation, group work, and discussion.

Review safety guidelines. Display **slide I.** Review the following lab procedures and clarify details as needed for your classroom.

- Wear splash goggles the whole time.
- Carry materials carefully to and from your work space in their bin.
- Use the dropper that coordinates with each cup's letter—do not cross-contaminate pipettes.
- Use only 5–6 drops of each solution for each section of your ice cube tray.
- Record detailed observations in your notebook.
- When finished, clean your ice cube tray as directed.
- Be sure all materials in your bin are neat and tidy when you return them.

Review material retrieval and clean-up procedures for your classroom. Say, *Each group's bin of ingredients contains solutions of all of the substances. Your bin will have a larger amount of the substance for the row you were assigned so you will have enough to mix with all the other substances. But remember, you only need 5–6 drops of each solution for each test you do—we want to conserve resources for other classes to use.*

Assessment Opportunity

Building towards: 4.A.2 Conduct an investigation to produce data to serve as the basis for evidence to determine which combinations (patterns) of substances in a bath bomb cause bubbles of gas to appear (effect).

What to look/listen for: As students conduct their investigation, note whether they are recording observations for all 9 combinations they are responsible for testing. They will then be able to contribute these to the class-wide data table, which will then be a resource they can use to notice patterns across groups. This larger set of data will help then meet the goal of their investigation: determining what combination of substances are causing bubbles to appear.

What to do: If you notice that students are not engaged with their groups, check in with those students. Encourage group members to swap turns in combining the substances for each cube in their tray. Also encourage students to discuss what they are observing in each cube in their tray with their group members, even if no bubbles are appearing.

Additional Guidance

It is recommended that you have a sink or large bin full of soapy water and a sponge ready so students can wash their own ice cube trays and leave them to dry for the next class. Depending on your situation, you may want to have more than one class set of ice cube trays available and ask a few students to help wash them all at once during a longer break between classes.

Carry out the investigation. Allow about 12 minutes for students to conduct their investigations. Circulate to hear what students are noticing, and take note of the way they coordinate group work to share the tasks and so everyone can see what is happening for each combination up close.

Collect classroom data. In the last 3 minutes of this lab, display **slide J.** While a few members of each group clean up, ask another member of the group to mark a "Y" on the class data chart for any combinations they found that caused bubbles. Depending on your situation, they may put a sticky note into that cell of the chart on the screen, or update the slide itself using your computer and projector or an interactive board, or mark on a printed copy of the chart displayed on a document camera. Explain that if there is already a mark in a cell, they should also mark their data there so we can see where other groups got similar results.

6. Analyze our lab data.

5 MIN

Materials: science notebook, computer, projector

Examine data and confirm results. Keep **slide J** displayed with the sticky notes (or other marks) from all groups on the chart. Ask the whole class to identify patterns in the data. Ask students how we can use this chart to make sure that each combination yielded the same results for both groups that tested them. Students should point out that the results were confirmed by multiple tests. The anticipated results are shown here:

Ingredients		A	B	C	D	E	F	G	H	I	J	Team
		Coconut oil	Olive oil	Baking soda	Epsom salt	Table salt	Sugar-free Lemonade mix	Citric acid	Sugar-based lemonade mix	Sugar	Corn starch	
A	Coconut oil	X										1
B	Olive oil		X									2
C	Baking soda			X			Y	Y	Y			3
D	Epsom salt				X							4
E	Table salt					X						5
F	Sugar-free lemonade mix			Y			X					6
G	Citric acid			Y				X				7
H	Sugar-based lemonade mix			Y					X			8
I	Sugar									X		9
J	Corn starch										X	10

7. Examine lemonade mix and add to Progress Tracker.

5 MIN

Materials: science notebook, *Lemonade Mix Labels* (optional)

Discuss the lemonade mix. Say, *So it looks like baking soda and water with either lemonade mix or citric acid were the combinations that produced a gas. Let's think about these ingredients a bit more. If we look back at Bath Bomb Ingredient Data, where we have some data about all the different ingredients, what did we say about the last two ingredients? How are they different from the rest of the ingredients listed in the table?*

Students should recall these last two ingredients are mixtures made of more than one substance, while the rest of the ingredients are substances. Say, *Let's look at an ingredient list for the lemonade mixes to see what they are made of.*

Display **slide K**. Direct students to turn and talk with a partner about this question:

- The lemonade mix is a mixture and contains more than one substance. What substances do you predict you would find on the ingredient label of the two lemonade mixtures?

Share predictions. Have a few students share what ingredient(s) their partner predicted might be in the lemonade mixes, and why they think that.

Analyze the lemonade mix ingredients. Direct students to work independently to look for patterns between the lemonade mix ingredient lists and the ingredients they tested that produced gas bubbles. Display **slide L**. If desired, distribute copies of *Lemonade Mix Labels*.

Update our Progress Trackers. Tell students to record their discoveries in a 2-column Progress Tracker entry. Display **slide M** if students need guidance about their Progress Trackers.

Assessment Opportunity

Building towards: 4.B Construct and present a written and oral argument supported by citing empirical evidence and scientific reasoning that only certain combinations (patterns) of substances (water, baking soda, and citric acid) result (cause) in the formation of a gas (effect).

What to look/listen for:

- Baking soda and water were in every combination that produced gas.
- Citric acid was also in every combination that produced gas.
- While there might be other substances in the lemonade mixtures as well, none of those were needed to produce a gas in one of the cases we tested (citric acid, baking soda, and water).

What to do: Support for encouraging students' responses to each other is listed in the text of the teacher guide. If students are struggling to connect the arguments to the patterns in the data, refer back to the whole-class data chart (**slide L**) and/or the lemonade mix ingredient lists to ask, *What similarities can we find here?*

8. Argue which substances in a bath bomb produce a gas and explain if the gas is a different substance.

15 MIN

Materials: chart paper, Arguing for (or Against) a Claim poster (from Lesson 2)

With about 15 minutes remaining in the period, shift to a whole-class discussion. Although you may not have time to gather in a full Scientists Circle, have students turn their chairs so they can see and hear others in the class, and others can hear their responses.

Assessment Opportunity

Building towards: 4.C Apply scientific ideas and evidence (patterns in properties) to co-construct an explanation that the substance(s) in the gas bubbles must be a different substance(s) than the water, baking soda, or citric acid.

*** Strategies for This Building Understandings Discussion**
Asking students to restate what another student has said supports the goal of students listening carefully to each other so that they can work with others' ideas. This move can feel odd to students at first, so it will help if you let them

know ahead of time that you will be asking this. It can also help to support this type of collaborative talk in the classroom to have sentence starters up on a bulletin board, or on a handout students could tape in their notebook and refer to.

What to look/listen for:

Listen for students posing and responding to relevant questions, and citing relevant sources of evidence such as are listed in the "Key Ideas" callout box during that discussion. The students should use patterns in the data to support their discovery of which substances combine to cause bubbles.

What to do: Support for encouraging students' responses to each other is listed in the text of the teacher guide. If students are struggling to connect their arguments to the patterns in the data, refer back to the whole-class data chart (**slide L**) and/or the lemonade mix ingredient lists to ask, *What similarities can we find here?* If students are struggling to support their claims with evidence and reasoning, you may choose to record the argument as shared writing as the class composes it, and then underline evidence and highlight key model ideas as you did in Lesson 2.

Suggested prompts	Sample student responses	Follow-up questions
Let's begin by taking stock of what you figured out.	*Baking soda, citric acid, and water are the ingredients needed to cause bubbles.*	*How many people agree with this statement?*
How do we know this? What evidence do we have of this?	*We tested one ingredient at a time and they did not react in water.*	*Who can restate what our last speaker said?*
	Only the citric acid with baking soda in water or the lemonade mix with baking soda in water caused bubbles to appear.	*Who can explain what ideas they agree with, disagree with, or can add to?*
	The only ingredient both lemonade mixes had that also was a substance we tested by itself (along with baking soda by itself) was citric acid.	

Facilitate a Building Understandings Discussion. Say, *OK, so we know that in the bath bombs, the substances that cause the gas bubbles are baking soda, citric acid, and water. But we still don't know what the gas is. Do you think this gas that appears is a different substance, or one of these substances?*

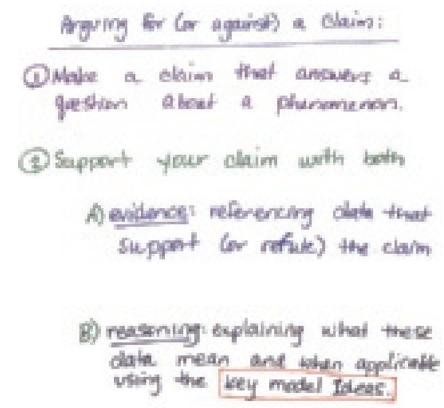
Display **slide N**. Ask students to read the following questions to themselves first and think about them for a minute.

- What claim can we make about the gas in the bubbles? Is it any of the substances we started with, or is it a new substance(s)?

Say, *As we develop our ideas about these questions, I will ask others to weigh in on what's being said. You might hear me say something like, "Can we restate what that person said? Can you explain why you agree or disagree? Does everyone agree?" In order for us to be able to hear and respond to everyone's ideas, we need to listen for understanding and speak clearly.**

Make sure the anchor chart for arguing for (or against) a claim from Lesson 2 is visible.

Say, *I am also going to ask us to listen specifically for people using evidence and key model ideas. Whenever you hear someone reference evidence, snap your fingers. Whenever you hear a key model idea we've agreed on, lightly tap your feet on the floor. You can snap or tap even if someone is repeating evidence or a key model idea they just heard from someone else. Then I might pause to ask where or how that evidence or key model idea was used to support our claim.*



Key Ideas

Purpose of this discussion: Develop an argument that citric acid and baking soda produce gas when combined with water *and* that the gas must be a new substance because it has different properties than the substances we started with.

Listen for these ideas:

- Claims that the gas in the bubbles is a new substance that was not there to start with
- Evidence**:** <u>The starting substances were solids and liquids at room temperature, while the substance(s) in the bubbles is a gas at room temperature.</u>
- Reasoning:
  - The state of matter of a substance at room temperature is a property.
  - A substance has properties that can help us identify it.
  - Since the starting substances have different properties from the gas bubbles, the gas must be a different substance than what we started with.

Suggested prompts	Sample student responses	Follow-up questions
What is that gas? Is it any of the substances we started with, or is it a different substance(s)?	*I think it is something new.* *Maybe it is baking soda or water or citric acid, just in gas form.*	*Tell us more about what you are thinking.* *What ideas do you have to support your claim?*
What did we observe about the state of matter of the substances we started with at room temperature?	*Baking soda was a solid, citric acid was a solid, and water was a liquid.*	*Does everyone agree that this is something we observed?*
So then what is true for any sample of baking soda we find at room temperature? What state of matter would it always be in?	*It should still be a solid.*	*How about citric acid? Water?*

Suggested prompts	Sample student responses	Follow-up questions
How do we know this? Why do we think its state of matter would not change?	*The state of matter at room temperature is a property.*	*Who can restate why baking soda and citric acid would always be a solid at room temperature and water would always be a liquid?*
So if the substance(s) that are in the bubbles are a gas, and not a liquid or a solid, then is the gas one of the substances we started with or is it a different substance(s)?	*The gas must be a different substance than the ones we started with.*	

Ask a student to restate the argument in support of the gas being a different substance(s), in order to help us practice the logic of the new claim we are trying to support. As the student(s) restates the argument, write it on chart paper or type it onto a blank slide so you will be able to clearly point out the evidence and key model idea(s).

After you scribe the argument, use prompts such as those shown below to call students' attention to where we used evidence and where we used key model idea(s) that support the argument. Multiple examples of marked-up arguments are shown on the next page for reference.

Example 1	Example 2	Example 3*
The gas is not one of the substances that were in the bath bomb. The substances in the bath bomb that make the gas are baking soda, citric acid, and water. Baking soda and citric acid are solids at room temperature. Water is a liquid at room temperature. But when these are combined, a gas forms. Since the state of matter of a substance at room temperature is a property and properties of substances never change, **the gas must be a different substance,** because it has a different property than any of the substances we started with.	Two of the ingredients, or substances, in a bath bomb are citric acid and baking soda. When these two are combined in water, a gas is produced. **This gas is a new different substance.** Citric acid and baking soda are solids at room temperature and water is a liquid. Since the state of matter at room temperature is a property and properties don't change for a substance, **the gas is a new different substance.**	So we tested combinations of ingredients. We found that when we combined baking soda plus citric acid a gas appeared. **We know that this gas is a new substance, different from the ones we started with**, because properties of a substance don't change, and the gas has different properties than baking soda, citric acid, or water. One important property is state of matter at room temperature, and none of these ingredients are gases at room temperature.

* Supporting Students in Engaging in Argument from Evidence

There are three examples of written arguments included here. They each include a claim, and evidence and reasoning support the claim, but notice that the way in which these unfold and are connected together in each argument is different. Arguments should be fluid. They should emphasize the logical connections between ideas, rather than a formulaic order. This means the claim does not need to be the first sentence in an argument with the evidence following it and the reasoning being the final section. Rather, when students develop an argument, they should be explaining what they know about a phenomenon and why or how they know it. This means you may see students include the claim at the end of a written argument or in the middle of their writing. This is perfectly acceptable. Focus on providing feedback to students to help them articulate a logical flow in their thinking while also making the key pieces of the argument visible rather than simply implied. In the example below the claim has been bolded.

Suggested prompts	Sample student responses
(Referencing what you just wrote on the poster or slide ...) Which part of our argument used evidence to support it? How do you know?	*We said we saw that baking soda was a solid, citric acid was a solid, and water was a liquid. This is evidence because it is a summary of the data; it was something we observed.*
Which part of the argument used key model idea(s)? How do you know?	*We know that properties don't change for the same type of substances. They are constant.*
What property helped us make this argument that the gas is a different substance?	*The state of matter at room temperature is a property.*

Navigate to the next lesson. Post the paper with the argument from this discussion where students will be able to reference it during the next lesson.

Emphasize the new insight this argument is providing us. Say, *We have made an argument that a new substance is in the gas bubbles that wasn't one of the substances we started with and yet it came from the matter that was in those substances we started with. So somehow this combination of substances resulted in the formation of a new substance. But what substance is it then? And what type of data would we need to be able figure that out? Maybe you have some initial ideas about that. When we're together next time, let's see if we can make progress on this question to see if we can figure that out.*

9. Navigation

5 MIN

Materials: notecards, chart paper

Hand out a note card to each student and display slide O. Say, *Write your name on your note card on one side. Then on the other side answer the two questions on the slide. We just collaborated on coming to a conclusion on what we know about the gas from the bath bomb up to this point in the unit. Everyone should feel like they played a critical role in helping to develop this argument. Take a couple of minutes and individually reflect on where you feel you are in your ability to develop evidence-based arguments. Use the questions on the slide to guide you. The second question on the slide has to do with our norms. Reflect on the norm "Respectful" and explain how this norm helps us to be able to collaborate as we developed this argument together.*

Give the students the last couple of minutes to answer the questions on the note card handed out. Collect these before the students leave and read through them before the next class.

ADDITIONAL LESSON 4 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.7.1. Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.

CCSS.ELA-LITERACY.SL.7.1.C Pose questions that elicit elaboration and respond to others' questions and comments with relevant observations and ideas that bring the discussion back on topic as needed.

In order to prepare students for success with these ELA goals, use student responses from the exit ticket that ended the last class to revisit, reinforce, or refine norms for collegial discussions.

Both of these goals are used in the opening Consensus Discussion about key model ideas and during the Building Understanding discussion after the investigation. The class will engage in arguments from evidence and draw on ideas from their individual Progress Tracker and key model ideas. The teacher should focus the discussion on having students restate and work with the ideas of their peers. This is an explicit support and scaffold for helping students engage in the first learning goal listed above.

SCIENCE LITERACY: READING COLLECTION 2

Chemistry Concepts

1 The Periodic Table
2 A Closer Look at Water
3 Kitchen Chemistry

Literacy Objectives

- ✓ Summarize key points related to elements, the properties of water, and how chemistry is involved in cooking.
- ✓ Identify examples of stability and change in small and large systems.
- ✓ Organize related details about chemical concepts using an outline framework.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 2–4.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a summarizing outline in response to the reading.

Instructional Resources

Student Reader

Collection 2

Science Literacy Student Reader, Collection 2
"Chemistry Concepts"

Exercise Page

EP 2

Science Literacy Exercise Page
EP 2

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 2 (Day 2): Where is the gas coming from?
- Lesson 3: What's in a bath bomb that is producing the gas?
- Lesson 4: Which combinations of the substances in a bath bomb produce a gas?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS1.B: Chemical Reactions Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Stability and Change

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

dissolve **solubility** **temperature**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

acid **base** **element** **property**

solute **solvent** **specific heat**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

Exercise Page

EP 2

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Chemical Reactions and Matter unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *You will read an infographic about the periodic table and how scientists use it to classify elements by their properties.*
    - *Next, you'll take a closer look at water and learn how the properties of this substance make it so important to life on Earth.*
    - *Finally, you'll take a crash course in the science all chefs need to know to transform basic ingredients into delicious dishes.*

- Distribute Exercise Page 2. Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to complete an outline that summarizes the three readings in Collection 2.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What are some properties of elements scientists use to distinguish them?	*color, state at room temperature, melting temperature, boiling temperature, how hard it is, how well it conducts electricity and heat*
What happens to the temperature of water in a container as it freezes?	*Its temperature drops to 0°C and stays at that temperature until all the water freezes. But then the temperature can drop some more.*
Why is water called "the universal solvent"?	*because so many substances can dissolve in water*
How is understanding chemistry useful when making a salad?	*When you make a salad dressing, there are tricks to make an emulsion that is less likely to separate.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What is meant when the author says, "Some elements react very easily with others, and some do not react at all"?	*To react means to interact with other elements to form different compounds, so elements that react easily form different compounds easily and elements that do not react remain as themselves.*
How do you know that salad dressing is a mixture?	*because its parts are blended but still have their own properties*

- Refer students to the Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to complete an outline focusing on stability and change that summarizes the selections in Collection 2.*
    - *That means using language that emphasizes change over time, whether it is fast or slow changes, or if some systems are more stable than others.*
    - *Don't worry about defining all the terms in the selections. Instead, use examples to illustrate them.*
    - *Notice that the outline framework uses complete sentences, so follow the same style for your additions.*
    - *The important criteria for your work are that you summarize all three readings and use language that shows stability and change in systems large and small.*
- Remind students that well-organized outlines have a hierarchy with big ideas at upper levels and details or examples at lower levels.
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 2

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. This collection begins with an infographic showing the periodic table of elements and details on some elements, including how they are organized in the table.

Pages 14–17 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "The Periodic Table"?	*It displays all the elements in one chart and describes some details about some of the elements.*
Neither sodium nor silver has the chemical symbol "S." What are possible reasons why?	*Only one element can have that letter, and it appears to be assigned to some other element on the chart.* *Maybe their symbols are from another language.*
In class you decided that "properties don't change for a substance." How does this reflect on the importance of the periodic table of elements?	*It means that the table will always be useful and might be worth getting used to reading and interpreting.*

The next selection is about a common and essential compound that is made from two elements.

Pages 18–19 Suggested prompts	Sample student responses
What is the general purpose of the second selection, "A Closer Look at Water"?	*It describes some properties of water, including how it affects Earth's climates.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals that water is a compound made of two elements—hydrogen and oxygen. The second article details some properties of water, such as its high specific heat and why it is called "the universal solvent."*
What does the graph show about how water heats up?	*It shows that at the temperatures at which water boils or melts, the temperature does not change for a while.*
How can you use the table to compare the specific heats of substances? Give an example.	*I can compare the numbers and estimate how many times greater water's specific heat is than that of other substances. For example, water's specific heat is about four times that of aluminum.*

Student Reader

Collection 2

Online Resources

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

CHALLENGE—Invite students who are curious about chemical symbols, atomic numbers, and the colors and arrangement of elements on the periodic table to learn more by exploring websites.

SUPPORT—If you have not already used the Lesson 3 "Attending to Equity" teaching strategy, now is a good time to do so. Then point out that the verb *dissolve* has other meanings, such as "to cause something to disappear" or "to bring to an end."

When they read the last selection in this collection, students should infer that knowing some chemistry is essential to being a proficient cook.

Suggested prompts	Sample student responses
What is the general purpose of the third article, called "Kitchen Chemistry"?	*It explains how basic cooking skills are related to certain chemical changes or chemical properties.*
What are some ways cooking changes the properties of food ingredients?	*Adding mustard, mayonnaise, or egg yolk to oil and vinegar makes a smoother salad dressing.* *Enzymes make meat tender.* *Lactic acid makes cheese more acidic.* *Acids make seafood taste almost like it is cooked.*
How does the third selection help you build knowledge on top of what you learned in the second selection?	*The second article talks about water as "the universal solvent" because so many substances can dissolve in it. The third article explains that not all parts of foods form a solution with water, but some do. This is what makes a soup.*

EXTEND—Some students may be inspired by this selection to explore these and more kitchen chemistry techniques. The American Chemical Society has a robust outreach effort that includes webpages called "Food and Cooking Chemistry" and "The Secret Science of Stuff." Students can also search the ACS video collection for food-related topics, such as how the Maillard reaction and fermentation make foods taste delicious.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 2, students should complete the provided outline framework to summarize Collection 2. A sample completed outline is shown below, with student writing in bold, but students' outlines may vary in wording and details. Look for evidence that students thought about the Crosscutting Concept Stability and Change as they summarized each selection and that they were consistent in using complete sentences, proper punctuation, and accurate spelling.

I. The periodic table organizes elements.
   A. Elements are organized by their properties.
      1. **The mass of one atom of the element is one way they are organized.**
      2. **Some atoms react easily, and others do not.**
   B. Elements with certain properties can be useful.
      1. **Neon glows when it is electrified.**
      2. **Silver can be shaped into all kinds of jewelry.**

II. Take a close look at water.

A. Kinetic energy and state change are connected.

B. **The high specific heat of water means it is slow to heat or cool.**

1. Coastal lands have more moderate climate than other places.

2. The ocean keeps planet Earth cooler than it would be without an ocean.

C. **Many substances can dissolve in water.**

III. **If you cook, you are using chemistry!**

A. Water is a solvent.

1. **Dissolving other substances in water makes a broth.**

2. **Some but not all ingredients dissolve in water.**

B. Eggs are mostly proteins, which affects how they are used.

1. **Proteins get stiffer the longer they are cooked.**

2. **Whipping eggs forms bubbles, and cooking them sets them.**

C. Emulsions are mixtures of liquids that are stable.

D. **Enzymes aid the breakdown of foods.**

E. **Turning milk into cheese involves several steps.**

1. Bacteria separate the liquids from the solids.

2. **Fermentation reactions lower acidity and make the curds smoother.**

3. **Rennet enzymes are added to further separate the solids and liquids.**

4. **The pH is controlled.**

F. Acids "cook" food proteins.

G. **Umami is a fifth taste to describe savory flavors from proteins.**

H. **Browning and charring cause chemical reactions that change the tastes of foods.**

LESSON 5

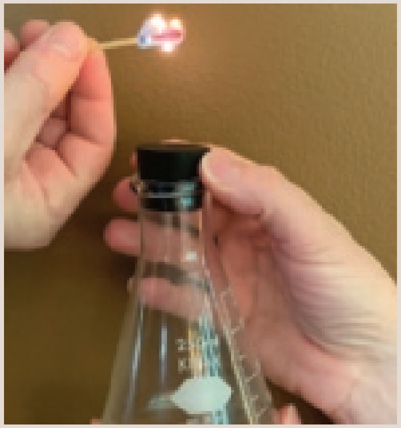
What gas(es) could be coming from the bath bomb?

Previous Lesson *We synthesized what we've figured out so far in the unit. We tested different combinations of substances from a bath bomb and used the results to support an argument that the gas is a different substance than those we started with and this substance must come from the matter that makes up baking soda, citric acid, and water.*

This Lesson

Investigation

2 DAYS



We brainstorm phenomena related to gases and identify some of their different properties. We analyze the data for common gases that includes their known densities and flammabilities. We test the flammability of air from the room, gas from the bath bomb, and helium gas. We carry out an investigation to see if gas from the bath bomb rises or sinks. We argue from evidence (density and flammability data) that the gas from the bath bomb can be narrowed down to three candidate gases.

Next Lesson *We will apply what we have figured out about properties to explain a related phenomenon (elephant's toothpaste). We will revisit our Driving Question Board (DQB) and reflect on what other related phenomena we might be able to explain using these same key model ideas.*

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

5.A Analyze and interpret the data for common gases to look for patterns that could be used to identify an unknown gas by its characteristic properties.

5.B Apply scientific reasoning based on patterns in the densities for a known set of gases to explain how either of two different possible outcomes from a future investigation could help us narrow down the sub-set of candidate substances from what could be in the unknown gas from the bath bomb.

5.C Construct, use, and present an oral and written argument for an explanation that the gas in the bubbles from the bath bomb can be narrowed down to only three possible substances (out of ten of the most common ones in the air) supported by the patterns in the results from density and flammability tests and data on their properties and the use of related key model idea.

What Students Will Figure Out

- Density and flammability are properties.
- In high concentrations, gases that are non-flammable will extinguish a flame.
- Gases or liquids that are less dense float upward when surrounded by gases or liquids that are more dense; gases or liquids that are more dense sink downward when surrounded by gases or liquids that are less dense.
- The gas from the bath bomb could be carbon dioxide, nitrogen, or argon.

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Brainstorm other gas-related phenomena and discuss the properties of gases that students can use to help figure out what gas comes from a bath bomb.	A–B	poster paper, marker
2	7 min	**ANALYZE AND INTERPRET PROPERTY DATA FOR GASES** Analyze and interpret the property data for several common gases to determine that density and flammability are good properties to use to identify a gas.	C	poster paper, marker
3	12 min	**TEST THE FLAMMABILITY OF OUR BATH BOMB GAS AND OTHER KNOWN GASES** Test the flammability of two known gases (helium and air in the room) and compare it to the gas produced from the bath bomb.	D–F	Flammability test for air vs. bath bomb gas
4	10 min	**INVESTIGATE AND PREDICT DENSITY EFFECTS FOR HELIUM** Predict and test how helium will interact with a flame in two different situations. Add ideas about floating and sinking gases to the scientific principles poster.	G–H	poster paper, marker, Density of helium lab
5	8 min	**MAKE PREDICTIONS ABOUT THE GAS FROM A BATH BOMB** Make predictive explanations about the possible behavior of the gas from a bath bomb.	I–J	*My Predictive Explanations for the Gas from a Bath Bomb*
				End of day 1
6	10 min	**TEST PREDICTIONS ABOUT THE GAS FROM A BATH BOMB** Test how gas from a bath bomb interacts with a flame above and below it. Update the Progress Tracker.	K	Testing the density of bath bomb gas
7	5 min	**UPDATE INDIVIDUAL PROGRESS TRACKERS**	L	*Some Common Gases*, *My Predictive Explanations for the Gas from a Bath Bomb*, Key Model Ideas chart, Anchor poster

Part	Duration	Summary	Slide	Materials
8	12 min	**NAVIGATION: ARGUE FROM EVIDENCE** Arrange students in groups of 3 and distribute the *Discussion Protocol: Density and Flammability* to each student. Give instructions, and then monitor groups for this task as they practice verbally giving evidence-based arguments.	M	*Some Common Gases, My Predictive Explanations for the Gas from a Bath Bomb, Discussion Protocol: Density and Flammability,* Key Model Ideas chart, Anchor poster
9	3 min	**GET READY TO WRITE AN ARGUMENT USING EVIDENCE** Identify a key model idea and important science ideas to strengthen arguments around claims to identify the gas(es) that come from a bath bomb.	N	
10	13 min	**CONSTRUCT WRITTEN ARGUMENTS ABOUT THE GAS FROM A BATH BOMB** Write an argument for what gases could be produced by a bath bomb that includes a claim supported by evidence and reasoning.		notebook paper
11	2 min	**NAVIGATION** Consider what has been figured out about properties of substances and how they can be used to identify a property. In the next class, we will be applying what we have learned about properties to a new phenomenon.	O	

End of day 2

Lesson 5 • Materials List

	per student	per group	per class
Flammability test for air vs. bath bomb gas materials			• 2-250 mL Erlenmeyer flasks • 2 -#6 rubber stoppers • 5 bath bombs • 100 mL water • matches • helium tank or helium balloons
Density of helium lab materials			• 1-250mL Erlenmeyer flask • 1-#6 rubber stopper • 5 bath bombs • 100 mL water • matches • helium tank or helium balloons

Testing the density of bath bomb gas materials		• plastic soda bottle and cap • water • 8 mini bath bombs from recipe B • matches • candle • small aluminum bread pan liner	
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *My Predictive Explanations for the Gas from a Bath Bomb* • *Some Common Gases* • *Discussion Protocol: Density and Flammability* • notebook paper		• poster paper • marker Key • Model Ideas chart • Anchor poster

Materials preparation

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Be sure you have materials ready to add the following words to the Word Wall: ***flammability*** and ***density***. Do not post these words on the wall until after your class has developed a shared understanding of their meaning.

Day 1: Flammability test for air, helium, and bath bomb gas

- **Group size:** Whole class
- **Setup:** Watch the videos to see how to do this lab. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) You will use 2 250-mL flasks, 2 #6 stoppers with no holes, 1 helium filled mylar balloon per class, 5 mini bath bombs, and wooden matches in this demonstration. The helium in one mylar balloon should be enough for both the flammability and density test per class.
- **Safety:**
    - Do not add more than the 5 recommended mini bath bombs to the flask. It may shatter if too much gas pressure builds up in it.
    - Make sure that you, the students that help you, and any other students near the demo are wearing goggles. Have a cup of water nearby to discard burnt matches and splints. Anyone with long hair should tie their hair back.
- **Disposal:** After the bath bomb is added to the water in the bottle, the liquid can be dumped down the sink.

- **Alternate:** If you are unable to have an open flame in your classroom to do the property tests of flammability and density, there are videos included to use with students. (See the **Online Resources Guide** for links to these resources. **www.coreknowledge.org/cksci-online-resources**)

Day 1: Density of helium lab

- **Group size:** Whole class
- **Setup:** Watch the video to see how to assemble the equipment and do this lab. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) This video shows how to use pre-filled helium balloons to do this. If you have a helium tank available you can use that instead of getting filled balloons from the store. If no helium is available, show this video to students in place of the live demonstration. (See the **Online Resource Guides** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) You will use a 250-mL flask and one #6 stopper with no holes, the helium from the same mylar balloon from the flammability test, and wooden matches in this demonstration.
- **Safety:**
    - **Do not be tempted to allow students to breathe** in helium from the balloon or to do it yourself. This common party trick that makes your voice sound different can be very dangerous. Even though it is usually harmless and many students or adults have never had any ill effects from breathing in helium, it can result in unconsciousness, collapsed lungs, or even death. These effects are caused from breathing in high concentrations of helium by directly sucking on an open helium balloon or breathing directly from any helium source. The helium released into the classroom through these investigations is not sufficient to cause any ill effects. There are also abrupt temperature changes that occur in gases that rapidly escape canisters that can lead to tissue damage when the gas is inhaled.
    - Make sure that you, the students that help you, and any other students near the demo area are wearing goggles. Have a cup of water nearby to discard burnt matches and splints. Anyone with long hair should tie their hair back.
- **Alternate:** If you are unable to have an open flame in your classroom to do the property tests of flammability and density, there are videos included to use with students. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)

Day 2: Testing the density of gas from a bath bomb lab

- **Group size:** Arrange students into 6 groups of 3–5 students
- **Setup**
    - Watch the video to see how to assemble the equipment and do this lab. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) Each group will use a soda bottle with a cap, a candle, a small aluminum bread pan, a small amount of water, 8 mini bath bombs ideally from recipe B since they produce more gas bubbles in a shorter time frame, and matches.
    - An alternate procedure is provided in **slide O** that may produce more consistent results than those provided in **slide J**. Try the one in **slide J** and if it doesn't work, try the one outlined in **slide O**. If the procedure in **slide O** is more reliable students will need alternate supplies (freezer bag, 1 teaspoon of citric acid, 2 teaspoons of baking soda, a 15 mL centrifuge tube filled with water, a candle, a small aluminum bread pan, and matches).

- **Safety:**
  - Remind students to hold the lit match at least 1" above their bottles (or plastic bags), and do not put them closer. The plastic can melt or burn if the flame comes into contact with it.
  - Make sure students are wearing goggles. Have a cup of water nearby to discard burnt matches and splints. Students should tie back long hair.
  - Do not add more than the recommended number of mini bath bombs to the bottle. It may rupture if too much gas pressure builds up in it.
- **Disposal:** After the bath bomb is added to the water in the bottle, the liquid can be dumped down the sink.
- **Storage:** Pans, candles, bottles, and caps can be saved and reused across classes and years.
- **Alternate:** If you are unable to have an open flame in your classroom to do the property tests of flammability and density, there are videos included to use with students. (See the **Online Resources Guide** for links to these resources. **www.coreknowledge.org/cksci-online-resources**)

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

This lesson is focused on figuring out the identity of the gas that comes from a bath bomb. This is accomplished by using the properties of density and flammability for several common gases.

Students should be able to draw on their experiences with helium balloons and experiences with thinking about how the particle density of air changes with temperature in the *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*, to reason whether helium will float or sink in air and how the reported density value for it in grams per mL (compared to air) is related to those predictions.

Students will narrow down ten possible candidate substances to three substances by the end of this lesson. The written explanation that students will construct at the end of this lesson targets a portion of MS-PS1-2: "Analyze and interpret data on the properties of substances before and after the substances interact to determine…." In this PE, students are trying to develop an argument for whether a chemical reaction occurred. While they will do this fully in future lessons, right now, they are developing a precursor argument that will become part of the foundation for that.

***Words we earn**:* In this lesson students will be introduced to the property of *flammability*. After analyzing data in a property chart for gases, as a class, flammability of two different gases will be tested in the classroom. This will help to develop a meaning for the word *flammability*. In addition, another property of gases included on the data chart is density. As a class the density of two different gases as compared to air will be tested. This will help to develop a meaning for the word *density* as a property. Both *flammability* **and** *density* will be added to the Word Wall in this lesson.

Where We Are NOT Going

Students will not calculate the density of a gas. They will compare relative densities based on evidence of sinking and floating of that gas in room air. Density will be calculated for different substances when they work with clear liquids in later lessons.

1. Navigation

8 MIN

Materials: science notebook, poster paper, marker

Turn and talk about the previous lesson. Display **slide A**. Say, *With an elbow partner, discuss what evidence we collected that helped us know that the gas bubbles from the bath bomb were not one of the three substances we started with (baking soda, citric acid, or water). Then discuss what kind of gas you think it might be. Feel free to brainstorm multiple predictions.*

Share ideas with the class. After a couple of minutes, have students share some possible gases it could be. Anticipated responses will be any gases that students already know. If students completed the *Storms Unit*, they are likely to mention some of the gases that make up the atmosphere, such as nitrogen, oxygen, and carbon dioxide.

Lead a short discussion to help students see that using properties to find out what kind of gas is coming from a bath bomb could be a good next step.

Say, *We know that there is more than one type of gas in our world. If we want to figure out what gas is in those bubbles, we could try to identify it based on its properties and compare it to the properties of other gases in the world around us. But what exactly are some different properties of gases? That seems tricky to determine because gases are invisible. Let's pause here and try to try to think of some related experiences with gases that might help us figure out some properties they have that we could use to tell them apart.*

Consider related phenomena around gases. Display **slide B**. Ask students to title a new page in their notebook "Gas-Related Phenomena." Tell them to list any experiences they have had with different kinds of gases. These can be gases that are used in different types of systems to make different things happen.

Then after brainstorming for a couple of minutes, ask students to share ideas. Student ideas may include:

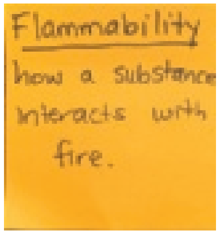
- gas in a balloon (helium),
- the Goodyear Blimp that sometimes appears at sports events,
- gas stoves to cook on,
- gas in grills or fireplaces, or
- the gas fizz in a soda.

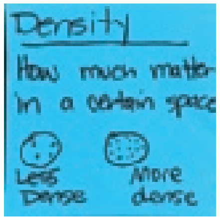
After getting some of these examples, say, *These are examples where different kinds of gases are used to make different things happen. Let's talk more about how the gases used in these systems can make these things happen.* Use the following example prompts to elicit student ideas about the properties of gases.

Suggested prompt	Sample student response
How would you describe what these gases are doing in the balloon or blimp?	*They make it float.*

Suggested prompts	Sample student responses
What you are describing is actually considered a property of a substance. It is called density. How have you used ideas related to density in your previous work related to gases in the Storms Unit?	*A batch/parcel of air can become more dense or less dense than the surrounding air when it is heated or cooled.* *When the spacing between the particles in gas changes, its density changes.*
The density of gases can change based on temperature, but it remains constant when measured under the same conditions. So if we always measure it at the same temperature and in the same location, then it is a property of a gas. Are there any types of gases that you know of that can be used to make things like a balloon float upward in the air because they are less dense than the surrounding air?	*Helium must be less dense than air because it makes balloons float upward.*
Do you think the gas from the bath bomb is less dense than air, as dense as air, or more dense than it?	*Accept all predictions.*
Can you give examples of some other ways that the gases are used?	*Well, some of them are used for cooking, heating, or in some fireplaces.*
What is done to the gas in these examples to get it to provide heat?	*It is lit on fire.*
Can you use any gas for fuel in these systems or only some? Why?	*Only some, because some gases burn, but others don't.*

Adding properties to the Word Wall. Say, *What you are describing is actually considered a property. Does anyone know what it is called?* If students do not know the property of flammability, introduce the term now. Have a student write the word "flammability" on a sticky note and add it to the Word Wall as another example of a property. An example definition for flammability: how a substance interacts with fire. If density is not on the wall, write it on a sticky note too, and add it to the Word Wall as another example of a property with the definition: how much matter there is in a certain space.





If odor wasn't added to the Word Wall in Lesson 3, students may suggest odor as a way to identify the gas because they may have smelled natural gas from a gas leak or they may remember that some bath bombs had an odor. Remind them that we think odor might be considered a property. Tell them that natural gas has an odor because another substance is mixed into it that has a rotten-egg-like odor to aid in the detection of gas leaks—the natural gas itself is actually odorless. Ask students if all bath bombs had an odor. Then ask students if they detected an odor when they combined the baking soda and citric acid. They should mention that they did not detect an odor when the baking soda and citric acid were combined, but they did detect an odor with most of the bath bombs.

Additional Guidance

Odor is usually shared by students as a characteristic of a substance, especially in Lesson 1 when a store bought bath bomb is added to the bowl of water. Usually there is a fragrance and/or essential oil added to these bath bombs. When they investigate the homemade bath bombs, they may smell an odor for three of the four bath bombs (coconut in Recipe

C and lemon/citrus smell for the two recipes containing lemonade drink mix). Odor is a property and can be used to identify a substance and though students have minimal data beyond reasoning that odor is a property, this will be further investigated in later lessons. If students are skeptical at this point as to whether odor is a property, it is okay to add it to the Word Wall with properties with a question mark for now, or to decide as a class not to add it as a property yet. It is also okay if odor hasn't been suggested at all as a characteristic of a substance since this will be revisited later in the unit in Lesson 13.

Say, *Let's look at some of these properties of different gases and compare them.*

2. Analyze and interpret property data for gases. 7 MIN

Materials: science notebook, poster paper, marker

Distribute *Some Common Gases* to students. Display **slide C**. Give students 2–3 minutes to look over the list of gases and share their noticings and wonderings verbally with a partner.

After students have had time to share with their partner, lead a short discussion to bring out their ideas.*

Assessment Opportunity

Building towards: 5.A.1 Analyze and interpret the data for common gases to look for patterns that could be used to identify an unknown gas by its characteristic properties.

What to look for/listen for: Students should notice patterns in the properties of gases, including melting point, density, and flammability.

What to do: If students are struggling with looking at all the data on *Some Common Gases* at once, encourage them to cover the last 3 columns of data with a blank piece of paper to hide those at first, and then after analyzing that part of the data table, slide the paper over to look at each subsequent column of data, one at a time.

Suggested prompts	Sample student responses	Follow-up questions
Will someone share one thing they noticed about this data?	*I noticed that it lists some gases that I've heard of and some that I haven't.*	*Which ones are new to you?* *Has anyone heard of that gas? What do you already know about it?*
Will someone share another thing they noticed about this data related to each of these gases?	*I noticed that there are a lot of different densities listed on the sheet.*	*Can you give some examples of gases that are more dense than air?* *Can you give some examples of gases that are less dense than air?*
What else did you notice about the data?	*There are some gases listed here that say they will explode.* *There are also some gases that are not flammable and others that help things burn.*	*Can you give an example of each?* *Which gases are those?*

*** Attending to Equity**
Universal Design for Learning: This discussion is one of many different ways students will express their understanding of types and forms of arguments they can make using property data related to gases. Other forms of expression in this lesson include:

- annotating *Some Common Gases*
- predicting and discussing the results of first-hand investigations as they happen
- writing a predictive explanation using sentence scaffolds
- verbally sharing their conclusions using a discussion protocol
- snapping their fingers and lightly tapping their feet in response to oral arguments
- writing a final argument

Providing students varied and multiple ways to express their understanding helps support them in accessing, building, and ultimately internalizing the strategies used in arguing from evidence in general, and not just for this specific case and context.

Suggested prompt	Sample student responses	Follow-up question
Does anyone want to share a wondering they had?	*I wonder what the gas from a bath bomb would do—would it explode?* *I wonder if we could test the gas from a bath bomb for its density and flammability and then maybe we can figure out what gas it is.*	*Do you want to try these ideas out?*

Alternate Activity

Extension Opportunity

Students may also notice that all of these gases have boiling points that are colder than room temperature. If students seem intrigued by this or want to talk about this further you could ask them to consider how this is connected to why these substances are a gas at room temperature.

If students bring up wonderings about what would happen if you cooled these gases, you ask students to consider how these boiling points could be used to make predictions about which gases would turn into liquids if you cooled them down to a certain temperature. This gives students an opportunity to connect what they learned in *Storms Unit* about boiling point and condensation point being the same temperature for a certain type of gas in the atmosphere (a substance). This thought experiment is one that some students might reference in their response to the last question in *Explaining another phenomenon* or *Alternate: Explaining another phenomenon* in the next lesson. Cooling and heating mixtures to different temperatures to get the substances in them to change phase from liquid to gas and back again is a technique used to identify and isolate substances through distillation and refining.

3. Test the flammability of our bath bomb gas and other known gases. 12 MIN

Materials: Flammability test for air vs. bath bomb gas, science notebook

Brainstorm how we could test the gas from the bath bomb for these properties. Ask students for some suggestions for ways to trap the gas from a bath bomb so that we can test it for these properties. Also ask them for ways to compare the gas in the bath bomb to other gases in the table. Students will likely suggest bottles or bags based on their experience from Lesson 2.

Say, *OK, let's plan to trap some gas first and then check it for one of these properties. Let's start with checking its flammability, and then we can look at density after that. One thing that scientists often do when testing the properties of an unknown substance is to compare it to the properties of some known substances. Such comparisons are called control conditions. This increases the reliability of the results for the unknown substance, since a comparison between the behavior of a known substance and an unknown substance can often reveal problems in the equipment you are using or in your experimental procedure. I have two gases we can use as controls for this comparison. I have some helium gas we can use and we can use air from the room. Let's review safety guidelines for these flammability tests.**

*** Supporting Students in Engaging in Planning and Carrying Out Investigations**
Over the course of the units students develop their skill of Planning and Carrying out an investigation. In this investigation, the class is trying to figure out what gas is formed when the bath bomb is added to water by comparing it to a gas that most students have had some

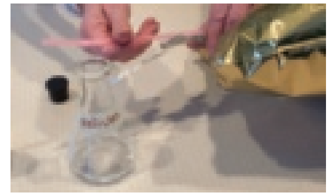
Review safety guidelines for this demonstration. You will need two volunteers to help. Have students put their goggles on and gather around the demonstration area.

Safety Precautions

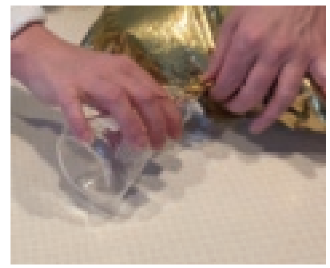
Make sure that you, the students that help you, and any other students near the demo are wearing goggles. Have a cup of water nearby to discard burnt matches and splints. Anyone with long hair should tie it back.

Fill one flask with helium and one with room air.

Use a straw to open up the bottom of the pre-filled balloon to release the helium.



Place the end of the straw that is sticking out of the bottom of the balloon into a flask. Keep the flask tilted so that the opening is facing down. Use a stopper to close the flask for now until you are ready to test the flammability.



Have a second flask that is filled with air with a stopper on it.

Safety Precautions

Do not be tempted to allow students to breathe in helium from the balloon or to do it yourself. This common party trick that makes your voice sound different can be very dangerous. Even though it is usually harmless and many students or adults have never had any ill effects from breathing in helium, it can result in unconsciousness, collapsed lungs, or even death. These effects are caused from breathing in high concentrations of helium by directly sucking on an open helium balloon or breathing directly from any helium source. The helium released into the classroom through these investigations is not sufficient to cause any ill effects. There are also abrupt temperature changes that occur in gases under pressure as they rapidly escape the canisters that can lead to tissue damage when the gas is inhaled.

experience with, helium. Here the idea of a control condition is discussed with students to help them see that comparing the data we get in this investigation to known identifiers or data (such as *Some Common Gases*) will help us to better identify the unknown situation (or the gas from the bath bomb).

*** Attending to Equity**

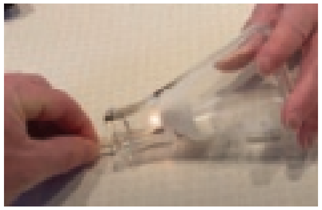
Universal Design for Learning: In addition to demonstrating the tests in real time, consider providing students access to the alternate videos of the investigations for students to re-watch or return to. These videos provide an additional option for representation that can help support students in processing the information and can be slowed down or re-watched as needed. Additionally if students have questions about what happened in the video, they can rewatch the video intentionally looking for evidence or data that could help them answer their question. This sets a purpose for them as they re-watch the video.

Multiple students in the class may ask to see the video again after watching it once. If this is the case, then ask them why they want to watch the video again. What are they wanting to see or look for? Through asking these questions and making students verbalize

Predict the flammability results of helium and air. Show **slide D**. Explain that you are going to light a match and slide it into each flask. Ask students to look back at their property data in *Some Common Gases* to make some predictions. Students should say the match put into the flask of room air should remain lit, but the one put into the flask of helium should go out.

Test the flammability of the helium gas and air.*

Have a helper tilt a flask filled with air on its side holding from behind. Light a match and bring it about 6 inches from the corked end. Have another helper remove the cork. Quickly slide the lit match into the opening and hold it there for three seconds prompting students to notice the flame.



The flame will remain lit. Remove the match and extinguish it.

Have a helper tilt a flask filled with helium on its side holding from behind. Light a match and bring it about 6 inches from the corked end. Have another helper remove the cork. Quickly slide the lit match into the opening and hold it there for three seconds prompting students to notice the effect. The flame will immediately go out upon entering the flask.

Alternate Activity

Alternative videos are provided for classrooms in which open flames are not allowed and/or helium is unavailable. You may also preview these videos to help you as you prepare for the set up of this investigation.* (See the **Online Resources Guide** for links to these resources. **www.coreknowledge.org/cksci-online-resources**)

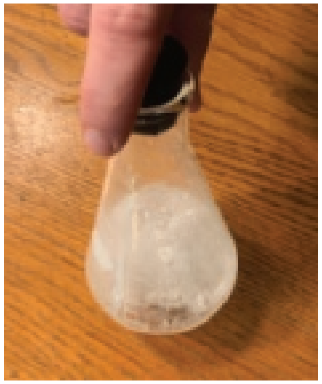
Discuss these results. Ask students why the flame went out in one but not the other. Students should say, *It is because helium will not support a flame but room air will.*

Capture gas from a bath bomb and test its flammability. Display **slide E.** Remove the stoppers from both flasks you just used. Use the flask you had for the room air if you have no additional flask available for this next test.

Add about 50 mL of water to an Erlenmeyer flask, and then add 5 mini bath bombs to a flask.

and identify why they want to watch it again, you are increasing access and engagement with the phenomenon. If students can't verbalize a reason they want to re-watch beyond just to see it again, then use your discretion as to whether you have time in your class period for this.

Let it bubble for a few seconds, and then seal it with a stopper.



Test the flammability of the gas from the bath bomb. Light a match. Have a helper tilt the flask on its side holding from behind. Light a match and bring it about 6 inches from the corked end. Have another helper remove the cork. Quickly slide the lit match into the opening and hold it there for three seconds prompting students to notice what happens. The flame will immediately go out upon entering the flask.

Show **slide F.** Say, *Now that we have this result, we can use it to strike through all the gases that do not have that property on our list of candidates.* Give students a few minutes to mark off gases from *Some Common Gases*. They should be eliminating air, oxygen, hydrogen, methane, and propane.

Assessment Opportunity

Building towards: 5.A.2 Analyze and interpret the data for common gases to look for patterns that could be used to identify an unknown gas by its characteristic properties.

What to look for/listen for: Students crossing off candidate gases in light of new evidence they collect.

What to do: If students are struggling with using their data to eliminate gases, you could lead a class discussion where students take turns stating one gas they eliminated and what data they used to eliminate it.

4. Investigate and predict density effects for helium.

10 MIN

Materials: Density of helium lab, science notebook, poster paper, marker

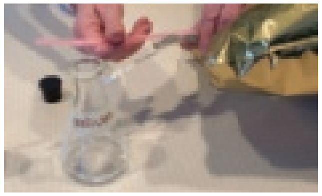
Introduce the idea of testing density. Say, *OK, we tested the flammability of the bath bomb gas, but there was another property listed that we wanted to test. What was that other property?* Students should say density.

Say, *The last time you studied the density of gases was in the Storms Unit. In that unit, you learned that when a gas or liquid is more dense than the surrounding gas or liquid it sinks downward and when it is less dense than the surrounding gas or liquid* *it floats upward. Let's look at helium's reported density and make predictions about what helium would do if we released it from a container into the surroundings.*

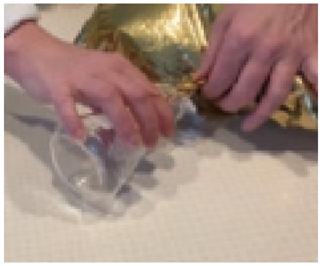
Predict the behavior of helium. Display **slide G.** Discuss predictions as a class. Students should predict it will float upward. Say, *Let's test it.*

Fill one flask with helium and one with room air.

Use a straw to open up the bottom of the pre-filled balloon to release the helium.



Place the end of the straw that is sticking out of the bottom of the balloon into a flask. Keep the flask tilted so that the opening is facing down. Use a stopper to close the flask for now until you are ready to test the flammability.



Say, *OK let's get ready to release it and see if it floats upward or sinks downward. Are you ready?* Wait about 10 seconds. Students are likely to raise a concern before you release the stopper, saying, *How will we be able to tell which way it goes? It's invisible!*

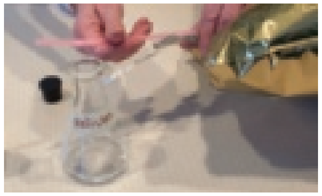
If students don't object, then simply open the stopper on the flask. Wait about 10 seconds and then ask, *Did the release gas travel upward like you predicted?* It is at this point that you will definitely get some objections from students, saying, *How were we supposed to be able to tell which way it went? It's invisible!*

Suggest using its flammability as a way to test whether it is less dense or more dense than air. Say, *Good point. We need a way to detect whether the helium gas traveled upward or downward. We already know something about its flammability though. So if we opened a bottle filled with the gas and held a match in front of it then opened and removed the cork, what should happen to the flame when the gas comes out of the bottle?* Students should say it would go out.

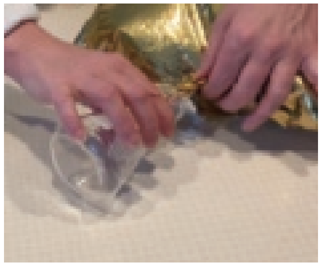
Share predictions. Show **slide H**. Give students a couple of minutes to discuss their ideas with a partner. Say, *Let's test this ourselves to see if our predictions are correct, and then we will use what we figured out and try to apply it to the gas from the bath bomb.*

Test the flammability of the helium gas in each case.

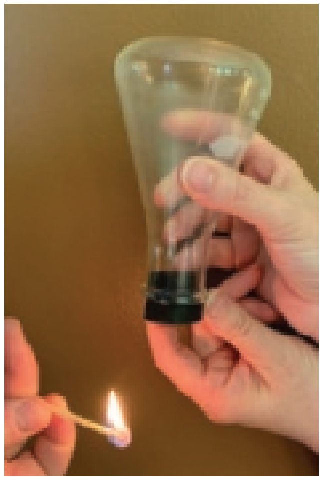
Use a straw to open up the bottom of the pre-filled balloon to release the helium.



Place the end of the straw that is sticking out of the bottom of the balloon into a flask. Keep the flask tilted so that the opening is facing down. Use a stopper to close the flask for now until you are ready to test the flammability.



While still holding the bottle upside down, have a student light a match under the bottle as you remove its cap. Students should notice that the flame does not go out.



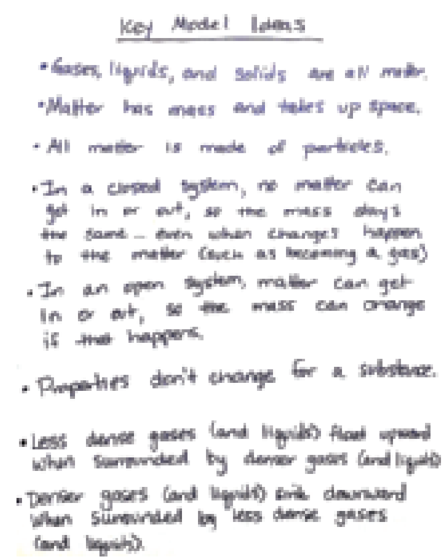
Now turn the bottle right side up. Ask a student to get ready to remove the cap. Light a match. Have the student remove the cap and move the match right over the opening of the bottle. The match will go out.

Alternate Activity

If no helium is available and/or you are unable to carry out a flame test in your school, show a video in place of first-hand helium testing. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)

Discuss these results. Ask students why the gas from the bottle extinguished the flames in one case but not the other. Students should say, *It is because of its density, and that if the gas floats upward, it will only put out a flame above it, not below it, because it won't fall downward out of the bottle.*

Updating the Key Model Ideas chart. Co-construct a key idea about density that says something like, "Less dense gases (and liquids) float upward when surrounded by denser gases (and liquids); and denser gases (and liquids) sink downward when surrounded by less dense gases (and liquids)." Add this to the Key Model Ideas chart. Remember it is important to use the wording your class comes up with for this key model idea whenever possible. Help students connect back to what they have seen in earlier units and what some groups may have seen in Lesson 4 with oil floating on water, if this is something they noticed, asking them what this shows about the density of oil compared to water. Students should say it shows that oil is less dense than water.



Additional Guidance

This is very similar to the key model idea that students developed in the *Storms Unit* and in *Everest Unit*. In these units, it was stated as "Less dense fluids float upward when surrounded by denser fluids, and more dense fluids sink downward when surrounded by less dense fluids." Students used the word "fluids" to refer to liquids and gases, and to describe similarities in their motion via convection. Students may suggest that word now (fluids). If so, feel free to include it. If they don't bring it up, then stick with the phrase "gases (and liquids)."

Introduce testing the bath bomb gas in a similar manner. Tell students that they will test the bath bomb gas in a similar manner tomorrow, but before they do you want them to make some predictions about what we could figure out about the gas from a bath bomb by doing a test similar to the one we just did, but with gas from a bath bomb trapped in a bottle or bag instead of helium gas.

5. Make predictions about the gas from a bath bomb.

8 MIN

Materials: *My Predictive Explanations for the Gas from a Bath Bomb*, science notebook

Making predictive explanations. Pass out a copy of *My Predictive Explanations for the Gas from a Bath Bomb*. Ask students to use this handout to make two different if-then statements that will describe what they could learn from testing the density and flammability of the gas coming from the bath bomb. Display **slides I** and **J** to show the structure of the information that their prediction should have.* Remind students that they will need to use *Some Common Gases* as a reference as they record their predictions on *My Predictive Explanations for the Gas from a Bath Bomb*.* Don't have students attach these predictions to their notebook because you will collect them at the end of the day and return them at the start of day 2.

Assessment Opportunity

Building towards: 5.B Apply scientific reasoning based on patterns in the densities for a known set of gases to explain how either of two different possible outcomes from a future investigation could help us narrow down the sub-set of candidate substances from what could be in the unknown gas from the bath bomb.

What to look for in student responses on *My Predictive Explanations for the Gas from a Bath Bomb*:

- If the gas from the bath bomb puts out a flame above it, that means it is __**less**____ dense than the room air, which has a known value between ___**1.160 to 1.161 g/L**_____. I know this because ____ **materials that are less dense float upward when surrounded by matter that is more dense**______. If evidence supports this prediction, it tells me that the gas from a bath bomb could be __**neon, and/or helium** ___________.
- If the gas from the bath bomb puts out a flame below it, that means it is __**more**____ dense than the room air which has a known value between ___**1.160 to 1.161 g/L**_____. I know this because ____ **materials that are more dense sink downward when surrounded by matter that is less dense**______. If evidence supports this prediction, it tells me that the gas from a bath bomb could be __**nitrogen, argon, and/or carbon dioxide**___________.

What to do: If you notice students are struggling when they are forming these for the first time, you could pause the activity. Then talk through the responses and rationale for what they would put in each of the blanks on **slide I,** together as a whole class for the first prediction. You could then have them individually write their understanding of what you just discussed, and have them try the same for the second prediction shown on **slide J**. For students who need additional scaffolding for this explanation, use *Alternate: My Predictive Explanations for the Gas from a Bath Bomb* that has sentence starters and other supports.

End of day 1

*** Attending to Equity**
Supporting Emerging Multilingual Learners

Scaffolds such as sentence starters and images can model and facilitate particular oral or written language production skills. Such scaffolds may be of particular benefit for emerging multilingual students to help them develop language skills to write or communicate their ideas to peers. It is important that scaffolds be used purposefully and removed when no longer needed. To support this, a modified handout has been made available *Alternate: My Predictive Explanations for the Gas from a Bath Bomb.*

*** Supporting Students in Engaging in Constructing Explanations and Designing Solutions**

We want to help students develop the practice of constructing a coherent explanation. This explanation includes both qualitative and quantitative relationships between variables that predict whether the gas would float upward or sink downward, as well as connections to a key model idea. The sentence frameworks help to scaffold the chain of logic between these relationships.

6. Test predictions about the gas from a bath bomb.

10 MIN

Materials: Testing the density of bath bomb gas, science notebook

Return student predictions. Hand back the copies of *My Predictive Explanations for the Gas from a Bath Bomb* or the alternative *Alternate: My Predictive Explanations for the Gas from a Bath Bomb* you collected. Have students share their predictions on this sheet with a partner for a minute.

Investigate the gas from a bath bomb. Display **slide K**. Review the first three bullets, asking students questions about safety related to these steps.

Suggested prompts	Sample student responses
You will be using a plastic soda bottle instead of a glass flask. Why is it important to not get the lit match closer than 1" above the top of the plastic bottle? What can happen to plastic if a flame touches it?	*It could melt if the flame touches it.* *Or it could catch fire and burn.*
What evidence do we have that indicates that the gas from bath bombs is not flammable and/or won't explode?	*We tested it already with a match in a glass bottle.*

Then introduce a potential problem and solution related to the liquid in the bottle and tipping the bottle over.

Suggested prompts	Sample student responses
After testing the flame above the bottle for 2 seconds, you will get ready to test a flame below the bottle. Can anyone see a problem with testing this gas the same way we tested helium?	*One problem with our bottles is that they will have liquid in them, so we can't simply put a match right below them and open the lid without the liquid spilling out.*
To address this potential problem, you will open and tilt the bottle in a particular order to prevent spilling liquid out. In the next few steps, you will light a candle and place it in a pan below the bottle, then you will upcap the bottle and tilt the bottle sideways to pour out the gas in it. If the gas is more dense, then what should it do?	*You will be able to see if it puts out a flame below it without tipping out the liquid inside of it.*

Safety Precautions

Make sure that you and the students are wearing goggles. Have a cup of water nearby to discard burnt matches and splints. Anyone with long hair should tie it back.

Do not have students add more than the recommended number of mini bath bombs to the bottle. It may rupture if too much gas pressure builds up in it.

Additional Guidance

Bath bomb Recipe B works best for this small-group investigation, but if you have enough leftovers from the homemade bath bombs you made for Lesson 1, then use those for this investigation instead. Recipe C will not produce as much gas as quickly as the other two, which is why these ones are not recommended for this investigation. If students ask why they are all using bath bombs from Recipe B, ask them to think back to the observations that were made in Lesson 1 about the interactions of the bath bombs when placed in water and the amount of gas or bubbles that were produced. They should suggest they saw Recipe B bubble and produce the most gas.

Alternate Activity

1. An alternate procedure is provided on **slide P** that may produce more consistent results. Try the original one and if it doesn't work, try using the one outlined in that slide instead, and replace **slide K** with **slide P**.
2. If you are unable to perform flame tests in your school, use the video with students. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)

Monitor students in the lab. Give students about 6–7 minutes to collect their data from the lab.

Additional Guidance

It will be important to remind students to hold the match at least one inch above the bottle when testing the density of the gas from above the bottle. If they hold the match too close to the bottle, then the flame may go out due to the flow of the escaping gas.

7. Update individual Progress Trackers.

5 MIN

Materials: *Some Common Gases*, *My Predictive Explanations for the Gas from a Bath Bomb*, Key Model Ideas chart, Anchor poster

Updating the list of possible gases. Display **slide L.** Tell the class, *Use the results of your investigation and your predictions to narrow down the substances the gas from the bath bomb could be.* Cue students to look back through *Some Common Gases* and *My Predictive Explanations for the Gas from a Bath Bomb* and individually cross off candidates that they have now eliminated as they transfer their discoveries to their Progress Tracker.

8. Navigation: Argue from evidence.

12 MIN

Materials: *Some Common Gases*, *My Predictive Explanations for the Gas from a Bath Bomb*, *Discussion Protocol: Density and Flammability*, Key Model Ideas chart, Anchor poster

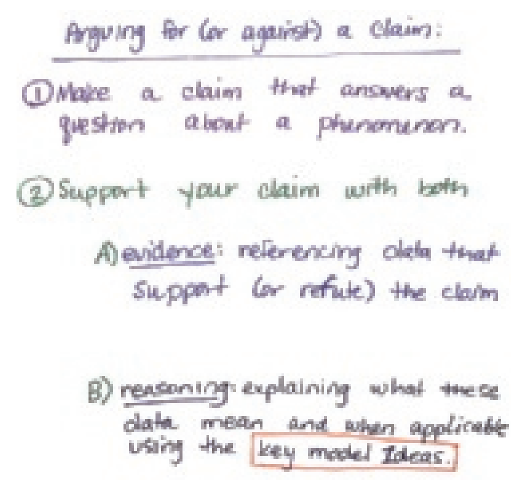
Return student predictions. Pass back the student predictions they made on *My Predictive Explanations for the Gas from a Bath Bomb*. Have students attach their predictions to their notebook.

Assessment Opportunity

Building towards: 5.C.1 Construct, use, and present an oral and written argument for an explanation that the gas in the bubbles from the bath bomb can be narrowed down to only three possible substances (out of ten of the most common ones in the air) supported by the patterns in the results from density and flammability tests and data on their properties and the use of related key model idea.

What to look for/listen for: Listen for how students draw on the evidence from their observations of the density and flammability tests and their previous work on *My Predictive Explanations for the Gas from a Bath Bomb* in small-group discussions, using the protocol on *Discussion Protocol: Density and Flammability*.

What to do: Encourage students to follow the protocol during the small-group discussions. If they are struggling with this, tell them to check off each step as they complete it.



Divide the students into small groups. Arrange your students in groups of 3. Mix them in groups different from their lab group from the previous class. They will need

- their notebooks turned to their last entry in the Progress Tracker,
- the data table from *Some Common Gases*,
- their predictive explanations from *My Predictive Explanations for the Gas from a Bath Bomb*, and
- the new handout, *Discussion Protocol: Density and Flammability*.

Set up the protocol. Display **slide M** and spend a few minutes as a whole class going over the protocol with students. Ensure that the anchor poster you made from Lesson 2 is clearly visible to all groups. Make sure they understand that everyone in the group will share their ideas in the form of making a claim about one gas that could be from the bath bomb or one gas it couldn't be. All students will participate in giving feedback to their peers. Have students practice snapping their fingers and lightly tapping their feet. Reserve at least 9 minutes for students to participate in this activity. Set a timer so that students know when a new classmate should offer their claims.

9. Get ready to write an argument using evidence. 3 MIN

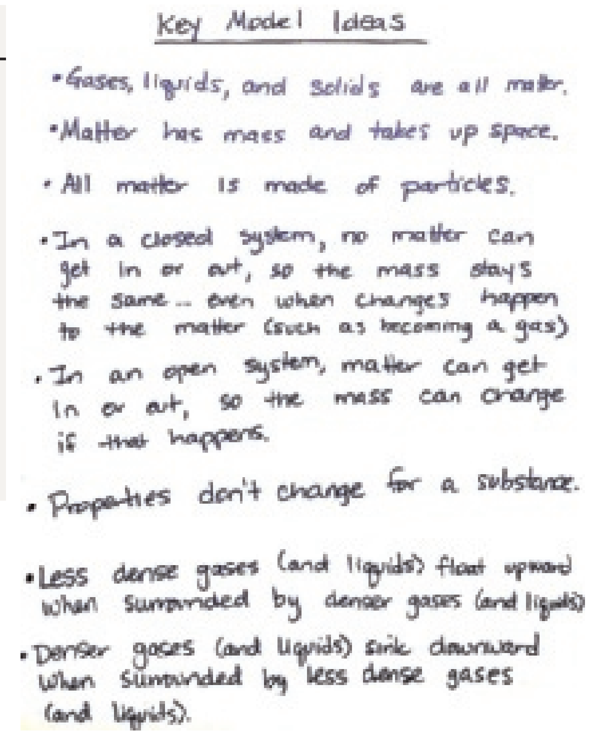
Materials: None

Identifying overarching key model ideas to call out in our argument. Use the Key Model Ideas chart, and work together with the class to determine if there is one main key idea they can use in a written argument that identifies the remaining possible gases that could come from a bath bomb. Use the dialog below as an example to guide your discussion.

Suggested prompt	Sample student responses	Follow-up question
What has been helpful to you for identifying the gases that could be coming from the bath bomb?	*Density!* *Flammability!*	*What do these two things have in common?*

Suggested prompts	Sample student responses	Follow-up question
You say that these are both properties, and we have them as examples on our Word Wall. Is there a key model idea that we would need to use in our argument as well?	*They are both properties, and we have one about properties—Substances have properties that can help us identify them (e.g., solubility, odor, state of matter at room temperature, melting point, density, flammability, and color).*	*Is the gas from the bath bomb considered a substance?*
Can you think of other key model ideas that we can use in our reasoning?	*The gas from the bath bomb sank down, so we could use the idea that gases that are more dense than other gases surrounding them, like air, will sink.*	

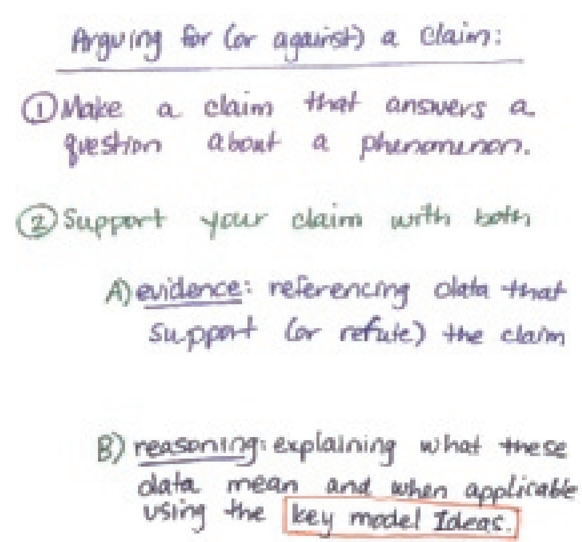
Review instructions for the task. Remind the class that the ideas on the Anchor Chart can be used to build a strong argument. Go over each part of the poster, reminding students about the important parts of a strong argument. Display the Anchor Chart and **slide N**. This slide has the question they should answer: "What gas(es) could be produced by a bath bomb?" Say, *Your written argument should answer this question. You should use evidence and key model ideas to support your claim. Use this anchor poster to remind you of what is important.*



10. Construct written arguments about the gas from a bath bomb. 13 MIN

Materials: science notebook, notebook paper

Give time for students to individually construct their arguments. Tell students where you want them to write their arguments, depending on how you want to gather their responses. If you want them to record their ideas in their notebooks, have them use a clean page and mark it so it is easy for you to find. Tell students that you will use this task as an assessment, so they should do their best work.



Assessment Opportunity

Building towards: 5.C.2 Construct, use, and present an oral and written argument for an explanation that the gas in the bubbles from the bath bomb can be narrowed down to only three possible substances (out of ten of the most common ones in the air) supported by the patterns in the results from density and flammability tests and data on their properties and the use of related key model idea.

What to look for/listen for: Use *Elements to look for in students' written arguments* for guidance on what to look for in their written argument. Use this guidance to provide feedback to students on their written arguments.

What to do: For students who struggle with writing this argument, you could provide them with anonymized copies of a couple of exemplar student responses for them to annotate. Ask them to circle the claim, underline the evidence, and highlight the use of key model ideas in both. Ideally provide them two arguments that have different structure and different flow in how all of this is sequenced and connected together.

Encourage students by reminding them that they have had multiple chances to practice these arguments in small teams and with the whole class. Now it is time for them to write their arguments individually and "show off" what they have learned. Tell them that they can use the posters around the room, their notebooks, the data table, and any other material from the lessons as a resource to write their argument.*

*** Supporting Students in Three-Dimensional Learning**

This is an opportunity for assessing students' engagement in all three dimensions of NGSS to explain a phenomenon, related to a target of Performance Expectation (PE) MSPS1-2. In this PE, students are trying to develop an argument for whether a chemical reaction occurred. They are developing a precursor argument and part of the foundation that will be developed fully in future lessons. They are arguing for what new substances could have been produced in the gas from the bath bombs. In this assessment, students are using DCIs related to PS1.A: Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. They are using the crosscutting concept of patterns (at a macroscopic scale), and they are developing an evidence-based argument based on their analysis and interpretation of data from laboratory experiments and known property information to determine the similarities and differences in findings.

11. Navigation

2 MIN

Materials: None

Display **slide O**. Say, *Wow, we have figured out some ways to identify substances using properties. This has helped us narrow down to three possible substances that could be produced from a bath bomb placed in water. We also know that the substance in the gas isn't one of the ones we started with, even though it came from the matter that made up the original substances. Without additional property data, this seems as far as we can go in figuring out what substance the gas is. It seems like we might need to take a different approach to investigating this process further, particularly if we want to figure out what is going on at the particle level that could explain how this is possible. But, before we continue our explorations of the bath bomb, I don't want us to forget that we didn't just want to explain what is happening in a bath bomb. We also have all these ideas on our related phenomena poster we wanted to be able to explain too. In our next class, let's try and use what we have figured out so far to see if it can help us explain what is going on in a different phenomenon.*

Share with students that during the next class period, they will have a chance to analyze some data from an investigation of a different related phenomenon and they will use this analysis to write multiple arguments about what is happening to the matter in the system.

ADDITIONAL LESSON 5 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

- **CCSS.ELA-LITERACY.W.7.1.A Introduce claim(s), acknowledge alternate or opposing claims, and logically organize the reasons and evidence.**
- **CCSS.ELA-LITERACY.W.7.1.B Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.**
- **CCSS.ELA-LITERACY.W.7.1.C Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.**
- **CCSS.ELA-LITERACY.W.7.1.D Establish and maintain a formal style.**

- **CCSS.ELA-LITERACY.W.7.1.E Provide a concluding statement or section that follows from and supports the argument presented.**
- **CCSS.ELA-LITERACY.W.7.2.C Use appropriate transitions to create cohesion and clarify the relationships among ideas and concepts.**
- **CCSS.ELA-LITERACY.W.7.2.D Use precise language and domain-specific vocabulary to inform about or explain the topic.**
- **CCSS.ELA-LITERACY.W.7.2.E Establish and maintain a formal style.**

The above learning goals are the focus of the written argument that students produce at the end of day 3 of this lesson.

CCSS.ELA-LITERACY.SL.7.1.B Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.

This is the focus of the small-group discussions on day 3 of this lesson. There is a discussion protocol to help transition the roles of each person in the group and contribute to the discussion in different ways.

LESSON 6

How can we explain another phenomenon where gas bubbles appear from combining different substances together?

Previous Lesson

We analyzed the density and flammability data for common gases. We tested the flammability of the gas from the bath bomb. We carried out an investigation to see if the gas from the bath bomb rises or sinks. We argued from evidence that the gas from the bath bomb can be narrowed down to three candidate gases.

This Lesson

Putting Pieces Together

1 DAY

We apply what we have figured out about properties to explain a related phenomenon (elephant's toothpaste). We revisit our Driving Question Board (DQB) and reflect on what other related phenomena we might be able to explain using the same key model ideas.

Next Lesson

As a class we will summarize key model ideas we figured out in earlier lessons. We will develop a new way to represent everything we figured out using an input/output table to represent the particles in the system. We will identify an unanswered question about where the particles that make up the substance(s) of the gas come from.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

6.A Apply key model ideas and patterns in mass and property data to construct three explanations for: a) why the mass of a system decreases when substances are mixed together, b) which substance(s) could or could not be produced in that process, and c) what additional tests could be done on the gas (or other gases) to help identify additional substances that aren't being produced in this process.

What Students Will Figure Out

- The mass of a partially open system where potassium iodide and hydrogen peroxide are combined decreases because a gas is formed and some of it escapes the system.
- The gas produced makes a glowing ember burst into flame and an already burning flame glow brighter.
- Flammability data can help us identify the types of gases that aren't being produced in this process.

- Testing the melting/freezing point, density and/or comparing the results of the flammability test to results from controls could help identify additional substances that aren't being produced in this process.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**NAVIGATION** We are introduced to a context for a new phenomenon to investigate using what we have figured out so far about identifying substances with their properties.	A	Related phenomena poster from Lesson 1, computer, projector, video (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)
2	20 min	**DEVELOP INDIVIDUAL ARGUMENTS** Construct explanations using key model ideas and evidence to account for three aspects of the phenomenon in the previous video.	B–C	*Explaining another phenomenon* or *Alternate: Explaining another phenomenon*, sticky notes, three different highlighters or colored pencils, computer, projector, video (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)
3	15 min	**REVISIT THE DRIVING QUESTION BOARD**	D	One copy of the Driving Question Board (DQB) questions, Driving Question Board
4	3 min	**NAVIGATION** Brainstorm what is happening between the particles of different substances to produce a new substance.	E	

End of day 1

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Explaining another phenomenon* or *Alternate: Explaining another phenomenon* • science notebook • sticky notes • three different highlighters or colored pencils	• One copy of the Driving Question Board (DQB) questions	• Related phenomena poster from Lesson 1 • computer • projector • videos (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) • Driving Question Board

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Be prepared to show the videos. (See the **Online Resources Guide** for links to these resources. **www.coreknowledge.org/cksci-online-resources**). Each student will need a copy of *Explaining another phenomenon* or *Alternate: Explaining another phenomenon*.

Online Resources

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

This assessment serves as a near transfer task for assessing students' engagement in all three dimensions of NGSS to explain a phenomenon that is very closely aligned to an NGSS PE (MSPS1-2), without an explicit focus yet on this being a chemical reaction.

Students are arguing for what gas could have been produced from an investigation combining potassium iodide and hydrogen peroxide (sometimes called "elephant's toothpaste"). In this assessment, students are using DCIs related to PS1.A: Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. They are using the crosscutting concept of patterns (at a macroscopic scale), and they are developing an evidence-based explanation based on their analysis and interpretation of data they receive from a laboratory experimentation demonstrated in a video and known property information from Lesson 5, to determine similarities and differences in findings.

Where We Are NOT Going

The reaction that occurs during the elephant's toothpaste investigation is exothermic and gets extremely hot initially. The focus in this assessment avoids any reference to temperature or energy changes in the system, and this aspect of the phenomenon should not be introduced. Energy changes in chemical processes will be a focus of the work students will be doing in their next unit *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit).*

LEARNING PLAN FOR LESSON 6

1. Navigation

7 MIN

Materials: Related phenomena poster from Lesson 1, computer, projector, videos (See the **Online Resources Guide** for links to these resources. **www.coreknowledge.org/cksci-online-resources**)

Connect to related phenomena. Bring the related phenomena poster from Lesson 1 to an area of the room where students can see it. Display **slide A**.

Say, *Up until now we have been trying to figure out what gas is produced when the bath bomb is placed in water. We have figured out some ways to collect data to try to identify this gas. Last class, we figured out that there are properties we can use to help us identify different gases. We used this property data to argue what gas could be produced from the bath bomb when added to water. But we also have identified other phenomena that we wanted to try to explain that also produce bubbles.*

* Attending to Equity

Supporting Universal Design For Learning:

When possible, returning to the Related Phenomena poster to see if they can be explained using what

Ask students to restate what some of those phenomena were.*

Say, *Let's take some time today to see if we can use what we have figured out about identifying substances in relation to the bath bomb to another related phenomenon. I have a video of this phenomenon. It is sometimes referred to as "elephant's toothpaste." Some of you may have heard of this. We will watch the video of it a couple times to see what happens. Then you will try to explain various aspects of what you see happening. Ideally, what we have figured out so far about bath bombs should be able to help us explain other related phenomena too. But we don't always know the limitations of these model ideas until we try using them to explain a wider range of phenomena. So this is our chance to test how generalizable our key model ideas are.*

Play the video once through. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) When it ends, pause for a couple of minutes to let students have time to record their observations. Then play it a second time if needed.

2. Develop individual arguments. 20 MIN

Materials: *Explaining another phenomenon* or *Alternate: Explaining another phenomenon*, science notebook, sticky notes, three different highlighters or colored pencils, computer, projector, video (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)

Introduce the transfer task questions. Show **slide B**. Distribute a copy of *Explaining another phenomenon*. Emphasize that the questions on the handout are an individual assessment and that these questions will help you gauge student progress on analyzing data and making arguments using key model ideas and evidence for a related phenomena.

Show **slide C.** Read through the top of the handout together as well as the instructions for the first question. Ask students if they have any questions.

Show the second video: (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Give students a couple of minutes to write down their observations and then show the video a second time.

Say, *Now that we have watched the video of the elephant's toothpaste phenomenon, let's look through the rest of the assessment and make sure we all know what we are being asked to do. For the assessment, you will use different resources from your notebook. Read through the prompts for questions 2–4 and think about how many resources you will need to reference for each question. Be ready to share with the class.*

Students will notice that they are asked to use 2 resources for question 2, 3 resources for questions 3 and none are specified for question 4. Suggest the students highlight with a different color, each of the resources they will need for question 3 first. Here is an example of that using yellow, green, and blue highlighting:

Use these three resources: A) your observations, B) your key model ideas, and C) the data table in your notebook of *Some Common Gases*, to make an argument to answer this question:

Next, suggest they color 3 corresponding sticky notes and add them to the relevant pages where these resources are found. In this example that would include adding:

- a yellow-colored note to the first page of *Explaining another phenomenon* or *Alternate: Explaining another phenomenon*

has been figured out in class can be very satisfying for students and helps to broaden their conceptual understanding of the content and practices they have been figuring out. In addition to referring to this phenomenon on the poster, you might place a checkmark or sticky note next to it to notate this is a phenomenon we are revisiting. This can help support student *engagement* as they see the shifts in the work they are doing in lessons like this (motivating a transfer task to take account of a related phenomenon) as still being very relevant to making progress on their original questions and ideas for investigations.

If your class has elephant's toothpaste on the Related Phenomena poster, then this next introduction to this transfer task could be altered to refer to that instead.

*** Supporting Students in Developing and Using Systems and System Models**

Up until this point in the unit, students have figured out that in closed systems, the mass shouldn't change because nothing can get in or out of the system. Yet, they also know that if the mass changes then it means something has left the system, and since they know gas has mass and is made of particles too small to see, they are combining what they know about

- a green-colored note to the corresponding page(s) in their Progress Tracker
- a blue-colored note to the data table *Some Common Gases* in their science notebook

Ask students to color code the remaining questions using the same color scheme. This will help save them time as they work through the assessment so they will not need to keep re-finding these resources. If students do not have colored highlighters available, they could use colored pencils and shade them or they could use three different symbols next to each resource instead.

Give students the remaining time to continue recording their observations and complete the remainder of the assessment.**

Assessment Opportunity

Building towards: 6.A Apply key model ideas and patterns in mass and property data to construct three explanations for: a) why the mass of a system decreases when substances are mixed together (potassium iodide and hydrogen peroxide), b) which substance(s) could or could not be produced in that process, and c) what additional tests could be done on the gas (or other gases) to help identify additional substances that aren't being produced in this process.

What to look for/listen for: Use *Elements to look for in students' written arguments* for guidance on what to look for in their written argument. Use this guidance to provide feedback to students on their written arguments.

What to do: For students who need additional scaffolding for the written argument, use *Alternate: Explaining another phenomenon* that has sentence starters and other supports for students.

3. Revisit the Driving Question Board. 15 MIN

Materials: One copy of the Driving Question Board (DQB) questions, Driving Question Board

Revisit the Related Phenomena poster. Say, *Now that you have analyzed data from a related phenomenon that also produced gas bubbles, do you think we might be able to use the same strategies to investigate other related phenomena on our poster?* Let a few students share their ideas.

Revisit the questions from the Driving Question Board (DQB). Show **slide D**. At the end of day 3 of Lesson 1, after all classes had developed their DQB, you should have created a record of all the questions that are on the board that you printed out for students to reference the next day. Using this same record of DQB questions, print out one copy per group prior to class. Pass out one copy to each group.

Say, *Now that we have figured out some things about different substances and ways to identify them, let's take stock of what questions on our DQB we could answer. With your group, look through the questions from our DQB. Mark*

- *questions your group feels you can fully answer with evidence with a* ✓✓ (tell students this represents questions that we feel we have made progress on **and** we have evidence for),
- *questions your group can partially answer but need more evidence with a* ✓, (tell students this represents questions we feel we have made progress on but don't yet have sufficient evidence for), and

matter with what they know about systems to conclude that matter must be flowing out of the system (it isn't completely closed) in this investigation. The rattling of the stopper on the flask seen in the videos is further evidence of this matter flow.

*** Attending to Equity**

Supporting Universal Design for Learning: Providing scaffolds such as sentence starters and images can support students in *expressing* what they have figured out. This modified assessment in *Alternate: Explaining another phenomenon* includes these scaffolds as well as pre-organized selections from extra resources students would otherwise need to pull from (their Progress Tracker, data tables, and anchor charts), so that students will have all these resources in one place. This provides additional support for *representing* the lines of evidence and ideas they can draw on, rather than relying on students also needing to manage and reference across multiple pieces of paper, which relies on strong executive functioning skills. This consolidated set of representations enables students to focus more on *expressing* what they have learned, rather than managing and organizing their resources. As this is an editable document, please edit to match the level of

- *questions your group can't answer yet by leaving them as is* (tell students these are the questions they feel we haven't made any progress on yet).

After students have had some time to work with their group looking through the DQB questions, pull the class back together.

Say, *Let's hear from a few groups about what percent of the questions you feel we have made progress on and have evidence for to help answer them. What percent have we made progress on but still need more evidence to answer? And, what percent have we not made any progress on?*

Have some students share their findings. You may choose to annotate the actual sticky notes on your DQB or move those questions to indicate which have been answered.

Say, *Great, it sounds like we have figured out some things, but we still have more work to do!* Tell students to tape this handout of DQB.

scaffolding your students require. It is important that scaffolds be used purposefully and removed when no longer needed.

Students who don't need this scaffold may find this task more *engaging* when they draw on the previous artifacts they created in their own science notebooks.

Additional Guidance

At the end of day 3 of Lesson 1, after all classes had developed their DQB, you should have created a record of all the questions that are on the board that you printed out for students to reference the next day. When revisiting the DQB here, having this list of questions available can support students in identifying which questions they feel they can now fully answer with evidence, partially answer but still need more evidence, or can't yet answer. This handout will be revisited once more in Lesson 12. Encourage students to tape this into their notebook to refer to in later lessons.

4. Navigation

3 MIN

Materials: None

Brainstorm possible explanations. Show **slide E.** *We've now seen two phenomena where a gas was produced from combining ingredients together that were not gases to start with. And we argued the gas that was produced in one case was different than the gas produced in another case.*

- *We still don't know what mechanism can explain how it is possible that we are able to produce different substances in each of these cases. What are some of your initial ideas about what is going on between the particles of matter in the system that could help explain this outcome?*

Pause the conversation before the end of the period and say, *This is interesting to keep thinking about. Even though we've made a huge amount of progress by reasoning about property changes, we still don't know* ***how*** *new substances are being produced. We still don't know what is happening at a particle level. We are going to have to shift to using some creative thinking about what could be happening at a particle level that could explain how this is possible along with everything else we know is happening in the system. Let's pick up here next time.*

LESSON 7

How can we revise our model to represent the differences in the matter that goes into and comes out of the bath bomb system?

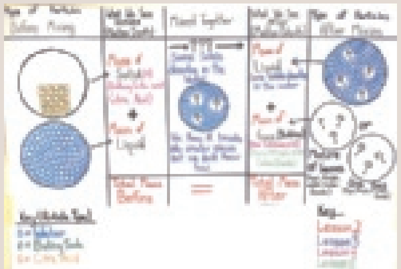
Previous Lesson

We applied what we figured out about properties to explain a related phenomenon (elephant's toothpaste). We revisited our Driving Question Board (DQB) and reflected on what other related phenomena we might be able to explain using these same key model ideas.

This Lesson

Putting Pieces Together

1 day



We work as a class to summarize the key model ideas we have figured out through all of the investigations. We develop a new way to represent everything we figured out using an input/output table to represent the particles in the system. We identify an unanswered question about where the particles that make up the substance(s) of the gas come from. And we argue for different ways we might revise our model ideas about particle level changes in the system to try to explain this.

Next Lesson

We will develop alternate models for making new particles from old particles using manipulatives. We will formulate questions about what happens when new substances are made from old. We will read about what Dalton and other scientists did to test this idea. We will outline a plan for a line of similar investigations to pursue.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MP-PS1-5

What Students Will Do

7.A Develop and revise a model to predict and describe the unseen interactions between particles in a system to show that matter is conserved in a process where the type of particles that make up the starting substances (system inputs) somehow change through their interactions to make different type(s) of particle(s) in the ending substances (system outputs).

What Students Will Figure Out

- The same substance is made of the same type of particles throughout.
- Different substances are made of different types of particles throughout.
- The particles that make up the substances in the gas bubbles from a bath bomb must be a different type of particle than any of those in the substances that were combined together to make it (water, baking soda, and citric acid).

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Gather in a Scientists Circle to review student responses from the end of the last class.	A–B	
2	17 min	**TAKING STOCK OF WHAT WE HAVE LEARNED** Remain in a Scientists Circle to summarize and review what the class figured out in Lessons 1–5. Record ideas in a new input/output model table.	C–F	prepared chart papers, different colored markers
3	17 min	**A NEW CONSENSUS MODEL** Remain in a Scientists Circle, and review how we represented particles in our initial class consensus model. Revise the new model table to reflect our new ideas for what is happening at the particle level.	G–I	*Self-evaluation: Engaging In Classroom Discourse*, chart paper, different colored markers, initial consensus model from Lesson 1
4	6 min	**NAVIGATION** Leave the Scientists Circle and have students consider individually how new substances might be made from the initial substances. Students should describe ideas in words and pictures in their science notebooks.	J	sticky note

End of day 1

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Self-evaluation: Engaging In Classroom Discourse* • sticky note		• prepared chart papers • different colored markers • chart paper • initial consensus model from Lesson 1

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Online Resources

Arrange desks in a Scientists Circle and have the initial consensus model displayed so that everyone can see it. You will be creating a new model that will be easier to draw if you have chart paper in landscape orientation. You may want to have multiple pieces of chart paper to use or you can use a long piece of butcher paper.

Markers chosen for the poster

- The colors shown in the example poster included in the teacher guide for this class model were intentionally chosen to support students who are color blind to allow them to be able to differentiate between the different color bands/shades of the particles. Since we are working together to figure out what is happening at the particle level and what is different between the different types of particles, it is important that all students can tell them apart.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

The lesson is designed to help foreground the difficult to reconcile aspects of what the class has figured out so far, namely that (1) a new substance(s) that wasn't in the system before, makes up the gas; this implies the formation of new types of particles, (2) the amount of matter in the system hasn't changed in the process that led to the formation of new particles; this implies the matter that makes up these new particles must have come from the matter that made up some of the particles in the system before the gas was produced, and (3) each of the three substances we started with that led to the formation of the new substance was made of its own type of particle throughout.

This seemingly contradictory set of occurrences is foregrounded at the end of this lesson. It is at this point that students are asked to try to revise the particle level model of the matter in the system to account for these occurrences, when they are asked to discuss these questions with a partner: *How can you take certain types of particles (point to the model you have drawn to represent the initial substances) and make them into new kinds of particles? You know the new stuff has to come from the old stuff because NONE of the matter disappears—we figured that out way back in Lesson 2. But HOW can both happen?* After this discussion, students are prompted to record their ideas in words and sketches on the notebook page they prepared. Some students may be stumped and that's OK. They don't have any direct evidence for what could be happening at the particle level. But giving them time to think through some possibilities is likely to get some students considering new ideas about what might be happening.

In the next lesson, the class will agree upon a new set of hypothetical model ideas that could account for the formation of the new substance(s) that make up the gas. Those will include: Maybe particles that make up substances (e.g., water molecules) can be joined together and/or broken apart. This set of hypothetical model ideas will motivate the entire work of the second learning set, to develop and refine a model of particle level interactions that necessitates the idea of atoms—which will be introduced formally in Lesson 11. By the end of this next learning set, the model will be used to develop an explanation of what is happening in the bath bomb and some other related phenomena where chemical reactions occur.

Where We Are NOT Going

Students may use the word "atoms" interchangeably with particles and/or molecules at this point but we are not introducing the idea of atoms in this lesson, nor the distinction between them and molecules. If students raise the idea of atoms independently, it is unlikely they have ever thought about why atoms are needed to explain certain phenomena in the world—in particular why they are needed to account for how new substances can be formed and what evidence we have for their existence.

The reason why you will want to avoid introducing these ideas now is that this lesson and the next few lessons are designed to give students opportunities to dig deeper into their own prior ideas and build on ideas the class develops and pursues through investigations. By the end of this lesson set, students will develop a conceptual understanding of how the idea of atoms and atom rearrangement are necessary for explaining the formation of new substances in chemical processes.

LEARNING PLAN FOR LESSON 7

1. Navigation

5 MIN

Materials: science notebook

Take stock of where we are in our thinking about how gas bubbles are formed from bath bombs. As students come into class, have the chairs or desks arranged in a Scientists Circle. Display **slide A.** Ask students to bring their science notebooks to the Scientists Circle. Begin by saying, *Let's recap and take stock of what we have figured out and what questions we still have about our bath bombs in relation to our Driving Question: **How** can we make something new that was not there before?** Allow students 2 minutes to work silently on the questions on the slide:

- What big ideas have we figured out about our bath bombs that help us explain our driving question?
- What questions do we still have about the gas bubbles that are produced from bath bombs?

Turn and talk about the questions on the slide. After students have had some time on their own to answer the questions, display **slide B** and direct them to share their thinking with an elbow partner.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**

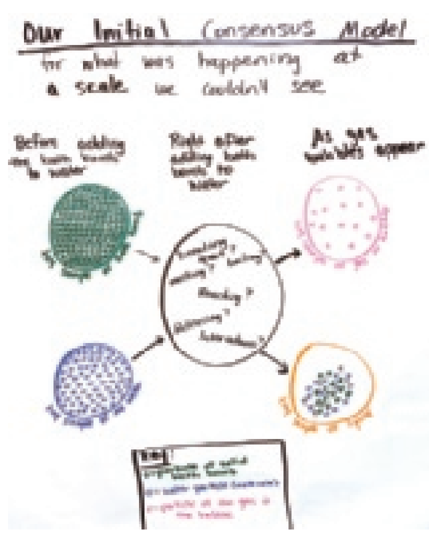
Having students take stock of the big ideas that they have learned during their previous investigations helps support students in taking stock of which questions students have fully answered, and what questions they have still not answered because they do not have evidence to fully answer them. Engaging in this practice will help students navigate from where they have been and what they need to do next to make progress on the unanswered questions.

2. Taking stock of what we have learned.

17 MIN

Materials: science notebook, prepared chart papers, different colored markers

Call students' attention to the initial class consensus model. Say, *We ended Lesson 1 with this Initial Class Consensus Model* (show the model). *We used this to represent what was happening at a scale we couldn't see. In looking at this model and listening to your discussions with your partner it seems we have a lot of new ideas that we have figured out from our investigations that are not represented in this model. I also noticed from your discussions that we still have some questions that need to be answered in order to explain **how** we can make something new that was not there before. Let's update our model by summarizing our work in a slightly different format to help us keep track of the matter in the system and also organize everything else we have figured out so far.**



*** Supporting Students in Three-Dimensional Learning**

Constructing this revised class model is an opportunity for students to draw on work they've done over many lessons to engage in all three dimensions of NGSS in order to make sense of the phenomena. The purpose of Lesson Set 1 (Lessons 1–5) was to establish that a new substance was

Assessment Opportunity

Building towards: 7.A.1 Develop and revise a model to predict and describe the unseen interactions between particles in a system to show that matter is conserved in a process where the type of particles that make up the starting substances (system inputs) somehow change through their interactions to make different type(s) of particle(s) in the ending substances (system outputs).

What to look/listen for: Connecting what we figured out from each lesson to our new model.

- In Lesson 1 we represented the different particles of matter in the system, including a way to show solids, liquids, gases, as well as mixtures vs. non mixtures.
- In Lesson 2 the gas is not part of the solid bath bomb, but the gas is produced from matter in the bath bomb.
- In Lesson 3 the bath bomb is a mixture made of more than one substance.
- In Lesson 3 none of the ingredients of the bath bomb when combined on their own with water produce a gas.
- In Lesson 4 the combination of baking soda and citric acid when combined with water produces gas bubbles.
- In Lesson 4 the gas is a different substance than any of the substances we started with.
- In Lesson 5, though we were able to narrow down what gas(es) this could be, we still don't know exactly what substance(s) it is.
- And we are still wondering how this happens—how particles that make up the original substances can become particles of a new substance.

What to do: Cue students to use their Progress Trackers and other resources in their notebooks to support what we figured out in each lesson. If some students are not sharing, use strategies such as Turn and Talk or Stop and Jot to provide students a minute to formulate their ideas before sharing with the whole group. You can also provide a quiet minute before each piece of the model is developed to ask students to look back in their notebook for pieces of evidence that support what they want to add to the model. In addition, reminding the class of the norms prior to starting the discussion will be a helpful reminder that when we are in the Scientists Circle. We need everyone's participation.

Prepare a table to represent our model. Draw a table similar to the one below on two pieces of chart paper that are landscape oriented to record this model as you summarize what is represented in the consensus model from Lesson 1. Leave room to add ideas to the three columns, and also leave room to add another column on the left and right of your initial table (shown in gray here) but do not initially draw these side columns.

	What we see unmixed (matter inputs)	Mixed together	What we see after (matter outputs)	

produced by the bath bomb and that the matter that makes up that substance came from matter already in the system. Revising and refining this model (SEP2) here helps: (1) keep the temporal relationships of what students observed intact, (2) provide additional space to add data (SEP4) in table form in a way that helps students see that a new substance was produced from the old substances in the bath bomb, and (3) keep track of the inputs and outputs (CCC4) of the process to show that matter wasn't entering or exiting the system (CCC5). The use of these practices and crosscutting concepts helps students develop and use important pieces of the DCI related to PS1.B.

* Supporting Students in Developing and Using Energy and Matter

Use this moment as an opportunity to focus students on systems modeling as a way of tracing inputs and outputs of the bath bomb when it is placed in water to produce gas bubbles. The purpose of Lesson 2 was to show students that the mass did not change before and after the bath bomb was placed in water, providing evidence that matter did not leave the system. Tracing these inputs and outputs in our model helps support students in connecting these ideas of matter conservation later when they go to explain and model the phenomena at a particle level.

Additional Guidance

Some teachers might find it useful to have the initial table pre-drawn on the pieces of chart paper before class. Then the class can discuss how this table setup connects to the class's Initial Class Consensus Model and proceed to add the inputs and outputs from Lesson 1.

Add inputs and outputs to the model table. Say, *It looks like we knew we had two different things to start with—a solid and a liquid—and we represented them in the two circles on the left-hand side of our poster.* Fill in the first column now.

Say, *We had a lot of questions about the middle circle that represents the time right after we added the bath bomb to water. You also had some ideas about the gas bubbles that appeared and the liquid that remained* (add arrows and question marks to the middle column and gas and liquid to the last column).

	What we see unmixed (matter inputs)	Mixed together	What we see after (matter outputs)	
	solid + liquid	→ **? ? ?** →	Liquid + gas (bubbles)	

Say, *We have learned a lot about how a bath bomb interacts with water and about the things (point to the last column) that are produced when that happens. Let's think about our journey—what we learned about bath bombs and the gas bubbles that form from each of our investigations, lesson by lesson.*

Additional Guidance

The Teacher Guide for this segment of the lesson provides detailed prompt/response examples as you lead this consensus discussion. *Teacher Reference for Investigating Gas from Bath Bombs in a Bottle* summarizes what we figured out in each lesson and provides sample images of the model as it is developed. You may want to print this teacher reference to have in front of you as you lead the discussion.

Review and record key ideas from Lesson 2. Ask students to turn to Lesson 2 in their science notebooks. The question in that lesson we were trying to figure out was: *Where is the gas coming from?* Have students reflect on the investigations they did in that lesson where they observed that the mass did not change before and after the bath bomb was placed in water.* Have students look specifically at the argument they wrote at the end of Lesson 2. Use the prompts below to elicit student ideas. Display **slide C.**

Suggested prompts	Sample student responses	Follow-up questions
The Lesson 2 question was: Where is the gas coming from? What did you figure out?	*It had to be coming from something that was already there.*	*How do you know that? What data was used as evidence for this?*
So the mass did not change before and after the gas was produced. What would you say to a student who still thinks that the gas was created as something brand new because a gas does not have any mass—so it would not change the mass after?	*Gases do have mass!* *A gas is matter and matter has mass.*	*How do you know that? What evidence do you have to support your claim?*

As students recall key model ideas, point them out on the chart. Do the same for vocabulary on the Word Wall that they use in their responses.

Adding to our new model table. Add the new information to the model table using a **red** marker. Use a new color for the addition of each lesson's information to the table and make a key as you go.

	What we see unmixed (matter inputs)	Mixed together	What we see after (matter outputs)	
	Mass of solid + Mass of liquid	→ ? ? ? →	Mass of liquid + Mass of gas (bubbles)	**Key**
	Total mass before	=	Total mass after	**Lesson 2**

Review and record key ideas from Lesson 3. Display **slide D.** Have students turn to their Progress Trackers and find the entry from Lesson 3. That lesson question was: *What's in a bath bomb that is producing the gas?* Work with the students to recall the investigations they did for this lesson. In those investigations, students looked at the list of ingredients for different bath bombs and recorded property data for each ingredient. They worked in small groups to individually test two different ingredients in water. They learned about the solubility of these substances in water.

Say, *Look at your Progress Tracker and the ideas you recorded in the "What I figured out" column.* Lead a short discussion to elicit student ideas about what they learned. Use the example prompts to guide your discussion.

Suggested prompts	Sample student responses	Follow-up questions
What were some things you figured out in this lesson?	*We figured out that some of the ingredients dissolved and some didn't.*	*Can you describe what happened that helped you know that?*
What does it mean to dissolve?	*It means that the particles in the solid break apart into particles too small to see and mixes completely with the water.*	*Is there a place we can capture this on our new model table?*

Adding to our new model table. Add the new information to the model table using a **blue** marker. Use a new color for the addition of each lesson's information to the table.

	What we see unmixed (matter inputs)	Mixed together	What we see after (matter outputs)	
	Mass of solid + Mass of liquid	→ ? ? ? → Some solids dissolve in the water	Mass of liquid Some solids dissolve in the water + Mass of gas (bubbles)	**Key** **Lesson 2**
	Total mass before	=	Total mass after	**Lesson 3**

Reviewing and recording key ideas from Lesson 4. Display **slide E.** Have students turn back in their science notebooks to what they have from Lesson 4. The lesson question was: *Which combinations of the substances in a bath bomb produce a gas?* Work with the students to recall the investigations they did for Lesson 4. In that lesson we combined the bath bomb ingredients two at a time to find out which ingredients were the ones that produced gas bubbles.

Lead a short discussion to elicit student ideas about what they learned. Use the example prompts to guide your discussion.

Suggested prompt	Sample student response	Follow-up question
What were some things you figured out by combining two substances at a time?	*We figured out that only two substances combine to produce the gas bubbles.*	*What two substances were the key ones for making the gas?*

Suggested prompt	Sample student response	Follow-up question
Did you find out anything else in this lesson?	*All bath bombs that produce gas bubbles have both baking soda and citric acid. Even the ones with lemonade mix have citric acid because the lemonade mix is a mixture that contains citric acid.*	*We have a little more information to add to our table. What should we add?*

Adding to our new model table. Add the new information to the model table using a **purple** marker. Use a new color for the addition of each lesson's information to the table.

Say, *Since we figured out that all bath bombs have baking soda and citric acid in them and those are the substances that interact to make the gas bubbles, can we just include these in the solids that we start with? All of the other ingredients are just "extra"—it is the baking soda and citric acid that give us the gas bubbles.* Add this to the first column.

Then say, *Wait! We start with solids and a liquid, and get liquid and a gas! That is weird! This gas is very different from the stuff we started with. We know from lesson 2 that the gas had to come from the stuff we started with but we want to make note that it is definitely different stuff in some important ways! Let's add that to our table.* Add that the gas is a new substance.

	What we see unmixed (matter inputs)	Mixed together	What we see after (matter outputs)	
	Mass of solid(s) (baking soda and citric acid) + Mass of liquid	→ ? ? ? → Some solids dissolve in the water	Mass of liquid Some solids dissolve in the water + Mass of gas (bubbles) (new substance(s))	**Key** **Lesson 2** **Lesson 3**
	Total mass before	=	Total mass after	**Lesson 4**

Review and record key ideas from Lesson 5. Display **slide F.** Have students turn in their science notebooks to what they have from Lesson 5 and hand out their completed model-based explanations from the end of that lesson if you haven't already. That lesson question was: *What gas(es) could be coming from the bath bomb?* Work with the students to recall the investigations they did for Lesson 5. In that lesson, they were able to determine the relative density and flammability of the gas from the bath bomb. With these properties, they were able to narrow down the possible gases to argon, nitrogen, and carbon dioxide.

Lead a short discussion to elicit student ideas about what they learned in this lesson. Use the example prompts to guide your discussion.

Suggested prompts	Sample student responses	Follow-up questions
What were some things you figured out about the properties of the gas that could be produced from the bath bomb?	*We figured out that the gas from the bath bomb was denser than room air.* *We also figured out that the gas from the bath bomb was not flammable.*	*How did you figure that out? What evidence do you have that this is true?*
Density and flammability are properties that were useful to help us figure out what gas is coming from the bath bomb. What gases have the properties that match what we saw in our investigations?	*argon* *carbon dioxide* *nitrogen*	*Do we have evidence that the gas from the bath bomb is just one gas? Could it be a mixture of these gases?* *Let's add this information to our model table.*

Adding to our new model table. Add the new information to the model table using a **green** marker.

Say, *Let's add the gases that we think it might be to our model table. It seems we are in agreement that this gas was not there to begin with.* Add this information to the last column.

	What we see unmixed (matter inputs)	Mixed together	What we see after (matter outputs)	
	Mass of solid(s) (baking soda and citric acid) + Mass of liquid	→ ? ? ? → Some solids dissolve in the water	Mass of liquid Some solids dissolve in the water + Mass of gas (bubbles) new substance(s) **(argon, nitrogen, and/or carbon dioxide)**	**Key** **Lesson 2** **Lesson 3** **Lesson 4** **Lesson 5**
	Total mass before	=	Total mass after	

3. A New Consensus Model

17 MIN

Materials: science notebook, *Self-evaluation: Engaging In Classroom Discourse*, chart paper, different colored markers, initial consensus model from Lesson 1

Point out key ideas from the initial class consensus model poster. Display **slide G.** Place the Lesson 1 initial class consensus model where everyone can see it.

Say, *Let's take a look at our original ideas again. Our Initial Class Consensus Model from Lesson 1 included our ideas about particles. We do not have anything about particles in our new model table. Let's add space to include our ideas about what is happening at the particle level that we cannot see.*

Add the two additional columns on the left and right side of the model table and add headings to these two new columns. It should look like this:

Type of particles before mixing	What we see unmixed (matter inputs)	Mixed together	What we see after (matter outputs)	Type of particles after mixing
	Mass of solid(s) (baking soda and citric acid) + Mass of liquid	→ ? ? ? → Some solids dissolve in the water	Mass of liquid Some solids dissolve in the water + Mass of gas (bubbles) new substance(s) **[argon, nitrogen, and/or carbon dioxide]**	**Key** **Lesson 2** **Lesson 3** **Lesson 4** **Lesson 5**
	Total mass before	=	Total mass after	

Record ideas in our science notebook. Display **slide H.** Have students think individually for a few minutes about what revisions they want to add to the particle models from the Initial Class Consensus Model. Ask students to record their ideas in their notebooks.*

Display **slide I.** Say, *Turn and talk to a partner about the ideas you have to update the consensus model. What do we need to change and why?* Allow students a couple of minutes to share their ideas with a partner.

Consider revision ideas as a class. After students have had time to discuss with a partner, say, *It seems you have lots of ideas on how to revise this model. Let's look at it together. We will move clockwise around the poster starting with how we represented water. Share your ideas for revision so we can make sure that we have everyone's ideas to consider.*

Use the suggested prompts to bring out student ideas.

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Developing models at the particle level is often abstract for students causing some students to be disconnected from the science ideas. This often happens because students are attempting to model ideas at a scale that is not visible for them. Reflecting on what students observed and figured out through each of the proceeding lessons, then mapping out those ideas at the particle level helps support students with the practice of applying the phenomena across scales. Students will have the opportunity to apply their understanding of these ideas at the particle level (a different scale) to show them what they know and to also inform them what parts of the phenomena they still have questions about.

Suggested prompts	Sample student responses	Follow-up questions
How did we represent the different particles in these materials?	*We used circles.* *But we used some different colors.*	*What did using different colors mean for our model?*
It looks like for water we used circles that were blue. What did that represent?	*That all the particles for water are the same. And they are spaced close together and their position is random—like a liquid.*	*Who remembers what we call matter that is made of the same type of matter throughout?* *Do you think we need to change this representation? (This representation is fine. Redraw it in the first column of the model table at the bottom of the first column. See the example of a completed table below.)*
So, water is a substance and we have represented it with the same type of particle throughout. What about the bath bomb? Is the way we represented it OK or do we need to revise our model?	*It looks like we used a different color because we knew it was different from water.* *But we used all the same color circles—a bath bomb is a mixture which is a blend of two or more substances.*	*How could we modify what we have, so that we account for the evidence we agree is important to consider? (Encourage the class to use different colored circles for every substance they have in the model. For the solid bath bomb, they should use two different colored circles to represent baking soda and citric acid. Begin a key for your models.)*
We drew the circle in the middle to represent what was going on right when the bath bomb was put in the water. I see a lot of question marks—we had lots of questions about what was going on there! Do you think we should revise this part? Have we learned anything that will help here?	*We learned that some of the things in a bath bomb dissolve in the water.*	*What about baking soda and citric acid, do they dissolve? Are they soluble?*
What does it mean to dissolve?	*Well, our definition says that when a solid dissolves in a liquid, the solid breaks apart into particles too small to see and it mixes completely in the liquid.* *We couldn't tell that the solid was there because we couldn't see it anymore.*	*Do we need to revise this part of the model?* *How should we revise it? Remember we have a circle for the liquid (bottom right).* *Do we still have questions about this part? (The class should agree on a way to represent dissolving (e.g., words or showing the particles smaller than before)).*

Suggested prompts	Sample student responses	Follow-up questions
Ok, let's represent the liquid after we mixed the substances together. Do you think that the liquid might also be something new since we got the new gas?	*Yes!* *I'm not sure.*	*Do you have ideas for what the liquid could be?* *How should we represent the mixed liquid? (For this representation, the students might represent it with question marks because it is still unclear what dissolving the bath bomb looks like at the particle level. Students may also suggest separating the bath bomb colored circles in the water.* *Draw blue circles representing water and since they still have questions, and there isn't class consensus on this yet, keep the question marks as part of the model.)*
*We also made the model of the gas. We used circles again and they were ______** in color. Do we need to change anything based on what we have figured out?* ***fill in with the color your class chose to represent the gas particles.*	*We know that the gas is something that is new and wasn't there to start, but we are not sure if there is only one type of gas, or a mixture of gases. Maybe we should add different colored circles to represent the three gases this could be?*	*Is there more evidence or clarification needed before we can come to an agreement? What is that?* *So, it seems we are not all in agreement on how we should represent the gas.*
Some think one gas is produced, and others think it might be a mixture of all three. Do we have evidence that it is one way or the other?	*Yes, we have evidence that the gas is more dense than air and non flammable.* *But argon, carbon dioxide, and nitrogen all have those properties—we don't know which one the gas is or if the gas is all of them mixed together.*	*It sounds like we don't have any evidence yet to help us come to consensus on one representation. How can we model this gas so that all of these ideas are represented until we learn more? (Add two circles for the gas bubbles—one that represents a single gas and one that represents a mixture of gases. Be sure to label these two circles and add them to the key.)*
Is there anything else we should revise about our model?	*Consider all responses.*	

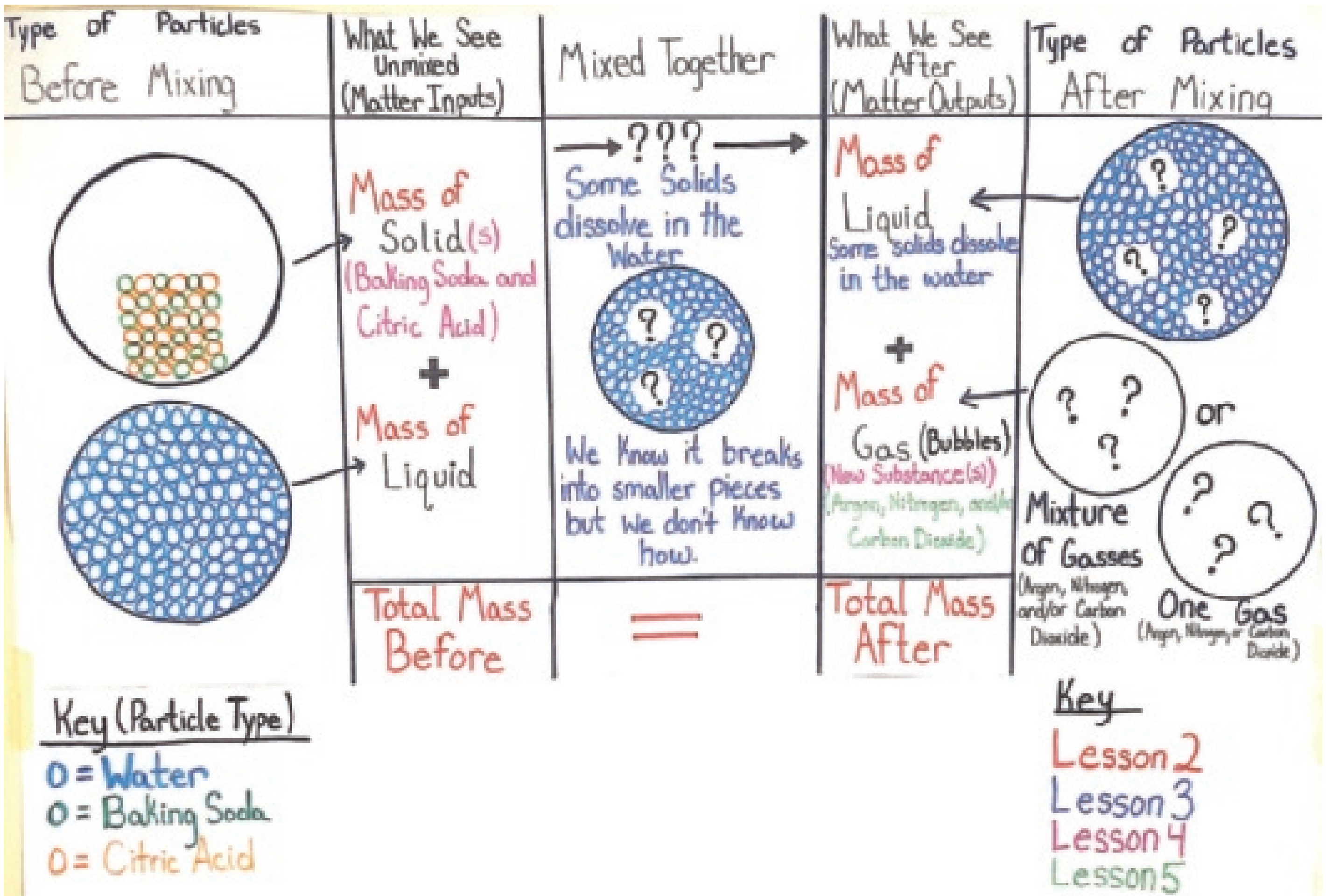
Additional Guidance

When they discussed how to represent the resulting gas in the right column, the students established that the gas is not a change of state from the original three substances (baking soda, citric acid, and water). If some students are still holding on to the idea that the gas is a change of state, resolve this by asking them to double-check the table of properties from the ingredients. They will see that the boiling points of these substances are much higher than room temperature.

Check in with the class. Ask the class, *Who feels like we have not heard or represented their ideas in our revisions?*

Handout *Self-evaluation: Engaging In Classroom Discourse* to each student and ask them to reflect on their engagement during the discussion. Collect these before they leave class.

Example of a completed table model:



If time permits, now is a good time to have students update their table of contents and page numbering in their science notebooks. Make sure to leave 7 minutes for the next step.

Materials: science notebook, sticky note

Ask students to return to their seats. Display **slide J.** Have students turn to a clean page in their notebooks and title the page, "Brainstorming Particle Level Interactions."

Ask the class, *When we combine particles of different substances together, they sometimes end up forming particles of a new substance. What is happening at a particle level that could help explain how this is possible?* Give students three minutes to record ideas on their own.

Sharing with a partner. Give students a couple of minutes to then discuss any ideas they have with a partner. Ask them to record any new ideas in words and/or sketches on the page of their notebooks that they prepared.* Have students mark this page with a sticky note so you can look at it before the next class begins.*

Assessment Opportunity

Building towards: 7.A.2 Develop and revise a model to predict and describe the unseen interactions between particles in a system to show that matter is conserved in a process where the type of particles that make up the starting substances (system inputs) somehow change through their interactions to make different type(s) of particle(s) in the ending substances (system outputs).

What to look/listen for:

- Particles that make up the initial substances could have been joined together to make new particle clusters that are new substances, but these are still made of the same type of smaller particles we started with.
- Particles in the initial substance can be broken apart into smaller particles that are new substances, but the particles we start with are made of the same type of particles we end up with.

What to do: For students who struggle with brainstorming ideas for what could be happening with the particles when new substances are formed, tell them that it is OK if they are not sure. Encourage them to think about anything that could be possibly going on at a particle level, because this is not something we can directly observe, so we have to push ourselves to use our imagination and creativity to come up with possible model ideas we have never considered before.

ADDITIONAL LESSON 7 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.7.1.C Pose questions that elicit elaboration and respond to others' questions and comments with relevant observations and ideas that bring the discussion back on topic as needed.

CCSS.ELA-LITERACY.SL.7.1.B Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.

Both of these ELA goals are the focus of the discussion in the Scientists Circle. The focus connecting questions, sources of evidence, what we observed, and key science ideas of other students create an agreed upon set of consensus ideas to add to the Progress Tracker. These facets of the Scientists Circle rely on both goals above.

*** Attending to Equity**

Universal Design for Learning: Allowing students to express their ideas using multiple modalities supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas.

*** Supporting Students in Engaging in Developing and Using Models**

Individual time gives students an opportunity to synthesize evidence and formulate their ideas. This is important so students are prepared to defend their ideas and evaluate others' ideas when they share with a partner and share out with the whole class in the next lesson. As students work, circulate among them prompting them to defend their model ideas (or part of their model) using evidence collected during investigations in Lessons 1 through 5. This can help students think through where their model ideas may have a hole prior to the collaborative group sharing.

LESSON 8

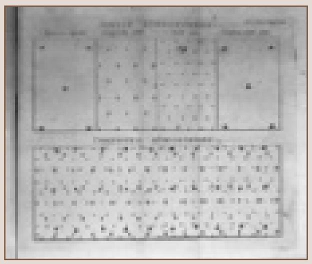
How can particles of a new substance be formed out of the particles of an old substance?

Previous Lesson *As a class we summarized key model ideas we had figured out through all of the investigations. We developed a new way to represent everything we figured out using an input/output table to represent the particles in the system. We identified an unanswered question about where the particles that make up the substance(s) of the gas come from.*

This Lesson

Problematizing

1 DAY



We develop alternate models for how new particles might be made from old particles using manipulatives (printed colored circles). We formulate questions we have about how we could figure out what happens when new substances are made from old substances. We read about what Dalton and other scientists did to see if adding energy to water could form new particles. We outline a plan for a line of similar investigations to pursue.

Next Lesson *We will carry out an investigation on the flammability of the gas produced by heating water. We will collect data on the mass and volume of this liquid that formed from that gas. We will argue that the resulting property data indicates that the gas we collected is made of the same particles that were in the water we started with.*

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

8.A Ask questions related to the development of alternate models for what is happening to the matter at a particle level (patterns) when old substances interact to produce new substances by combining or rearranging parts/particles (systems and system models), and determine ways we might go about investigating these ideas.

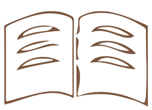
What Students Will Figure Out

- When new substances form from old substances, the particles of the old substances might break apart and/or stick together to form new combinations of particles.
- We have a new line of investigations to pursue to see if new substances are formed when energy is added to a single substance (water).

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	23 min	**SHARING AND REPRESENTING INITIAL IDEAS** Students work with the class to share ideas from the last class period and work with manipulatives to test their ideas for making new substances from old substances.	A–C	scissors, tape, glue sticks, poster paper titled What is happening to particles when new substances are made?, 2–3 copies of *Circles as Particles* with the individual colored circles cut out ahead of time
2	22 min	**READING: A LOOK BACK IN HISTORY** Students read about James Dalton and other scientists' historical investigations and questions as they try to figure out how new particles can come from old ones.	D	*Reading: Dalton's Investigations*, poster paper titled Adding energy to water investigations, a second blank poster paper *End of day 1*
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 8, students are ready to read Student Reader Collection 3 and then respond to the writing exercise.		Student Reader Collection 3: *Matter from one Place to Another*

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Reading: Dalton's Investigations*		• scissors • tape • glue sticks • poster paper titled What is happening to particles when new substances are made? • 2–3 copies of *Circles as Particles* with the individual colored circles cut out ahead of time • poster paper titled Adding energy to water investigations • a second blank poster paper

Materials preparation (15 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Online Resources

Prepare 2–3 copies of *Circles as Particles*. Cut out the different colored circles ahead of time. Have these ready for the discussion in the first part of this lesson when students are arguing for their ideas of what is happening to particles when new particles are made.

In Lesson 11, you will want to have some of the blue circles cut out and ready for a discussion. You may wish to make a few extra copies and cut them all at once and then just put some of the blue ones aside for Lesson 11. You will need between 5–10 extra blue circles per class for Lesson 11.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 5, students were left wondering how new particles are made. In this lesson, students model their ideas about how these new particles can come from old particles. Brainstorming different possible ways that particles may break apart and rearrange to make new particles will support reinforcement of the idea of conservation of mass that has been foregrounded in the input/output table developed in Lesson 7. This idea will be revisited several times. Students will read that Dalton and other scientists tried to see if they could add energy (thermal and electrical) to water and make new particles. In the next two lessons, students will do both of these investigations with water and figure out that splitting particles with either thermal or electrical energy produces a gas.

Where We Are NOT Going

In this lesson, students do not figure out what kind of gas results from boiling and from electrolysis—they will figure that out in the next lesson. Though there are two different types of energy being added to water (thermal and electrical) this is not the focus of these few lessons. We will refer to both instances as adding energy to water. In the next unit, *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit)*, students will investigate the relationship between adding energy and chemical reactions.

LEARNING PLAN FOR LESSON 8

1. Sharing and Representing Initial Ideas

23 MIN

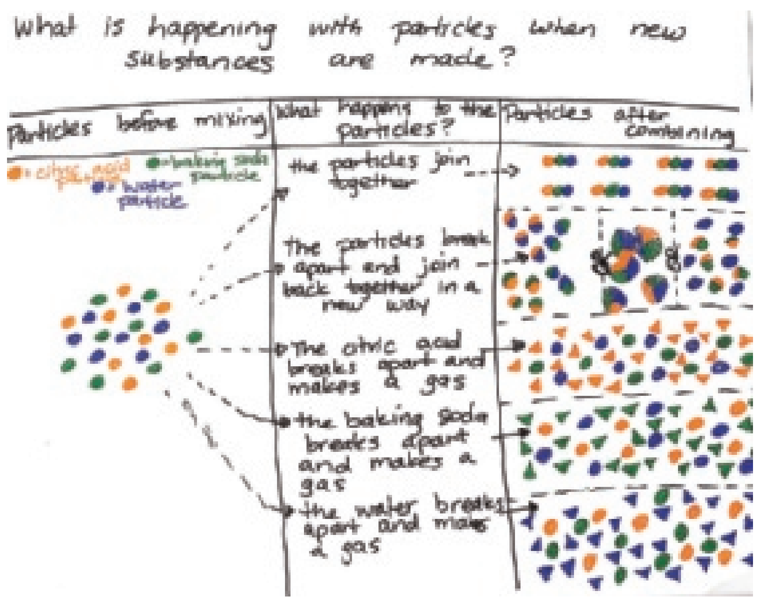
Materials: science notebook, scissors, tape, glue sticks, poster paper titled What is happening to particles when new substances are made?, 2–3 copies of *Circles as Particles* with the individual colored circles cut out ahead of time.

Convene in a Scientists Circle. Show **slide A.** Have students turn their notebooks to the page they marked with a sticky note from last class. This is where they recorded ideas from the end of Lesson 7 about how they think particles can become different particles. Have students share their ideas with an elbow partner.

Say, *You had some ideas about how to make different substances (or the gas from the bath bomb) out of the beginning substances (citric acid and baking soda). Let's take a few minutes and have partners share these ideas. As we share ideas, let's decide how we might use some manipulatives (shapes) to represent the different ideas.*

Display **slide B.** For each idea that is shared, ask students to share how they would use the paper colored shapes to represent their ideas. Then ask them to add their idea to the class poster using tape. Have the shapes from *Circles as Particles* available for students to use as they share their ideas for how new substances are made from old substances. It will be helpful to have multiple circles for each substance so more than one idea can be represented and added to a poster.

Post each of these on a poster titled *What is happening with particles when new substances are made?* Capture each unique predictive representation with the colored circles in a new row. Include a summary in words of what students think happened to the particles in that case. An example is included:



Suggested prompts	Sample student responses
We know that the substances that make the gas in a bath bomb are citric acid and baking soda when combined in water. We also know that the gas that is produced is argon, carbon dioxide, and/or nitrogen. We are trying to figure out how citric acid, baking soda, and water become these gases. What was one idea you and your elbow partner shared?	*Maybe the particles join together to make the gas...like the baking soda, citric acid, and water become one new particle, which is a gas.*
Okay, so one idea I hear is that the particles of these substances join together to make a new particle that is the bath bomb gas. Do you think the opposite can also happen? Can these larger particles be broken apart into smaller pieces?	*Maybe either the particles of the citric acid or baking soda or water break apart and then join back together in a different way that is a gas.*
Do any other partners have a different idea for how the particles of the gas could be made from these substances? (Allow groups to share until 2–3 different ideas surface.)	*The particles of the citric acid might break apart and make a gas.* *The particles of the baking soda might break apart and make a gas.* *The particles of the water might break apart and make a gas.* *The particles of both solids break apart and make a gas.*
Okay, so if the particles of citric acid and baking soda break apart and this makes a particle of the bath bomb gas, do you think the opposite can also happen? Can these smaller pieces be connected back together to make larger particles?	*Possibly… maybe some parts of the citric acid particle and some parts of the baking soda particle join together to make the gas after they have broken apart.* *Maybe the water particles break apart and part(s) of it recombines with the citric acid particle and the other part combines with the baking soda particle.*
We've been working with this idea of being able to break apart particles of matter, which raises the question: Does anyone think there is a piece of matter that is so small it cannot be broken apart any further?	*Accept all answers.*

Develop a new key model idea to summarize all of the ideas represented on the poster. Say, *Looking back at our poster of ideas for what happens to the particles of the original substances when new substances are made, let's see if we can summarize what we all are saying happens to the particles of the original substances. The left side of our poster shows that we all know we are starting with certain types of particles that make up original substances we started with (baking soda, citric acid, and water) and the right side of our poster shows all our ideas of what the resulting particles look like after they are combined and the gas is produced. Though we have many different representations for what could be happening to result in these different particles in the end, we all think something happens to the original substances. Let's summarize that "something" in a couple of words and add it to our* Key Model Ideas *chart.*

Write this starting sentence stem on the board:

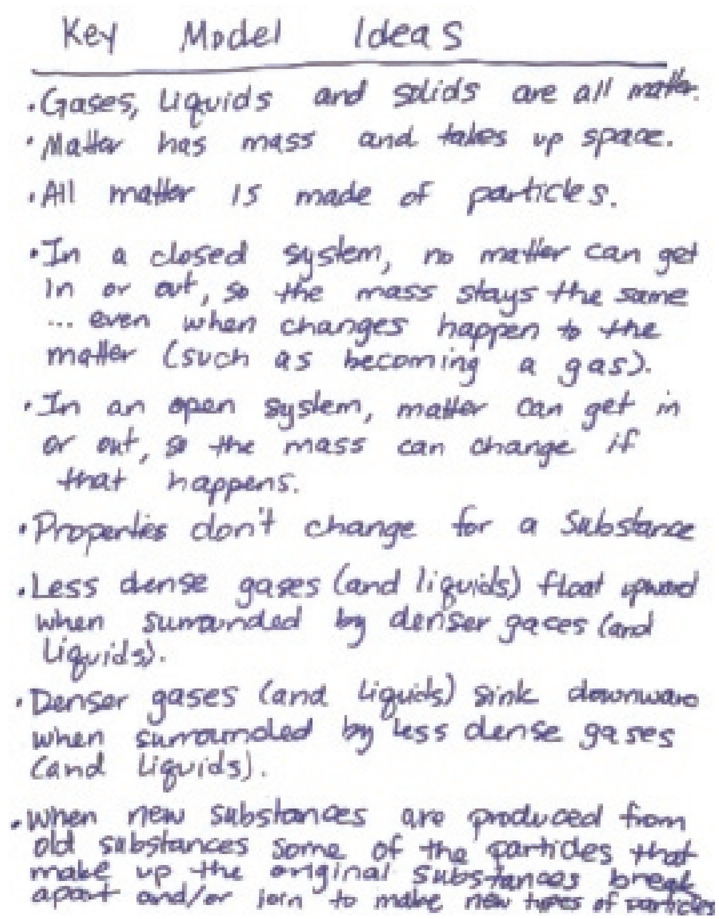
- When new substances are produced from old substances some of the particles that make up the original substances...

Ask students for suggestions on how to phrase the remaining portion of this idea to represent what we are showing happening in every case on the poster. Look for students to say:

- they break apart and/or
- they join together.
- This results in them making new types of particles.

Make sure to ask other students to restate these ideas a few times so you can establish that the whole class agrees with this summary. Record this on the *Key Model Ideas* chart. An example is to the right.

- When new substances are produced from old substances some of the particles that make up the original substances break apart and/or join together to make new types of particles.



Discuss student ideas and link to upcoming reading. Once all the ideas are represented on the poster, take a moment to reflect on what has been developed. Show **slide C.**

Say, *Now that you've shared your own proposed ideas and heard other people's proposed ideas for what could be happening at the particle level to cause a new substance to form, what questions do you now have about all these possibilities? Take a moment to record the questions you have about these ideas. But I want us to use our individual Progress Trackers to record the questions you each now have, so that you can return to that page in the Progress Tracker to make a record of what you've figured out after we do some additional investigations.*

Continue to show **slide C.** Give students three minutes to record the questions they now have in their Progress Trackers.

Assessment Opportunity

Building towards: 8.A Ask questions related to the development of alternate models for what is happening to the matter at a particle level (patterns) when old substances interact to produce new substances by combining or rearranging parts/particles (systems and system models), and determine ways we might go about investigating these ideas.

What to look for: Students

- preparing to engage in the reading by recording the individual questions they have before starting it, in their individual Progress Trackers,
- annotating the reading as they read or after a second pass, and
- recording what they feel they have figured out from the reading in their individual Progress Trackers.

What to do: Though we expect that given an opportunity to create individual questions many of these questions students generate will be in the space of "can particles of a new substance be formed out of the particles of an old substance in the ways we've come up with?", you might find some students develop a different line of questions. That is OK. As a reminder, individual Progress Trackers are not an assessment to be graded. The purpose instead is as a space for students to organize their thoughts. Here we want students to have that space before they go into the reading so that the purpose of it is student-question driven.

2. Reading: A Look Back in History

22 MIN

Materials: *Reading: Dalton's Investigations*, science notebook, poster paper titled Adding energy to water investigations, a second blank poster paper

Set up for the reading. Say, *To help us make progress on your questions I have a short reading that summarizes some related phenomena scientists observed in the past, where a gas formed and they had similar questions about what was happening at the particle level in those cases. How might comparing our ideas with the questions and ideas for investigations they came up with when they were thinking about the same sort of stuff help us make progress on the questions you wrote?*

Possible student responses include:

- *If they have investigation ideas similar to those we have, we might want to try them.*
- *Or maybe we should see what they figured out from the investigations they tried too.*
- *If they have new ideas for investigations, that might help us think of whether we could do something similar in our classroom.*
- *Maybe they came up with some evidence that addresses some of our questions.*
- *Maybe they came up with new questions we haven't considered, which we should.*

Say, *OK, so we have a purpose for our reading.*

Show **slide D.** Review the directions and distribute *Reading: Dalton's Investigations* to each student. Ask students to have a pen or pencil to use as they read.

Give instructions for active reading. Tell students that as they read, they should keep track of ideas or questions they have by writing them on the handout. They can write them in the margins or anywhere else there is room. Tell them to summarize what they figured out in their Progress Trackers when they finish, including new ideas/questions that the reading led them to consider, even if they weren't specifically mentioned in the text.*

Allow time for reading and recording responses. Give students 10 minutes to read and record their responses and notes. Once they are done, lead a short discussion of the reading to summarize. Use the example dialog to guide the discussion.*

*** Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

One of the middle school Nature of Science understandings is that science knowledge is cumulative and many people, over many generations and from many different backgrounds, have contributed to science knowledge. It is helpful to us as scientists to critically read about what others have already figured out so we can use that scientific information to refine our own questions and ideas for investigations.

Suggested prompts	Sample student responses	Follow-up questions
Were there any similarities between what Dalton figured out or what he was wondering and what we have figured out and are wondering?	*Yes! He also was investigating what air was made of and trying to figure out things about gases. He found that there are different types of gases that make up the air.* *Yeah… and that these different types of gases have different properties from each other.* *He figured out that air is made up of different types of gases. He was able to identify 4 different gases by comparing their properties. We also know that air is made of the same four gases he figured out, and our data table shows that we know these days that there are more than four gases that make up the air.*	*Was this similar to what we have figured out about air?* *What are the four gases that Dalton figured out? Are any of these four what the bath bomb gas could be?*
What were some of the investigations that Dalton and his peers tried?	*Dalton tried heating and cooling them to see what would happen. Some of his peers also tried putting electricity through them, which seems kind of dangerous.*	*How could using these ideas for investigations help us figure out more about what is happening with the particles in any system, like in the bath bomb?*

*** Attending to Equity**

Supporting Universal Design for Learning: To support students in engaging with and accessing the text you could include an audio recording so students can listen as they read the text.

Say, *One substance that Dalton and other scientists tried this on was water. And both heating it and putting electricity through it caused bubbles to form. Have you seen either of these phenomena before?* Accept all responses.

Show **slide E**. Give students two minutes to discuss the related questions with a partner. Then continue discussing these questions as a whole class.

Suggested prompts	Sample student responses
What substances do you think are in the gas bubbles? Is it the same substance in each case?	*Accept all responses.*
If we could capture the gas, what are some tests we could do to help us answer these questions?	*We can test the properties.* *If each thing we capture has different properties, then they are different substances.*

Say, *Though heating water and running electricity can be dangerous, we've argued that there is something to be gained by doing such investigations. Therefore, if we want to pursue these we will need to figure out a way to do both of these kinds of investigations safely. So let's make a plan to do that, using super safe guidelines and precautions. One of these will be to use really small amounts of electricity from a battery. These will be something we will do together, after I pull together the safety equipment we need for it, but just like our earlier flammability tests, this is not something you should try to do at home.*

Take out a sheet of poster paper, title it "Adding Energy to Water Investigations" and outline the plan the class has articulated. Hang a copy of this plan near your *Ideas for Future Investigations* poster:

- We want to heat water and produce bubbles.
- We want to run electricity through water and produce bubbles.
- We want to capture the gases from both and test their properties.
- We want to do this in a super safe manner together in class only, because working with electricity and water is dangerous and so is really hot water.
- We think these investigations can help us figure out more about what is happening with the particles that make up substances.

Safety Precautions

Over the next couple of lessons students will be engaging in these investigations. There are safety considerations and protocols that will need to be followed for each investigation. It can't hurt to remind students often that they will have the opportunity to do both of these investigations in the science classroom with safety precautions in place and they should not go home and try either of them on their own.

SCIENCE LITERACY: READING COLLECTION 3

Matter from One Place to Another

1 **Science Fair Project: Modeling a Convection Current**

2 **Matter on the Move**

3 **The Smokeless O_2 Stove**

4 **Everyday Reactions**

Literacy Objectives

- ✓ Identify differences in scale related to matter on the move.
- ✓ Determine the veracity of evidence supporting a claim.
- ✓ Distinguish between credible and noncredible sources.
- ✓ Write a script to guide video production.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 5–8.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Develop a script for a video in response to the reading.

Instructional Resources

Student Reader

Collection 3

Science Literacy Student Reader, Collection 3
"Matter from One Place to Another"

Exercise Page

EP 3

Science Literacy Exercise Page
EP 3

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 5: What gas(es) could be coming from the bath bomb?
- Lesson 6: How can we explain another phenomenon where gas bubbles appear from combining different substances together?
- Lesson 7: How can we revise our model to represent the differences in the matter that goes into and comes out of the bath bomb system?
- Lesson 8: How can particles of a new substance be formed out of the particles of an old substance?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS1.B: Chemical Reactions Some chemical reactions release energy, others store energy.

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Systems and System Models

CCSS
English Language Arts

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

combustion **density** **flammability**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

convection current

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

Exercise Page

EP 3

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Chemical Reactions and Matter unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read a mock laboratory report as it might be written by some tenth grade students who modeled convection currents in an Earth science class.*
    - *Next, you'll read a simulated online science article explaining how matter moves over long and short time spans in some very large Earth systems.*
    - *Then, you'll read an imitation advertorial—it reads like a magazine article or editorial but is really an advertisement—for a no-smoke outdoor stove.*
    - *Finally, you'll read an infographic describing examples of chemical reactions used by humans and found in nature.*

- Distribute Exercise Page 3. Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate a script for a short educational video targeted at fifth graders.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
In the science fair model, what was the function of the sock filled with hot rice?	*It was a source of heat that moved from the sock to the water in the tank.* *It helped set in motion the convection current in the water.*
What did the graph in the reading "Matter on the Move" reveal?	*that the amount of carbon dioxide in Earth's atmosphere has been increasing since 1960*
What can an O_2 stove do that most outdoor fireplaces cannot?	*It burns wood without producing smoke.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
Is the pattern described by the water cycle a large-scale or small-scale pattern? Explain.	*It's a large-scale pattern because the water cycle involves the ocean, the land, and the atmosphere all over Earth.*
What parts of the O_2 stove system are flammable?	*the wood*
What is combustion?	*a chemical reaction involving burning and high heat*
What do the equations in the reading "Everyday Reactions" show?	*They show how particles of different kinds of matter move around and get rearranged to form particles of other kinds of matter.*

- Refer students to the Exercise Page 3. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to develop a script for a one-minute educational video about matter on the move that will grab the attention of fifth graders.*
    - *That means you should think about how to make your video interesting enough that a fifth grader would voluntarily watch to the end. Try using elements of surprise or humor to keep it interesting.*
    - *Don't worry about including all the science terms in the readings.*
    - *Proofread your script for clarity, spelling, and grammar.*
    - *The important criteria for your work are that the script accurately communicates the main idea of this collection and does so in an interesting way suitable for video.*
- Explain that a well-organized script must be clear enough for another person to produce the video.
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 3

4. Facilitate discussion.

Facilitate class discussion about the reading collection and writing exercise.

Pages 24–27 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Science Fair Project: Modeling a Convection Current"?	*It is a science fair report describing the materials and a procedure and discussing the results.*
What exactly is a convection current?	*It is the movement of energy and matter due to differences in density of Earth materials such as water, air, and rock.*
Did the setup the students used best model convection currents in the hydrosphere, atmosphere, or geosphere?	*maybe the hydrosphere, because the current moved through water, as it would in the ocean*
How does the students' model show a pattern?	*because the convection current cycled, meaning it repeated itself in the same way constantly*
What role does the property of matter called density play in convection currents?	*The water in the tank sank when it was denser, and it rose when it was less dense.* *More dense water also moved sideways to fill the space as less dense water rose.*
What is the general purpose of the second selection, "Matter on the Move"?	*It is a science article describing three large-scale examples of matter in motion.*
What is the main idea and what are the details in this reading?	*The main idea is that matter on Earth is on the move.* *The details are three examples of moving matter—the water cycle, the ground rising and falling, and the movement of carbon from the ground into the air and ocean.*
What do you know about carbon dioxide from our investigations?	*We know that carbon dioxide is a gas at room temperatures.* *We thought it might be the substance in the bubbles from our bath bombs.* *We know that particles of carbon dioxide can be the product of chemical reactions.*

Student Reader

Collection 3

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Explain to students the cause-and-effect relationship between increases in carbon dioxide in the atmosphere and climate change. Point out that scientists have collected evidence that increases in carbon dioxide over millions of years are correlated with increases in atmospheric temperature. Carbon dioxide causes this change because it absorbs heat more easily than other gases in the atmosphere, such as oxygen and nitrogen.

Proceed with discussion of the last two selections of the collection, an advertorial for a smokeless fireplace and a description of some common chemical reactions.

Pages 28–33 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article, "The Smokeless O_2 Stove"?	*It tries to persuade the reader to buy an outdoor stove because it produces less smoke and doesn't make climate change worse.*
How does the chemical reaction inside the working stove involve energy?	*The reaction releases energy as the wood burns.* *Energy is released as light and heat.*
Look at the "Spot the BS" box. Could one design of wood-burning stoves or fireplaces have a smaller carbon footprint than another design?	*maybe, but only if you burn less wood when you use this fireplace* *The O_2 stove may leave less ash and produce less smoke, but carbon dioxide is still produced.* *Any combustion involving wood and oxygen produces carbon dioxide.*
Look at the "Consider the Source" box. An advertorial is one technique for selling products. What are some other online selling techniques you have encountered?	*photos of celebrities wearing certain brands of clothing* *personal blogs that have links to stores* *paid ad links that appear at the top of search results* *apps and games that display products while you play* *text messages with links to products or services* *ads that appear before a video you want to watch*
What is the general purpose of the fourth article, "Everyday Reactions"?	*It describes examples of chemical reactions that take place all the time and all around us.*
How does the fourth selection help you build knowledge on top of what you learned in the third selection?	*The third article reveals that when wood burns there is a chemical reaction of a type called combustion, in which oxygen combines with a hydrocarbon. The fourth article reveals that the products of the reaction are usually water and carbon dioxide.*
Using the language from our investigation discussions, explain what the chemical equation for photosynthesis describes.	*The particles that make up water and carbon dioxide rearrange themselves during a series of chemical reactions to produce new substances, specifically sugar and oxygen gas.*

SUPPORT—Explain to students that increases in carbon dioxide in the ocean due to human activity also have environmental impacts. The ocean absorbs carbon dioxide from the atmosphere. When carbon dioxide mixes with water, chemical reactions produce acidic substances. A more acidic ocean makes it harder for some ocean species to survive.

CHALLENGE—Have interested students draw labeled diagrams summarizing one of the everyday reactions described that reflects their model-making work in Lesson 8. Students should focus on showing the reactant particles and the product particles.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 3, students should develop a script for a one-minute science video suitable for fifth grade students. Look for evidence that students understood the structure and parts of a script and were able to synthesize science concepts from two or more readings in the collection. While the science should be accurate, the scripts should also show understanding of the online video medium and what might hold the attention of students two years younger than themselves. A sample student response is shown below.

Audio—dialogue and sound effects	Visuals—live video action or animation, photos, graphics
Stacy: Hey, science fans! My name is Stacy, and I'm here to show you how matter is on the move in some weird ways. Get ready to think big—really big!	Teenage female wearing a lab coat and standing in a science lab, speaking directly to the camera. Behind her is a poster on the wall with the word *Scale* in large letters.
[Sound effects: birds chirping.] Stacy: Did you ever think a huge mountain range could move upward? It can happen! If there is no rain or snow for a long while, the mountains dry out. Less water, less weight. Then all that dry rock rises upward. Pretty weird!	Video panning a huge mountain range. Stacy standing in front of the video. Animation showing the mountain range at a low position and then popping up a bit. Show an arrow pointing up.
[Sound effects: wind rustling leaves of a tree.] Stacy: Now think small. The matter inside plant cells is always moving, but the cells are too small to see and the matter inside is even smaller. How do we know? Plants give off oxygen gas into the air when the sun shines. That matter comes from rearranging particles (atoms and molecules) during a process inside cells called photosynthesis. Pretty cool, huh? Come back next week for more about matter!	Stacy standing in front of an animation. Animation shows a tree, then zooms in to a cell in a leaf. Then animation shows the atoms involved in the photosynthesis reaction moving around to form new molecules as below: $6H_2O + 6CO_2 \text{ (+ energy)} \Rightarrow C_6H_{12}O_6 + 6O_2$

Does heating liquid water produce a new substance in the gas bubbles that appear?

Previous Lesson

We developed alternate models for making new particles from old particles using manipulatives. We formulated questions about what happens when new substances are made from old. We read about what Dalton and other scientists did to test this idea. We outlined a plan for a line of similar investigations to pursue.

This Lesson

Investigation

2 days

We carry out an investigation to test the flammability of the gas produced by heating water. We collect data on the mass and volume of different samples of the water we started with and two other clear liquids and compare the mass and volume of each to the substance we collect from the gas produced by heating this water. We analyze graphs of the data and determine that the ratio of mass to volume for a substance is constant and that this is a property (density). We argue that the property data indicates that the gas is made of the same particles that were in the water we started with.

Next Lesson

We will carry out an investigation to test the flammability of gases produced by providing energy to water with electricity. We will construct an explanation for whether the gas(es) produced from water using energy from a battery were made of the same particles as those produced from heating the water.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

9.A Use mathematical and computational thinking by graphing mass vs. volume data for different substances and finding the ratio of mass to volume (a unit rate) [scale, proportion, quantity] for the samples measured to determine the density of different clear liquids.

9.B Argue from evidence and critique two arguments on the same topic; strengthen these arguments by using additional empirical evidence (patterns) and scientific reasoning to support an explanation for whether the substances collected from the gas produced by the heated water is made of different types of particles or the same type of particles (patterns) as those in the water that we started with.

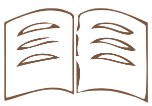
What Students Will Figure Out

- Density is determined as a ratio of mass to volume (a unit rate). It is constant (a property) for any sample of a substance, regardless of size.
- The gas produced by the heated water is made of the same type of particles as those in the water that we started with.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Review some of the tests we wanted to do on the gases we can capture from the bubbles forming in the heated water and what question(s) these tests would help us answer.	A	
2	20 min	**CARRYING OUT PROPERTY TESTS ON THE GAS FROM THE HEATED WATER** Orient to the heated water collection setup, conduct a flammability test, and make observations of the liquid that appears at the exit of the system.	B	Heated Water Lab
3	20 min	**PROBLEMATIZING, PLANNING, AND CARRYING OUT A NEW INVESTIGATION** Introduce the problem of identifying the clear liquid, when there are lots of clear liquid substances. Plan which data are needed to determine the density of liquids and carry out the investigation.	C–G	white board markers, projector, computer, Mass and volume data collection lab
				End of day 1
4	17 min	**ANALYZING AND INTERPRETING DATA** Plot data collected from the previous investigation and analyze and interpret patterns in the data plotted using graphs and tables.	H–L	calculator, 12 small sticky notes per group of 4 students, 4 ceramic magnets, 3 graphs and tables on poster paper for recording mass vs. volume data collected
5	8 min	**COLLECTING DATA ON THE DENSITY OF THE CLEAR LIQUID**	M–N	index card or scrap paper, 3 graphs and tables on poster paper for recording mass vs. volume data collected, clear liquid collected from heated water, 25 mL graduated cylinder, digital scale, 2 small sticky notes
6	17 min	**ARGUING FROM EVIDENCE** Evaluate arguments, identify elements (evidence and key science ideas) to include to strengthen each argument, and write a revised argument.	O–Q	*Evaluating and improving alternate arguments*, Arguing from Evidence poster from Lesson 2
7	3 min	**NAVIGATION** Make predictions about the gas we could collect from a test where we use a battery to run electricity through water.	R	
				End of day 2

Lesson 9 • Materials List

	per student	per group	per class
Heated Water Lab materials	• safety goggles		• hot plate • two 250 mL Erlenmeyer flasks • water • #6 cork with hole in it connected to 2 eyedroppers connected to 1–2 ft vinyl tubing • wooden matches • digital thermometer • #6 cork with no hole
Mass and volume data collection lab materials		• 25 mL graduated cylinder • digital scale (shared between groups of 4)	• soapy water bin • rinse water bin • 1 L container of rubbing alcohol • container of glycerine • container of water
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • calculator • index card or scrap paper • *Evaluating and improving alternate arguments*	• 12 small sticky notes per group of 4 students • 4 ceramic magnets	• white board markers • projector • computer • 3 graphs and tables on poster paper for recording mass vs. volume data collected • clear liquid collected from heated water • 25 mL graduated cylinder • digital scale • 2 small sticky notes • Arguing from Evidence poster from Lesson 2

Materials preparation (15 minutes)

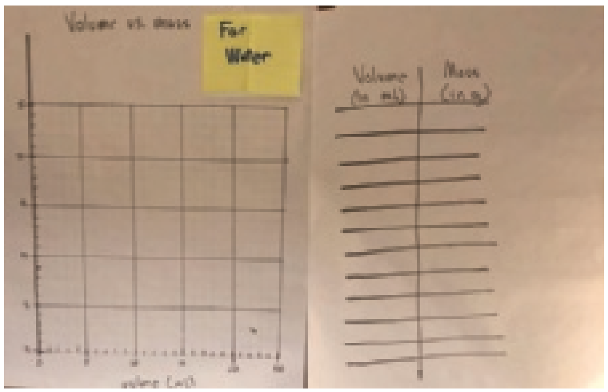
Online Resources

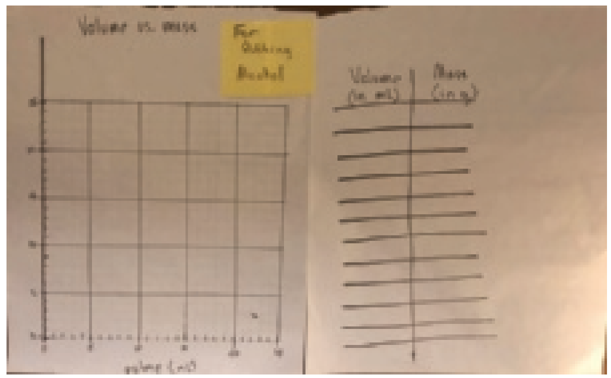
Review teacher guide, slides, and teacher references or keys (if applicable).

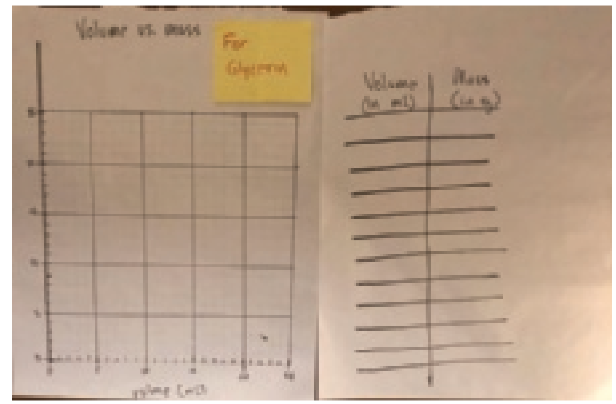
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Day 2: Prepare 3 poster-sized graphs and 3 data tables that will be used to post mass and volume data. The graphs can be created by placing a tick mark in increments of every 2 cm (or every 1.5 cm) on the *x*-axis and *y*-axis for every 1 mL and every 1 gram.

Partition the room into 3 sections and post a graph and data table for water in one section, a graph and data table for rubbing alcohol in another section (about 8 feet away), and a graph and data table for glycerine in another section (about 8 feet away from the rubbing alcohol section), so that three lines of students can easily access each of these posters. An example image of one of these is shown here:







Day 1: Heated Water Lab

- **Group size:** Whole class
- **Setup:**
  - Connect a 1–2 ft piece of vinyl tubing and two eye droppers by sticking the pointed end of one eye dropper into one end of the tubing and the non-pointed end of the second eyedropper into the other end of the tubing. Each eyedropper should be pushed into the tubing at least ¼ inch. Because the glass can break if you push it too hard, prepare the vinyl tubing prior to doing this by submerging each end in very hot water (130–160 °F), which will make it more pliable to work with. It is recommended to do this while wearing protective gloves, in the event that the eyedropper breaks. Final assembly shown to the right.
  - Materials needed: hot plate, two 250 mL Erlenmeyer flasks, water, #6 cork with hole in it connected to 2 eyedroppers connected to 1–2 ft vinyl tubing, wooden matches, digital thermometer, #6 cork with no hole
  - Fill one flask with 100–150 mL of water before students arrive and place it on the hot plate. You will want to begin heating this at the beginning of class.
  - The second flask will be used to collect water vapor from the tubing.
  - Test the procedure for this lab as outlined in the learning plan.

- **Safety:**
  - Wear safety goggles and use hot mitts when working with heated water and glassware.
  - Keep lit matches at least 1 inch away from the end of the tubing where hot gas is escaping.
  - The hot gas escaping from the tubing can scald and burn skin. Be careful to not hold your hand directly in front of it.
- **Storage:**
  - Save the liquid generated from all classes that conduct this lab in a clear beaker. Collect at least 20 mL of the liquid. You will measure its mass and volume on day 2.

Day 1: Mass and Volume Data Collection Lab

- **Group size:** 4 students, with sub-groups (pairs) in each group.
- **Setup:**
  - Prepare a soapy water wash bin and rinse water wash bin students can use to quickly wash and rinse out their graduated cylinders when they are done with them. This will be particularly important to do for cylinders used to measure the glycerin.
  - Label the containers from which students will get water, glycerin, and rubbing alcohol.
  - Put out the digital scales and graduated cylinders that students will also need for the lab.
- **Safety:** Keep rubbing alcohol far away from heat sources. It is flammable.
- **Storage:** You can recover and reuse the rubbing alcohol and glycerin if you wish (if you are sure they weren't contaminated or mixed).
- **Disposal:** The contents can be disposed of down the drain when the lab is complete.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

This lesson helps students measure, determine, and use density as a property of a liquid. We again emphasize that properties are measured in the same conditions (e.g., room temperature), but do not dwell on the role atmospheric pressure plays when such measurements are taken (i.e., properties are measured at locations with the same atmospheric pressure, for example, at sea level).

Students often think that the gas in the bubbles produced by heating water is air, rather than water vapor. One piece of evidence to support that this gas is not air, or at least that it consists of more water vapor than the air around us, will be the result of a flammability test.

Students will collect mass and volume data of two different liquids using digital scales and graduated cylinders. Though this is the first time that students will be using a graduated cylinder to measure volume of a liquid in the scope and sequence, students should also be able to draw on experience in prior math classes with determining liquid volume. And in 3rd–5th grades, students' use of the crosscutting concept of scale, proportion, and quantity should have given them experience with measuring physical quantities such as volume using standard units before.

Students will discuss sources of error and the need to calculate a mean in the class data that is collected. This draws on previous experiences with similarly structured data that they collected in labs they had done in *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit).*

At the start of day 2, students plot mass vs. volume data for two different substances they collected. Working with directly proportional relationships is a 6th grade CCSS math target learning goal. But there are three other aspects of what students are doing in this lesson that are CCSS math target learning goals for 7th grade. These are:

- Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.
- Identify the constant of proportionality (unit rate) between pairs of quantities (mass and volume) in tables and graphs.
- In a proportional relationship, the slope of the line representing the relationship is the same as the constant of proportionality. Students may talk about the steepness of the line on the graph (the unit rate) informally as the slope of the line.

Since this unit is designed to be the first 7th grade unit for coordinate with your 7th grade math teachers to determine when students will be encountering these ideas in their math class this year.

Where We Are NOT Going

We do not introduce the fact that 1 mL is equivalent to 1 cubic centimeter, though you can make this connection if you wish.

We do not distinguish that the gas coming out of the flask from the heated water is likely a mixture of the gas above the water (air) and the water vapor released from the gas in the water bubbles when they reach the surface.

LEARNING PLAN FOR LESSON 9

1. Navigation

5 MIN

Materials: science notebook

Set up the materials for the investigation. Before students arrive to class you will want to have the materials set up for doing the heating water test. Fill a flask with 100–150 mL of water and place it on a hot plate. Turn it on as class starts so it will heat up as the class discusses the questions on slide A. Prepare the tubing ahead of time as explained in the materials preparation section of this lesson. Have a second flask, oven mitts, and a match ready to use during the demonstration.

Start heating the water in the flask.

Connect to the previous lesson. Project **slide A**. Discuss the questions on the slide:

- Why did we want to try to produce bubbles by adding energy to water using heat and electricity?
- What were some of the properties of each of these gases we wanted to test?
- What question(s) would that help us answer?

Suggested prompts	Sample student responses
What were some of the properties of each of these gases we wanted to test?	*We wanted to test its flammability and its density.*
What question(s) would these tests help us answer?	*They would help us figure what substance was in the gas bubbles.*

Explain that you have some water heating to make it produce gas bubbles for us to start investigating.

2. Carrying Out Property Tests on the Gas from the Heated Water

20 MIN

Materials: Heated Water Lab, science notebook

Prepare students to record observations. Say, *Let's get ready to do some tests on this gas coming from this heated water.* Show **slide B**. Give students a minute to prepare their notebooks by titling a page "Property data from gas produced when water is heated."

Have students put on splash goggles.

Additional Guidance

One purpose of this investigation is to support students in figuring out how to tell if a new substance is made everytime we see gas bubbles forming. Though many may argue that we are just boiling the water and it is still water, going through this investigation will be supporting what we have been practicing during this unit, that we need evidence to support our arguments. You will carry out this investigation one day and then test the liquid in the second flask on day 2 of the lesson. Be sure to put a stopper on this flask and keep it for the next day.

Conduct a flammability test and make observations of the liquid collected.

Gather students around the flask of heated water. The water should already be boiling at this point. Remind students that we discussed testing the flammability of the gas in the bubbles rising from the water.

Point out the bubbles rising to the surface of the water.

Show students the cork and tubing system and point out how similar it is to what was used to test helium gas.

Using two hot mitts, attach the system to the Erlenmeyer flask.

Strike a match and hold the flame near the gas coming out of the end of the eyedropper at the end of the vinyl tube (about 1–2 inches from the end). The flame will go out. Have students record this observation in their notebooks.

Point out that this might be because the gas is coming off the tube pretty fast, and maybe it simply blew out the flame. However, if that isn't the case, then maybe the gas itself isn't flammable. Ask students to look back at their table of gas properties and identify which gases are flammable, and thus are ruled out. Students should say that the gas can't be hydrogen, oxygen, methane, or propane.

Capture some of the gas coming out of the tube. Lift the end of the tube with the second eyedropper and drop it into another Erlenmeyer flask. Do not seal this second flask with a cork. Point out that you are leaving this partially open for safety reasons to avoid shattering the container from too much pressure.

Let this run for a few minutes so students can make observations and so liquid begins collecting in the second flask. Ask students to describe what they notice happening on the walls of the container over the next couple of minutes (students may have already seen this on the tubing itself). Students should say that they notice clear liquid droplets appearing on the walls. Have students record this observation in their notebooks.

Ask students what they think this clear liquid might be; they will likely say it is water. Remove the tubing from the second flask. Label it as "clear liquid collected from gas produced by heated water". Once the liquid it is cooled to room temperature, stopper it with a #6 cork with no hole. Eventually you will return to this liquid to measure its density to provide evidence of what it is.

Alternate Activity

If open flames are not available in your classroom, use the video. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**). This video is a little long as it shows the whole investigation with the flame test being done at the end. If you are able to set up the investigation and only need to show the flame test, you can skip the very end of the video.

Say to students, *The gas is coming out of one flask and moving into another. But clear liquid is appearing as the gas cools down. Do you think the gas is made of the same type of particles as the water we started with or different types of particles?*

Students are likely to say it is most likely made of water particles, but accept all responses.

3. Problematizing, Planning, and Carrying Out a New Investigation

20 MIN

Materials: Mass and volume data collection lab, science notebook, white board markers, projector, computer

Problematize how the clear liquid might be a new substance. Show students the clear liquid that has been collected again. Say, *Though the clear liquid we collected looks like water, we can't be certain it is water without testing its properties. There are many other clear liquids besides water in our world. In fact, some homemade bath bomb recipes suggest using two different substances in them that are also clear liquids, glycerin and rubbing alcohol.*

Show **slide C.** Say, *Glycerin is a clear liquid that some people use in place of the olive oil or coconut oil to help hold the dry ingredients together. Rubbing alcohol is sometimes used for the same purpose. Water, glycerin, and rubbing alcohol are all different substances, which means they are made of different particles. Each cup shown here is filled with one of these different substances. Based on the photograph alone what makes it hard to tell which one is filled with which substance?*

Students will say they are all clear and they are all liquids at room temperature. Discuss other ways we might be able to tell the liquids apart.

Suggested prompts	Sample student responses
How else might we be able to tell these liquids apart?	*We could smell them (odor).* *Maybe they feel different?*
What were some ways we were able to tell gases apart?	*Density and flammability.*

Reintroduce the role of density as a property. Say, *we know density is a property and it is something that we can actually determine using other properties we can measure. Let's try and find the densities of some of these known, clear liquids that are found in some bath bomb recipes and compare them to the density of the liquid we captured after heating the water. We can then use that data to support an argument for whether the clear liquid is a new substance or if it is the same substance that we started with.*

Plan an investigation. Show **slide D.** Read the text on the slide to remind students of the range of the density values they have looked at so far and the units in which they were reported. Discuss how we might measure a sample of liquid in grams and liters.

Suggested prompts	Sample student responses
The densities are reported as g per L. The g in these units stands for grams. How could we measure the number of grams of a liquid sample?	*We could weigh it.* *We could put it on a digital scale.*
The L stands for liters. Another unit of measurement that is used is milliliters. There are 1000 millimeters in a liter. What could we use to measure the number of liters or milliliters of a liquid in a sample?	*We could use a beaker or graduated cylinder.*

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

In 3rd–5th grade, students' use of scale, proportion, and quantity should have given them experience with measuring physical quantities such as volume using standard units. Students should also be able to draw on experience in prior math classes with determining liquid volume and using multiplicative thinking to make unit conversions. They should be used to talking about volume in similar ways in their math and science classes, specifically referring to volume as how much space an object or substance takes up.

If you find that students are struggling to understand the relationship between liters and milliliters, you can use a t-chart with equivalent values and ask students to notice patterns in the numbers. Students should notice that the numbers are related by multiplication or division of a common factor (1,000) depending on the direction in which they compare numbers across the table.

Say, *We know how to get the mass of the container with the sample in it and subtract the mass of the container before we put the sample in it. Let's talk a bit more about how to measure the volume. Getting a very precise measurement of the volume can be a bit tricky because of the way liquids behave in containers.*

Introduce how to measure liquid levels. Show **slide E.** Project this image onto a surface you can write on (a white board or poster paper). Discuss the questions on the slide. Students should notice that the liquid level is curved. Tell students that this effect is common when measuring liquids in glass containers and the convention is to measure the volume of the liquid at the lowest point on this curved surface (called the meniscus of the liquid).

Point out that between the 10 mL and 15 mL marks there are 10 markings, or graduations. Ask students to determine the value of each line. Students should say that each line is an additional 0.5 mL. Use a marker to annotate these lines on the slide projected on (a white board or poster paper), to help show that the bottom of the meniscus is about halfway between 13.0 mL and 13.5 mL. Point out that a reasonable estimate for the bottom of the meniscus might be 13.2, 13.25, or 13.3 mL.

Distribute copies of *Density calculations of clear liquids*. Show **slide F**. Have students take a minute to record their predictions and add this handout to their notebook.*

Ask students to share their predictions. Expect almost all students to argue that doubling the volume will result in double the mass (16.0 g) and halving the volume should result in half the mass (4.0 g).

Say, *It sounds like we think there is a predictable relationship between the volume and the mass of a sample of a substance. This suggests that even if different groups measure different amounts of the same substance, the ratio of mass to volume should still be the same. That's great because when we collect data on different clear liquids, we won't have to control for the amount of volume different groups measure out. If one group gets a pouring sample of a liquid and they pour twice as much volume as another group, they should get twice as much mass as the other group when they weigh their sample. It sounds like we should collect some data to see if our predictions are correct.*

Assign teams. Make two subgroups per each group of four students. Have the first subgroup of two students add the name "rubbing alcohol" to their data table on *Density calculations of clear liquids* as the second liquid they will investigate (in addition to water). Have the second subgroup of two students add the name "glycerin" to their data table on *Density calculations of clear liquids* as the second liquid they will investigate (in addition to water). Tell students that they will share a single digital scale between each group of four students.

Show **slide G.** In order to collect evidence to support density as a property, divide the number of small groups into thirds. Each third will test the density of the different liquids using a different starting amount of liquid. Therefore for each test, assign one third of the groups to measure out around 10–14 mL of liquid, another third of the groups to measure out around 15–19 mL of liquid, and the final third of the groups to measure around 20–24 mL of liquid.

Carry out the lab. Keep this procedure posted for the remainder of the time students are completing day 1 of the lesson.

End of day 1

Liters (L)	Milliliters (mL)
1	1000
4	4000
7.2	7200
0.5	500
0.25	250

4. Analyzing and Interpreting Data

17 MIN

Materials: science notebook, calculator, 12 small sticky notes per group of 4 students, 4 ceramic magnets, 3 graphs and tables on poster paper for recording mass vs. volume data collected

Plot data collected from the previous investigation. Show **slide H.** Pass out four sticky notes and ceramic magnets to the groups of students. Review the instructions on the slide.

*** Supporting Students in Engaging in Analyzing and Interpreting Data**
Students have discussed sources of error and calculated a mean before in tabular data from measurement they have taken before that has shown variation like this before for similar reasons, in their previous work in *Cup Design Unit*.

Assessment Opportunity

Building towards: 9.A.1 Use mathematical and computational thinking by graphing mass vs. volume data for different substances and finding the ratio of mass to volume (a unit rate) [scale, proportion, quantity] for the samples measured to determine the density of different clear liquids.

What to look for: Small group work determining mean (average) densities across samples from multiple groups that yields:

- close to 1.0 g/mL for water,
- close to 0.78 g/mL for rubbing alcohol, and
- close to 1.26 g/mL for glycerin.

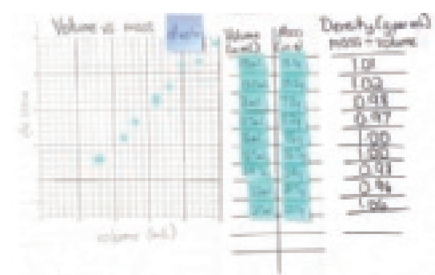
Though some classes may have results that are within a range of +/- 0.1 g/mL of these values, students in any single class should all find the same relationship between values using data from their particular class.

What to do: If students struggle with finding or using unit rates in the context of density or averages you could:

- Provide additional measurements of water or alcohol for students to practice determining unit rates.
- Coordinate with the grade level math teacher to provide other examples and practice finding unit rates students have been working with (or will be working with) in math class.

Show **slide I.** Orient students to the places where the posters for the three different substances are located. Explain that they should form a line in front of the poster for one of the substances they tested, place their magnet at the appropriate coordinates, and then move to the right and post their sticky notes on the table, allowing the next person to post their magnets and sticky notes. Ask the students who have data for glycerin to start with that poster, students who have data for rubbing alcohol to start with that poster, and the second person of each sub-group pair should post data for water. This should take about three minutes to post all the data.

Example of the water data to the right.



Analyze and interpret patterns in the graphs and tables. Show **slide J.** Allow students 3 minutes to record what patterns they notice in the data on a new page of their science notebooks.

Ask students to share out some of the patterns they noticed. Start with patterns within the graph and table for one substance and then shift to having students compare the graphs and tables of different substances.

Supporting Students in Making Connections in Math

The goal of this discussion is to make connections to the work that students are doing in their 7th grade math classes, related to two ideas. Students should:

- Decide that mass and volume are in a directly proportional relationship for each substance (for example, this might be demonstrated by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin).
- Identify the constant of proportionality (the unit rate) from tables, graphs, or an expression and identify this unit rate (mass divided by volume) as the density of that substance.

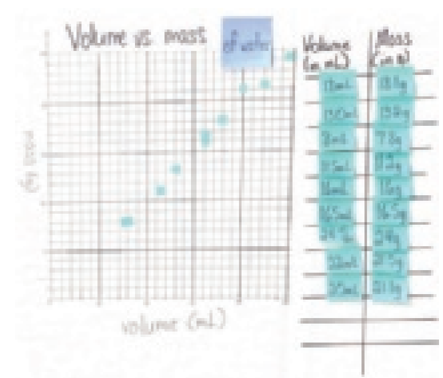
Suggested prompts	Sample student responses
What patterns do you notice about the shape of each of the graphs?	*They form nearly straight lines.*
How does the steepness of the line in each of the three graphs compare?	*The line for glycerin is the steepest and the line for rubbing alcohol is the least steep.*
Looking at the table for water, what would you say is the increase in grams for each additional mL of the liquid?	*Water is about an extra 1 g for every 1 mL.*
Looking at the table for glycerin, what would you say is the increase in grams for each additional mL of the liquid?	*Glycerin goes up about 1.2 grams for every additional mL.*
Looking at the table for rubbing alcohol, what would you say is the increase in grams is for each additional mL of the liquid?	*Rubbing alcohol goes up about 0.8 grams for every additional mL.*

Say, *You've seen straight line relationships like this before in math. It looks like this line goes through 0, 0 (zero mL of the substance is 0 grams). When that is the case, we call this sort of pattern a directly proportional relationship. Directly proportional relationships have a constant unit rate—that means as one quantity changes, the other changes in a predictable way. We can find the unit rate for this graph by taking any coordinate point on the graph and dividing the y-value by the corresponding x-value. In our case, that would be any amount of mass in grams divided by a corresponding amount of volume in mL. This will give us the unit rate in grams per mL, which will be the density of the substance. Let's find the density of water from the relationship between mass and volume for a few different coordinates from our graph.*

Add a third column next to each table using a sheet of chart paper that can later be removed. Title this column **"mass (C) / volume (D) = density, which is a unit rate (in grams per mL)."**

Show **slide K.** Pass out four more sticky notes to each group. Ask each group to find this ratio for their own rows and record it in column E in *Density calculations of clear liquids*. Have students individually record each of these densities on their own sticky note and post them on the corresponding third column of the tables that you posted in the room. This should take about 3 minutes.

An example of this for water is shown here. Students should post a similar finding for density next to their corresponding row of the data in the class tables for glycerin and rubbing alcohol.



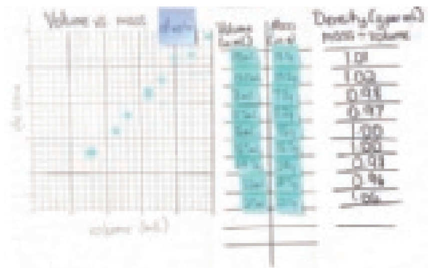
Ask students what they notice about all the values in this column in each table. They should say values are very similar to each other.

Say, *The values are very close to each other because density shouldn't change for the same substance. Any differences in the values here must be due to experimental or measurement error. Three times as much volume should have three times as much mass and half as much mass should take up half as much volume. The ratio of mass to volume should be constant for a substance measured in the same conditions (e.g., at room temperature).*

Add this idea on the Word Wall:

- Density is a unit rate that can be described as the ratio of mass to volume for a given substance. It is a property (a constant) for any sample of a substance, regardless of the amount of the sample.

Say, *Even though the density values shown here are very similar to each other, they aren't exactly the same. What are some sources of error that could contribute to some of the small differences we see in these results?* Accept all answers.



Ask students how we can take data like this, that we know has some variation in it, and determine what the typical and expected value for the density of this substance would be. Students should say that we can calculate the mean of the data.*

Show **slide L.** Have students work with a small group to calculate the averages for each of the substances and record them in their third table on *Density calculations of clear liquids*. Allow 3 minutes for this.

Compare our averaged densities to known densities for these substances Have a few students report these average densities. Write them on the board. Say, O*ther scientists have done similar experiments and determined the average densities of these substances to be 1.0 g/mL for water, 0.78 g/mL for rubbing alcohol, and 1.26 g/mL for glycerin*. It is likely that students will have a similar ranking (glycerin is the most dense and rubbing alcohol is the least dense), though the exact densities may be off by +/- 0.1 g/mL.

Check understanding of these units by scaling up the values. Ask students, *If we know water is 1.0 gram per mL, then how many grams would 100 mL of water be?* Students should say 100 g.

Emphasize what they have discovered by saying, *The relationship between mass and volume found by dividing mass by volume for any substance should always be the same at room temperature conditions. That constant ratio is its density.*

5. Collecting Data on the Density of the Clear Liquid — 8 MIN

Materials: science notebook, index card or scrap paper, 3 graphs and tables on poster paper for recording mass vs. volume data collected, clear liquid collected from heated water, 25 mL graduated cylinder, digital scale, 2 small sticky notes

Make predictions about the density of the unknown liquid. Bring out the flask of clear liquid collected from heated water that you have corked and stored from the prior class period and show it to students. Show **slide M.** Give students a minute to share their predictions about the density of this clear liquid with a partner.

Invite students to gather around a demonstration table where you have a sample of the clear liquid collected from the heated water setup for students to measure its mass and volume.

Collect data needed for determining the density of the unknown liquid.

- Use a digital scale to determine the mass of an empty 25 mL or 100 mL graduated cylinder. Have a student record this on the board.
- Pour the clear liquid that you collected from the heated water into the graduated cylinder.
- Use a digital scale to measure the mass of the container with liquid in it again. Have a student record this on the board.
- Read the volume of liquid in the graduated cylinder. Have a student record this on the board.

Students determine the density of this liquid. Pass out index cards to students. Show **slide N.** Ask them to independently answer the questions on the slide on an index card and turn them in to you when they are done. This should take less than two minutes.

Assessment Opportunity

Building towards: 9.A.2 Use mathematical and computational thinking by graphing mass vs. volume data for different substances and finding the ratio of mass to volume (a unit rate) [scale, proportion, quantity] for the samples measured to determine the density of different clear liquids.

What to look for: The following responses on student index cards:

- Q1) The density of the clear liquid is close to 1.0 grams per mL
- Q2) The same density as in Q1 (1.0 grams per mL)

What to do: If students struggle with determining or using unit rates in the context of density you could:

- Provide additional measurements of water or alcohol for students to practice finding unit rates.
- Coordinate with the grade level math teacher to provide other examples and practice finding unit rates students have been working with (or will be working with) in math class.

Ask, *Is the density of this liquid similar to any of the three known clear liquids?* Students should say that it is very close to the density of water (1.0 g/mL).

Identify and mark the coordinates for this data point (volume, grams) on the water graph for the sample you just measured. Show that the same coordinate on the other graphs does not match the linear trend in the data plotted on those graphs.

Say, *It seems like the graphs and tables that helped us find the density of each liquid also provide us strong evidence about what the unknown clear liquid is. I think we can use this and our earlier observations about the other properties of that gas to make some evidence based arguments about whether or not the gas we collected is made of a different type of particle (a new substance) than the water we started with.*

Ask students to turn and talk with an elbow partner for a minute about this question before heading back to their seats.

Materials: *Evaluating and improving alternate arguments*, science notebook, Arguing from Evidence poster from Lesson 2

Evaluate alternative arguments. Show **slide O.** Read the text on the slide and have students talk with a partner about the slide content. While they are doing this, pass out copies of *Evaluating and improving alternate arguments* to students. Listen for students to agree with both arguments, which are making the same claim (the gas in the bubbles is made of water particles), but are structured in different ways. After 3 minutes, bring students back together as a class.

Say, *Though we might agree with these claims, they are lacking what we said makes a strong, evidence-based argument.* Refer back to the anchor poster from Lesson 2 to emphasize that there is lots of evidence that could be used to make a stronger argument and stronger connections to key science ideas.

Identify elements to include to strengthen each argument. Say, *Use this handout to list observations we took that we could use to strengthen this argument. What data did we collect? Take 3 minutes to individually list the key pieces of data in part 2 of your handout.*

Alternate Activity

You can also have students complete part 2 of their handouts individually rather than with a partner.

Show **slide P.** Briefly have students pause and say, *Now shift to looking back at the key science ideas that we have. Identify which ones are relevant and write those down in part 2 on your handout.*

Write a revised argument. After 3 to 4 minutes, have students pause again. Project **slide Q**. Read the text on the slide and orient students to a similar prompt in part 3 of *Evaluating and improving alternate arguments*. Say, *Take the remaining time to work individually to write a revised argument on a separate sheet of paper.*

A few minutes before the end of the period, have students staple their completed *Evaluating and improving alternate arguments* to their separate sheet of paper and turn in both sheets.*

Additional Guidance

If you notice students are not using key model ideas in their explanations or if they are struggling with where to find these, remind them that they can use what they have highlighted in their Progress Trackers and/or the key model ideas recorded on the classroom chart.

Assessment Opportunity

Building towards: 9.B Argue from evidence and critique two arguments on the same topic; strengthen these arguments by using additional empirical evidence (patterns) and scientific reasoning to support an explanation for whether the substances collected from the gas produced by the heated water is made of different types of particles or the same type of particles (patterns) as those in the water that we started with.

*** Supporting Students in Three-Dimensional Learning**

This is an excellent 3D assessment opportunity, as students have been practicing engagement in the SEP of arguing from evidence at multiple points in previous lessons. Students will need to apply the crosscutting concept of patterns at the macroscopic level (property based observations) to what must be happening at a particle level (patterns). They will also need to draw on the disciplinary core ideas that (1) properties (like density, flammability, and state of matter at room temperature) are unique characteristics of substances and (2) that the properties of substances are based on the structure of the particles that make up those substances.

What to look for: See *Scoring Guidance: Evaluating and improving alternate arguments*

What to do: See *Scoring Guidance: Evaluating and improving alternate arguments*

7. Navigation

3 MIN

Materials: None

Show **slide R**, and read the text. Ask students to discuss this question with a partner.

Alternate Activity

Have students talk with a partner about this question and then revisit it in a whole-class discussion at the start of the next lesson.

If time is short, you can have students consider this question for the first time at the start of the next lesson.

ADDITIONAL LESSON 9 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.7.1.A Introduce claim(s), acknowledge alternate or opposing claims, and organize the reasons and evidence logically.

CCSS.ELA-LITERACY.W.7.1.B Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.

CCSS.ELA-LITERACY.W.7.1.C Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.

CCSS.ELA-LITERACY.W.7.1.D Establish and maintain a formal style.

CCSS.ELA-LITERACY.W.7.1.E Provide a concluding statement or section that follows from and supports the argument presented.

CCSS.ELA-LITERACY.W.7.2.C Use appropriate transitions to create cohesion and clarify the relationships among ideas and concepts.

CCSS.ELA-LITERACY.W.7.2.D Use precise language and domain-specific vocabulary to inform about or explain the topic.

CCSS.ELA-LITERACY.W.7.2.E Establish and maintain a formal style.

The above learning goals are the focus of the written argument that students produce at the end of day 2 of this lesson.

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.7.RP.A.2.A Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.

CCSS.MATH.CONTENT.7.RP.A.2.B Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.

MP.2 Reason abstractly and quantitatively.

This lesson calls for students to go back and forth between the mathematical representation of quantities for mass and volume, the relationship between those quantities, and what those symbols represent in the context of a substance's density.

These focal math goals represent important understandings for middle school students. Density is a traditionally tricky concept in science and leveraging students' math experiences with ratios and rates may be useful. In 6th grade, students are used to representing ratios with a colon or words. Depending on where students are in their math learning, they may initially be confused by a ratio represented using fraction notation as is often done when comparing mass and volume to determine density. Students also learn that every ratio of two quantities has two associated rates. The ***rate*** is a quantity derived from the ratio by division, as is the case with density, and this rate has units (i.e., grams per milliliter). If two quantities are in a proportional relationship, then the quantities are related by a ***constant factor***. Students sometimes call this the ***constant of proportionality***—a numerical value with no units. The progression of ideas from ratio and rate to constant of proportionality and slope represents students' growing understanding of how to describe relationships between two quantities. Referring to the relationship between mass and volume and making comparisons between these two quantities will resonate with students' math experiences and support their understanding of density as a property of a substance and a relationship between two measured quantities rather than an abstract calculation.

The question of whether the relationship between mass and volume is proportional is motivated through prediction questions about what would happen to the mass of a sample of a substance if you tripled or halved the volume of the sample. Students should notice that as one quantity increases, the other quantity increases in a predictable pattern. Students plot the data they collect and analyze and interpret the plots of data at the start of day 2. They look for whether the graph is a straight line through the origin, compare values for the mass and volume to determine the ratio of grams to mL for each sample, and use this ratio to find the unit rate (grams per 1 mL) for each graph. Students are familiar with linear expressions ($px + q = r$) and could write an equation to represent their graphs. Students are not introduced to the term slope until 8th grade.

LESSON 10

When energy from a battery was added to water, were the gases produced made of the same particles as were produced from heating the water?

Previous Lesson *We carried out an investigation on the flammability of the gas produced by heating water. We collected data on the mass and volume of the liquid that formed from the gas. We argued that the resulting property data indicates that the gas we collected is made of the same particles that were in the water we started with.*

This Lesson

Investigation

1 day

We carry out an investigation to test the flammability of gases produced by providing energy to water with electricity. We construct an explanation for whether the gas(es) produced from water using energy from a battery were made of the same particles as those produced from heating the water.

Next Lesson *We will gather and summarize information from a reading on investigations that Dalton and other scientists did and will compare the models they developed for the particles that get broken apart, rearranged, and put together in chemical reactions to the models we developed. We will use Dalton's models to represent what happens with water molecules during the electrolysis lab.*

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

10.A Students apply scientific ideas and evidence (property data) to construct an explanation for whether the gas(es) produced from water using energy from a battery were made of the same particles (patterns) as those produced from heating the water.

What Students Will Figure Out

- Two different gases with different properties are produced from adding energy from a battery to water.
- The particles that make up these different gases must be different from each other; they must also be different than the ones that were produced from heating water.
- The matter that makes up all of the substances must come from matter that made up some of the original water particles.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Revisit the reasons why we wanted to conduct different investigations related to adding energy to water.	A	Adding Energy to Water Investigations poster
2	15 min	**OBSERVING THE SET UP OF ADDING ENERGY TO WATER WITH ELECTRICITY** Make observations of the set up for investigating what happens when electricity is added to water.	B–C	Investigation of Electrical Energy and Water
3	15 min	**TESTING THE GASES COLLECTED AFTER ADDING ELECTRICITY TO WATER** Demonstrate flammability tests for the two gases produced by electrolysis. Discuss what the data mean.	D–E	What's happening to particles when new substances are made? poster from Lesson 8, Investigation of Electrical Energy and Water
4	10 min	**CONSTRUCTING AN EXPLANATION** Construct an explanation about whether the gases in the test tubes produced when energy from a battery was added to water are the same as the gas produced when water was heated.	F	*Some Common Gases* from Lesson 5
				End of day 1

Lesson 10 • Materials List

	per student	per group	per class
Investigation of Electrical Energy and Water materials	• safety goggles		• Use *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* for directions on how to build Setup A and Setup B. • test tube clamp

	per student	per group	per class
			• ring stand • matches • a beaker with water • a captured gas sample from test tube A • a captured gas sample from test tube B
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Some Common Gases* from Lesson 5		• Adding Energy to Water Investigations poster • What's happening to particles when new substances are made? poster from Lesson 8

Materials preparation (120 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Investigation of Electrical Energy and Water

- **Group size:** Whole-class demo
- **Setup:**
  - Prepare three parts to this demonstration. *See Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* for directions for how to set these three parts up:
    - **Setup A: electrolysis apparatus with no test tubes.**
    - **Setup B: electrolysis apparatus with test tubes.**
    - **Capturing the gases in test tubes to test:** Set aside samples of already captured gases from an electrolysis setup for each gas: a captured gas sample from test tube A and a captured gas sample from test tube B. Have at least one sample of each ready to test for every class.
  - You will be testing the captured gas in test tubes A (hydrogen) and B (oxygen) for flammability. You will need to have a couple of test tubes of each gas that you collected to practice with before you demonstrate it for the first time in front of the students. **Do not skip this part!** Additionally, you will need at least 1 test tube of each gas for each class. If you want to repeat the demo, then you will need two tubes of each gas. To prepare multiple tubes to test, you may want to prepare three setups to run in parallel. The supplies for doing this are provided for you in the standard materials kit.

- **Prepare the tubes to collect the gas.** Read *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* to see how to set up the electrolysis apparatus to collect the gases. Watch the video for additional guidance. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)
    - **Test the gas in tube A (hydrogen) for flammability.** Read *Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced* to see how to test the flammability of gas A (hydrogen) and gas B (oxygen). Watch the video for additional guidance. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)
    - **Notes for during the lab:** Have a cup of water available to discard burnt matches into.
- **Safety:** Follow the same safety guidelines as those for the students when you test the gases:
    - Wear safety goggles.
    - Teacher and student volunteers should tie back long hair.
    - Don't connect the battery until you have completely set up the system.
    - Don't allow the two wires or alligator clips to come in contact with each other. They will become hot quickly.
    - Do not allow the battery to come in contact with the water.
    - Disconnect the clip from the battery as soon as you have made observations.
- **Storage**
    - Store batteries separately from each other.
    - Batteries will last longer when stored in the freezer.
    - Dry the alligator clip ends if they get wet to prevent rusting. If the alligator clips become rusted or oxidized (brownish-orange colored), they will tend to not conduct electricity to items they come into contact with. Here is how to clean them off:
        - Submerge the ends in soda pop or carbonated water for a couple of hours.
        - Remove them and scrub the ends with a wire brush, steel wool, or toothbrush.
        - Dry the ends immediately with a cotton swab or paper towel.
- **Disposal**
    - Check your county's regulations for disposal of alkaline batteries when depleted. Different counties have different regulations.

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

Students will figure out that the gases produced from providing energy from a battery to water (electrolysis) are different gases and also different from the gas produced by boiling water.

Students will construct an explanation that this must be happening due to creation of new types of particles. This explanation draws on a line of evidence related to properties as related science ideas. This is also the first time that students are bridging the idea that there must be new particles being produced as an explanation for the formation of a new substance, based on evidence of changes in properties. This is an important advancement in using the cross-cutting concept of patterns, related to the idea that macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Students also compare evidence for matter conservation in this process (electrolysis) to what they figured out earlier with the bath bomb in the soda bottle in their whole-class discussion in slide E. This will help them see how mass conservation can be accounted for in the next lesson, when they refine their understanding of where the particles of the new substances are coming from (that molecules of old/starting substances can be broken apart into atoms that combine in new ways to make molecules of new substances).

This process of adding electricity to water and producing gas is sometimes also called electrolysis. When electricity is run through water with dissolved electrolytes in it, those electrolytes enable electric current to pass through the water. The electrolytes serve as catalysts that enable the hydrogen and oxygen atoms in water molecules to separate and rearrange to form into hydrogen and oxygen molecules.

Where We Are NOT Going

In this lesson, we will not name the particles as "atoms" or "molecules." That vocabulary is developed in the next lesson. We will not develop the idea that water is made of two hydrogen particles and one oxygen particle. Some students may introduce the idea that they have heard that water particles are made of oxygen and hydrogen, based on a common reference they may have seen before that "water is H_2O." Encourage students to work with whatever ideas come to mind in their explanations, but don't establish this as a convention yet for referring to water.

It is not important that students identify either of the gases produced through electrolysis. It is only important that they have enough evidence to argue that they are not the same substance (based on the flammability test results).

Instead of using pure distilled water in the electrolysis production, you are making a solution of magnesium sulfate and distilled water. The dissolved particles of magnesium sulfate help speed up the process of electrolysis that produces the hydrogen and oxygen gas. Avoid introducing and describing the role of this additional substance to students, as it is peripheral to the source of the matter that the gases form from (the water molecules). Additional guidance is provided in a callout in the lesson if you run out of distilled water and need to use tap water instead.

No attempt is made to introduce electrons, ions, or bonds in this process. All of these ideas are above grade level.

LEARNING PLAN FOR LESSON 10

1. Navigation

5 MIN

Materials: science notebook, Adding Energy to Water Investigations poster

Connect to the previous lessons. Direct students to the *Adding Energy to Water Investigations* poster you made in Lesson 8. Say, *We started investigating some of the things we said we wanted to do on this poster. Let's remind ourselves, before we move on to the next investigation listed here, how did we get here and why did we want to do all of this stuff with water?*

Project **slide A**. Discuss the questions on the slide as a whole class.

Suggested prompts	Sample student responses
Why did we want to try the two investigations we read about (adding energy to water using heat and electricity)?	*We wanted to see if we could produce gas bubbles in both cases, and if there was anything different about the gas in those bubbles.*
What question(s) would these tests help us answer?	*We wanted to try these to figure out if this (adding energy) was another way to make a new substance.*
We brainstormed different ideas for what could be happening at a particle level when new substances are made. How will these investigations provide us data to help support or refute these ideas?	*All of our ideas were about ways that new kinds of particles might come from old types of particles. This would help us see if any of these are possible starting with something that we know is made of only one type of particle throughout (water).*

Ask students if heating water produced new types of particles or not. Students should say it did not. The water particles that we started with in the liquid are still there in the liquid we ended with.

Connect to phase change ideas from prior units. Say, *We've seen this sort of sort of process before, where a substance turns into a gas, but remains the same type of particle throughout. In the case of water, we heated it to its boiling point, which caused the water particles to speed up enough to break away from neighboring particles and move through space as water vapor. Then when that gas cools down and the particles slow down enough, they clump together and condense back out to a liquid. This process of phase change is something you modeled in your work in Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit). But now that we are conducting investigations that may sometimes yield new substances, testing the properties of what we have before and after will provide us the data we need to determine whether this is the case in our next investigation we wanted to try.*

Additional Guidance

Students' prior work with phase change investigations in *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* involved working with magnetic marbles to simulate adding energy (speeding up the particles) and removing energy (slowing down the particles). The results showed that those particles behave very differently in collisions depending on the initial speed of the particles. Slower moving particles tend to stick together in a collision. Faster moving particles tend to bounce off of each other in a collision. These differences in particle behavior helped explain how and why phase changes occur when water reaches a certain temperature (boiling/condensation point).

2. Observing the Set Up of Adding Energy to Water with Electricity

15 MIN

Materials: Investigation of Electrical Energy and Water, science notebook

Prepare to record observations. Display **slide B.** Give students a minute to prepare their notebooks for further observations. They should title a new page, "Adding energy to water with electricity." Tell them to use this page to make observations during the investigation.

Introduce the equipment. Ask students to gather around a demonstration area in a central location to orient them to the equipment used for running electricity through water. Have them bring their notebooks with them.

Show students the following equipment you used to build an apparatus to safely run electricity through water. This is **Setup A** (no test tubes added to it).

- beaker, 600 mL, with water in it
- three 9-volt batteries ready to hook up to alligator clips that are connected to two separate stainless steel electrode wires

Safety Precautions

Point out that you have small batteries here to ensure that the amount of electricity we are using is safe and won't harm anyone. Emphasize that electricity from the socket in the wall is way too much electricity to use safely for this investigation with water and that electricity from wall sockets should never be put near water, as it is dangerous and can badly harm us when in contact with water. Emphasize that the setup you put together is one that is safe, as long as we take necessary safety precautions.

Additional Guidance

It is recommended for you to add magnesium sulfate (Epsom salts) $MgSO_4$ (you will use 60 g for every 500 mL of distilled water you make) to a gallon of distilled water as a catalyst so the electrolysis will occur faster. Students do not need to know this preparation detail as it will raise barriers to constructing an explanation of where the new particles are coming from in this investigation, which won't be a time efficient detour to follow.

In addition, if you run out of distilled water, but your tap water is hard and contains minerals, the investigation should still work fine as the minerals will act as catalysts and should increase how fast the electrolysis occurs. It is recommended that you start capturing the gases to test in class a day ahead of time so that you produce enough gas samples in time for all of your classes.

Have students put on goggles now and wear them until the property tests are complete.

Safety Precautions

Students should wear splash goggles during this investigation and until the property tests are completed.

Observe Setup A. Attach the alligator clips to the batteries in Setup A so students can observe the bubbles coming directly off the stainless steel electrode wire. Prompt students to record what they observe. Give all students a chance to come up close to this setup to examine it further.

At this point ask if they can touch the side of the beaker to see if they can detect a temperature change. Or they may ask if they can measure its temperature. If they do, encourage them to do this.

Ask students to share their observations. Students will say they notice bubbles coming off of both wires, and that one wire appears to have more bubbles coming off it than the other, or bubbles coming off of it faster. If they measured the temperature of the liquid or felt the side of the container, they will also say that it doesn't appear to be at higher or lower temperature than room temperature.

Observe Setup B. Point out that this setup is the same as Setup A, but has an addition of two test tubes each filled with water placed upside down, one over each end of the two electrodes. Ask students how adding the test tubes to this setup might help us determine what the gas in the bubbles is. Students will say it will help us capture the gas so we can do property tests on it.

Detach the alligator clips from the stainless steel electrode wire in Setup A and attach them to the same wires in Setup B. Ask students to record what they notice. Students will say that one test tube is filling up with gas more quickly than another.

Say, *The test tubes are what I am using to capture the gas in this system. Since the bubbles are produced relatively slowly, I set another system just like this up before class and ran it until the test tubes were filled with gas. I then detached the batteries, reached under the water and put a stopper/cork over the mouth of each test tube to keep the gas trapped inside. I also labeled the two test tubes to keep track of which one has more gas bubbles going into than the other. The one that had more going into it I labeled Gas A, and the one that had less going into it I labeled Gas B.*

Orient students to the corked test tubes you have collected. Point out that you have one test tube labeled Gas A and one labeled Gas B and that both were captured using the same set up as Setup B and then corked.

Show **slide C.** Ask students to turn and talk with someone next to them about this question: Do you think the gas we collected in each test tube from running electricity through the water is made of the same particles that were produced from heating the water?

After students have had time to talk with a partner, discuss this question further as a whole class, and follow up with the additional line of questions outlined below:

Suggested prompts	Sample student responses
Do you think the gas(es) we collected in each test tube from running electricity through the water is made of the same particles that were produced from heating the water?	*Yes, both produce a clear gas.* *No, this gas wasn't heated up.* *How can we tell? It's hard to tell clear gases apart without doing additional tests on them.*
Because this investigation takes longer than our class period and I had run it overnight, these test tubes have been sitting in the room for a while, similar to the flask that we captured the gas from boiling. How does what is in the test tubes compare to what we saw in the flask in the last lesson?	*There was clear liquid in the flask at room temperature, but there is no clear liquid in the test tubes.*
So based on what we observe about the state of matter at room temperature for what is in these test tubes, what are some claims we could make about whether they contain the same substance we started with?	*They can't contain the same substance we started with, because they contain a gas. And that is a different state of matter at room temperature than water is, which is a liquid at room temperature.* *And since the state of matter at room temperature is a property and different substances have different properties, this can't be water.*

Now switch the focus of the discussion to whether the gas in each test tube is the same substance or not.

Suggested prompts	Sample student responses
We have two test tubes of gas produced. We are pretty sure that it must be a new substance in both of them. But are they the same new substance in both? Or is there a different new substance in each?	*It's hard to know.*
If it's hard to tell if the gas in each test tube is the same substance or not, what additional tests could we do on these gases to help answer that question?	*We could test/compare more of the properties of each.* *We could test/compare the flammability of each.* *We could test/compre the density of each.*

Say, *Let's see what we can figure out from testing the property of flammability of the gas in each test tube. Let's make a data table together to record the results of this test in your notebooks.*

Add additional space to record data. Work with the class to construct an observation chart for flammability tests on the two test tubes. Record this on the board and tell students to add this to their notebooks. Take no more than 2 minutes to plan and copy this observation chart. Here is what that might look like:

	Gas A (more gas bubbles)	Gas B (less gas bubbles)
Observations from the flammability test		

Alternate Activity

If your classroom is a flame free classroom, you can use a video with your students so they can collect the flammability data from each of the test tubes of gas. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)

3. Testing the Gases Collected After Adding Electricity to Water

15 MIN

Materials: Investigation of Electrical Energy and Water, science notebook, What's happening to particles when new substances are made? poster from Lesson 8

Remind students that you have collected gas from Setup B. Show them the two tubes labeled Gas A and Gas B that you have prepared. Reassure students that you have tested these tubes already and know that this flammability test is safe. Emphasize that students need to keep their safety goggles on for the entire test.

Safety Precautions

Follow these instructions to ensure safety for you and your students as you do the demonstration described below.

- It is very important that you practice this test before you do it with students. When practicing and while doing the demonstration, be sure to tie back long hair and remove any dangling jewelry.
- If you have baggy sleeves, either push them up or secure them with an elastic tie.
- Be sure that the test tube of gas is pointing away from students and away from you.
- Make sure to mount the stoppered test tube you are about to test on a test tube clamp on a ring stand.
- Any student that assists you in the demonstration should follow the same safety procedure.
- Make sure that there is a cup of water nearby to discard the burnt matches or wooden splints.

Test gas A for flammability. Show students the set up. Each test tube will be mounted to a ring stand using a test tube clamp. This way no one will be holding it when we test the flammability. Tell students we will start with the test tube labeled Gas A. Tell students you are going to strike a match and then uncork the test tube and slide the match inside. Tell the class to listen carefully and make observations with their eyes and ears. Light the match and move it toward the opening of the tube. Make sure it has a burning flame on it. There should be a small explosion that sounds like a bark when the splint reaches the opening or enters the tube.

Allow students time to record their observations and discuss. If you have made more tubes ahead of time, repeat the test.

Show **slide D**. Lead a quick discussion about this test to get students to compare this gas with the gas from boiling water and to make predictions about the gas in tube B. An example dialog is shown below.

Suggested prompts	Sample student responses
Wow! That was pretty exciting. How does that result compare to the data we collected on the gas produced from boiling water?	*It was way different!* *The gas from the boiling water put out the flame and this one exploded!*
Besides the substance in the test tubes being a gas at room temperature, how does this provide additional evidence that the particles that make up this gas are not water particles?	*Flammability is a property and different substances have different properties.* *Also we know that different substances are made of different particles and since it has a different flammability than the gas from the boiling water, it is a different substance, which must be made of different particles.*
What could doing this test on the gas in test tube B tell us about the particles that make it up?	*If it does the same thing, it could tell us whether it might be made of the same type of particles as in the tube labeled Gas A. But there were lots of gases that explode when a flame is brought near them, so that result might still not be conclusive.* *If it does something different, it could tell us whether it might be a different type of particle than in test tube A.*

Test gas B for flammability. Keep **slide D** projected. Reassure students that you have already tested this and you know what it does is safe as well.

Test gas B the same way that you tested gas A. Students should notice the flame burn brighter when inserted into the test tube after being uncorked.

Allow students time to record their observations and then discuss. Lead a quick discussion about this test to get students to compare this gas with the gas from boiling water and the gas from test tube A. An example dialog is shown below.

Suggested prompts	Sample student responses	Follow-up questions
What does this result tell you about this gas compared to the gas in tube A?	*It seems to be flammable but it behaved differently.*	*Do you think that means it is a different gas?*
How do these two flammability tests help tell us if the gases are different or if they are the same?	*I remember that the property of flammability had different descriptions on the big data sheet we looked at earlier.*	*So, do you think we can find some answers on the data sheet, Some Common Gases?*

Tell students to look at *Some Common Gases* from Lesson 5 and use the flammability data to help them figure out what gases might be captured in the tube. Tell students to record their ideas in their notebooks below their data table, or in each cell in their data table.

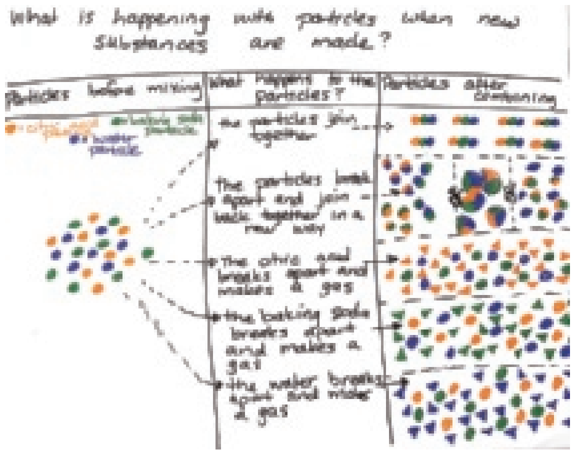
Additional Guidance

It's not critical that students identify which gases these could be at this point. You are just giving them a chance to practice using their property data table again here to narrow down possible candidates. The key punchline in this sense making is that the gas in each test tube must be a different substance, and therefore must be made of different particles because they had different flammability (a different property).

In the end of the next lesson students will use Dalton's line of reasoning to identify that these gases must be hydrogen and oxygen. Some students may make that inference now, based on previous things they have heard about the composition of water particles, outside of this unit. Some students may also say that this gas in test tube B behaves like the gas from the elephant's toothpaste investigation from Lesson 6. For any of these ideas that students raise, encourage them to write them down so we can talk about them further as a class at a later point.

Connecting to mass data. Show **slide E**. Say, *When other scientists have done these types of investigations, they also took measurements to see if the amount of matter in the system changed. They have collected such measurements in a closed system. They found that the mass of everything in the system before adding electrical energy was the same as the mass of everything in the system after the gas was produced.* Continue with a short discussion using the dialog below as a guide.

Suggested prompts	Sample student responses
How does this result compare to what we found in the bath bomb system in the soda bottle?	*The mass of our soda bottle didn't change either.*
What does that tell us about where the matter that makes up the gas particles is coming from in all of these systems?	*The matter that makes up the gas particles must come from the matter that was there to begin with.*



Reflect on what we have figured out. Direct students attention to the *Adding Energy to Water Investigations* poster. Say, *If we look back at our Adding Energy to Water Investigations poster, we can see that we wanted to do these investigations to see if they could help us figure out more about what is happening with the particles that make up substances.*

4. Constructing an Explanation

10 MIN

Materials: *Some Common Gases* from Lesson 5, science notebook

Preparing to construct an explanation. Show **slide F**. Have students take out a clean sheet of paper. Have students record the question on the top of the paper. Tell students they are going to take a couple of minutes to construct an explanation to answer the question: "When energy from a battery was added to water, were the gases produced by this made of the same particles as were produced from heating the water?" They should use data they have in their notebooks from the investigations and any key model ideas in their explanation. Remind students to reference *Some Common Gases* as they develop an answer to that question. Give students 7 minutes to complete this and collect it before they leave.

Assessment Opportunity

Building towards: 10.A Students apply scientific ideas and evidence (property data) to construct an explanation for whether the gas(es) produced from water using energy from a battery were made of the same particles (patterns) as those produced from heating the water.

When to look for: See *Sample Student Response for Written Explanation* for guidance.

What to do: See *Sample Student Response for Written Explanation* for guidance.

Go over to the *Adding Energy to Water Investigations* poster. Direct students' attention to this poster. And add sticky notes with check marks to both of the ideas for investigations the class has now completed.

Say, *Let's take stock of where we are. We have tried both of the investigations we wanted to do with water based on what we read about. And you all just constructed an explanation based on evidence we collected that new types of particles were produced from water particles in one of the investigations. That seems directly related to the key idea we summarized at the end of Lesson 8, related to what had shown on our* What is happening with particles when new substances are made? *poster. In our next class let's revisit that poster and evaluate those ideas in light of the explanations you constructed.*

LESSON 11

How do Dalton's models of the particles that change in a reaction compare to the ones we developed?

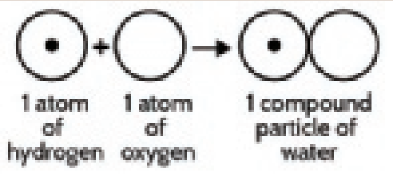
Previous Lesson

We carried out an investigation to test the flammability of gases produced by providing energy to water with electricity. We constructed an explanation for whether the gas(es) produced from water using energy from a battery were made of the same particles as those produced from heating the water.

This Lesson

Investigation

2 days



We gather and summarize information from a reading on investigations that Dalton and other scientists did and compare the models they developed for the particles that get broken apart, rearranged, and put together in chemical reactions to the models we developed. We use Dalton's models to represent what happens with water molecules during the electrolysis lab.

Next Lesson

We will revise our consensus model with the molecules of the reactants and the gas produced from the bath bomb. We will explain how other possible products could be produced in this chemical reaction. We will develop a model to represent what is happening to particles in different chemical processes. We will revisit the Driving Question Board (DQB) to identify questions we made progress on.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

11.A Gather and communicate information from a scientific text adapted for classroom use to determine the central ideas of Dalton's atomic theory with regard to the patterns in the particulate structure of matter that makes up all substances.

11.B **Construct an explanation using models of** the molecular structures of different substances to predict which gas must be produced (effect) in the bath bomb reaction based on the types of atoms that make up the substances (patterns), and use it to explain what is happening to the particles (matter) in the system to cause the production of this new substance.

What Students Will Figure Out

- Molecules are made of atoms and all the substances in our world are made of very few types of atoms.
- The same substance is made of the same type of molecules (or atoms throughout). The number, type, and arrangement of atoms in the molecules that make up a substance are unique to that substance.

- In a chemical reaction, the particles that make up old substances can be broken apart and the atoms that make them up can be rearranged to form new molecules to make new substances.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION: INDIVIDUAL PREDICTIONS** Share individual predictions and connections about whether particles of other substances (besides water) can be broken down into smaller pieces.	A	What is happening with particles when new substances are made? poster, Key Model Ideas chart
2	6 min	**SETTING GOALS FOR THE READING AND ENGAGING IN THE FIRST PART** Read and annotate an historical reading about Dalton and his questions, investigations, and findings as he developed ideas about the particles of a substance.	B	*A summary of some historical investigations and discoveries into the particle nature of matter*, *Some Common Gases*, white board, markers
3	9 min	**ENGAGING IN THE 2ND PART OF THE READING** Continue to read more about Dalton's work and annotate the reading.	C	*A summary of some historical investigations and discoveries into the particle nature of matter*
4	5 min	**ADDING TO INDIVIDUAL PROGRESS TRACKERS** Add science ideas from the reading to the individual Progress Trackers	D	*A summary of some historical investigations and discoveries into the particle nature of matter*
5	15 min	**USE ATOMS TO REVISE OUR CLASS PARTICLE MODELS** Move to a Scientists Circle to share ideas.	E-G	*Representing Dalton's Atoms in Different Molecular Models of Water*, chart paper, markers, Key Model Ideas chart, What is happening to particles when new substances are made? poster
				End of day 1
6	7 min	**NAVIGATION** Continue making sense of what happens to the atoms of water molecules when energy from a battery is added and two gases are made.	G–H	
7	10 min	**EXPLORATION OF MOLECULAR MODELS** Discuss various types of models to represent atoms and molecules. Discuss strengths and limitations of different model types.	I–J	scratch paper
8	5 min	**COMPARE MOLECULAR STRUCTURES OF OTHER SUBSTANCES** Facilitate a brief Consensus Discussion to review ideas the class has figured out.	K	a copy of *Molecular Models of Different Substances*

Part	Duration	Summary	Slide	Materials
9	5 min	**REVIEW WHAT WE KNOW ABOUT THE SUBSTANCES IN THE BATH BOMB CHEMICAL REACTION** Facilitate a brief Consensus Discussion to review ideas the class has figured out.	L	
10	18 min	**USE MOLECULAR MODELS TO REVISE AN EXPLANATION OF THE ANCHORING PHENOMENON** Revise explanations of the anchoring phenomenon using molecular models.	M	*Constructing a revised explanation*
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 11, students are ready to read Student Reader Collection 4 and then respond to the writing exercise.		Student Reader Collection 4: *Combinations of Atoms*

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *A summary of some historical investigations and discoveries into the particle nature of matter* • *Some Common Gases* • science notebook • *Representing Dalton's Atoms in Different Molecular Models of Water* • a copy of *Molecular Models of Different Substances* • *Constructing a revised explanation*	• scratch paper	• What is happening with particles when new substances are made? Poster • Key Model Ideas chart • white board • markers • chart paper • What is happening to particles when new substances are made? poster

Online Resources

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

You will need to have 5–10 blue circles per class cut out from *Circles as Particles* for students to use as they share their ideas to represent what happened to the water particles in the electrolysis investigation.

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

We will be introduced to many of Dalton's ideas related to atomic theory. These ideas will not be new to students. Most of these concepts simply formalize and confirm the ideas we have built up from trying to make sense of phenomena up to this point. They also introduce scientific names to a few things we have been talking about. For example, students learn to refer to smaller particles as "atoms" and clusters of these smaller particles as "compound particles" or "molecules."

Future lessons in this unit will continue to distinguish between atoms and molecules when referring to particles that make up matter. Ideas about what changes are occurring to this matter will also be discussed.

The idea that in a chemical reaction the particles that make up old substances can be broken apart and the atoms that make them up can be rearranged into new compound particles (molecules) to make new substances was drafted in an earlier lesson, without naming the particles as atoms or molecules. The updated description of what is happening to the matter in a chemical reaction, as discussed in this lesson, will be revisited in subsequent units, such as *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit)*, *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)* and *Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*.

Where We Are NOT Going

We use the word "compound" as an adjective to describe a type of particle that is made of more than one smaller piece (atom) in a way that is analogous to how the term is used for describing "compound words" in language, rather than emphasizing the scientific definition of a "compound," which is a substance composed of two or more separate elements. We do not introduce the word "element" in this lesson.

Some of the molecular models students work on in day 2 show representations of the bonds between atoms within molecules as lines. Other models do not represent bonds. No effort is made to discuss what the lines in the models show, other than as a geometric arrangement and orientation. Bonds are a concept that is not introduced in this unit. They are not discussed in other units either, as they are a high school disciplinary core idea.

LEARNING PLAN FOR LESSON 11

1. Navigation: Individual Predictions

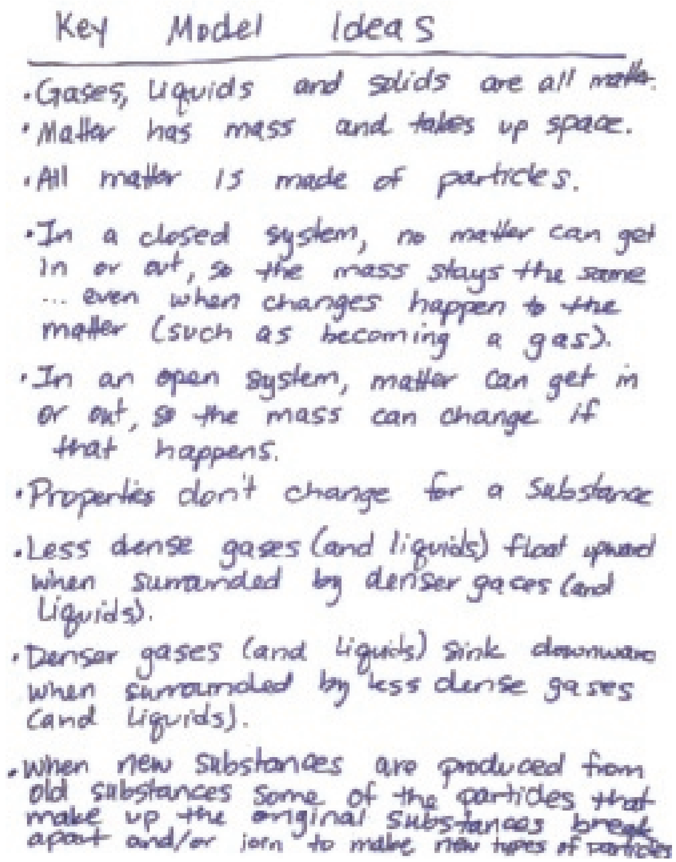
10 MIN

Materials: What is happening with particles when new substances are made? poster, Key Model Ideas chart

Hand back students' explanations that they turned in last time.

Convene a Scientists Circle. Show **slide A.** Have students gather into a Scientists Circle around the *What is happening with particles when new substances are made?* poster and the *Key Model Ideas* chart that was added to in Lesson 8.

Say, *Last time you all constructed an explanation based on evidence we collected that new types of particles were produced from water particles in one of the investigations. That seems directly related to the key model idea we summarized related to the models we had shown on our* What is happening with particles when new substances are made? *poster. Let's review and evaluate that new key model idea and see whether this poster captures all of our current thinking.*



Refer to the *What is happening with particles when new substances are made?* poster and the *Key Model Ideas* chart that was added in Lesson 8:

- When new substances are produced from old substances, some of the particles that make up the original substances break apart and/or join together to make different types of particles.

Ask students to evaluate this idea as written to see whether it could explain what is happening to the water particles when energy from a battery is added to it. Use the following prompts to guide this discussion.

Suggested prompt	Sample student response
So in the investigation from last class when we added energy from a battery to water, how many different new substances did we produce?	*We produced two new gases (at least).*

Suggested prompt	Sample student responses
When we made this poster we were brainstorming how the particles in the different substances in the bath bomb could interact together to end up creating particles to produce (at least) one new substance. But in our last investigation with the battery and water, we started with only one substance, added energy to it, and ended up with two different substances. Is this idea, that one particle can produce two new substances, represented on our poster?	*No.* *We only showed what we think might happen when multiple particles are combined together.*

Say, *Let's think about how we could add this to our poster to represent what could be happening at a particle level. Let's start with how we represented water particles last time, which was using blue circles. Talk with a partner first to discuss how you could use the same manipulatives we used before to represent a water particle, a blue circle, to make two different kinds of particles from this one type of particle.*

After a couple of minutes pause and have students report out.

Anticipate students suggesting either the first or both of these possibilities:

1. Ripping a water particle into smaller pieces.
2. Ripping a water particle into smaller pieces and sticking/recombining those pieces together into different shapes/combinations.

Follow up each line of ideas that students raise by giving those students some cut out paper blue circles to demonstrate their thinking to the whole class. After they do so, use tape to add a representation of what they show to the poster. You may need to add an extra piece of chart paper to the bottom of the poster to do this.

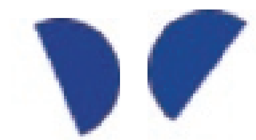
Follow up with asking other students to articulate this idea in words, so that you can capture a description of what they say is happening to the second column of the poster.

Suggested prompts	Sample student responses
What could you do with a water particle representing a blue circle to make two different kinds of particles out of it?	*Rip it into two different parts.*
How could we do this and still show that we are getting different types of particles to account for two different substances that were produced?	*We don't have to rip it in half. We could rip them into a smaller and bigger piece. Each piece is a different type of particle.*
How would others describe this idea in words? What are we saying could be happening to the water particles when energy from a battery is added?	*The energy from the battery could cause a water particle to break apart into smaller pieces.*
What does each different kind of piece represent?	*A particle of one of the substances. And a particle of the other substance.*

Make sure this idea is added to the poster in pictures and words before seeing if students have a second possible idea. Some classes might not. That is OK. Ask the first question below to see if they do. If they do, then follow up with the subsequent questions.

Suggested prompts	Sample student responses
What else could happen to the broken up pieces that could still result in making new types of particles?	*Maybe they combine back together in different ways, to make different shaped particles made of some of the pieces.*
How would others describe this idea in words? What are we saying could be happening to the water particles when energy from a battery is added?	*The energy from the battery could cause the water particles to break apart into smaller pieces and then those smaller pieces connect together in different arrangements.*

If this idea is one students came up with, make sure it is added to the poster in pictures and words too. One example of how this might look on the poster is represented below:

Before adding energy from a battery	What happens to the water particle	After
	The water particle comes apart to make two new particles.	

Ask students to reevaluate the last key model idea that was added to the *Key Model Ideas* chart in Lesson 8 and see if it still describes the entire set of ways that starting particles of substances can interact to produce new types of particles.

Students will suggest that we need to modify the phrase "old/original substances" to show that it can either be singular or plural. Add that modification to the key model idea, using your class's suggestions (crossing part of it out, adding annotations with a caret, or rewriting the model idea completely). One possible revision is shown below, with the underlined text showing the new addition.

- When new substances are produced from <u>one or more</u> old substances some of the particles that make up the original substance(s) break apart and/or join together to make different types of particles.

Introduce the term "chemical reaction." Say, this key model idea we developed is one that scientists refer to as a chemical reaction. Let's add this new term next to our key model idea.

- When new substances are produced from <u>one or more</u> old substances some of the particles that make up the original substance(s) break apart and/or join together to make different types of particles **= a chemical reaction.**

Compare this type of particle level change to a phase change. Say, *In a chemical reaction, the type of particle level change that is occurring is different from what we would say is happening when we boil water. What do we know happens to the particles of water when we increase their temperature as they change from liquid water to water vapor?*

Based on prior work in *Storms Unit* students should say things like:

- They speed up.
- They spread apart.

- They go into the air.
- They break away from neighboring water particles in the liquid.

Emphasize that in this process, we have evidence from Lesson 9 that no new substances were made, which is why we know the water particle itself never changed. Summarize that this is why we consider boiling and condensing a phase change, but it is not considered a chemical reaction, because no new types of particles are created and no new substance was produced.

Say, *So we developed and revised a particle base model to try to explain how new substances can be produced from old substances in a chemical reaction, like the bath bomb when added to water or when we added energy to water with a battery. Dalton also developed a set of model ideas about what is happening at a particle level based on similar experiments with electricity and water. He revised these ideas over time as did other scientists who contributed to the development of that model. Let's read some more about what Dalton figured out and see how his models compare to our models for what is happening to particles when chemical reactions occur.*

2. Setting Goals for the Reading and Engaging in the First Part

6 MIN

Materials: *A summary of some historical investigations and discoveries into the particle nature of matter, Some Common Gases*, science notebook, white board, markers

Frame the purpose of the reading.* Have students return to their regular seats. Display **slide B.** Say, *I have a reading that summarizes some of the results and discoveries from Dalton and other scientists. Similar to other times you have read informational text, it can be helpful to identify a particular question or questions you want to try to answer before starting the reading. This helps you look for different things in the text than if you didn't have a framing question or questions. And if you get a reading that it is OK to write or highlight on, it is also helpful to write that question or questions at the top of the text you are about to read. Please do that with this reading. Write our question from this slide at the top of the copy of the reading you will be getting:* ***"How do Dalton's models of the particles that change in a chemical reaction compare to the ones we developed?"***

*** Attending to Equity**

Supporting Universal Design for Learning: This reading is multiple pages of informational text. For some students, such as Emerging Multilingual Learners or students who need reading support, creating an audio recording as an alternate *representation* of this text that these students can listen to as they follow along on the reading can help students access the text.

Additional Guidance

There are two copies of each reading. One copy is the color copy located in the back of the Student Edition behind the reading section. The other copy is a handout to download and print. If you want students to mark the text, they can use the handout version. Otherwise, students can read the text using their Student Editions. The readings include: *A summary of some historical investigations and discoveries into the particle nature of matter.*

Assessment Opportunity

Building towards: 11.A Gather and communicate information from a scientific text adapted for classroom use to determine the central ideas of Dalton's atomic theory with regard to the patterns in the particulate structure of matter that makes up all substances.

What to look for: Students highlighting and annotating pieces from the reading about how Dalton and others represented atoms and molecules. Once they have finished the reading, they should record what they have figured out about how their representations of particles (molecules) and parts of particles (atoms) relates to what Dalton and his colleagues used as explained in the reading.

What to do: If you find some students going straight to highlighting, remind them to engage in step 1 first (reading through one page), as it is a strategy useful for making sense of any text they read. If you find some students not interacting with their reading after a few minutes, again, quietly go up to them and ask to look over the annotations they made so far. If they have a couple of annotations made, give them positive feedback (e.g., a thumbs up) and then encourage them to start thinking about how these ideas might be used to explain what is happening with the bath bombs.

Distribute copies of *A summary of some historical investigations and discoveries into the particle nature of matter*. Say, *As you are reading, look for connections that help answer this question.*

Say, *When you are done, I want to collect this reading from you to assess your progress toward interacting with the text in ways that are helping you develop answers to the questions we are trying to make progress on as a class. First, let's work with a small part of the text to start with to practice this.*

Summarize the steps of the reading protocol on the slide. Ask if there are any questions. Say, *Read the first page of the reading, pausing to think about and answer the two questions. Be ready to share your ideas.*

Monitor student reading. Give students about 5 minutes to complete the protocol.

Share out ideas. Ask students to share some examples of connections they found and their predictions for the two gases they identified as being produced from the battery investigation. Listen for ideas related to the introduction of atoms as smaller particles or pieces that make up larger particles. Help foreground that the term atom gives a name to an idea we previously developed in Lesson 8—that there might be smaller pieces that can be broken off of bigger particles—and in this case, it looks like atoms are the smaller pieces.

Additional Guidance

Students may make connections to many everyday phenomena. This is great if they do. It is likely that students may have heard the word "atom" before. However, since this is the first time it has been introduced in a unit, it is important to make sense of it together as a class, in the context of how it was introduced.

3. Engaging in the 2nd Part of the Reading

9 MIN

Materials: *A summary of some historical investigations and discoveries into the particle nature of matter*

Display slide C. Say, *Continue to use these reading strategies with the remaining text.* Remind students that you would like to collect their handout at the end of class to assess their progress on working with text to help answer the lesson question.

Monitor students as they read and annotate.*

*** Attending to Equity**
Instead of waiting until the end of the period to review and assess the student work to engage in this practice, use this window of independent work time to

4. Adding to Individual Progress Trackers 5 MIN

Materials: science notebook, *A summary of some historical investigations and discoveries into the particle nature of matter*

Update individual Progress Trackers. Show **slide D.** Encourage students to keep their annotated copy of *A summary of some historical investigations and discoveries into the particle nature of matter* out to refer to as they do this.

Give students the remaining time to update their individual Progress Trackers.

In preparation for the next step, look at a few samples of student entries as they are writing. This will help you get a sense of some of the ideas you will have to work with in preparation for the next step.

5. Use atoms to revise our class particle models. 15 MIN

Materials: science notebook, *Representing Dalton's Atoms in Different Molecular Models of Water*, chart paper, markers, Key Model Ideas chart, What is happening to particles when new substances are made? poster

Facilitate a Consensus Discussion. Show **slide E.** Move to a Scientists Circle and ask students to bring their science notebooks. Have them turn to the last entry in their Progress Trackers.

Emphasize that the goal of this discussion will be for them to share what they figured out and have recorded in response to the question in their Progress Trackers.*

Key Ideas

Purpose of this discussion

- Develop a shared set of ideas about atoms, molecules, chemical reactions, and substances and add them to the *Key Model Ideas* chart.
- Connect these to the *What is happening to particles when new substances are made?* poster the class has developed so far.

Listen for and help foreground key model ideas similar to these:

- Particles are made of molecules and atoms.
- Molecules are made of more than one atom connected together.
- There are only a few types of atoms that make up all the many different substances (and types of molecules) in our world.
- In a chemical reaction, the molecules that make up old substances can be broken apart and the atoms that make them up can be rearranged into new molecules to make new substances.

It is also possible that students will raise this idea:

- Atoms are really small particles that can't be divided or destroyed.

If they do, add this idea. If other students suggest that this may not be true based on other phenomena they have heard of related to nuclear processes, you could suggest that we modify the idea to say:

identify individual students in need of additional coaching. It's important to do this coaching very subtly so as not to distract other students or draw attention to the students you see could use some more guidance. If you find some students going straight to highlighting, quietly approach and squat down to talk with and help redirect them so no other students can hear. Remind them to engage in step 1 first, as it is a strategy useful for making sense of any text they read. If you find some students not interacting with their reading after a few minutes, again, quietly go up to them and ask to look over the annotations they made so far. If they have a couple of annotations made, give them positive feedback (e.g., a thumbs up) and then encourage them to start thinking about how these ideas might be used to explain what is happening with the bath bombs. If they have neglected to make annotations on pages 1 or 3, ask them to revisit those pages to see if they can document one important connection on each.

*** Strategies for This Consensus Discussion**

Since the framing question of the Progress Tracker was "How do Dalton's models of the particles that change in a chemical reaction compare to the ones we developed?", responses that make

- Atoms are really small particles that can't be divided or destroyed in chemical reactions or through phase changes.

It is also possible a student will suggest this idea:

- When a chemical reaction occurs, energy is added to one or more substances.

Ask other students to weigh in on this. Ask them to consider if that happened with all phenomena we investigated where we made a new substance from old substances. This will likely help them recall that this did not happen with the bath bomb (the temperature actually decreased in the system).

Connect these ideas to what is shown in the *What is happening to particles when new substances are made?* poster. Use the Suggested prompt below to help identify the parts of the model that we can see are relevant to using these new ideas.

Suggested prompts	Sample student responses
Earlier today we added some rows to this poster to show what happens to water particles when energy is added from a battery. Where is a molecule of water shown in this?	*The water molecules are represented by the blue circles that were just added to the poster.*
Where were we showing that it could be broken into smaller pieces like atoms?	*The torn up pieces of the blue circles.*
How many types of atoms did Dalton think made up a water molecule?	*Two.*
What were they?	*Hydrogen and oxygen.*
Where in our model does it show that the molecules of water are breaking apart and the atoms that made them up are forming new substances?	*That is what we described in words and pictures, but we didn't call the pieces "atoms" and didn't call the starting and ending particles "molecules."*

Say, *OK, so if our pieces of the blue circles we were using to represent the same basic ideas that Dalton figured out, about molecules and atoms, then we should be able to use Dalton's representation to represent our thinking.*

Display slide F. Distribute *Representing Dalton's Atoms in Different Molecular Models of Water*. Say, *This was how Dalton initially represented a molecule of water. Though this model for a molecule of water has been revised since then, let's start with Dalton's model of a molecule of water and see if we can use it to represent what we think is happening to the particles when we add energy from a battery to water.*

Encourage students to think on their own about this question and then ask students to share their ideas. Students will say, *The water molecule must come apart into atoms that end up forming two new substances that are gases—hydrogen and oxygen.*

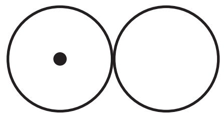
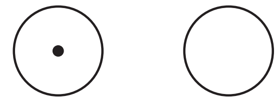
Prompt students to write that in column 2 of row 1 of *Representing Dalton's Atoms in Different Molecular Models of Water.* Then ask, *How would you represent that in the 3rd column, which shows the outputs of this process? How would we represent the differences in the resulting particles that make up these two different gases?* Students should say, *Draw the two circles separated from each other and one of the circles should have a dot in the middle and the other should*

clear connections to this question are what you are looking for. It is important that ideas are suggested and you ask everyone to weigh in on each proposed idea (e.g., they should consider if they had a similar idea). If so, have them give a non-verbal signal (like a shaking thumb). It is also important for students to work on restating and re-phrasing the ideas suggested before you write it down. Revise these ideas as students make suggestions that others in class agree would help clarify the proposed idea.

Don't have students write the ideas down again at this time. They already have a draft of these in their individual Progress Trackers. Have them work on listening and linking to the ideas that other people share.

*** Supporting Students in Developing and Using Systems and System Models**

Making this connection here can help foreground that this input, output, and process thinking is generalizable, not just so it can be reused in this unit, but also so students are reminded of it as a crosscutting concept that can be useful in other domains and systems. This also helps students get ready to work with more abstract representations of molecules and atoms in *not*. Emphasize that the separation of the original two-atom molecule into two separate atoms that are each their own different particle is what we need to show. Prompt students to record that. An example is below:

Particle Model	Particle(s) in the starting substance (water)	What happens to the particle(s) when energy was added from a battery	Particle(s) in the new substance that are produced
#1	 one molecule of water	The water molecule must come apart into atoms that end up forming two new substances that are gases—hydrogen and oxygen.	

Listen for whether students suggest we should "tear atoms into smaller pieces too." Ask what others think about this, in light of what Dalton and others were modeling. Students should say that from the reading we found out, "*Scientists decided that atoms cannot be divided and cannot be destroyed, even in a chemical reaction.*"

Connect this to input and output thinking. Say, *OK so we just used Dalton's initial model of a water molecule to represent the inputs of this chemical reaction, the outputs, and what is happening to the matter in this process. We used this input, output, and process thinking to represent what is happening to a water molecule and the two types of atoms that make it up that can explain how two new substances are produced. This type of thinking has been really helpful for us over the entire unit and has been useful in other units of study too. Let's keep using this input, output, and process thinking for making sense of what is happening in every model of a chemical reaction we develop and use.**

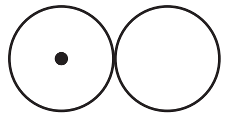
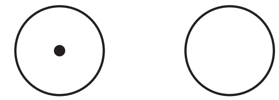
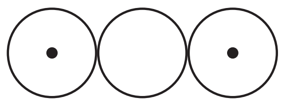
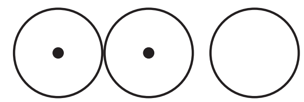
Introduce a second particle model of water. Say, *But the reading also suggests that this model of a water molecule was later revised based on additional evidence. How did scientists revise that model to show that though they still thought water molecules are made of hydrogen and oxygen atoms, there are actually three total atoms in each water molecule? How many atoms of hydrogen were there in it? How many atoms of oxygen?*

Students will say, *2 hydrogen atoms and 1 oxygen atom.* If students are not sure, encourage students to reference their reading again.

Show slide G. Say, *Let's revise our model for water based on this information using the same atom symbols that Dalton originally used.* Instruct students to work with a partner to complete row 2 of the table, describing and showing what must happen to the atoms in this water model of a water molecule to produce two new substances—hydrogen and oxygen.

Give students two minutes to work with a partner. An example is below:

chemical formulas and the related symbolic representations used in chemical reactions in future lessons (and grades). It can help them see that the reactants in a chemical reaction are the inputs, the products are outputs, and the arrow between them represents an implied process (atom rearrangement). Making regular connections to input, output, and process thinking in this unit will also lay an important foundation to thinking about energy changes in the system occurring along with the matter changes in chemical reactions, which will be a new aspect of chemical reaction related phenomena introduced in the next unit of study in *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit).*

Particle Model	Particle(s) in the starting substance (water)	What happens to the particle(s) when energy was added from a battery	Particle(s) in the new substance that are produced
#1	 one molecule of water	The water molecule must come apart into atoms that end up forming two new substances that are gases—hydrogen and oxygen.	 hydrogen and oxygen gas
#2	 one molecule of water	The water molecule must come apart into atoms that end up forming two new substances that are gases—hydrogen and oxygen.	 hydrogen and oxygen gas

Wrap up by saying, *Let's keep developing these models over time, and start thinking about how this idea of atoms could help us refine our model for what is happening to the particles that make the substances in a bath bomb.*

If time was short and you didn't get to this introduction to a second particle model of water, start with that next time, rather than starting with the third particle model of water, which is how the next day of this lesson starts off.

End of day 1

6. Navigation

7 MIN

Materials: None

Orient students to where we left off. Show slide G again. Ask students to share what they showed happening to this model of a water molecule that can still explain how two new substances are produced when energy from a battery is added to water. Students will say, *The water molecule must come apart into atoms that end forming two new substances that are gases—hydrogen and oxygen.*

Say, As scientists started to revise their models of water to include more atoms of hydrogen, they also found evidence that oxygen gas and hydrogen gas are also made of more than one atom. Show **slide H**. Say, *Here is what they currently think a single molecule of hydrogen gas and a single molecule of oxygen gas is made of.* Ask students what they notice. Students will say they are each made of two of the same type of atom (hydrogen or oxygen) connected together. This is the example from slide H:

Hydrogen gas Oxygen gas

Introduce the third modeling task. Keep **slide H** displayed**.** Say, *On the slide is a representation of hydrogen gas and oxygen gas using the atom representations that Dalton used. Draw these two gas molecules in the last box of the third row of your handout. Think about this: If we draw just one water molecule in the first box, will we have enough atoms to make these two gases? Talk with an elbow partner about how many water molecules you would need to be able to make these two gases.*

Give about a couple of minutes for students to work on this. Students may point out that they don't have enough atoms to make both gases, and/or if they have more water molecules then they have left over atoms. Or they may ask what to do with the leftover atoms that are in the water molecules that don't become hydrogen molecules or oxygen molecules. If they do, emphasize that this is an excellent critique of the model, since it suggests that they are using the idea that atoms can't just disappear or come out of nowhere in chemical reactions, which is a key model idea that Dalton developed as well.

Revise our definition of a chemical reaction. Refer students to the key model idea for this that you updated at the start of the lesson. Say, *OK, based on the work we are doing here with representing and manipulating molecules and atoms, let's update our definition of a chemical reaction to reflect this. What part of our previous definition for a chemical reaction should refer to atoms? What part should refer to molecules?*

Look for students to suggest the underlined changes and crossed off word changes to the definition shown below. Update this definition as a class on the *Key Model Ideas* chart:

- When new substances are produced from one or more molecules of the old substances, some of the atoms ~~particles~~ that make up the molecules of the original substance(s) break apart and/or join together to make different types of molecules ~~particles~~ **= a chemical reaction.**

7. Exploration of Molecular Models

10 MIN

Materials: science notebook, scratch paper

Connect to why looking at alternate molecular models could be useful: *We started our own way of representing particles with different colored circles and we saw that Dalton also came up with his own way to represent them. Since then, scientists have revised Dalton's model and have come up with quite a few different ways to represent atoms and molecules. Some of these might be ones we find useful as we develop our final models and explanations for what is happening in our bath bomb, while others may be ones that we find less useful. Let's get ready to compare and evaluate some of these representations.*

Compare molecular models of water. Show **slide I.** Prompt students to turn and talk with a partner about the patterns they notice between the different models of water. Bring students back together after three minutes. Help students articulate patterns such as these:

- In every case, atoms are represented as parts of a whole molecule.
- Different atoms are represented with letters and/or a different color or shape (e.g., a circle).
- In some cases, the atoms are shown connected in a certain order together but not in other cases (e.g., the chemical formula).
- Small numbers are used in the chemical formula to indicate how many of a particular type of atom there is in the molecule, if there isn't just one of it.
- Large numbers are used before the chemical formula to indicate how many molecules there are, if there isn't just one of it.

Interpret and extend the chemical formula notation. Help students extend the number representation in the chemical formula and recognize limitations and advantages of the chemical formula model. Use the Suggested prompt below.

Suggested prompts	Sample student responses
In the models included on the slide, the chemical formula for water is written as H_2O. What does the small 2 between the H and O represent?	*It represents two hydrogen atoms.*
OK, so if the 2 indicates how many of the hydrogen atoms there are in one molecule of water, then why do you think there isn't a number after the oxygen?	*Maybe when there is only one of an atom in a molecule you don't need to write a 1, like in math when we are working with variables.*
OK, so what does the 3 represent in the next column, where it says $3H_2O$?	*It represents three molecules of water.*
How would we represent five molecules of water?	*$5H_2O$*

Introduce how this notation can be used to represent the molecules of a different substance, hydrogen peroxide.

Suggested prompts	Sample student responses
There is a different substance that we saw in Lesson 6 that has the same type of atoms in it as water, but has a different number of atoms in every molecule of it. That substance is hydrogen peroxide. One molecule of hydrogen peroxide has two atoms of hydrogen and two atoms of oxygen in it. How would we write that in chemical formula notation?	*H_2O_2 (Write and label this response on the board.)*

Write and label this response on the board:

- H_2O_2 = one molecule of hydrogen peroxide

Use this notation to represent a larger number of molecules of each substance. Show **slide J.** Have students write their responses on scratch paper (or small dry erase boards if you have them). Check what students write. Students should show the following:

- $7H_2O$ = seven molecules of water
- $10H_2O_2$ = ten molecules of hydrogen peroxide

Emphasize that there may be tradeoffs in using this type of model. Say, *There may be some tradeoffs to using this type of model to represent the number of atoms in a molecule and the number of molecules in a system compared to the other models shown on the slide. Let's look at other molecular models for some other substances to get a sense of what some of those tradeoffs might be.*

8. Compare molecular structures of other substances. 5 MIN

Materials: science notebook, a copy of *Molecular Models of Different Substances*

Compare molecular models of other substances. Show **slide K.** Pass out copies of *Molecular Models of Different Substances* to students. Give students five minutes to compare the molecular structures in small groups.

Additional Guidance

There are two copies of this handout in case you do not have the capability to print the handout in color. One copy is the color copy located in the back of the Student Edition behind the reading section as a reference. The other copy is a handout to download and print. If you want students to mark the text, they can use the handout version. Otherwise, students can read the text using their Student Editions. The handout includes colored molecular representations that may be difficult to distinguish if printed in just black and white. Another option is to print a class set with one color copy per group that is placed in a sheet protector. These can be used over and over again. The handout is *Molecular Models of Different Substances* and the reference is *Molecular Models of Different Substances*.

9. Review what we know about the substances in the bath bomb chemical reaction. 5 MIN

Materials: science notebook

Facilitate a Consensus Discussion. Show **slide L.** This is a brief discussion designed to review things we already know. Ask students to share which combinations of these substances we know caused a gas to form. Tell students to put a star on their handout next to these in their copy of *Molecular Models of Different Substances*. Next ask students to share which of the three substances we thought the gas that was produced might have been based on data collected. Encourage them to circle the substance on their handout.

Key Ideas

Purpose of this discussion:

- Help the class recall and identify the substances we thought were involved in producing the gas from Lesson 5 and that might make up the gas.

Listen for ideas similar to these:

- We narrowed down the key substances that interacted with each other to produce the gas from water, citric acid, and sodium bicarbonate (baking soda).
- We narrowed down the possible substances that could be in the gas to these three: argon, nitrogen, and carbon dioxide.
- These are the only substances we need to look at to explain how the new substance(s) in the gas bubbles were produced.

10. Use molecular models to revise an explanation of the anchoring phenomenon. 18 MIN

Materials: science notebook, *Constructing a revised explanation*

Develop a revised explanation. Show **slide M.** Pass out copies of *Constructing a revised explanation*. Remind students that back in Lesson 1, they wrote an explanation for what is causing the gas bubbles to appear when a bath bomb is added to water. Tell them they should be able to revise their explanation of the anchoring phenomena, in light of what we have figured out in the last couple of lessons about atoms to explain what gas is produced from a bath bomb and how the molecules of the substances in the bath bomb interact through this chemical reaction to produce this gas.

Encourage students to use the resources in their notebook, the anchor charts around the room, and other key model ideas from their Progress Trackers. Let them know that they should have enough evidence and key model ideas to fully answer this question now and that you will be using this as an assessment that you will want to collect when they are done. Remind students to use the models on *Molecular Models of Different Substances* in their responses, the key model ideas posted in the room, and anything in their science notebooks to complete the assessment.

Assessment Opportunity

Building towards: 11.B Construct an explanation using models of the molecular structures of different substances to predict which gas must be produced (effect) in the bath bomb reaction based on the types of atoms that make up the substances (patterns), and use it to explain what is happening to the particles (matter) in the system to cause the production of this new substance.

What to look for: Students should be able to argue this by connecting the molecular models from *Molecular Models of Different Substances*. On this handout they can compare the atoms in baking soda, citric acid, and water to the three gases we had identified as possibly being produced (argon, nitrogen, and carbon dioxide). Using the new key model idea around chemical reactions, students should be able to argue the only possible gas it could be is carbon dioxide.

What to do: If students are struggling with these ideas, they have an opportunity to compare their predictions and explanations with their small group at the start of the next lesson. Provide feedback to those students in the form of comments or notes that direct them to compare their responses to their peers and to resolve any differences.

Give students the remaining time to work on their responses. Collect *Constructing a revised explanation* from students before they leave.

SCIENCE LITERACY: READING COLLECTION 4

Combinations of Atoms

1 **Electrolytes and Sports**

2 **Potable Water in a Pinch**

3 **Atomic Theory**

4 **Modeling Molecules**

Literacy Objectives

- ✓ Summarize key points related to atoms, molecules, and compounds.
- ✓ Determine the veracity of evidence supporting a claim.
- ✓ Contrast pros and cons of four ways to model molecules.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 9–11.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Develop a storyboard in response to the reading.

Instructional Resources

Student Reader

Collection 4

Science Literacy Student Reader, Collection 4
"Combinations of Atoms"

Exercise Page

EP 4

Science Literacy Exercise Page
EP 4

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 9: Does heating liquid water produce a new substance in the gas bubbles that appear?
- Lesson 10: When energy from a battery was added to water, were the gases produced made of the same particles as were produced from heating the water?
- Lesson 11: How do Dalton's models of the particles that change in a reaction compare to the ones we developed?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS1.A: Structure and Properties of Matter Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Scale, Proportion, and Quantity

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RT.6-8.5: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

RT.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

atom **compound** **electrolyte**

molecule

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

model

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Exercise Page

EP 4

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Chemical Reactions and Matter unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read a selection consisting of a science article and a mock advertisement about electrolytes.*
    - *Next, you'll read a simulated outdoors magazine article that describes three ways to turn potentially dangerous water into safe-to-drink water.*
    - *Then, you'll read an encyclopedia-style article surveying some of the big ideas of atomic theory along with a timeline highlighting some scientists and how they contributed to atomic theory.*
    - *Finally, you'll encounter an infographic offering three ways to visualize molecules.*

- Distribute Exercise Page 4. Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate a storyboard that could be the basis for a skit about atoms, compounds, and molecules.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What advice does the selection about electrolyte drinks give to people who play sports?	*One or two of these drinks during competition is fine, but there is no reason to completely replace water when exercising.*
What are three ways to get safe water to drink when you can't turn on a faucet?	*Set up a solar still with a sheet of plastic and a cup.* *Filter dirty water and boil it.* *Add water purification tablets to water that could be dangerous to drink.*
What's the main idea of the timeline in "Atomic Theory"?	*that scientists have been thinking about the building blocks of matter for at least 2,500 years.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How is electricity involved in "Electrolytes and Sports" and your investigations in Lesson 10?	*In Lesson 10, we investigated how electrical energy supplied to water causes two different gases to be released. In this reading, we read how certain substances dissolved in water allow electrical energy to be conducted.*
How does the selection "Atomic Theory" build on the Lesson 11 handout called "A Summary of Some Historical Investigations and Discoveries into the Particle Nature of Matter"?	*The reading selection explains that atoms have parts called electrons, protons, and neutrons.* *It also has more details on people who contributed to understanding atoms beyond Dalton and Perey.*
When we modeled molecules in Lesson 11, they were drawn as side-by-side circles—one for each atom. What are some ways the models in "Modeling Molecules" differ from what we drew?	*One shows how they share electrons, another shows relative sizes of each kind of atom, and two can show double bonds.*

Exercise Page

EP 4

- Refer students to the Exercise Page 4. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to draw a four-panel storyboard that can be used to plan a short skit about atoms.*
    - *That means you'll want to choose some of the most interesting ideas about atoms presented in this collection.*
    - *You'll also have to decide what characters will be in the skit. They can humans, other animals, even robots—whatever makes most sense for an interesting skit.*
    - *Don't worry about your drawing ability. Stick figures are perfectly acceptable in a storyboard.*
    - *If you want to use more than four panels, that's okay, too.*
    - *An important criterion for your work is that you show a plan for an interesting skit about atoms that can be followed by someone else.*
- Explain that a well-designed storyboard should have just enough detail that it can be handed off to a creative team to write and direct a skit.
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

(Friday)

Facilitate class discussion about the reading collection and writing exercise. The collection begins with an explanation of how sports drinks work to improve performance—to a degree.

Student Reader

Collection 4

Pages 34–43 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Electrolytes and Sports"?	*There are two parts to this selection. The first part is to explain how electrolyte drinks work on the body. The second part is an advertisement intended to persuade people to buy a sports drink called "Winner-ade."*
What is the importance of atoms with electrical charges in the human body?	*These ions are needed for nerves to signal muscles to contract and relax, to keep muscles from cramping, and for the brain to process information.*
Take a look at the "Spot the BS" box on page 35. How is the ad playing fast and loose with the truth about electrolytes?	*It suggests that electrolytes are more important than water when running a marathon, so people can just eat a gel and not drink. But not getting enough water when you sweat so much could be life-threatening.* *Also, when the ad says, "Why waste your time with water?" it ignores the facts that energy drinks are mostly water and that water is very important to the body.*
What is the general purpose of the second selection, "Potable Water in a Pinch"?	*It compares three methods of getting drinkable fresh water in a situation where there is no supply available.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article explains how body systems need water to function. The second article details three technologies that solve the problem of how to get safe, drinkable water to survive from seawater, swamp water, or water that may contain dangerous organisms.*
If you were to make a chart to compare and contrast the three solutions for getting drinkable water, what would be the headings at the tops of the chart columns?	*Headings: Name of device, Source of water, Advantages, Disadvantages*
What is the general purpose of the third article, "Atomic Theory"?	*It describes what's inside atoms, shows a timeline of the development of ideas about atoms, and explains that when atoms are attached to one another, they form molecules.*
How do compounds differ from the elements you read about in the Collection 2 article "The Periodic Table"?	*Elements are made of only one type of atom, while compounds are made of two or more types of atoms.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Show English learners that the prefix *electro–* means "related to electricity" and *–lyte* means "to be able to cut apart or loosen." Explain that this is related to how these substances behave when they are dissolved in water. Then have students find and list other words that contain this prefix (e.g., *electron, electronic, electromagnet*).

Pages 34–43 Suggested prompts	Sample student responses
What could you learn about atomic theory by just reading the headings and looking at the graphics in this selection?	*that atomic theory has to do with what is inside an atom* *that people have been thinking about atoms for more than 2,000 years* *that atoms combine with atoms of the same element and also with different elements to make molecules* *that those molecules arrange themselves in different ways*
Do all molecules with two or more atoms form compounds? Explain.	*No. If a molecule is made of two atoms of the same element, it is not a compound.* *Also, the word* molecule *only means the atoms share electrons.*
What is the general purpose of the fourth article, "Modeling Molecules"?	*It compares and contrasts five different compounds and four ways to model their molecules.*
What are pros and cons of each type of model?	*Formula: Pro—easy to write, shows what kinds of atoms there are; Con—does not show how the atoms are arranged* *Structural Formula: Pro—easy to draw, shows how the atoms are bonded to one another, shows what kinds of atoms, shows the type of bond; Con—arrangement of atoms is 2-dimensional* *Space-Filling Model: Pro—shows relative sizes of the atoms, looks 3-dimensional; Con—doesn't show bonds, doesn't name the kinds of atoms* *Ball-and-Stick Model: Pro—looks 3-dimensional, shows the type of bonds, shows relative sizes of the atoms; Con—doesn't name the atoms*
Which type of model is easiest to use when you want to know the total number of atoms in the molecule? Explain.	*The formula model is easiest because all you do is add up the numbers in the subscripts and, if there is no number, add 1.*

SUPPORT—Challenge interested students to research solutions to the problem of having enough potable water on board space stations and on the surface of the moon or Mars. Suggest that they search online and use a table to compare and contrast various proposed solutions.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 4, students should develop a storyboard for a skit that summarizes four main ideas from this collection of readings. Look for evidence that students used the template effectively, that they identified characters and dialogue, and that they made sure that the storyboard was easy to read by being neat and avoiding spelling and grammatical errors. While some students will put great effort and skill into drawing the characters, don't use drawing skill as a criterion for evaluation. Use the rubric provided on the Exercise Page to supply feedback to each student.

EXTEND—Some students may enjoy using a free online tool to develop their storyboards. Depending on the app they use, they may be able to use photos instead of drawing the characters and scenes.

Online Resources

How can a new substance (a gas) be produced and the total mass of the closed system not change?

Previous Lesson

We gathered and summarized information from a reading on investigations that Dalton and other scientists did and compared the models they developed for the particles that get broken apart, rearranged, and put together in chemical reactions to the models we developed. We used Dalton's models to represent what happens with water molecules during the electrolysis lab.

This Lesson

Putting Pieces Together

2 days

We revise our consensus model with the molecules of the reactants and the gas produced from the bath bomb. We explain why it could be possible that water is also a product in this chemical reaction. Using property data we argue whether one of the solids found in the container after the water has been boiled off is a new substance. We use molecular models to support this argument. We develop a model to represent what is happening to particles in three different chemical processes. We revisit the Driving Question Board (DQB) and identify which questions we have made progress on.

Next Lesson

We will carry out an investigation about the scents of different substances to see if we can identify these substances by their odors. We gathered information from a reading about how sensory receptors in our nose work. We will use what we figure out from the odor lab and the reading to write an explanation about why different substances have different odors and how we detect them.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

12.A Construct an explanation for how the atoms in the molecules of the starting substances rearrange to form new products in the bath bomb, but the number and types of atoms do not change and thus mass is conserved and evaluate two different molecular models for different ratios of reactant and product molecules to determine which better supports this explanation.

12.B Construct an explanation for whether additional substances could have been produced in the bath bomb reaction based on the patterns in the atoms that make up the molecules of the different substances.

12.C Analyze and interpret data on the properties of substances (patterns) before and after substances interact to determine if the chemical reaction that produces gas in a bath bomb also produces another new substance.

What Students Will Figure Out

- In a chemical reaction, the amount of matter at the beginning (in the reactants) is the same amount of matter at the end of the reaction (in the products). This is because all of the atoms we started with are still there. No new atoms can appear that weren't there to start with.
- Chemical reactions, phase changes, and dissolving are all chemical processes that involve rearrangement of the particles that make up the matter in the system.

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**COMPARING MODELS AND EXPLANATIONS** Gather in small groups and use a discussion protocol and *Constructing a revised explanation* to learn from classmates and get feedback on the models and explanations they created in the previous lesson.	A	completed copies of *Constructing a revised explanation*
2	10 min	**REVISITING CONSENSUS MODEL** Move to a Scientists Circle to discuss revisions to the consensus model from Lesson 7. Students work as a class to identify places to revise the model and questions that their model should answer.	B	consensus models from Lesson 7, *2-D Molecule Cutouts*
3	25 min	**INDIVIDUAL ASSESSMENT** Students will analyze the composition of the molecules of the reactants and possible products to determine what could be produced from the bath bomb in addition to carbon dioxide.	C–D	*Explaining New Aspects of the Anchoring Phenomena*
				End of day 1
4	7 min	**COMPARING AND DEVELOPING MODELS WITH A PARTNER** Partners work with molecular models to figure out what other products are made from the bath bomb.	E	*Explaining New Aspects of the Anchoring Phenomena*
5	13 min	**UPDATING OUR CLASS CONSENSUS MODEL** Partners work with molecular models to figure out what other products are made from the bath bomb.	F–G	*Comparing Molecular Ratios in a Chemical Reaction* and/or *Comparing Molecular Ratios in a Chemical Reaction*, *Explaining New Aspects of the Anchoring Phenomena*, *2-D Molecule Cutouts*
6	10 min	**TAKING STOCK OF CHEMICAL PROCESSES** Record questions for peer feedback on models. Post models and questions for review in the next class.	H	sticky notes, one copy of *Water 2-D Molecule Cutouts* (printed and cut apart ahead of time)

Part	Duration	Summary	Slide	Materials
7	10 min	**REVISIT THE DRIVING QUESTION BOARD QUESTIONS** Evaluate which additional questions on the Driving Question Board (DQB) can be answered now and which questions still need further investigation.	I	Driving Question Board, markers
8	5 min	**IDENTIFY NEXT STEPS RELATED FOR OUR ODOR RELATED QUESTIONS** Evaluate which additional questions on the DQB can be answered now and which questions still need further investigation.	J	Driving Question Board, markers

End of day 2

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • completed copies of *Constructing a revised explanation* • *Comparing Molecular Ratios in a Chemical Reaction* and/or *Comparing Molecular Ratios in a Chemical Reaction* • sticky notes	• *Explaining New Aspects of the Anchoring Phenomena* • science notebook • *2-D Molecule Cutouts*	• consensus models from Lesson 7 • *2-D Molecule Cutouts* • one copy of *Water 2-D Molecule Cutouts* (printed and cut apart ahead of time) • Driving Question Board • markers

Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prepare these cards for the Word Wall:

- **Reactants** - The original substances you start with before the chemical reaction occurs.
- **Products** - The new substances that are produced from a chemical reaction.

Prior to day 1 of the lesson, cut apart models from *2-D Molecule Cutouts*. You need one set of these to be used and reused between classes.

For day 2: *Water 2-D Molecule Cutouts*, printed and cut apart ahead of time. These paper molecular model representations will be used during a discussion about what happens differently to water molecules during different processes. You may want to print one per class so there will be enough for pairs of students to use as they make sense of the different chemical processes.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

Students will model and explain the chemical reaction of a bath bomb in water. Students will discover that the reactants in the bath bomb dissolve in water, react to make products, and that these new products have different properties than the reactants. They will figure out that the atoms and molecules that make up the products are the same atoms that were in the reactants. They will figure out that mass is conserved in this process and generalize that this concept applies to all chemical processes. They will figure out that the molecules that make the reactants and products are made from atoms and that the number, type, and arrangement of these atoms make each substance what it is.

Where We Are NOT Going

While students will be able to explain many parts of the chemical reactions, there will still be parts of the reactions that students cannot explain. The molecular structures of the substances in the reactions are simplified and ionic compounds are represented as individual particles rather than as extended structures. Students will not know that the ionic compounds dissociate in water

Balancing chemical equations, is an idea that is above grade band. A balanced equation was introduced in the middle of day 2 in the lesson to provide a model that could be used to support the idea that matter is conserved because the total number of each type of atom is conserved in chemical reaction. There is no further work with working with balanced equations in this unit.

Water is included as a reactant in the chemical equation representing the reactants and products in the chemical reaction between baking soda. This serves to help reserve a spot for water playing a role in this process, without addressing what that role is (Is it a catalyst? Does it break down and then re-form? etc.). No attempt is made to discuss the role of water further in this process.

LEARNING PLAN FOR LESSON 12

1. Comparing Models and Explanations

10 MIN

Materials: science notebook, completed copies of *Constructing a revised explanation*

Additional Guidance

Use the student ideas, models, and explanations that were demonstrated on *Constructing a revised explanation* and on *Representing Dalton's Atoms in Different Molecular Models of Water* to determine how to prioritize your interactions with the small groups during the upcoming discussion time. Note which students had incomplete or divergent understandings of concepts and visit their small group discussions early. Listen for responses to any incomplete explanations or misinterpretations from other members of these students' groups.

Small group work discussion protocol. Pass back the completed copies of *Constructing a revised explanation*. Have students meet in groups of 3–4 students. Say, *In our last class, we figured out that we could use different models to* *represent what was going on in a bath bomb. We could also use those models to explain to others what was going on. Take time now to share any questions that your models or your explanation raised by following this discussion protocol.* Have students refer to their work on *Constructing a revised explanation*.

Display slide A and read through the protocol. Give students 2 minutes to read over any comments you may have left on their handout and to read the protocol on the slide before they share with their group. Encourage them to keep each person's time to share to about 2 minutes.

<u>Discussion Protocol</u>

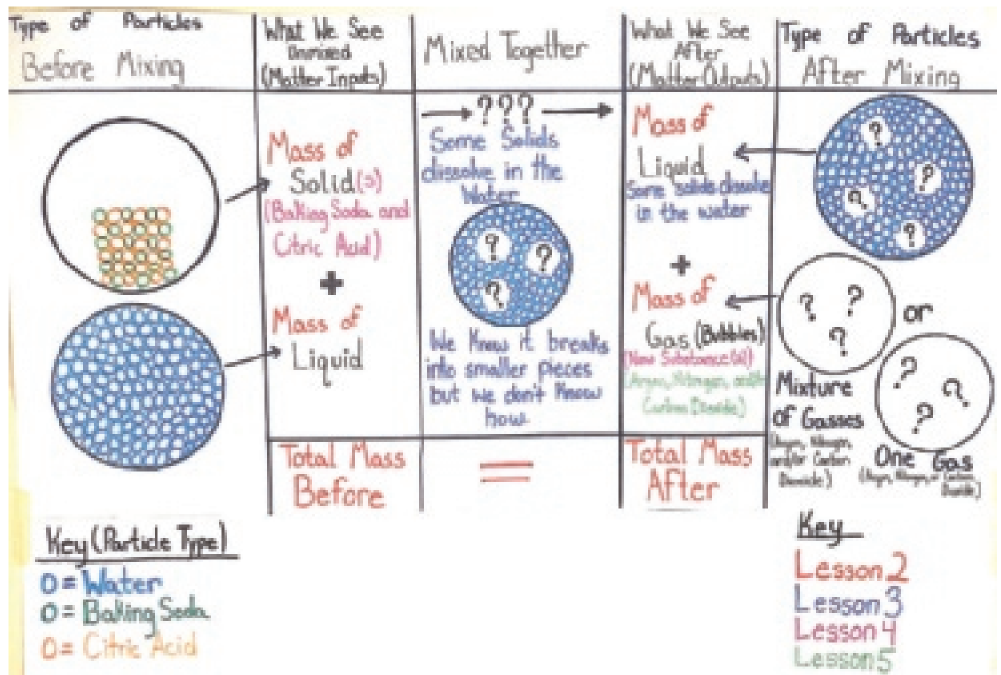
1. Decide who will go first and move clockwise around your group.
2. Share your model with the group as you use it to explain where the new molecules of the new substance come from. Be sure to explain *how* the new substance was made.
3. Discuss how your model helped you understand and explain what you cannot see because it is occurring at a scale too small to see.
4. Think about the questions you had about your model. Listen to others' ideas and see if you need to use some of their ideas to improve your model.
5. If you still have questions about how to show something in your model after everyone has shared, ask your teammates for help.

2. Revisiting Consensus Model

10 MIN

Materials: science notebook, consensus models from Lesson 7, *2-D Molecule Cutouts*

Gather in a Scientists Circle. Display **slide B.** As students gather in a Scientists Circle, call their attention to their model from Lesson 7, shown here.



Say, *The last time we updated our consensus model we came up with this representation for the chemical reaction that happens between a bath bomb and water. Take a minute to look over our model and think about more details we can add or things we need to change.*

Give students 2 minutes to think about revisions individually. Then say, *Looking at our model, the substances we start with that are represented on the left side are different than the substances we end with represented on the right side. Scientists have names for the substances we begin with and the substances that are made during a chemical reaction. The substances we start with in this chemical reaction—the baking soda, citric acid, and water—are on the left side of the poster and are called* ***reactants.*** *Why would we want to call these "reactants"?*

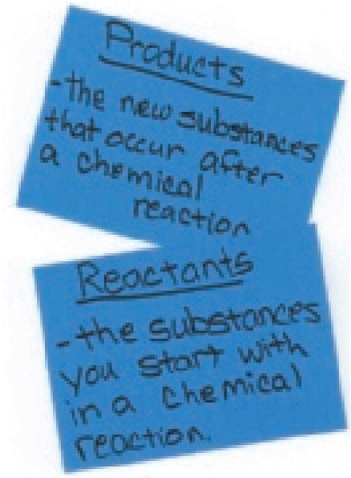
Students should say because they react when they are combined, or because a chemical reaction happens when they are combined.

Say, *We call the substance(s) that we have after the chemical reaction the* ***products****. Why would we use the word "products" to describe these substances?*

Students should say because these substances are made or produced from the chemical reaction.

Write the words "Reactants" and "Products" above the representations on the model.

Add new vocabulary to the Word Wall. Add the cards you have prepared for reactants and products to the Word Wall.



Say, *Let's go through this model and mark the places where we need to change information based on evidence we have from our investigations and readings.* Continue with a dialog similar to that below to identify places for revisions.

Suggested prompts	Sample student responses
Let's start with the reactants side of our model. We now know, with evidence, which of the bath bomb ingredients cause the gas to form and we have them on our model. And we now know more about these substances. In our current model we have each of these substances represented using different colored circles. What do we know now about the structure of the particles that make up these substances?	*We know they are not just made of one thing or one particle. They are made of many parts or pieces, so our circle representation is incorrect.* *Right, we know now that they are molecules made of different atoms.*
How could we update the structure of the particles of these substances to better represent what we know about the atoms that make up their molecules?	*We could draw or tape the molecular models we used in the last lesson to replace the single colored circles.*

Have the 3 molecules of baking soda, citric acid, and water that you cut out from *2-D Molecule Cutouts* ready.

Say, *OK, so let's revise our model and use molecular representations of each part of the reactants. I have printed and cut out some representations of molecules of citric acid, baking soda, and water like the ones you saw in Lesson 11. For simplicity's sake, let's revise the reactants part of our model by taping them up over the colored circles. And, to save on time and space, let's use only 3 molecules of baking soda, 3 molecules of citric acid, and 3 molecules of water, just to capture the idea that there isn't just one molecule of each substance, though in reality there are billions in a single gram of the substance.*

Tape the molecules up on top of the colored circles to capture this revision of the model.

Note: It is recommended that you tape the molecular models of the reactants and products on the consensus model as you work through revising the model with the class. Later in the lesson you will be prompted to remove some of these molecules, so tape them up in a way that they can be removed for this class, and then use the same process for any other sections of classes you have.

Suggested prompt	Sample student response
OK, now let's move over to the right side of our model where the products are represented. What is the one substance that is a product that we now know must be produced?	*We now know the gas that is produced is carbon dioxide.*

Suggested prompt	Sample student response
I have some representations of carbon dioxide from the same handout you used in Lesson 11. Let's revise the products part of our model by taping them up. Where would we place these?	*We should tape them up over the stuff we had shown on the right because that is where we were modeling what particles the gas was made up of.*

Update the right side of the class consensus model to replace what was there with 3 molecules of carbon dioxide. Transition to discussing the bottom right circle in the model.

Suggested prompt	Sample student responses
OK, we updated both of the circles for inputs of the chemical reaction, which are the reactants. And we updated one of the circles for the output of the chemical reactions, which is one product—the gas we know is produced. But what about this other circle on the right side of the initial model? What were we trying to show in this part of the outputs of this process?	*We were trying to show what was in the liquid that was left over after the bath bomb was done reacting with the water.* *We were trying to show what we saw in the bowl after the bath bomb was all done.*

Say, *So it sounds like we still have some things to figure out. Let's pause here and spend some time digging into some more data to help us figure out what happens in this liquid. Is it some of the molecules we started with, like the other ingredients in the bath bomb? How much of it is still water? Are there any other new substances in the liquid that weren't there before? You will work on these questions individually and then we will use what you all figured out to come to some consensus on how to further revise our model.*

3. Individual Assessment

25 MIN

Materials: *Explaining New Aspects of the Anchoring Phenomena*

Introduce the individual assessment. Display **slide C.** Handout *Explaining New Aspects of the Anchoring Phenomena* to each student. Summarize the scenario, or read question #1 aloud with students. Encourage them to underline or highlight any useful information that will help them figure out what else could be produced from the bath bomb. Say, *Use your resources, our class consensus model, and the data on the handout to answer the questions. You will turn this in before you leave class.*

Give students the rest of the class period, or 25 minutes, to complete the assessment.

Assessment Opportunity

Building towards: 12.A.1 Construct an explanation for how the atoms in the molecules of the starting substances rearrange to form new products in the bath bomb, but the number and types of atoms do not change and thus mass is conserved and evaluate two different molecular models for different ratios of reactant and product molecules to determine which better supports this explanation.

What to look for: Use scoring guidance for question 1 on *Explaining New Aspects of the Anchoring Phenomena*.

What to do: See *Explaining New Aspects of the Anchoring Phenomena* for guidance.

Assessment Opportunity

Building towards: 12.C Analyze and interpret data on the properties of substances (patterns) before and after substances interact to determine if the chemical reaction that produces gas in a bath bomb also produces another new substance.

What to look for: Use scoring guidance for question 3 on *Explaining New Aspects of the Anchoring Phenomena*.

What to do: See *Explaining New Aspects of the Anchoring Phenomena* for guidance.

Separate the individual portion of the assessment to turn in. Display **slide D.** Three minutes before the end of the period, ask students to **turn in questions 1 and 2** and tape question 3 and the last page of *Explaining New Aspects of the Anchoring Phenomena* into their student notebooks, so that they can reference next time to compare their ideas on this to a partner.

End of day 1

4. Comparing and Developing Models with a Partner

7 MIN

Materials: *Explaining New Aspects of the Anchoring Phenomena*, science notebook

Hand back the portion of *Explaining New Aspects of the Anchoring Phenomena* **you collected last period.**

Show **slide E.** Give students at least 5 minutes to work with a partner on question 3. It is up to you if you want to collect this partner-based assessment item. Assessment guidance is provided below for either collecting the item, or simply listening in to the discussions that students are having and giving just-in-time feedback.

Assessment Opportunity

Building towards: 12.B Construct an explanation for whether additional substances could have been produced in the bath bomb reaction based on the patterns in the atoms that make up the molecules of the different substances.

What to look for: Use scoring guidance for question 3 on *Explaining New Aspects of the Anchoring Phenomena*.

What to do: See *Explaining New Aspects of the Anchoring Phenomena* for guidance.

5. Updating Our Class Consensus Model

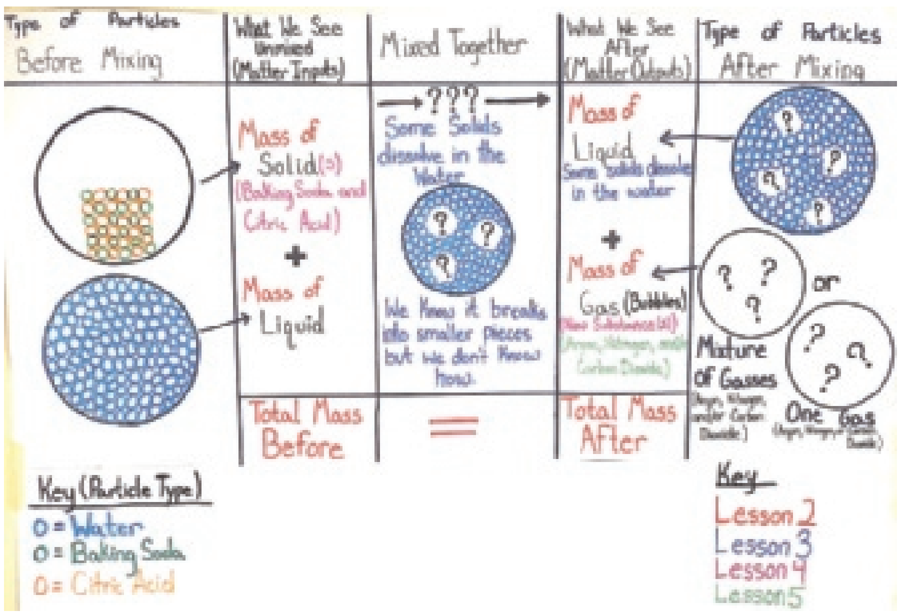
13 MIN

Materials: *Comparing Molecular Ratios in a Chemical Reaction* and/or *Comparing Molecular Ratios in a Chemical Reaction*, *Explaining New Aspects of the Anchoring Phenomena*, science notebook, *2-D Molecule Cutouts*

Convene in a Scientists Circle around the consensus model you updated the previous day. Show **slide F.** Discuss student ideas related to question 3 to further update the model.

Suggested prompts	Sample student responses
OK, let's look back on your responses to question 1. Is it possible that a chemical reaction between baking soda and citric acid could also have produced some new water molecules?	*Yes.*
Why? What is it about the structure of baking soda molecules and citric acid molecules that tells us it is possible?	*They contain hydrogen and oxygen atoms, which are the two types of atoms that make up water molecules.*
So that seems like a key idea we are going to want to add to our class model. How can we show that there are actually more water molecules in the liquid than we started with?	*We could tape up more than three water molecules in the bottom right corner of the model.*

*** Supporting Students in Developing and Using Energy and Matter**
Reinforce the idea that matter is conserved because atoms are conserved in chemical processes.



Update the right side of the class consensus model to replace what was there with 6 molecules of water. This is 3 more water molecules than you had put in the bottom left circle. Transition to discussing the bottom right circle in the model.

Suggested prompt	Sample student response
With your partner, did you come to any conclusions about what one other substance listed could also be produced from the bath bomb in addition to the carbon dioxide?	*The only substance that could be produced is sodium citrate.*

Suggested prompts	Sample student responses
Do other groups agree with this? Or did you find that one of the other options could have been produced?	*We found the same. The sodium citrate is probably another product of the bath bomb reaction.*
How did you come to the conclusion sodium citrate is a product and not another substance?	*We looked at the atoms that are part of the reactants and compared them to the potential products. We know we can't make new atoms and we don't lose any atoms, so this was the only possibility that had atoms that matched.* *Yeah! We agree. The other options for the products had a nitrogen atom in their molecule. And that type of atom was not part of any of our reactants.*
So if we think this is a third new substance that is produced in the chemical reaction of the bath bomb, why don't we see this sodium citrate in the liquid? What in question 2 helps us explain that?	*If sodium citrate is the unknown white substance left over when you boil off the water, then you wouldn't see it when it is in the water, because the substance is soluble in water, which means it dissolves in water.*

Say, *OK, let's add some sodium citrate molecules to our model to show that we think there is some of that new substance in the liquid left over.*

Update the portion of the model that shows the liquid after the reaction on the right side of the class consensus model to add 1 molecule of sodium citrate interspersed with water molecules. At this point, on the right side of the model there should be carbon dioxide molecules, water molecules, and now a sodium citrate molecule.

Connect to prior evidence from Lesson 4. Say, *In our model so far, we've only taped up baking soda and citric acid and water. Remind me again, why aren't we considering things like epsom salt, sugar, or olive oil, which are substances we know are in some of the bath bombs? Why did we decide we don't need to include those in this model to explain where the gas is coming from?*

Students should say that we figured out in Lesson 4 that none of those other substances are part of the chemical reaction.

Critique the representation of the number of molecules shown in the model. Say, *OK, so we know there are other molecules in the system, but we also know that they aren't part of what causes the chemical reaction, which is why we chose to ignore them. Let's now consider the number of molecules we have shown here. In the model we've only taped up 3 molecules each of baking soda and citric acid and water as inputs to the chemical reactions, but do you think there is only this number of molecules of these substances in the bath bomb?*

Students should say no! Molecules are very small so there must be many molecules of each in the bath bomb.

Say, *Right! There are many molecules but we don't want to have to draw the number that is included in the bath bomb so we used a few molecules of each to represent the types of atoms that make up the substances involved in this chemical reaction. When we start to consider how many molecules of reactants and products should be included in a chemical reaction, one of the things we may start to notice is whether all of the reactant molecules would be used up or not. How do we know all the atoms of the molecules of the reactants need to be used up?*

Students should say because we figured out that atoms don't disappear. We figured this out when we took the mass of the bath bomb before and after adding it to water in a closed system.

Say, *Right. We figured out that none of the atoms disappear so they have to be part of the products. As you think about this, it may lead you to determine that you need more of one type of reactant than another in order to produce all of the products. I'd like us to consider this idea further, to think about how adjusting the ratio of citric acid molecules could also help explain why the mass of all the matter in the system didn't change in the soda bottle when the bath bomb reaction occurred.*

Show slide G. Say, *Our model shows a 3 to 3 ratio, or a 1 to 1 ratio of citric acid to baking soda to water for the reaction to occur. This second model shows a 3 to 1 ratio of baking soda to citric acid molecules is needed for the reaction to occur. Which of these models is a stronger model for supporting an explanation for why the mass of the closed system didn't change during the reaction?*

Keep students in a Scientists Circle. Distribute *Comparing Molecular Ratios in a Chemical Reaction*. Give students a few minutes to use these references to work with an elbow partner on this question.

Additional Guidance

The molecular models included on *Comparing Molecular Ratios in a Chemical Reaction* are in color to help students make sense of the different atoms and be able to match the ones in the reactants to the ones in the products. There is a color copy of *Comparing Molecular Ratios in a Chemical Reaction* in the student handbook (*Comparing Molecular Ratios in a Chemical Reaction*) for students to refer to as they work with their partner on *Comparing Molecular Ratios in a Chemical Reaction*, so it does not need to be printed in color.

Assessment Opportunity

Building towards: 12.A.2 Construct an explanation for how the atoms in the molecules of the starting substances rearrange to form new products in the bath bomb, but the number and types of atoms do not change and thus mass is conserved and evaluate two different molecular models for different ratios of reactant and product molecules to determine which better supports this explanation.

What to look for: Students comparing the different models to account for all the atoms in the reactants also being in the products. They should be looking for the amount of atoms as well as the type of atom.

What to do: If students are not accounting for there being the same number of atoms in both the reactants and products, ask some probing questions to remind them of what we figured out about the mass of the bath bomb when in a closed system. When they say the mass didn't change, refer them to *Comparing Molecular Ratios in a Chemical Reaction* and encourage them to count up all the atoms to determine whether the same amount of matter is in the reactants as is in the products in both models.

Then bring students back together and have them share their ideas.

Additional Guidance

Balancing chemical equations is an idea that is above grade band. A balanced equation was introduced at this point in the lesson to provide a model that could be used to support the idea that matter is conserved because the total number of each type of atom is conserved in a chemical reaction.

No attempt is made to address the role of water in the balanced chemical equation posted at this point in the lesson. An arbitrary amount of water was chosen to be included in the equation in the reactants. If one removes the water from the reactants, then the chemical reaction would show that 3 molecules of water are produced in the reaction. Though this simplified equation is how students might see chemical reactions represented in high school, removing the water from the left side of the equation would be problematic for students at this point, since the evidence they collected suggests that it is needed for the reaction to occur. Leaving the 3 molecules of water in the left side (reactant side) of this chemical equation helps reserve a spot for water playing a role in this process, without addressing what that role is (Is it a catalyst? Does it break down and then re-reform? etc.).

Suggested prompts	Sample student responses
Which of these models is a stronger model for supporting an explanation for why the mass of the closed system didn't change during the reaction?	*Model B*
Why?	*It doesn't have any missing atoms.* *Model A has more atoms in the reactant molecules than in the product molecules.* *Model B has the same total number of atoms in the reactant molecules as in the product molecules.*
So why would showing that no atoms appear or disappear in a chemical reaction be an important idea for explaining why the mass of a closed system shouldn't change in chemical reaction?	*Because mass is a measure of the amount of stuff something is made of, so if the amount of atoms (or molecules) changes, then the mass will change.* *Right…but from the reading we figured out that atoms don't appear or disappear. So in a closed system, the mass should stay the same.* *Yeah…and this matches what we did in Lesson 2 when we put the bath bomb in the bottle and saw the reaction yet the mass didn't change.*

Say, *Let's add this idea to our* Key Model Ideas *chart.**

- In a chemical reaction, the total number of each type of atom doesn't change (it is conserved), and thus the mass does not change.

Say, *Let's also revise our class consensus model poster to show a more accurate representation of the ratio of molecules in this chemical reaction. We want this revision to represent this new key model idea that mass will not change by having a 3 to 1 ratio of molecules of baking soda to citric acid.*

Remove two citric acid molecules from the reactants shown on the poster so that only 1 remains.

Say, *We can also represent this ratio of molecules reacting using something referred to as a chemical equation, by using chemical formulas, and representing the breaking apart of the molecules with an arrow.*

Write the Bath Bomb Chemical Equation below on a piece of poster paper and hang it below the class consensus model.

Three different reactants	*chemically react to form*	Three different products
$C_6H_8O_7 + 3\ NaHCO_3 + 3\ H_2O$	---------------------------->	$Na_3C_6H_5O_7 + 6\ H_2O + 3\ CO_2$
(citric acid) + (baking soda) + (water)		(sodium citrate) + (water) + (carbon dioxide)

6. Taking Stock of Chemical Processes

10 MIN

Materials: science notebook, sticky notes, one copy of *Water 2-D Molecule Cutouts* (printed and cut apart ahead of time)

Say, *Okay we have a really solid model and understanding of what is happening in chemical reactions. But this isn't the only way we have seen matter change in the different processes we have explored in the unit. Let's think back to some of the related investigations we did, where something different was happening with the matter that wasn't a chemical reaction.*

Suggested prompts	Sample student responses
Where was another time we saw evidence of a chemical reaction happening besides the bath bomb?	*When we added energy to water with a battery.* *Elephant's toothpaste.*
Cool. What about when we heated water? Was that a chemical reaction?	*No, it wasn't because when we collected the gas bubbles in a flask and it was removed from heat, we found that it was still water. It became a liquid again at room temperature and when we found the density, it matched the density of water.*
OK, so what were the water particles doing when we heated them up and turned the liquid into a gas?	*They were moving faster when heated and when they moved fast enough, they moved apart from each other to become water vapor.*
Why did they turn back into a liquid when the water vapor cooled back down?	*When the heat was removed, the water molecules slowed down until they became a liquid again, which is the state of matter when water is at room temperature.*

Say, *Let's take a few minutes to use a more detailed molecular structure of a water molecule to show what we picture is happening in these processes.*

Work with manipulatives. Distribute some cut out water molecules from *Water 2-D Molecule Cutouts* that you cut out prior to class to pairs of students. Show **slide H.** Give partners three minutes to work with the manipulatives to show what is happening to water molecules for the related questions on the slide.*

*** Attending to Equity**

Supporting Universal Design for Learning: Conceptualizing the unseen can be difficult for students, so using paper representations of molecular structures can help students be able to picture what is happening to the molecules during different chemical processes. It is recommended you have many of the water molecule *representations* on *Water 2-D Molecule Cutouts* available so students can have the space and freedom to tear them apart, tape them together, etc., to *express* what they visualize is happening to the molecules based on the evidence they have collected over the course of the unit.

Facilitate a consensus discussion around particle level changes in chemical reactions vs. phase changes vs. dissolving. Prepare to record these on a new piece of poster paper.

Key Ideas

Purpose of this discussion:

- To describe what we know about particle level changes occurring in chemical reactions vs. in a phase change.
- To identify that we don't have enough evidence to know whether dissolving of each substance in water is a rearrangement of the molecules vs. a rearrangement of the atoms that make up the starting substances.
- To summarize the result of each process and what evidence we can collect for it happening.
- To categorize chemical reactions, phase changes, and dissolving as different chemical processes.

Listen for ideas such as:

- See what is added to each cell of the table below on the chemical processes poster.

Say, *OK so we have two very different processes we've shown where something different is happening to the molecules in the system. One is a chemical reaction and the other is a phase change. Let's start summarizing these different processes.*

Draw three columns and four rows on a piece of chart paper and label them as shown here. Leave extra space for an additional fourth column to add at the end, and additional space to add an additional category label at the top of the poster.

	Chemical reactions	Phase changes
<u>Changes</u> In all of these cases the particles rearrange in some way.		
<u>Result</u>		
<u>Evidence</u>		

Discuss what should go in each cell. For each idea suggested, ask other students to restate it and whether they agree. Update the poster to reflect the following ideas shown here.

After doing this, ask students to recall one additional process they noticed in Lesson 3.

	Chemical reactions	Phase changes
Changes In all of these cases the particles rearrange in some way.	*Atoms rearrange.*	*The arrangement of the molecules may change, but the atoms within the molecules stay together.*
Result	*New substance(s).*	*New state of matter; not a new substance.*
Evidence	*Property tests provide us evidence that a new substance was formed.*	*Property tests provide us evidence that it is still the same substance.*

Suggested prompts	Sample student responses
Let's consider one other set of changes we saw happening in Lesson 3. This is when we added each substance, one at a time, to water. What did some of those substances do when we added them to water?	*We saw some of the substances dissolve.*
So do we know then what happens to the particles in the case of dissolving? Can we say for sure if the atoms are rearranging vs. just the molecules rearranging, or is this something we aren't entirely sure about because we don't have enough evidence yet to know which it is?	*We aren't entirely sure what is happening at a particle level in the case of dissolving.*

Add a third column to the table and label it "Dissolving." Record this idea related to changes happening at a particle level for dissolving.

Discuss what should also go in the related cells for result and evidence. For each idea suggested, ask other students to restate it and whether they agree. Update the poster to reflect the following ideas shown here.

Then say, *Each of these different processes are considered chemical processes, because they all involve particle arrangement.* Add this as a label at the top of the poster, pointing to the three types of process below it.

Chemical Processes

	Chemical reactions	**Phase changes**	**Dissolving**
Changes In all of these cases the particles rearrange in some way.	Atoms rearrange.	The arrangement of the molecules may change, but the atoms within the molecules stay together.	We're not entirely sure how the particles rearrange. We don't have enough evidence.
Result	New substance(s)	New state of matter; not a new substance	A mixture (a solution)
Evidence	Property tests provide us evidence that a new substance was formed.	Property tests provide us evidence that it is still the same substance.	We can't test its properties, because property tests don't work on mixtures.

Additional Guidance

We are leaving dissolving ambiguous in terms of what particles are breaking apart. Some substances dissolve by the molecules that make them up rearranging (sucrose), while others dissolve by the atoms that make them up rearranging (e.g., sodium chloride). The mechanisms and processes that distinguish these different ways that substances can dissolve is above grade band.

Save this poster for the next unit. You will reference it again in the first couple of lessons in *Unit 7.2: How can we help people design a flameless heater? (Homemade Heater Unit).*

7. Revisit the Driving Question Board questions.

10 MIN

Materials: Driving Question Board, markers

Revisit the questions from the DQB and check off additional questions that students can now answer.

Additional Guidance

At the end of day 3 of Lesson 1, after all classes had developed their DQB, you should have created a record of all the questions that are on the board that you printed out for students to reference the next day. Then at the end of Lesson 6, students should have worked with a partner to identify which questions could be answered at that point of the unit. Then they should have taped this into their notebook. Have them refer to this document in their notebook to see what questions can be answered now.

Pair students up with new partners to work on revisiting the questions from the DQB you gave students from Lesson 1, and again in Lesson 6. Remind students that they taped this in their notebooks back in lesson 6.

Display **slide I.** Instruct students to stand up and join their partner and relocate to another part of the room to evaluate and record which additional questions we can now answer.

After about 7 minutes regroup as a whole class around the physical DQB, and have students share an estimate of what fraction or percent of questions they think we have answered. Listen for students to suggest 75% or more. Emphasize that this is a substantial amount of progress we've made, and it may make sense for us to wrap up our unit soon, but it still may be feasible to make a bit more progress on some of the lingering questions.

Ask students to share any of the questions they saw on the DQB that were related to odor and whether we've made any progress on these. Accept all responses.*

Ask students what we know about odor. Students will say we know odor is a property and may point it out on the Word Wall.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**
Revisiting the DQB at the end of the unit helps students see the progress they made toward answering questions that are important to them at the outset of the unit. Students were tasked with asking questions "that require sufficient and appropriate evidence to answer." Through the investigations in the unit and individual and whole group sense-making, they can now answer many of the questions. This final visit to the DQB also allows students to see how their hard work toward a shared learning goal helped them figure out the phenomenon but can also explain lots of the other phenomena in the world.

8. Identify next steps related for our odor related questions.

5 MIN

Materials: Driving Question Board, markers

Show **slide J.** Have students reconvene in a semi-circle around the projected image and say, *These are another type of bath bomb you can buy at the store. Do you think they have the same odor as the one we started our unit with? Why? What exactly is going on when you detect a different odor anyway? How could we investigate these questions? Talk about these questions with someone you are standing next to.*

Pause the conversations a couple of minutes before the end of the period and ask students to share how we might investigate these questions further. Students are likely to say we could get an actual sample of these substances and see what they smell like. They may also say that we could find more information about how our nose works.

ADDITIONAL LESSON 12 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

- **CCSS.ELA-LITERACY.W.7.1.A Introduce claim(s), acknowledge alternate or opposing claims, and logically organize the reasons and evidence.**
- **CCSS.ELA-LITERACY.W.7.1.B Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.**
- **CCSS.ELA-LITERACY.W.7.1.C Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.**
- **CCSS.ELA-LITERACY.W.7.1.D Establish and maintain a formal style.**
- **CCSS.ELA-LITERACY.W.7.1.E Provide a concluding statement or section that follows from and supports the argument presented.**
- **CCSS.ELA-LITERACY.W.7.2.C Use appropriate transitions to create cohesion and clarify the relationships among ideas and concepts.**
- **CCSS.ELA-LITERACY.W.7.2.D Use precise language and domain-specific vocabulary to inform about or explain the topic.**
- **CCSS.ELA-LITERACY.W.7.2.E Establish and maintain a formal style.**

The above learning goals are the focus of the written argument that students produce as part of the assessment.

LESSON 13

Why do different substances have different odors and how do we detect them?

Previous Lesson

We revised our consensus model with the molecules of the reactants and the gas produced from the bath bomb. We explained how other possible products could be produced in this chemical reaction. We developed a model to represent what is happening to particles in different chemical processes. We revisited the Driving Question Board (DQB) and identified which questions we made progress on.

This Lesson

Putting Pieces Together

1 day

We carry out an investigation about the scents of different substances to see if we can identify these substances by their odors. We gather information from a reading about how sensory receptors in our nose work. We use what we figure out from the odor lab and the reading to write an explanation about why different substances have different odors and how we detect them.

Next Lesson

We will apply what we figured out about properties to explain a related phenomenon (pollution and erosion on marble). We will revisit our Driving Question Board (DQB) and reflect on what other related phenomena we might be able to explain using these same key model ideas.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

13.A Read scientific texts adapted for classroom use to determine how the molecular structure of different substances (patterns) is related to their odor, how those molecules reach our nose (cause), and how those molecules interact with different sensory receptors there that each cause a different signal to travel through our nerve cells that leads to the perception of different scents (effect).

What Students Will Figure Out

- Odor is a property of a substance, that is determined by the number, type, and arrangement of atoms that make up that substance.
- Molecules of substances must travel into our nose in order for us to detect an odor from them.

- Our nose has many different cells that each have different structures (sensory receptors for odor) that different shaped molecules can fit into, which will cause that cell to send a signal to other nerve cells that relay that signal to our brain.
- The perception of different scents is the result of the combination of signals that the brain receives from these different nerve cells.

Lesson 13 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Remind ourselves of the remaining questions we have about odors and ways we wanted to investigate these.	A	
2	5 min	**PREPARING FOR ODOR LAB** Set up our notebooks to record data from the odor lab.	B–C	
3	12 min	**ODOR LAB AND READING** Smell four different substances that are added to bath bombs to see if there is an odor that is detectable.	D–E	*Molecular Models of Different Substances, Odor Lab*
4	13 min	**READING ABOUT RECEPTORS** Set a purpose for reading about how we detect odors.	F	*Reading: How do we detect odors?*
5	10 min	**DEVELOP AN EXPLANATION** Write an explanation about what an odor is and how we detect them.	G	*Molecular Models of Different Substances, Odor Lab, Reading: How do we detect odors?*
				End of day 1

Lesson 13 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Molecular Models of Different Substances* • *Odor Lab* • *Reading: How do we detect odors?*		

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Odor lab

- **Group size:** 6 groups
- **Setup**: Prepare one set of odor vials per group of students as explained in *Setting up Odor Lab*.
- **Safety:** Though none of the substances that students will be smelling should be harmful, it is good practice to show students how to waft for odors. Check for allergies. If you have students who are allergic to vinegar, vanilla, lavender, menthol, or lemon you will want to confirm their allergy is not airborne. If it is, they should use observations from a partner for the smelling portion of the lab. They will be able to participate through looking at the accompanying molecular structure cards and the reading.
- **Disposal**: All materials can be washed down the drain with cold or warm water, if needed. But it is assumed that you will save and reuse the odor vials to reuse in future years.
- **Storage:** Seal and store odor vials to reuse in the future. They should last many years.

Online Resources

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

This lesson is one of a few that are included across the units in the middle school curriculum that helps students gain understanding toward the NGSS performance expectation of MS LS1-8 (Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.). In this lesson students will work with 4 different substances that have identifiable odors and will read about the connection between the nose and the brain in helping people identify odors.

Where We Are NOT Going

We are not getting into the other ways a human receives messages through the other sensory receptors. And we will not be going into the relationship between such signals and memories.

Other units in the curriculum address other parts of the related DCI LS1.D, that each receptor responds to different inputs. Electromagnetic receptors are addressed in *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*. Mechanical receptors are addressed in *Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)* and *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*. The related lessons that engage students in developing and using this idea also have students develop and use the related SEP of LS1-8 (Gather and communicate information) and the related CCC (cause and effect).

LEARNING PLAN FOR LESSON 13

1. Navigation

5 MIN

Materials: None

Recap what we still feel we need to figure out about odors from the questions left on our Driving Question Board (DQB). Display **slide A.** Say, *Turn and talk with a partner for a minute about the questions on the slide:* What were some remaining questions we had about odor? And what were some ideas we had for investigating those questions?

Ask a few students to share what they discussed with their partner. They should share that we have odor listed as a property, but it is kind of confusing as a property because we don't all smell things the same way. So we want to investigate odors.

2. Preparing for odor lab.

5 MIN

Materials: science notebook

Prepare a notebook page to record what we figure out during the odor lab. Display **slide B.** Say, *Based on the questions we have left on our Driving Question Board about odors, it seems like we have two goals for our investigation today—we want to figure out why different substances have different odors and how we detect an odor.*

Ask, *Are there times that you have smelled something without being able to see where the odor is coming from, but you could still identify what the smell was coming from?*

Have some students share their experiences with smells that are familiar to them.

Ask, *How did you know what substance the odor was coming from?*

Students should say something like:

- Because I had smelled it in the past (when I visited a friend's house, or family members' house, or somewhere like a gym).
- Because it is something I smell all the time in my house (like a food scent, or cleaning scent).

Display **slide C.** Say, *Today with your group, you will be given different substances to smell to see if you can determine what they are by their odor. Let's set up a page in our Progress Trackers to record what we figure out. Turn to your Progress Tracker section and use a new page. Draw a two-column tracker. Then draw a horizontal line halfway down the page. Record the first question (Why do different substances have different odors?) on the slide in the top section and write the second question (How do we detect odors?) in the bottom section. As you go through the lab today, use this space to record what you figure out about each of the questions on this page.*

3. Odor Lab and Reading

12 MIN

Materials: science notebook, *Molecular Models of Different Substances*, *Odor Lab*

Demonstrate how to waft odors. Display **slide D.** Say, *There are 4 vials with different substances in them for you to smell and see if you can identify the substance by the odor. Before you smell each one, let's talk about* how you should smell *different odors of substances in the lab. Whenever you don't know what a substance is, you want to be careful how you smell it with your nose because some substances have odors that can be harmful to your nose. Because of this, we will use a technique called "wafting" in order to determine if these substances have an odor and what the odor is. You do not want to stick the vial with the substance right under your nose. Instead you want to hold the vial about 6 inches from your nose and using your other hand you wave it over the air right above the vial toward your nose, like you are scooping the air above the vial toward your nose.*

Pause and demonstrate with one of the vials how to smell and odor using wafting.

Safety Precautions

Though none of the substances that students will be smelling should be harmful, it is good practice to show students how to waft for odors.

Check for allergies. If you have students who are allergic to vinegar, vanilla, lavender, menthol, or lemon you will want to confirm their allergy is not airborne. If it is, they should use observations from a partner for the smelling portion of the lab. They will still be able to participate through looking at the accompanying molecular structure cards and the reading.

Explain the odor lab procedure. Display **slide E.** Handout *Odor Lab*. Tell students that they will tape this into their notebooks later, but they should keep it out for now so they can record on this handout and in their Progress Tracker section at the same time. Say, *There are 4 different odors for you to smell with your group. Use Odor Lab to record what you think the substance is based on the smell and what, if anything, this smell reminds you of. After you all have had a chance to smell each of the vials, analyze the molecular structure for the substance that is in each of the 4 vials. In your handout, write down what you notice about the molecules of the different substances. After everyone has had a chance to smell each of the vials and analyze and compare the molecular structure of each, we will compare. Be ready to share.*

The following directions for students are projected on the **slide E:**

1. Take turns smelling each of the vials and recording your observations.
2. Return the vials to the center of the table.
3. Pick up *Molecular Models of Different Substances*.
4. Compare the different molecules and names of the substances and record your noticings on your handout.

Once students have finished the lab and analyzed the molecular models, suggest a few share some of their noticings about the different substances and how the molecules compare.

4. Reading About Receptors 13 MIN

Materials: *Reading: How do we detect odors?*

Display **slide F**. Say, *Now that we have all tested our ability to identify different substances by their odors, can we answer our two questions about odors:*

1. *Why do different substances have different odors?*
2. *How do we detect odors?*

Have a few students share. You will hear them say things like:

- All the odors smell different from each other.
- All the molecules are different, but they are all made of the combinations of the same atoms: carbon, hydrogen, and oxygen.
- All the molecules besides vinegar are pretty large.
- Odor must be a property because each of these molecules is different and we figured out earlier that different substances are made of one type of atom or molecule.

Ask, *Why would these different molecules have different odors if they have the same type of atoms that make them up?* You will hear students say something like:

- The arrangement and number of each type of atom in the molecule of the substance must also be related to this odor.

Say, *So it sounds like we have some things we have figured out to help us answer the first of our two questions about why different substances have different odors. And we've developed an argument that this property is based on the number, type, and arrangement of the atoms that make up the molecules of the substance. But we still need to figure out more about how we detect odors. I have a short article that might help us figure more out about this.*

Hand out *Reading: How do we detect odors?* to each student. Tell them to write the question "How do we detect odors?" at the top of their reading. Say, *As you read, highlight information you read and annotate sections that have anything that will help answer this question. Also remember to be adding to your Progress Trackers anything you figure out from the reading for the two questions recorded there.*

Give students 8 minutes to read the article.

5. Develop an explanation. 10 MIN

Materials: science notebook, *Molecular Models of Different Substances*, *Odor Lab*, *Reading: How do we detect odors?*

Explain what an odor is and how we detect odors. Display **slide G.** Say, *Use the next blank page in your science notebooks to explain what you have figured out to answer: What is an odor and how do we detect it? Use the resources you have in your Progress Trackers, on Molecular Models of Different Substances, Odor Lab, and Reading: How do we detect odors?. You will have about 10 minutes to write this. When you are finished please flag the page with a sticky note so I will know where to find your explanation in your notebooks.*

Assessment Opportunity

13.A Read scientific texts adapted for classroom use to determine how the molecular structure of different substances (patterns) is related to their odor, how those molecules reach our nose (cause), and how those molecules interact with different sensory receptors there that each cause a different signal to travel through our nerve cells that leads to the perception of different scents (effect).

When it happens: Students develop an explanation for what an odor is and how we detect it in a page in their notebooks, flagged with a sticky note based on the central ideas they gathered from a reading.

What to look for: If students don't develop this chain of cause and effect, provide structured prompts to ask students to respond to:

- What do the patterns in molecular models on *Molecular Models of Different Substances* help you explain about odors?
- What has to happen to particles of the matter that makes up a substance in order for it to reach your nose?
- What happens to those particles when they reach your nose that cause some (but not all of them) to be detected and recognized by you?
- How could some scents be the result of more than one type of particle being detected by more than one sensory receptor?

What to do: See *Sample Student Response for Written Explanation* for additional scoring guidance.

Alternate Activity

Extension: Most likely some students will be highly interested if other living organisms also detect odors the same way we do. Or there will be some students who are interested in odors and how they affect organisms. Encourage these students to do a little research outside of class to find out more about this and then make time for them to share with the class what they have figured out.

Tell students that in our next class we will take all that we have figured out and see if we can apply it to another phenomenon in the world and that this other phenomenon will be the content for our final assessment for the unit. Emphasize that this will be a great test of how generalizable our ideas are if we can use them to explain yet another related phenomenon, as well as a good measure of individual growth when we see what each of us can explain now that we would not have been to explain earlier at the start of the unit.

(Optional): If time permits, display **slide H** and ask students to give non-verbal feedback on their confidence in:

- Planning and carrying out an investigation to determine if a chemical reaction occurred.
- Analyzing and interpreting data to support or refute an argument about whether a chemical reaction occurred.
- Using molecular models to determine what substances could be produced in a reaction, based on the atoms that make them up and the available atoms in the reactants.

Alternate Activity

This sort of informal survey of student readiness for the final assessment might also be useful to assign as an out of class assignment that students respond to before the next lesson, and then revisit again at the end of the next lesson (after the assessment). Such meta-cognitive reflections before and after a major assessment can help students develop a more accurate sense of what they know and can do over time.

ADDITIONAL LESSON 13 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

- **CCSS.ELA-LITERACY.W.7.1.A Introduce claim(s), acknowledge alternate or opposing claims, and logically organize the reasons and evidence.**
- **CCSS.ELA-LITERACY.W.7.1.B Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.**
- **CCSS.ELA-LITERACY.W.7.1.C Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.**

LESSON 14

What is happening to the Taj Mahal?

Previous Lesson

We carried out an investigation about the scents of different substances and tried to identify these substances by their odors. We gathered information from a reading about how sensory receptors in our nose work. We used what we figured out from the odor lab and the reading to write an explanation about why different substances have different odors and how we detect them.

This Lesson

Putting Pieces Together

2 DAYS

We apply what we have figured out about properties to explain a related phenomenon (pollution and erosion on marble). We carry out an investigation to collect data about what happens when different substances in the air interact with marble. We identify what other evidence we would want to collect in terms of property data to be able to argue whether a chemical reaction occurs.

Next Lesson

There is no next lesson.

Building Toward NGSS

MS-PS1-1, MS-PS1-2, MS-PS1-5, MS-LS1-8

What Students Will Do

14.A Collect data to produce evidence and use the patterns in the properties of substances to make an argument about whether malic acid secreted by algae is causing a chemical reaction to break down the calcium carbonate in the marble of the Taj Mahal.

14.B Use molecular models to explain which products could be produced (patterns) from a chemical reaction between either a) the calcium carbonate in the marble surface of the Taj Mahal and pollutants in the air or b) iron in the rods and clamps of the Taj Mahal and pollutants in acid rain.

14.C Analyze and interpret data and use it as evidence in an explanation to the government of India about which pollutants in the air around the Taj Mahal could be causing the marble surface of the Taj Mahal to break apart and wash away (effect).

Additional LLPE for Alternate Assessment: Plan an investigation individually and in the design: identify what tools are needed to do the gathering, how measurements will be recorded, and what data is needed to provide evidence for whether one or more acids is chemically reacting (cause) with the iron in the rods and clamps of the Taj Mahal and in this process ends up producing two new substances (effect).

What Students Will Figure Out

- Two pollutants in the air around the Taj Mahal are interacting with the surface causing a chemical reaction to occur and changing the surface to a new substance.
- Algae that is on the surface of the Taj Mahal secretes different acids that cause a chemical reaction to occur with the (calcium carbonate) marble surface.
- The algae and pollutants in the air around the Taj Mahal are causing it to crumble and fall apart due to the chemical reactions that are occurring.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**NAVIGATION** We are introduced to a context for a new phenomenon to investigate using what we have figured out so far about identifying substances with their properties.	A–C	*Part 1: Explaining Marble Changes in the Taj Mahal*
2	35 min	**PART ONE OF ASSESSMENT** Work through part 1 of the assessment.	D	*Part 1: Explaining Marble Changes in the Taj Mahal*, Calcium Carbonate and Malic Acid Lab
3	3 min	**CLEANUP AND COLLECTION** Clean up lab stations and turn in part 1 of the assessment before the end of the period.		*Part 2a: Explaining Marble Changes in the Taj Mahal, Part 2b: Explaining Iron Changes in the Taj Mahal*
				End of day 1
4	3 min	**REVIEW THE OPTIONS FOR PART 2 OF THE ASSESSMENT** Choose a version of the second part of the assessment.	C	
5	30 min	**PART TWO OF ASSESSMENT** Work through part 2 of the assessment.	E	*Part 2a: Explaining Marble Changes in the Taj Mahal, Part 2b: Explaining Iron Changes in the Taj Mahal*
6	12 min	**REFLECTING ON NORMS AND CELEBRATING ACCOMPLISHMENTS** Revisit classroom norms and have students self-assess how well they did on the norms. Then celebrate class accomplishments.	F–G	notecard
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 14, students are ready to read Student Reader Collection 5 and then respond to the writing exercise.		Student Reader Collection 5: *Signs of Chemical Reactions*

Lesson 14 • Materials List

	per student	per group	per class
Calcium Carbonate and Malic Acid Lab materials	• goggles • ~1 g of calcium carbonate • ~20 mL container of water • 1 capsule of malic acid • a spoon • 1 wooden stirrer • 6 clear cups or condiment containers		• set of digital thermometers to share between students
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Part 1: Explaining Marble Changes in the Taj Mahal* • science notebook • *Part 2a: Explaining Marble Changes in the Taj Mahal* • *Part 2b: Explaining Iron Changes in the Taj Mahal* • notecard		

Materials preparation (20 minutes)

Online Resources

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Calcium Carbonate and Malic Acid Lab

- **Group size:** Individual
- **Setup:** Students also may ask to use a digital thermometer. Prepare a set of these to share between students. Prepare the following materials for each student to carry out the investigation portion of the assessment:
    - goggles
    - ~1 g of calcium carbonate
    - ~20 mL container of water. Limit the amount of water to no more than 20 mL. More water will dilute the concentration of the reactants, making the reaction harder to detect.
    - 1 capsule of malic acid (~800 mg)
    - a spoon (optional)
    - a wooden stirrer
    - 6 clear cups or condiment containers to transfer samples to and collect observations from

- **Clean-up:**
  - The solution should be emptied into the trash can since the calcium chloride is not soluble in water.
  - The containers used in the investigation can be rinsed out and reused between classes.
- **Safety:** Students should wear safety goggles during the investigation.

Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

This lesson provides a series of transfer tasks for assessing students' engagement in all three dimensions of NGSS to a variety of phenomena related to things happening to the marble surface and iron clamps and rods that make up the Taj Mahal.

The assessment has two parts. Part 1 is designed as something all students will do. It involves planning and carrying out an investigation as well as arguing whether a chemical reaction occurred based on the results. This is the focus of the first day of this two-day lesson.

Part 2 provides a choice for two different paths that students can follow. It is assumed most students will benefit from engaging in the default path, which is referred to as part 2a. The items on it revolve around trying to explain further what is happening to the marble that the Taj Mahal is made of and advising the Indian government on what pollutants might be responsible for this. Part 2b is a more challenging set of tasks that revolve around trying to explain what is happening to the iron rods and clamps that are being used to hold this marble together. Item F on it is particularly challenging.

The lesson as written gives students the choice to select which option to follow (part 2a or 2b) after completing part 1. You may however wish to choose part 2b for students that you think would benefit from the challenge. Or you may want to reserve some or all the questions from part 2b as a set of items that students can try again at a later time if they struggle with any of the original items on the test.

To determine which items are well aligned to a particular combination of SEPs, DCIs, and related CCCs, refer to *Item alignment guide*.

Where We Are NOT Going

It is not expected that students who answer question E on part 2b of the assessment will reason out that oxygen was taken out of the atmosphere in the chemical reaction. But some students may. Those students may inquire as to whether they can investigate whether this actually happens. You may want to provide that opportunity for extension if students inquire about this.

No attempt is made to explain why there is a (II) or (III) in the name of iron (II) sulfate or iron (III) nitrate. Balanced chemical equations are referenced in question F of part 2b, and though the idea of what the numbers in such an equation represent was introduced in Lesson 11, understanding what balanced equations represent is not a focus of that assessment question. Its focus is on planning investigations to collect related property data to support or refute the ideas that different substances might be produced from reactions between substances in acid rain and iron.

LEARNING PLAN FOR LESSON 14

1. Navigation

7 MIN

Materials: *Part 1: Explaining Marble Changes in the Taj Mahal*

Say, *A few days ago we determined that we made a lot of progress on our Driving Question Board and we identified one remaining area of questions related to odor that we wanted to make progress on. What was one of the most interesting things you discovered in the work you did in the last lesson related to odor?*

Show slide A. Have students share their ideas with the whole class.

Bring the *Related Phenomena* poster over to the front of the room so everyone can see it. Refer to it as you summarize the different types of phenomena students investigated over the course of the unit.

Say, *We've revisited this poster a few times to remind ourselves that the work we were doing with the bath bomb should ultimately help us figure out how to explain some of these other phenomena too. This led us to see if we could apply our ideas we developed early in this unit to explaining a related phenomenon—elephant's toothpaste. It led us to explore other bubble-producing phenomena like boiling and adding electricity to water to produce hydrogen and oxygen gas. Each of the phenomena we investigated early in the unit involved gas production when a new substance was made. And in Lesson 12 we figured that the chemical reaction that occurs when the bath bomb is added to water produced not only carbon dioxide gas, but also water and sodium citrate. So chemical reactions don't only produce gases, they can also produce liquids and solids.*

Additional Guidance

Supporting Universal Design For Learning: Returning to the *Related Phenomena* poster at the end of the unit to see if any other phenomenon can be explained using what has been figured out in class can be very satisfying for students and helps to broaden their conceptual understanding of the content and practices they have been figuring out. At this point in the unit, you might place a checkmark or sticky note next to any of the phenomena students feel they could now explain. This can help support student *engagement* as they see the shifts in the work they are doing in the lessons over the course of the unit as still being very relevant to making progress on their original questions and ideas for investigations.

Introduce the assessment goal. Say, *Up until now we have been working with everyday substances that we can use in the science classroom to help us figure out what is happening at a molecular level when they go through different chemical processes. Ideally, we should be able to use and apply what we have figured out so far to explain lots of other related phenomena, beyond those that we initially brainstormed. We don't always know the limitations of our model ideas until we try using them to explain a wider range of phenomena. So today is our chance to test how generalizable our key model ideas are. Today you will be presented with a new scenario and be asked to explain what is happening in it as well as design an investigation to test some of your ideas. This scenario is our end of unit assessment, which will be an excellent opportunity for you to demonstrate everything you have figured out.*

Orient students to the context of the assessment. Display **slide B** (of Taj Mahal)**.** Say, *Let's get oriented to the context together, before you start the individual portion of the assessment. In the assessment you will try to explain what is* *happening to this monument called the Taj Mahal, which is one of the seven wonders of the world. How many of you have seen or heard of this monument before?*

Accept all responses.

Say, *Let's see more about what is happening to this monument to prepare you for planning an investigation, writing an argument, and using a model to explain what is happening to it.*

Distribute *Part 1: Explaining Marble Changes in the Taj Mahal*. Read through the first part of the assessment together, up until "Plan an investigation." Say, *The rest of this packet are tasks that you will do individually this period and the next.*

Give students an overview of what students will work on in part 1 and 2 of the assessment. Display **slide C**. Explain that all students will do part 1, and then using what they did in part 1, they will have a choice for two different paths they will follow for part 2.

Say, *Part 2a is a challenging set of modeling and explanation tasks that revolve around trying to explain further what is happening to the marble that the Taj Mahal is made of and advising the Indian government on what pollutants might be responsible for this. Part 2b is an even more challenging set of modeling and explanation tasks that revolve around trying to explain what is happening to the iron rods and clamps that are being used to hold this marble together. You should be able to finish part 1 today, but you may not have time to start part 2. That is OK; you can start it tomorrow. But whenever you are done with part 1, decide which path you'd like to follow next. Both part 2a and 2b are available for you to choose from but you will not do both. Pick only one path to follow.*

Additional Guidance

There are multiple reactions that are occurring between air pollution and environmental factors around the Taj Mahal that is causing it to crumble and fall apart. These pollutants are part of acid rain that affects the monument as well as acids released by algae that has grown on the side of the monument. Asking students to explain all of these factors would be too cumbersome for one task. Yet, we also don't want students to think there is only one factor causing the changes to the monument. For these reasons, we have developed this task so *all* students will interact with one cause of the changes to the marble through carrying out an investigation and constructing an explanation. This first part of the task has students exploring how the algae on the Taj Mahal is affecting the marble surface. The second part of the task is divided into two parts. Students can choose which part they want to do. They will explore how the pollutants in the air are affecting different parts of the monument—either the marble itself (part 2a) or the iron clamps and rods that have been installed to help hold it together (part 2b).

Besides providing students the opportunity to choose which version of part 2 they want to work through, having these two options provides a path for a second try if a student struggles with one version of part 2, they could work through the other version. Both versions provide evidence of how students have grown in reaching the unit level performance expectations.

Item alignment guide provides a matrix that aligns each item of all parts of this task to the unit level performance expectations.

2. Part One of Assessment

35 MIN

Materials: Calcium Carbonate and Malic Acid Lab, *Part 1: Explaining Marble Changes in the Taj Mahal*, science notebook

Introduce part one of the task. Show **slide D**. The assessment includes incremental steps that students work through to carry out an investigation with calcium carbonate and malic acid to collect evidence about one thing that is happening to the marble. You should not need to go over all these steps as this is part of what is being assessed (students' ability to plan and carry out an investigation). But you will need to provide directions to your students for where to get supplies from, where to carry out their investigation, and where students should clean up and return used supplies. Then provide students the rest of the class time to complete part 1. There are a few minutes left at the end of this day of the lesson for cleanup and collection of the students' assessments.

Assessment Opportunity

Building towards: 14.A Collect data to produce evidence and use the patterns in the properties of substances to make an argument about whether malic acid secreted by algae is causing a chemical reaction to break down the calcium carbonate in the marble of the Taj Mahal.

What to look for: See scoring guidance in *Part 1 of the Assessment*.

What to do: See scoring guidance in *Part 1 of the Assessment*. If students struggle with particular items on this assessment, use *Item alignment guide* to identify related items on the alternate part 2 assessment that could be used for supporting relearning/mastery learning. Each item on the assessment has been aligned with different parts of the performance expectations so the alternate assessment could be used as a reassessment.

3. Cleanup and Collection

3 MIN

Materials: *Part 2a: Explaining Marble Changes in the Taj Mahal, Part 2b: Explaining Iron Changes in the Taj Mahal*

Conclusion of part one. Use these last three minutes to ensure all students have cleaned up the supplies they have used to carry out the investigation and that everyone turns in part 1 of the assessment before they leave class. If there is extra time left, you could survey the students about which of the two choices *Part 2a: Explaining Marble Changes in the Taj Mahal* or *Part 2b: Explaining Iron Changes in the Taj Mahal* they want to do the next day. This will allow you to make sure you have enough copies of each.

Note for cleanup: It may be helpful to have a bin or waste basket set aside for students to empty the contents of the mixtures. The solids that are not soluble should not be put down the sink.

End of day 1

4. Review the options for Part 2 of the assessment.

3 MIN

Materials: None

Orient students to the second part of the transfer task. Remind students that they completed part 1 during the previous class and will be finishing part 2 of the assessment today. Display **slide C again**. Review again that students will have a choice for two different paths they will follow for part 2 and which part is more challenging.*

*** Attending to Equity**

Supporting Universal Design for Learning: Providing students the opportunity to choose the level of perceived challenge can support student engagement and help develop self-determination, pride in accomplishment, and increase the degree to which they feel connected to their learning.

5. Part Two of Assessment

30 MIN

Materials: *Part 2a: Explaining Marble Changes in the Taj Mahal*, *Part 2b: Explaining Iron Changes in the Taj Mahal*, science notebook

Provide time for students to work on part 2 of the assessment. Display **slide E.**

Assessment Opportunity

Building towards: 14.B Use molecular models to explain which products could be produced (patterns) from a chemical reaction between either a) the calcium carbonate in the marble surface of the Taj Mahal and pollutants in the air or b) iron in the rods and clamps of the Taj Mahal and pollutants in acid rain.

Building towards: 14.C Analyze and interpret data and use it as evidence in an explanation to the government of India about which pollutants in the air around the Taj Mahal could be causing the marble surface of the Taj Mahal to break apart and wash away (effect).

What to look for: See scoring guidance in *Part 2a of the Assessment* and *Part 2b of the Assessment*.

What to do: See scoring guidance in *Part 2a of the Assessment* or *Part 2b of the Assessment*. If students struggle with particular items on this assessment, use *Item alignment guide* to identify related items on the alternate part 2 assessment that could be used for supporting relearning/mastery learning. Each item on the assessment has been aligned with different parts of the performance expectations so the alternate assessment could be used as a reassessment.

If students choose to do part 2b, then there is an extra Lesson Level Performance Expectation they will be meeting: Plan an investigation individually and in the design: Identify what tools are needed to do the gathering, how measurements will be recorded, and how what data is needed to provide evidence for whether one or more acids is chemically reacting (cause) with the iron in the rods and clamps of the Taj Mahal and in this process ends up producing two new substances (effect).

What to look for: See scoring guidance in *Part 2a of the Assessment* and *Part 2b of the Assessment*.

What to do: See scoring guidance in *Part 2a of the Assessment* or *Part 2b of the Assessment*. If students struggle with particular items on this assessment, use *Item alignment guide* to identify related items on the alternate part 2 assessment that could be used for supporting relearning/mastery learning. Each item on the assessment has been aligned with different parts of the performance expectations so the alternate assessment could be used as a reassessment.

Alternate Activity

Extension: It is not expected that students who answer question E on part 2b of the assessment will reason out that oxygen was taken out of the atmosphere in the chemical reaction. But some students may. Those students may inquire as to whether they can investigate whether this actually happens. You may want to provide that opportunity for extension if students inquire about this.

6. Reflecting on Norms and Celebrating Accomplishments

12 MIN

Materials: notecard

Take a moment to revisit the *Science Classroom Norms*. Display **slide F.** Ask students to look back at *Science Classroom Norms*. Give them a moment to read through the norms. Ask students to privately note which norms they feel they did well with and which norms should be personal goals moving forward. If time allows, ask students to share their thinking with a partner.

At the very end of the unit, celebrate the class accomplishments. Display **slide G.** Have students reflect on their experiences with the unit. Have them record their ideas on an exit ticket.

- What was most rewarding in this unit?
- What was most challenging?
- What might you want to do differently the next time you engage in making sense of phenomena in your next unit of study?

ADDITIONAL LESSON 14 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

- **CCSS.ELA-LITERACY.W.7.1.A Introduce claim(s), acknowledge alternate or opposing claims, and logically organize the reasons and evidence.**
- **CCSS.ELA-LITERACY.W.7.1.B Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.**
- **CCSS.ELA-LITERACY.W.7.1.C Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.**
- **CCSS.ELA-LITERACY.W.7.1.D Establish and maintain a formal style.**
- **CCSS.ELA-LITERACY.W.7.1.E Provide a concluding statement or section that follows from and supports the argument presented.**
- **CCSS.ELA-LITERACY.W.7.2.C Use appropriate transitions to create cohesion and clarify the relationships among ideas and concepts.**
- **CCSS.ELA-LITERACY.W.7.2.D Use precise language and domain-specific vocabulary to inform about or explain the topic.**
- **CCSS.ELA-LITERACY.W.7.2.E Establish and maintain a formal style.**

The above learning goals are the focus of the written argument that students produce as part of the assessment.

SCIENCE LITERACY: READING COLLECTION 5

Signs of Chemical Reactions

1 **Ways That Atoms Recombine**

2 **Spotting Chemical Reactions**

3 **Detecting Odor**

4 **Carbon in a Cycle**

Literacy Objectives

- ✓ Summarize key points related to chemical reactions and conservation of matter.
- ✓ Organize related details to construct a paragraph.
- ✓ Interpret visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 12–14.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a well-reasoned paragraph in response to the reading.

Instructional Resources

Student Reader

Collection 5

Science Literacy Student Reader, Collection 5
"Signs of Chemical Reactions"

Exercise Page

EP 5

Science Literacy Exercise Page
EP 5

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 12: How can a new substance (a gas) be produced and the total mass of the closed system not change?
- Lesson 13: Why do different substances have different odors and how do we detect them?
- Lesson 14: What is happening to the Taj Mahal?

Standards and Dimensions

NGSS

Disciplinary Core Idea PS1.A: Chemical Reactions Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2) (MS-PS1-5) The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5)

LS1.D: Information Processing Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. (MS-LS1-8)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Energy and Matter; Systems and Systems Models

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

chemical reaction **product** **reactant**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

chemical energy **chemical weathering**
olfactory **phase change**
precipitate **system**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Exercise Page

EP 5

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Chemical Reactions and Matter unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read about three chemical reactions, each with a different way to recognize that a chemical change has occurred.*
    - *Next, you'll look outside your classroom at an assortment of chemical reactions in Earth systems, some related to humans and others not.*

- *Then, you'll take a look—or should I say "sniff"—at how humans and other animals detect and process information about molecules in fluids.*
    - *Finally, you'll read how energy and matter are transformed and stored during chemical reactions in living and nonliving systems.*
- Distribute Exercise Page 5. Preview the writing exercise. Share a brief summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate a thoughtful and well-constructed paragraph in response to a quotation from a scientist working in the 1700s.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What information does the formula for a chemical reaction show?	*It shows the substances that are reactants and the substances that are the products. It may also show if heat is needed or released.* *It shows how many atoms are involved.*
How is the shape of a molecule important in detecting its odor?	*There are different kinds of receptor cells for different molecules. A scent molecule must be the right shape to fit into the receptor and be detected.*
What series of chemical reactions in your body releases thermal energy that makes you feel warm?	*cellular respiration*

Suggested prompt	Sample student responses
What does the graphic modeling the carbon cycle show?	*It shows places on Earth where carbon is stored, such as in plants and animals.* *It has arrows to show chemical reactions that move carbon from one place to another.* *It shows where and how a lot of energy is stored and released.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
In our class discussion, we talked about inputs and outputs of chemical reactions. How do they relate to products and reactants?	*Inputs are the reactants, and products are the outputs.*
What did we decide the arrow in a chemical formula stands for?	*"chemically react to form"*
In a class discussion we figured out that the number, type, and arrangement of atoms in a molecule cause different substances to have different odors. How does this support the lock-and-key model of detecting odor?	*The odor molecule is the "key," and since molecules have different sizes and shapes, maybe that's what allows the key to fit the lock.*

Exercise Page

EP 5

- Refer students to the Exercise Page 5. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to compose a well-constructed paragraph that reflects on an idea from the pioneering chemist Antoine Lavoisier.*
  - *That means thinking about what Lavoisier meant in the context of your investigations and readings in this unit. But you will also need to ponder how your observations outside of school support his idea.*
  - *Since the purpose of this paragraph is to demonstrate understanding about science, maintain a formal style throughout your paragraph.*
  - *For your topic sentence, try restating what Lavoisier said based on discussions we had in class.*
  - *Do use science vocabulary in your paragraph, but make sure your use is precise.*
  - *The important criteria for your work are that you support your interpretation with clear details from three sources and that your paragraph is well-organized.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. The first selection includes a guide to reading chemical equations and shows how they support the law of conservation of matter.

Pages 44–53 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Ways That Atoms Recombine"?	*It explains what chemical reactions are and how to recognize them.*
What are three telltale signs that a chemical reaction has taken place?	*the release of heat, the appearance of a precipitate, and the release of light*
How does a chemical equation demonstrate the law of conservation of matter?	*The equation shows that the number and kinds of atoms on the left are the same as the number and kinds of atoms on the right.*
Does the law of conservation of matter also apply to phase changes? Explain with an example.	*Yes. If liquid water changes to ice, there are still the same number of water molecules and the same number of atoms of hydrogen and oxygen in the solid water as there were in the liquid water.*
What is the general purpose of the second selection, "Spotting Chemical Reactions"?	*It explains, with examples, that chemical reactions take place in many Earth systems.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article reveals how chemical equations show that matter is conserved. The second article provides more chemical equations that support this idea.*
What is chemical weathering?	*It's the science term for the breaking down of rock formations due to chemical reactions between the rocks and air or rain.*
So, are you saying that chemical reactions take place in systems outside of science labs? What's another example?	*yes* *when plants make food during photosynthesis* *when an old steel ship rusts* *when gravestones are worn down by acid rain* *when I clean the kitchen drain with baking soda and vinegar*
What is the general purpose of the third article, "Detecting Odor"?	*It explains in detail how humans and other animals detect and react to odors.*

Student Reader

Collection 5

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Explain to English learner students that the word *olfactory* is derived from a Latin word meaning "to smell." Then have students find all the uses of this word in Selection 3 (*olfactory epithelium, olfactory neuron receptors, olfactory bulbs, olfactory senses*) and draw a word map to display them.

CHALLENGE—Share with students the lyrics to the Harry Nilsson song "Think About Your Troubles" (1970), and then invite them to write their song verse(s) but focused on the law of conservation of energy, instead of matter. (See the **Online Resources Guide** for a link to the lyrics. **www.coreknowledge.org/cksci-online-resources**)

Pages 44–53 **Suggested prompts**	**Sample student responses**
How do graphics in this article build on the handout reading "How do we detect odors?"	*There are two graphics that help. The first visualizes the lock-and-key mechanism as some simple shapes that fit together. The second is a concept map that shows relationships between olfactory structures and brain structures.*
Does water have an odor? Explain how you know.	*I don't think so because there is often lots of water vapor in the air and I don't smell it.* *I'm not sure because when I smell a glass of tap water, sometimes it has a slight odor.*
What is the general purpose of the fourth article, "Carbon in a Cycle"?	*It explains how matter and energy are neither created nor destroyed, only moved around.*
What does this reading explain about chemical energy, and how does it add to your understanding of what happens in chemical reactions?	*It explains that there is energy stored in the chemical bonds of molecules and that some chemical reactions transform this chemical energy to other forms, such as heat, motion, or electrical energy.* *This adds to what we discussed in class about how some chemical reactions occur only when energy (electrical) is added.*
Why do you think the author chose the word sink to describe where chemical energy is stored? Go ahead and look up the definition if you wish.	*A sink is like a basin that can hold stuff. So, underground locations with petroleum, methane, or coal are like underground sinks.* *There is another meaning for the noun sink—a pool, a pit, or a depression in the land—that also works in this context.*

4. Check for understanding.

Evaluate and Provide Feedback

For Exercise 5, students should write a well-constructed paragraph to explain the meaning of an idea attributed to 18th-century scientist Antoine-Laurent Lavoisier: “Nothing is lost, nothing is created, everything is transformed.” Look for evidence that students understand how this idea likely refers to the law of conservation of matter and that students know how to blend a topic sentence, supporting details, and a conclusion into an effective paragraph.

Students can also make a legitimate claim that the idea refers to the law of conservation of energy and support their argument with three examples.

EXTEND—Explain to students that nearly all the prominent figures in the recorded history of science are male. This is due to restrictions on girls and women common at that time. For example, females were rarely educated in math and science, rarely allowed to work outside their homes, and rarely permitted to belong to scientific organizations. Suggest to students that they explore websites focused on sharing information about women in the history of science and learn more about the contributions of Marie-Anne Paulze Lavoisier to chemistry.

Teacher Resources

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ASSESSMENT SYSTEM OVERVIEW

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial Model Handout Driving Question Board	**Pre-Assessment** The student work in Lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn where students are coming in and what ideas they have that you can build on in this unit. The more ideas in your classroom the better. Specifically, look for students' initial understandings of modeling, asking questions, patterns, cause and effect, and matter and energy. Collect students' initial models on *What Happens to a Bath Bomb When Put in Water?* and *Initial Model-based Explanation* at the end of day 1 to pre-assess their fluency in three-dimensional learning. Look for students to include both macroscopic and microscopic elements in their initial models of the bath bomb. See the related Assessment callout box in the teacher guide for additional guidance. The Driving Question Board is another opportunity for pre-assessment. Listen for questions that are open (how/why) and testable versus closed (yes/no) in the classroom. Also listen for questions that are specific to the bath bomb and questions that are about related phenomena when solids are added to liquids. See the related Assessment callout box in the teacher guide for additional guidance.
Lesson 2	Construct an argument in science notebooks. Scoring guidance: *Sample Student Response for Written Argument*	**Formative** In Lesson 2 students construct their first written argument with scaffolding. This serves as a formative assessment for where students are in their development of this practice. Look for the use of key model ideas and observations as evidence in their responses. See *Sample Student Response for Written Argument* and the related Assessment callout box for additional guidance.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 5	*My Predictive Explanations for the Gas from a Bath Bomb* Individual argument on notebook paper or in student notebooks. Scoring guidance: *Sample Student Response for Written Argument*	Students develop a predictive argument around two claims about the evidence they would need to collect in order to determine what the gas that is produced from the bath bomb could be. They carry out investigations to collect property data of the gas and use this evidence to develop an individual argument. **Formative** Check students responses on *My Predictive Explanations for the Gas from a Bath Bomb* at the end of day 1 and provide feedback. See Assessment callout box in the teacher guide at the end of day 1. **Summative** Collect students' written arguments at the end of the lesson (end of day 2). Use *Elements to look for in students' written arguments* for guidance on what to look for in their written arguments.
Lesson 6	*Explaining another phenomenon* *Alternate: Explaining another phenomenon* Scoring guidance: : *Elements to look for in students' written arguments*	**Summative** This lesson offers students an opportunity to use their ideas to explain a related phenomenon. This is the first time in the unit that students have tried to explain a different phenomenon than the bath bomb. This offers a good midpoint summative assessment opportunity but also can be used to inform whether additional remediation or review is needed in subsequent lessons. Collect students' written arguments on *Explaining another phenomenon* or *Alternate: Explaining another phenomenon*. Use *Elements to look for in students' written arguments* for guidance on what to look for in their written arguments.
Lesson 10	Individual argument on notebook paper. Scoring guidance: *Sample Student Response for Written Explanation*	**Summative** In Lesson 10, students collect evidence from an investigation where energy is added to water using a battery. Two gases are formed when this happens and students use property data to determine this and write an argument. At the end of the lesson, they construct an argument about whether the gas(es) produced from water using energy from a battery is made of the same particles that were produced from heating the water. Use *Sample Student Response for Written Explanation* for guidance on what to look for in their written arguments.
Lesson 12	*Explaining New Aspects of the Anchoring Phenomena* Scoring guidance: *Explaining New Aspects of the Anchoring Phenomena*	**Summative** In this assessment students construct two explanations having to do with the bath bomb reaction. One explanation is around how the same atoms that are in the molecules of the starting substances rearrange to form new products made of different molecules. The second explanation is about whether more than one substance can be produced during a chemical reaction. Use *Explaining New Aspects of the Anchoring Phenomena* for guidance on what to look for in their explanations.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 13	Individual argument on notebook paper. Scoring guidance: *Sample Student Response for Written Explanation*	**Formative** Students develop an explanation for what an odor is and how it is detected after conducting an investigation and reading informational text. Since this is only the second time in the scope and sequence that students will have gathered and synthesized information that sensory receptors respond to stimuli by sending messages to the brain, and students will still have two additional experiences with this in later 8th grade units: *Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)* and *Unit 8.2: How can a sound make something move? (Sound Unit)*, it is recommended that you use this as a formative assessment.
Lesson 14	*Part 1: Explaining Marble Changes in the Taj Mahal* and *Part 2a: Explaining Marble Changes in the Taj Mahal* or *Part 2b: Explaining Iron Changes in the Taj Mahal* Scoring guidance: *Part 1 of the Assessment* and *Part 2a of the Assessment* or *Part 2b of the Assessment*	**Summative** Students analyze data about interactions between different substances in the environment around the Taj Mahal and the marble surface of the monument to determine if a chemical reaction is occurring between any of the substances and the marble that could be causing it to be crumbling and falling apart. Through this summative assessment, students will show growth toward all components of the three unit level PEs. The lesson as written gives students the choice to select which option to follow (part 2a or 2b) after completing part 1. However, you may wish to choose part 2b for students that you think would benefit from the challenge. Or you may want to reserve some or all the questions from part 2b as a set of items that students can try again at a later time if they struggle with any of the original items on the test. If students struggle with particular items on this assessment, use *Item alignment guide* to identify related items you could use for supporting relearning/mastery learning.
After each lesson	Lesson Performance Expectation Assessment Guidance	**Formative** Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Occurs in most lessons	Progress Tracker	**Formative and Student Self-Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in their Progress Trackers reflects their own thinking at that particular moment in time. In this way, Progress Trackers can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative grade other than for completion.

When	Assessment and Scoring Guidance	Purpose of Assessment
Anytime after a discussion	Student Self-Assessment Discussion Rubric	**Student Self-Assessment** The student self-assessment discussion rubric can be used any time after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try next time to improve such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive.
After students complete substantial, meaningful work	Peer Feedback Facilitation: A Guide	There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work. Rather, peer feedback will be more valuable to students if they have time to revise after receiving the peer feedback. It should be a formative, not summative, type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	**1.A** Develop a model showing what is happening at a scale smaller than we can see (patterns) to help explain what happened to the matter in the solid bath bombs (matter) and what caused the gas bubbles to appear (matter). **1.B** Ask questions that arise from our observations of different bath bombs before and after they were added to water in order to seek additional information about what caused the changes (effects) we saw occurring. This includes what happened to the matter in the solid bath bombs and what caused the gas bubbles to appear as well as what kind of changes are happening to the matter in examples of other related phenomena we raised.	**1.A Developing and Using Models; Patterns, Systems, and System Models** **When to check for understanding:** Collect students' initial models on *What Happens to a Bath Bomb When Put in Water?* and *Initial Model-based Explanation* at the end of day 1 to pre-assess their fluency in three-dimensional learning. **What to look for/listen for:** Look for students to include both macroscopic and microscopic elements in their initial models of the bath bomb. See the related Assessment callout box for additional guidance. **1.B Asking Questions; Cause and Effects; Matter and Energy** **When to check for understanding:** When students generate questions on sticky notes with their initials on back. You may also want to look through student notebooks to see their individual ideas for future investigations to pursue. **What to look for/listen for:** Listen for questions that are open (how/why) and testable versus closed (yes/no) in the classroom. Also listen for questions that are specific to the bath bomb and questions that are about related phenomena when solids are added to liquids. See the related Assessment callout box for additional guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	**2.A** Collaboratively plan and carry out an investigation in a closed system to answer the question, *"Where does the gas produced by the bath bomb come from?"* **2.B** Construct and present an oral and written argument supported by empirical evidence and scientific reasoning to support the claim that gas is not trapped in the bath bomb to start with but must come from some change to the matter that was already in the system to begin with.	**2.A Planning and Carrying Out Investigations; Energy and Matter** **When to check for understanding:** 1. On day 1, during the class discussions about how to investigate where the gas bubbles come from and what data to collect for both the bag and bottle investigations. 2. On day 2, when small groups carry out the bottle investigation and collect their data. **What to look for/listen for:** 1. Listen for ideas students have for testing the bath bomb in a closed system (sealed container) to see if its mass or volume changes. As the class continues to plan the investigations from crushing the bath bombs to adding them to water, students should suggest similar protocols, including measuring the mass of the entire contents of the system before and after crushing or mixing. 2. As students carry out the bottle investigation, look for students to include measuring the mass of the entire contents of the bottle system before and after crushing or mixing. **2.B Engaging in Argument from Evidence; Energy and Matter** **When to check for understanding:** On day 2, students will construct an argument in writing that answers the lesson question, "Where is the gas coming from?". **What to look for/listen for:** Look for the use of key model ideas and observations as evidence in their responses. See *Sample Student Response for Written Argument* and the related Assessment callout box for additional guidance.
Lesson 3	**3.A** Analyze and interpret data to identify patterns in the characteristic properties of substances. **3.B** Plan and carry out an investigation to collect data to identify patterns in the characteristic properties of substances from a bath bomb when they are individually added to water.	**3.A Analyze and Interpret the Data; Patterns** **When to check for understanding:** 1. On day 1, when students are comparing and analyzing the different bath bomb recipes and when observing bath bomb ingredients and recording these in their Notice and Wonder charts in their notebooks. 2. On day 2, when the class is discussing the results by mixing the individual ingredients with water. **What to look for/listen for:** 1. Day 1: Look for students to observe and mention what ingredients were similar among the different recipes and connect this to the idea that these ingredients might be responsible for the bath bombs bubbling. 2. Day 2: As students report out their observations with the rest of the class in the whole class discussion listen for them to explain how the water looked after each substance was combined with water one at a time.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		3.B Plan and Carry Out an Investigation; Energy and Matter **When to check for understanding:** On day 2 when planning and carrying out the investigation. **What to look for/listen for:** • Looking for evidence of bubbles coming from the ingredients when they are placed in water. • The physical observation of what happened to each ingredient when it was added to water. • Testing only one ingredient at a time so that they know what ingredient is potentially responsible for producing the bubbles.
Lesson 4	**4.A** Conduct an investigation to produce data to serve as the basis for evidence to determine which combinations (patterns) of substances in a bath bomb cause bubbles of gas to appear (effect). **4.B** Construct and present a written and oral argument supported by citing empirical evidence and scientific reasoning that only certain combinations (patterns) of substances (water, baking soda, and citric acid) result (cause) in the formation of a gas (effect). **4.C** Apply scientific ideas and evidence (patterns in properties) to co-construct an explanation that the substance(s) in the gas bubbles must be a different substance(s) than the water, baking soda, or citric acid.	**4.A Planning and Carrying Out Investigations; Patterns** **When to check for understanding:** 1. On day 1, students work with small groups to plan for the data they will collect. 2. On day 2 students carry out their investigation. **What to look/listen for:** 1. Day 1: Listen for discussions about how much data are needed (see Assessment Guidance box for **4.A.1**). 2. Day 2: Note whether students are recording observations for every spot in the ice tray (9 total). They will then be able to notice patterns in the class-wide data to meet the goal of their investigation: what substances are causing bubbles to appear. **4.B, 4.C Engaging in Argument from Evidence to Construct an Explanation; Patterns** **When to check for understanding:** At the end of day 2, during whole-group discussion. **What to look/listen for:** Listen for students posing and responding to relevant questions, and citing relevant sources of evidence. The students should use patterns in the data to support their discovery of which substances combine to cause bubbles.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 5	**5.A** Analyze and interpret the data for common gases to look for patterns that could be used to identify an unknown gas by its characteristic properties. **5.B** Apply scientific reasoning based on patterns in the densities for a known set of gases to explain how either of two different possible outcomes from a future investigation could help us narrow down the sub-set of candidate substances from what could be in the unknown gas from the bath bomb. **5.C** Construct, use, and present an oral and written argument for an explanation that the gas in the bubbles from the bath bomb can be narrowed down to only three possible substances (out of ten of the most common ones in the air) supported by the patterns in the results from density and flammability tests and data on their properties and the use of related key model idea.	**5.A Analyzing and Interpreting Data; Patterns** **When to check for understanding:** 1. On day 1, students discuss noticing and wonderings from *Some Common Gases*. 2. On day 1 students annotate *Some Common Gases* to indicate which gases can be eliminated based on their data. **What to look for/listen for:** 1. Students noticing patterns in the properties of gases, including melting point, density, and flammability. 2. Students crossing off candidate gases in light of new evidence they collect. **5.B Construct an Explanation; Patterns** **When to check for understanding:** Check students' responses on *My Predictive Explanations for the Gas from a Bath Bomb* at the end of day 1 and provide feedback. **What to look for/listen for:** See assessment guidance box at the end of day 1. **5.C Arguing from Evidence; Patterns** **When to check for understanding:** 1. Listen in on small-group discussions in the middle of day 2. 2. Collect students' written arguments at the end of the lesson (end of day 2). **What to look for/listen for:** 1. Listen for how students draw on the evidence from their observations of the density and flammability tests and their previous work on *My Predictive Explanations for the Gas from a Bath Bomb* in small-group discussions, using the protocol on *Discussion Protocol: Density and Flammability*. 2. Use *Elements to look for in students' written arguments* for guidance on what to look for in their written arguments. Use this guidance to provide feedback to students on their written arguments.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	**6.A** Apply key model ideas and patterns in mass and property data to construct three explanations for: a) why the mass of a system decreases when substances are mixed together, b) which substance(s) could or could not be produced in that process, and c) what additional tests could be done on the gas (or other gases) to help identify additional substances that aren't being produced in this process.	**6.A Construct Explanations; Patterns; Systems and System Models** **When to check for understanding:** Students apply key model ideas to construct three explanations in their responses to questions on *Explaining another phenomenon* or *Alternate: Explaining another phenomenon*. **What to look for/listen for:** Use *Elements to look for in students' written arguments* for guidance on what to look for in their written argument. Use this guidance to provide feedback to students on their written arguments.
Lesson 7	**7.A** Develop and revise a model to predict and describe the unseen interactions between particles in a system to show that matter is conserved in a process where the type of particles that make up the starting substances (system inputs) somehow change through their interactions to make different type(s) of particle(s) in the ending substances (system outputs).	**7.A Develop and Revise a Model; Matter, Systems and System Models** **When to check for understanding:** 1. During the whole-group consensus discussion as we revise the class model. 2. The page students mark what they recorded in their student notebooks at the end of the lesson. **What to look/listen for:** 1. Connecting what we figured out from each lesson to a new class model to represent what happens when the original substances in the bath bomb are added to water and a gas is produced. 2. The end of this lesson is a key opportunity to take stock of students' initial ideas before the next lesson, which is where you will need to draw on hypothetical model ideas that students come up with for the formation of the new substance(s) that makes up the gas at a particle level. Those model ideas are likely to include the following: Maybe the particles that make up different substances can be joined together or broken apart (or both). It will be useful to determine if these are ideas that some students are moving toward independently and/or if students are bringing prior ideas about what is happening with the particles (atoms) that make up molecules during the process that formed the substances in the gas (a chemical reaction).

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	**8.A** Ask questions related to the development of alternate models for what is happening to the matter at a particle level (patterns) when old substances interact to produce new substances by combining or rearranging parts/particles (systems and system models), and determine ways we might go about investigating these ideas.	**8.A Ask Questions; Develop and Use Models; Patterns** **When it happens:** Students develop their own individual questions to frame the purpose/goals for reading an informational text about lines of questions and investigations other people/scientists have pursued in the past to try to figure out what particles make up substances. And they record answers to these questions in their Progress Trackers. **What to look for:** • Students preparing to engage in the reading by recording the individual questions they have in their individual Progress Trackers before starting the reading. • Annotating the reading as they read or after a second pass. • Recording what they feel they have figured out from the reading in their individual Progress Trackers.
Lesson 9	**9.A** Use mathematical and computational thinking by graphing mass vs. volume data for different substances and finding the ratio of mass to volume (a unit rate) [scale, proportion, quantity] for the samples measured to determine the density of different clear liquids. **9.B** Argue from evidence and critique two arguments on the same topic; strengthen these arguments by using additional empirical evidence (patterns) and scientific reasoning to support an explanation for whether the substances collected from the gas produced by the heated water is made of different types of particles or the same type of particles (patterns) as those in the water that we started with.	**9.A Use Mathematical and Computational Thinking; Scale, Proportion, Quantity** **When it happens:** 1. Students determine the ratio of mass to volume and the mean (average) unit rate (density) across samples from multiple groups for each substance in small groups before the end of day 1. 2. Students individually determine what the density of a clear liquid is and predict what number of grams the liquid would be if the volume of the liquid was doubled. They record this on an index card at the end of day 1. **What to look for:** 1. Small-group work determining mean (average) densities across samples from multiple groups that yields: • close to 1.0 g/mL for water, • close to 0.78 g/mL for rubbing alcohol, and • close to 1.26 g/mL for glycerin. Though some classes may have results that are within a range of +/-0.1 g/mL of these values, students in any single class should all find the same patterns in ratios using data from their particular class. 2. Look for these responses on student index cards: • Q1) The density of the clear liquid is close to 1.0 grams per mL • Q2) an answer that is twice the volume of the sample the class just measured, or • Q3) an answer that is double the number of grams of the sample the class just measured.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		9.B Argue from Evidence; Patterns **When it happens:** At the end of day 2, students use a separate sheet of paper to write a revised evidenced-based argument to support the claim, "The gas inside the bubbles is made of water particles." They turn this in along with *Evaluating and improving alternate arguments*, which is where they outlined the sources of data and related key model ideas they planned to use in the argument they have revised. **What to look for:** See *Scoring Guidance: Evaluating and improving alternate arguments*.
Lesson 10	**10.A** Students apply scientific ideas and evidence (property data) to construct an explanation for whether the gas(es) produced from water using energy from a battery were made of the same particles (patterns) as those produced from heating the water.	**10.A Constructing Explanations and Designing Solutions; Patterns** **When this happens:** An individual explanation for whether the gas(es) produced from water using energy from a battery is made of the same particles that were produced from heating the water is constructed at the end of this lesson. **When to look for:** See *Sample Student Response for Written Explanation* for guidance.
Lesson 11	**11.A** Gather and communicate information from a scientific text adapted for classroom use to determine the central ideas of Dalton's atomic theory with regard to the patterns in the particulate structure of matter that makes up all substances. **11.B** Construct an explanation using models of the molecular structures of different substances to predict which gas must be produced (effect) in the bath bomb reaction based on the types of atoms that make up the substances (patterns), and use it to explain what is happening to the particles (matter) in the system to cause the production of this new substance.	**11.A Gather and Communicate Information; Patterns, Matter, and Energy** **When this happens:** On day 1 when students read and gather information from *A summary of some historical investigations and discoveries into the particle nature of matter.* **What to look for:** Students highlighting and annotating pieces from the reading about how Dalton and others represented atoms and molecules. **11.B Develop and Use a Model, Construct an Explanation and Design a Solution; Patterns, Cause and Effect, Matter and Energy** **When this happens:** At the end of day 2 students use molecular models for the substances in the bath bomb and possible gases that were produced in *Molecular Models of Different Substances* to: • predict what gas is actually produced (effect) in the bath bomb reaction, and • explain what is happening to the atoms in the molecules of the starting substance (matter/ patterns) in the system to cause this (unobservable mechanisms). **What to look for:** Students should be able to argue this by connecting the molecular models from *Molecular Models of Different Substances*. On this handout they can compare the atoms in baking soda, citric acid, and water to the three gases we had identified as possibly being produced (argon, nitrogen, and carbon dioxide). Using the new key model idea around chemical reactions, students should be able to argue the only possible gas it could be is carbon dioxide.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 12	**12.A** Construct an explanation for how the atoms in the molecules of the starting substances rearrange to form new products in the bath bomb, but the number and types of atoms do not change and thus mass is conserved and evaluate two different molecular models for different ratios of reactant and product molecules to determine which better supports this explanation.	**12.A Constructing Explanations and Designing Solutions; Develop and Use a Model; Matter and Energy** **When it happens:** 1. On day 1 on *Explaining New Aspects of the Anchoring Phenomena*. 2. On day 2 on *Comparing Molecular Ratios in a Chemical Reaction*. **What to look for:** 1. See *Explaining New Aspects of the Anchoring Phenomena* for guidance. 2. Students comparing the different models to account for all the atoms in the reactants also being in the products. They should be looking for the amount of atoms as well as the type of atom.
	12.B Construct an explanation for whether additional substances could have been produced in the bath bomb reaction based on the patterns in the atoms that make up the molecules of the different substances.	**12.B Constructing Explanations and Designing Solutions; Patterns** **When it happens:** On day 1 on *Explaining New Aspects of the Anchoring Phenomena*. **What to look for:** See *Explaining New Aspects of the Anchoring Phenomena* for guidance.
	12.C Analyze and interpret data on the properties of substances (patterns) before and after substances interact to determine if the chemical reaction that produces gas in a bath bomb also produces another new substance.	**12.C Analyze and Interpret Data; Patterns** **When it happens:** At the end of Day 1 on *Explaining New Aspects of the Anchoring Phenomena*. **What to look for:** Use scoring guidance on *Explaining New Aspects of the Anchoring Phenomena*.
Lesson 13	**13.A** Read scientific texts adapted for classroom use to determine how the molecular structure of different substances (patterns) is related to their odor, how those molecules reach our nose (cause), and how those molecules interact with different sensory receptors there that each cause a different signal to travel through our nerve cells that leads to the perception of different scents (effect).	**13.A Obtaining, Evaluating, and Communicating Information; Patterns; Cause and Effect** **When it happens:** Students develop an explanation for what an odor is and how we detect it in a page in their notebooks, flagged with a sticky note based on the central ideas they gathered from a reading. **What to look for:** See the detailed guidance in the assessment callout box within the lesson. **What to do:** See the detailed guidance in the assessment callout box within the lesson.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 14	**14.A** Collect data to produce evidence and use the patterns in the properties of substances to make an argument about whether malic acid secreted by algae is causing a chemical reaction to break down the calcium carbonate in the marble of the Taj Mahal. **14.B** Use molecular models to explain which products could be produced (patterns) from a chemical reaction between either a) the calcium carbonate in the marble surface of the Taj Mahal and pollutants in the air or b) iron in the rods and clamps of the Taj Mahal and pollutants in acid rain. **14.C** Analyze and interpret data and use it as evidence in an explanation to the government of India about which pollutants in the air around the Taj Mahal could be causing the marble surface of the Taj Mahal to break apart and wash away (effect). **Additional LLPE for Alternate Assessment:** Plan an investigation individually and in the design: identify what tools are needed to do the gathering, how measurements will be recorded, and what data is needed to provide evidence for whether one or more acids is chemically reacting (cause) with the iron in the rods and clamps of the Taj Mahal and in this process ends up producing two new substances (effect).	**14.A Plan and Carry out Investigations; Engaging in Argumentation from Evidence; Patterns; Cause and Effect** **When it happens:** This happens on day 1 when students complete *Part 1: Explaining Marble Changes in the Taj Mahal*. **What to look for:** See scoring guidance in *Part 1 of the Assessment*. **What to do:** See scoring guidance in *Part 1 of the Assessment*. If students struggle with particular items on this assessment, use *Item alignment guide* to identify related items on the alternate part 2 assessment that could be used for supporting relearning/mastery learning. Each item on the assessment has been aligned with different parts of the performance expectations so the alternate assessment could be used as a reassessment. **14.B Develop and Use Models; Constructing Explanations and Designing Solutions; Patterns** **When it happens:** This happens on day 2 when students complete *Part 2a: Explaining Marble Changes in the Taj Mahal* or *Part 2b: Explaining Iron Changes in the Taj Mahal*. **What to look for:** See scoring guidance in *Part 2a of the Assessment* and *Part 2b of the Assessment*. **What to do:** See scoring guidance in *Part 2a of the Assessment* or *Part 2b of the Assessment*. If students struggle with particular items on this assessment, use *Item alignment guide* to identify related items on the alternate part 2 assessment that could be used for supporting relearning/mastery learning. Each item on the assessment has been aligned with different parts of the performance expectations so the alternate assessment could be used as a reassessment. **14.C Analyze and Interpret Data, Constructing Explanations and Designing Solutions; Cause and Effect** **When it happens:** This happens on day 2 when students complete *Part 2a: Explaining Marble Changes in the Taj Mahal* or *Part 2b: Explaining Iron Changes in the Taj Mahal*. **What to look for:** See scoring guidance in *Part 2a of the Assessment* and *Part 2b of the Assessment*. **What to do:** See scoring guidance in *Part 2a of the Assessment* or *Part 2b of the Assessment*. If students struggle with particular items on this assessment, use *Item alignment guide* to identify related items on the alternate part 2 assessment that could be used for supporting relearning/mastery learning. Each item on the assessment has been aligned with different parts of the performance expectations so the alternate assessment could be used as a reassessment.

Recipes for Homemade Bath Bombs

Below are the ingredients for ***four different homemade bath bomb recipes***. Using four different recipes gives students a chance to compare and discuss their observations with classmates, and allows the class to investigate a wide variety of substances when considering properties of matter.

Each recipe will make 160 mini bath bombs if you're using the mini ice cube trays included in the materials kit. If you do not have these trays, other ice cube trays will work, but drying time and total recipe yield will be different.

Refer to the materials preparation section of the Teacher Guide for specific directions about how to use the bath bombs in each lesson. To help you plan, the following table outlines how many bath bombs you'll need for each lesson per class (based on six groups of students in a class). You will need to multiply the total per class by how many classes you teach to arrive at the grand total number of bath bombs you'll need to prepare altogether.

Number of mini bath bomb cubes needed					
Lesson	**Per student**	**Per pair**	**Per group**	**Per class for whole-group demonstration**	**Total for one class (based on 30 students in 6 groups)***
1	1 (distribute from all four recipes)				30 (7 or 8 from each recipe)
2		1 from any recipe	8 from Recipe B	8 from Recipe B	15 from any recipe, plus 56 from Recipe B
5			8 from any recipe		48 from any recipe

Adjust if you have more or less than 30 students per class. Then, multiply this number by the number of classes you teach to plan how many bath bombs you need to prepare altogether. Here is a suggested distribution of how you could use cubes from each recipe in each lesson for one class (of 32 students working in 6 groups):

	Lesson 1	Lesson 2	Lesson 5	Total
Recipe A	8	5	12	29
Recipe B	8	56	12	72
Recipe C	8	5	12	29
Recipe D	8	5	12	29

- Lesson 1: Ideally have equal numbers of students testing each recipe of bath bomb in order to collect enough data about how each of the four recipes behave when added to water. Each recipe makes 160 of each of the four recipes in the mini ice cube trays, or 640 total bath bombs. As only one is needed per student for this lesson, save the rest for later lessons by sealing them in a ziplock baggie or air tight container. Recipe B is ideal for further investigations carried out in Lesson 2 and 5, so it is suggested you make three extra sets of recipe B while making these for Lesson 1.
- Lesson 2: For one class working in six groups, you will need 56 cubes of Recipe B and one additional bath bomb per pair of students of any recipe (even broken pieces will be fine). Multiply this by the number of classes to determine how many you need for Lesson 2. For example if you teach 6 sections, you will need 6*56 = 336 of Recipe B.
- Lesson 5: (48 bath bombs per class for 6 groups = 288 bath bombs) Each group of students will need 8 bath bombs to do the investigation in this lesson. It doesn't matter which recipe is used for this so any leftovers that were made for Lessons 1 and 2 can be used here, but if you do not have left over bath bombs and need to make more for this lesson, then it is suggested you make more of Recipe B.

Store any unused bath bombs in airtight containers until they're needed. Additional supplies needed for preparing these recipes:

- Medium or large mixing bowl, Waxed paper or parchment paper for laying out and drying the finished bath bombs, a mini ice cube tray per recipe per batch, and an electronic scale, 500 g range at least, accurate to 0.1 g

Recipe A		
grams	**volume**	**ingredient**
88	⅓ c	baking soda
40	⅙ c	Epsom salts
31	⅙ c	sugar-free lemonade mix (2 "pitcher packets")
10	1 T	cornstarch
5	1 t	olive oil
1.5	⅓ t	water

Recipe B		
grams	**volume**	**ingredient**
88	⅓ c	baking soda
40	⅙ c	Epsom salts
38	⅙ c	citric acid
5	1 t	olive oil
1.5	⅓ t	water

Recipe C		
grams	**volume**	**ingredients**
132	½ c	baking soda
56	¼ c	citric acid
6	1 t	table salt
5	1 t	sugar
38	2 T	coconut oil

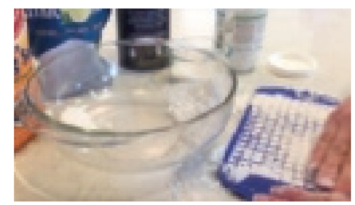
Recipe D		
grams	**volume**	**ingredients**
88	⅓ c	baking soda
40	⅙ c	Epsom salts
30	⅙ c	original lemonade mix (with real sugar)
5	1 t	olive oil
1.5	⅓ t	water

The directions for preparing these recipes are shown here, and you may also watch a video demonstration. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**) Note: Some teachers have had more success preparing bath bombs at home rather than at school, possibly due to higher humidity levels at school.

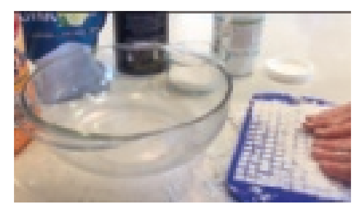
1. Measure the dry ingredients for one recipe into your mixing bowl. We recommend using your digital scale to measure ingredients by mass directly into the bowl as shown in the video. Use your hands (if you are sensitive to any of the ingredients, wear gloves or use a spoon or whisk) to blend the dry ingredients together.

2. Add the oil (and water, if needed) to the bowl. The water will fizz a little bit, and that's OK.

3. Use your hands (wear gloves if you are sensitive to any of the ingredients) to mix and knead the ingredients together for about a minute until they are completely blended. You should be able to squeeze the mixture together at this point, and it will stick together (like a snowball).



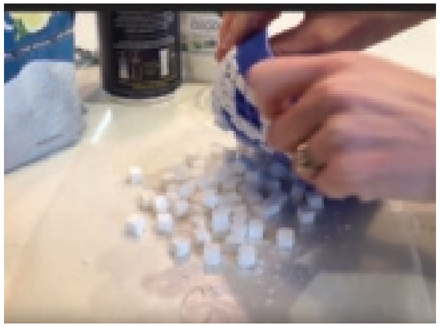
4. Spread each mixture into its own mini ice cube tray.



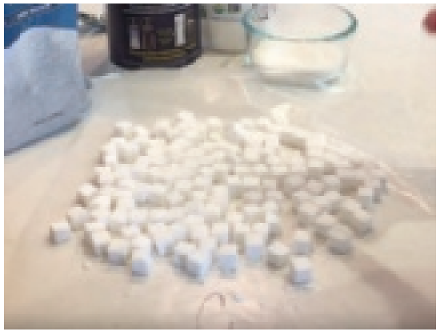
5. Tightly pack down the material into each spot with your finger.

6. Wipe out or wash out and dry the mixing bowl.
7. Repeat the previous steps for the next recipe listed above until you have made all recipes and packed each into their own mini ice cube tray.
8. Let the mini bath bombs dry in their mini ice cube trays for about 1 hour. Note: Recipe C may need to spend some time in the fridge to dry and help solidify the coconut oil.
9. Flip each tray upside down onto a piece of waxed paper labeled with the corresponding recipe letter.

10. You may need to push some of the bath bombs out by pressing on the backside of the mini ice cube tray with your thumb.



11. Let the mini bath bombs dry on the waxed paper for another hour or more. Drying time may vary depending on the humidity level where you're preparing them. After drying, these homemade bath bombs are now ready to use.



LESSON 2: TEACHER REFERENCE

Teacher Reference for Investigating Gas from Bath Bombs in a Bottle

These are the procedures students will follow in their groups to answer the question "Is the gas coming from the bath bombs already there to start with?"

1. Measure 100 mL (100 g) of water into the bottle.
2. Put 8 mini bath bombs (from Recipe B) into a small plastic test tube.
3. Carefully slide the test tube of bath bombs into the bottle so they don't spill into the water.
4. Tighten the cap onto the bottle.
5. Obtain the mass for the whole system. Record the mass.
6. Turn the bottle over to mix the bath bombs into the water.
7. Wait for the bubbles to stop fizzing.
8. Obtain and record the mass of the whole system again.
9. Slowly remove the cap.
10. Obtain the mass of the whole system (including the bottle cap). Record the mass.
11. Rinse out the bottle for other students to use, and put away materials as directed.

Sample Student Response for Written Argument

Students were asked to use evidence from our investigations to answer the lesson question: *Where is the gas coming from*? Their argument should include both of the following: (A) appropriate evidence and (B) reasoning connected to relevant key model ideas.

This may or may not be the first experience students have with writing arguments, and as such this task is an excellent formative assessment opportunity. Their responses will allow you to see where they are with this skill and how much additional support they need across future lessons.

Look for the following ideas in your students' responses (their wording may be different). Including all of these elements would be considered an exemplary response. At this point in the year, it is expected that students will support their claim with one piece of evidence and reasoning.

+Claim: The gas is not new matter. It must come from something that is already there to start with.

+Evidence: In the investigation of mixing bath bombs with water in a closed bottle, the mass did not change from before to after, even though we saw bubbles of gas in the bottle.

+Reasoning with key model idea: Since we know that matter of any kind (solid, liquid, or gas) has mass, when the mass of the closed system did not increase, it meant that no new matter had been added.

+Evidence: When we opened the bottle's cap, we could hear the hiss of matter leaving the system. The mass went down after we opened the bottle.

+Reasoning with key model idea: Gas is matter and has mass, so when the gas escaped, the mass decreased (it would have increased if new matter was added).

+Evidence: When we crushed the dry bath bomb in a closed bag, the bag did not inflate.

+Reasoning with key model idea: Since we know that gases take up space, and the bag's volume didn't change, we can tell that the gas did not come from the dry bath bombs alone.

You may find it helpful when providing feedback to your students to underline their evidence and highlight the key model ideas they use. An example student response with this coding is shown below.

The gas must come from something that is already there to start with. It is not new matter. We know that it came from something already there because when we did our investigation of mixing bath bombs with water in a closed bottle, the mass did not change from before to after, even though we saw bubbles of gas in the bottle. Since we know that matter of any kind (solid, liquid, or gas) has mass, when the mass of the closed system did not increase, it meant that no new matter had been added. Also, when we opened the bottle's cap, we could hear the hiss of matter leaving the system. The mass went down after we opened the bottle, so that also shows us that gas is matter that has mass. Some people thought the gas was just trapped in the bath bombs themselves, but when we crushed the dry bath bombs in a closed bag, the bag did not inflate. Since we know that gases take up space, and the bag's volume didn't change, we can tell that the gas did not come from the dry bath bombs alone. The gas must have come from what was already in the water and the bath bomb together—it is not new matter.

Elements to look for in students' written arguments

Scoring this Argument

The elements described below would be considered part of an exemplary response at this point in the unit. When scoring the evidence students use to support their claim, students need to provide evidence that is coordinated with their claim. However, they ***do not*** need to provide every piece of evidence listed below.

SEP (Arguing from Evidence): Supporting a claim with reasoning that explains why the data they are using supports the claim (evidence) and by using key model ideas to support their argument, students are demonstrating their understanding and ability to engage in this practice.

CCC (Patterns): In their reasoning, students will be engaging in using the crosscutting concept of patterns in property data. For example, students should use the reasoning that the gas from the bath bomb is one of the non-flammable ones in the common gas properties table because the gas they tested extinguishes a flame.

Look for the following elements in students' written arguments (their wording may be different):

- **A claim**
    - that answers the question, "What gas(es) could be coming from the bath bomb?"
    - that identifies three possible substances that could be in the gas from the bath bomb: nitrogen, argon, and/or carbon dioxide.
- **Evidence**
    - that the gas from the bath bomb extinguished a flame.
    - that the gas poured out or released from a container with trapped gas inside it caused a flame below it to go out, but not a flame above it.
    - that the air has a known density (1.161 g/L).
    - that argon, nitrogen, and carbon dioxide have known densities greater than air.
    - that argon, nitrogen, and carbon dioxide have known flammabilities (none of them are flammable).
- **Reasoning** (which includes the use of these ideas)
    - that substances have properties that can help us identify them.
    - that flammability and density are properties.
    - that the gas from the bath bomb must be non-flammable because it extinguishes a flame.
    - that the gas from the bath bomb must be denser than air because it is made of materials that are more dense and sink downwards when surrounded by matter that is less dense.

Explaining another phenomenon

You watched the video of the elephant's toothpaste, which was the result of combining three different ingredients together: potassium iodide (a substance), a mixture of hydrogen peroxide and water, and soap (a mixture).

To help us figure out what is going on, here are the results from tests of different combinations of the three ingredients.

Combination	Ingredients combined	Bubbles?
A	hydrogen peroxide + soap	No
B	potassium iodide + soap	No
C	hydrogen peroxide + potassium iodide	Yes, lots!

Since combination C was the only one that produced bubbles, we will analyze a video showing what else happens when those two ingredients are combined.

1. Watch this second video and record your observations below.

Observations:

Mass of the system before mixing the ingredients:

Mass of the system after mixing the ingredients:

2. Use these two resources: a) your observations and b) your key model ideas to make an argument to answer this question:
    - After combining these ingredients what could have caused the mass of the system to change?

3. Use these three resources: a) your observations, b) your key model ideas, and c) the data table in your notebook of *Some Common Gases*, to make an argument to answer this question:
   - What gases could not have been produced in this process?

4. Another student claims that the gas that was produced in this process was methane. If you wanted to collect additional evidence to either help support or refute this claim you would need additional data. Use the data table in your notebook of *Some Common Gases*, to make an argument to answer this question:
   - Describe one additional test you could do that would help you collect additional data. How could the results help you either support or refute the student's claim?

Alternate: Explaining another phenomenon

You watched the video of the elephant's toothpaste, which was the result of combining three different ingredients together: potassium iodide (a substance), a mixture of hydrogen peroxide and water, and soap (a mixture).

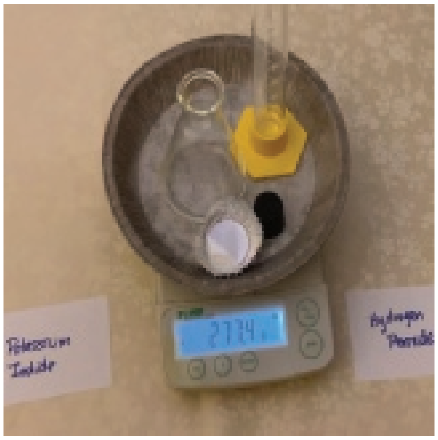
To help us figure out what is going on, here are the results from tests of different combinations of the three ingredients.

Combination	Ingredients combined	Bubbles?
A	hydrogen peroxide + soap	No
B	potassium iodide + soap	No
C	hydrogen peroxide + potassium iodide	Yes, lots!

Since combination C was the only one that produced bubbles, we will analyze a video showing what else happens when those two ingredients are combined.

1. Watch this second video and record your observations below.

Observations:

Mass of the system before mixing the ingredients:	Mass of the system after mixing the ingredients:
	

Use these resources in your answer to the next question:

Key Model Ideas:

- Gas is a type of matter and has mass and takes up space.
- In an open system matter can get in and out of the system and when this happens the mass may change.

2. Use the resources above to make an argument to answer this question:
   - After combining these ingredients what could have caused the mass of the system to change?

When _______________ and _________________ were combined together there were a lot of bubbles that were produced and the mass went _______________. This means a ____________ was made.

I know this because (use one or more of the key model ideas listed above):

____

____

____

____

____

Use these resources in your answer to the next question:

Key Model Ideas:

- Gas is a type of matter and has mass and takes up space.
- In an open system matter can get in and out of the system and when this happens the mass may change.
- A substance has properties that can help to identify it. Some properties are more useful than others.
- Flammability is a property.

Some Common Gases Data:

Gas	Flammability
Nitrogen	Will extinguish a flame
Oxygen	Will increase a flame or cause a glowing ember to burst into flame.
Argon	Will extinguish a flame.
Carbon dioxide	Will extinguish a flame.
Neon	Will extinguish a flame.
Helium	Will extinguish a flame.
Methane (natural gas)	Will increase a flame. Can create an explosion.
Hydrogen	Will increase a flame. Can create an explosion.
Propane	Will increase a flame. Can create an explosion.
Air with 5% humidity	Can maintain an open flame.

3. Use the resources above to make an argument to answer this question:
   - What gases could *not* have been produced in this process?

The gas from the elephant's toothpaste could *not* have been nitrogen, oxygen, argon, carbon dioxide, neon, helium, methane, hydrogen, propane, air. (circle all that apply) When the gas was tested with a flame it went out/glowed brighter (circle one). We can use ________________________ to help identify substances. When the gas was tested with a flame, we were testing its _______________________. Since the flame went out / glowed brighter (circle one), we know the gas is flammable/not flammable (circle one) and therefore it can't be nitrogen, oxygen, argon, carbon dioxide, neon, helium, methane, hydrogen, propane, air. (circle all that apply).

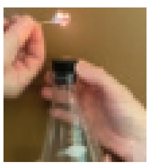
Use these resources in your answer to the next question:

Key Model Ideas:

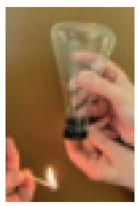
- Gas is a type of matter and has mass and takes up space.
- In an open system matter can get in and out of the system and when this happens the mass may change.
- A substance has properties that can help to identify it. Some properties are more useful than others.
- Flammability is a property.
- Density is a property.

This is how we tested density of a gas before:

Holding a flame above a flask filled with helium:



Holding a flame below a flask filled with helium:



Some Common Gases Data:

Gas	Density ((g/L) measured at 0°C)
Nitrogen	1.250
Oxygen	1.430
Argon	1.780
Carbon dioxide	1.960
Neon	0.900
Helium	0.179
Methane (natural gas)	0.714
Hydrogen	0.090
Propane	2.000
Air with 5% humidity	1.160

4. Another student claims that the gas that was produced was methane. The class discussed ways to collect evidence to support or refute this claim. They decided that testing the density of the gas could provide them helpful evidence for this argument.
   - What test could you do on the gas from the elephant's toothpaste?
   - How would the results of that test help you either support or refute the student's claim?

LESSON 6: ANSWER KEY

Elements to look for in students' written arguments

The elements described below would be considered an exemplary response at this point in the unit. When scoring the evidence students use to support their claim, students need to provide evidence that is coordinated with their claim. However, they ***do not*** need to provide every piece of evidence listed below.

SEP (Arguing for Evidence to Explain): Through writing a claim supported by evidence with reasoning that explains why their evidence supports their claims through connecting them to key model ideas, students are demonstrating their understanding and ability to engage in the practice of argumentation.

CCC (Patterns): In their reasoning, students will be engaging in the crosscutting concept of patterns through explaining the patterns of cause and effect relationships in property data. For example, students should use the reasoning that the gas produced when Substance A and Substance B of Elephant's Toothpaste are combined is flammable because when the glowing wood came in contact with the gas, it glowed brighter. These patterns come from students' *Some Common Gases*. This is an example of using a pattern from the property table to support their claim (e.g., how the cause and effect relationship of the gas making a flame glow brighter [effect] means the gas is therefore flammable [cause]).

In the guide below, there are examples of what students may include in their answers notated with a +. These +'s are not meant to be all inclusive; they are suggestions for what you may see your students include.

KEY:

You watched the video of the elephant's toothpaste, which was the result of combining three different ingredients together: potassium iodide (a substance), a mixture of hydrogen peroxide and water, and soap (a mixture).

To help us figure out what is going on, here are the results from tests of different combinations of the three ingredients.

Combination	Ingredients combined	Bubbles?
A	hydrogen peroxide + soap	No
B	potassium iodide + soap	No
C	hydrogen peroxide + potassium iodide	Yes, lots!

Since combination C was the only one that produced bubbles, we will analyze a video showing what else happens when those two ingredients are combined.

1. Watch this second video and record your observations below.

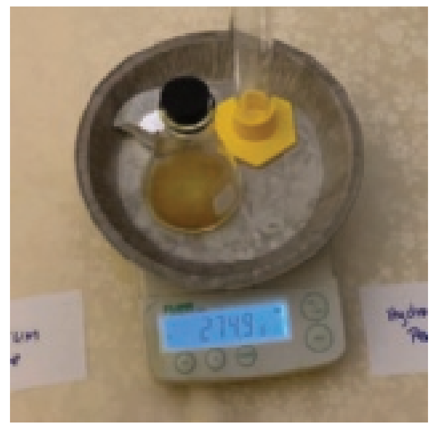
   Observations:

   Student responses should include:

   + The potassium iodide is a white powder beforehand.
   + The hydrogen peroxide is a clear liquid beforehand.
   + As soon as the powder is poured into the liquid, the color changes (orangish/brown).
   + Bubbles begin immediately and fill the flask half way up.
   + When the stopper is put on the flask, it moves around and rattles.
   + Bubbling slows down/stops after a few seconds and there is an orangish liquid left.
   + By the end of this process the mass of the system decreases by X g.

Mass of the system before mixing the ingredients:

Mass of the system after mixing the ingredients:



2. Use these two resources: a) your observations and b) your key model ideas to make an argument to answer this question:

   • Why does combining these ingredients cause the mass of the system to change?

   Students should explain that the mass changed for this combination of materials because a gas was formed and left the system. The data shows that a lot of bubbles were formed when hydrogen peroxide and potassium iodide were combined and that the mass went down for this combination. In the second video clip, there were a lot of bubbles produced and the cork on the top actually moved up and down as if the gas was escaping. Students should use key model ideas in their explanation. Some may choose to include:

   + Gas is a type of matter and has mass and takes up space.

   + In an open system matter can get in and out of the system and when this happens the mass may change.

   + The mass is less because a gas was formed in the video.

   + We saw stuff (the gas) leaving the flask, which is why the mass went down.

   + We saw bubbles in the video; when we see bubbles it means there is a gas.

3. Use these three resources: a) your observations, b) your key model ideas, and c) the data table in your notebook of *Some Common Gases*, to make an argument to answer this question:

   • What gases could *not* have been produced in this process?

   Student responses should include:

   + A claim stating that the gas COULD NOT be nitrogen, argon, carbon dioxide, neon, helium, or air because they do not increase a flame.

   + Evidence from the lit match in the flask getting brighter in the gas.

   + Reasoning using the science principles in the anchor chart (and notebook) that the class has agreed upon for example.

     + Substances have properties that can help us identify them.

     + Flammability is a property.

     + The gas from the elephant's toothpaste must be flammable because it made a flame burn brighter.

     + Since the flame burned brighter and didn't go out, the gas produced can't be any of these.

Example Student Response:

The gas that was collected from the elephant's toothpaste investigation can't be nitrogen, argon, carbon dioxide, neon, helium, or air because it doesn't put out a flame. We know this based on the flammability of these gases. Flammability is a property, which means it doesn't change for a substance. Some gases are flammable, which means a flame in them gets brighter or bursts into flames. Some gases are not flammable, which means a flame goes out in them. The gas from the elephant's toothpaste made a flame burn brighter so it is flammable and this means it can't be any of the non-flammable gases like nitrogen, argon, carbon dioxide, neon, helium, or air.

4. Another student claims that the gas that was produced in this process was methane. If you wanted to collect additional evidence to either help support or refute this claim you would need additional data.

   Describe one additional test you could do that would help you collect additional data. How could the results help you either support or refute the student's claim?

   Student responses could include any of the following (i, ii, or iii):

   i) A density test

      + I could do what we did with helium in class where we tested the density using a flame above and below.

      + If the ember glows brighter and flares up/explodes when the container is opened with this gas in it, then it could be methane because methane is less dense than air and should float upward.

      + If it doesn't then it is probably more dense than air and the flame would flare up when this gas is poured on it.

   ii) Comparing to controls:

      + I could test some controls—each of known gases that I haven't eliminated yet (that are flammable when they interact with an ember or flame).

      + I could compare what they do with an ember to see what is different about when they burst into a flame (oxygen) or create something more like an explosion (methane, hydrogen, or propane).

      + I could then argue which one it best matches with or which ones it doesn't match with.

   iii) A boiling point/condensation point test:

      + I could try capturing and cooling down the gas until it turns into a liquid and measure the temperature at which this happens.

      + The temperature at which this happens is a property (boiling/condensation point).

      + This should help me determine which gas it is.

Example student response:

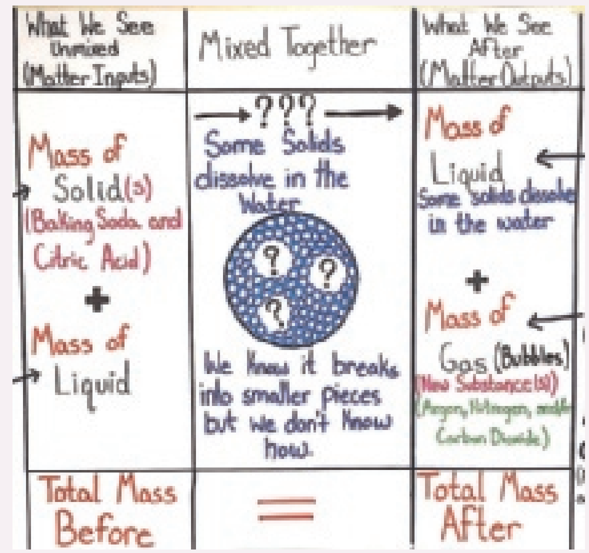
Methane is a gas that will increase a flame, so it is possible that it could be the gas produced from the elephant's toothpaste. But there are other gases on the Some Common Gases data table, so I would want to collect more data to help me narrow it down to methane. One test I could do with the gas is test its density. Density is a property that doesn't change for a substance, so testing its density could help me determine what it might be. In class we tested the density of gases with a flame by holding a flame above and below the gas to see if the gas is denser or less dense than air. Since methane is less dense than air, if I could collect some of the gas from the elephant's toothpaste, then I could hold a flame above and below it. If only the flame that is held above it gets brighter the gas is less dense than air and could be methane. If only the flame that is held below it gets brighter, the gas is more dense than air and could not be methane.

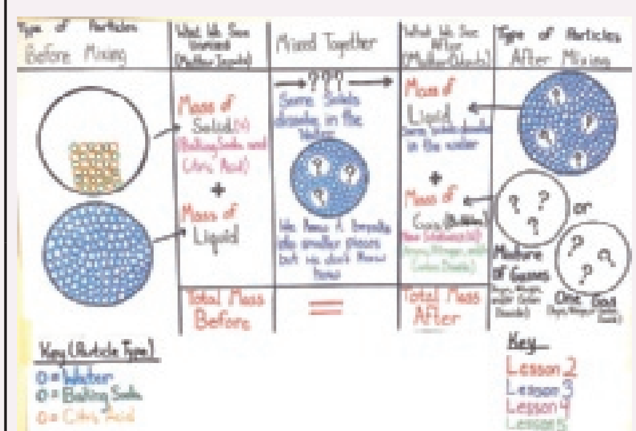
Self-evaluation: Engaging in Classroom Discourse

Setting	Criteria	Absent I do not do this	Developing I occasionally do this (sometimes)	Proficient I often do this	Mastery I consistently do this
In large/whole group settings (Scientist circle discussions, gallery walks, etc…)	**Shares one's own thinking** by contributing new ideas, questions, and additional clarification.				
	Listens actively to others, rephrasing, repeating and/or reusing the ideas others have shared and asking others to repeat their statements or to clarify ideas when they are difficult to hear or understand.				
	Respectfully provides and receives critiques about explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions.				
	Invites others to share their thinking and contribute their ideas.				

Teacher Reference for Building New Class Consensus Model

Lesson 2 (Red)	**Question:** Where is the gas coming from? **What we did:** • Measured the mass of bath bombs in both closed and open systems. **What we figured out:** • Mass did not change before and after the reaction in the closed system.
Lesson 3 (Blue)	**Question:** What's in the bath bomb that is producing the gas? **What we did:** • Looked at the ingredients of bath bombs. • Mixed individual ingredients in water. • Looked at the property data table. **What we figured out:** • Some solids dissolve in water. • Substances have properties.
Lesson 4 (Purple)	**Question:** Which combination of substances in a bath bomb produces a gas? **What we did:** • Students mixed pairs of ingredients in water. **What we figured out:** • When citric acid and baking soda are combined together with water, gas bubbles are produced. • The gas is a different substance than the substances originally in the bath bomb.
Lesson 5 (Green)	**Question:** What gas(es) could be coming from the bath bomb? **What we did:** • Analyzed data from different gases. • Investigated the gas from the bath bomb to see how it relates. **What we figured out:** • The gas from the bath bomb could be carbon dioxide, nitrogen, or argon.





How to set up and run the heating water lab

Before students arrive to class, fill a flask with 75 mL or so of water. Place the flask on the hot plate and turn it on to start heating the water. The water should be boiling enough that there are gas bubbles forming.

Gather students around the flask of heated water. The water should already be boiling at this point. Remind students that we discussed testing the flammability of the gas in the bubbles rising from the water.

Point out the bubbles rising to the surface of the water.

Show students the cork and tubing system and point out how similar it is to what was used to test helium gas.

Using two hot mitts, attach the system to the Erlenmeyer flask.

Strike a match and hold the flame near the gas coming out of the end of the eyedropper at the end of the vinyl tube (about 1–2 inches from the end). The flame will go out. Have students record this observation in their notebooks.

Point out that this might be because the gas is coming off the tube pretty fast, and maybe it simply blew out the flame. However, if that isn't the case, then maybe the gas itself isn't flammable. Ask students to look back at their table of gas properties and identify which gases are flammable, and thus are ruled out. Students should say that the gas can't be hydrogen, oxygen, methane, or propane.

Capture some of the gas coming out of the tube. Lift the end of the tube with the second eyedropper and drop it into another Erlenmeyer flask. Do not seal this second flask with a cork. Point out that you are leaving this partially open for safety reasons to avoid shattering the container from too much pressure.

Ask students to describe what they notice happening on the walls of the container over the next couple of minutes (students may have already seen this on the tubing itself). Students should say that they notice clear liquid droplets appearing on the walls. Have students record this observation in their notebooks.

Ask students what they think this clear liquid might be; they will likely say it is water.

Scoring Guidance: Evaluating and improving alternate arguments

At the end of the lesson, students were asked to construct an explanation to support the claim that: *The gas in the bubbles that was produced from heating the water was made of water particles*. Their argument should include both of the following: (A) appropriate evidence and (B) reasoning connected to relevant key model ideas.

Guidance is provided for what to look for in your students' explanations. Their wording may be different, but by this point in the unit, it should be expected that students will support their claim with an adequate amount of evidence and the use of key model ideas in their reasoning.

Look for the following elements in student responses:

Most relevant evidence:

- The liquid we collected had an average density of ~1.0 g/mL.
- Water also has an average density of ~1.0 g/mL.

Additional evidence using observations **(optional):**

- The gas from the heated water put out a flame.
- When the gas cooled to room temperature, liquid formed in the container that was collecting the gas.
- That liquid was clear.
- Water is a clear liquid at room temperature that can put out a flame.

Reasoning using these key model ideas:

- Properties don't change for substances.
- Density is a property (as are state of matter at room temperature, color, and flammability).

Example reasoning that uses this evidence and key model ideas to provide a particle based explanation: The gas in the bubbles that was produced from heating the water was made of water particles. We know we started with water. Because what we ended with had the same properties as the water we started with, it must also be the same substance. Since it is the same substance it must also be made of the same type of particles throughout (water particles). One property we measured to determine this was density. Density is the ratio of the mass of an object to its volume. The liquid we collected had an average density of 1.0 g/mL. Water also has an average density of 1.0 g/mL. Since the liquid we collected has the same density as water and density is a property, this is how we know the liquid must be water, and therefore made of water particles.

Additional possible reasoning: Other properties like flammability, color, and state of matter at room temperature were also the same for the substance we ended with and the liquid we started with. Like water, the gas put out a flame. The gas was clear as it cooled back down to room temperature, all of which are the same as water. Since the liquid we collected had all of these three properties in common with water, this also supports the claim that the liquid we ended up with is made of the same type of particles we started with (water molecules).

What to do: If students are struggling with developing their reasoning, provide them with additional practice by giving them copies of two different anonymized examples of strong arguments that were developed by students in other classes. For each of the two arguments, ask students to underline the evidence provided and highlight instances of the incorporation of scientific principles.

Setting Up the Electrolysis Apparatus and Capturing and Testing the Gases Produced

Materials Needed

- magnesium sulfate (Epsom salts) $MgSO_4$ (you will use 60 g for every 500 mL of distilled water you make)
- distilled water, 1 gallon
- beaker, 600 mL, 1
- 9-volt battery, 3
- alligator clip, 2
- stainless steel electrode wire, 2
- test tube, 150 mm, 2
- rubber stopper, #2, 2
- lab glassware tape
- crucible tongs or forceps
- wooden matches
- test tube clamp
- ring stand

Safety Precautions

Wear chemical splash goggles. Be sure the area is dry before closing the circuit on the battery. Use only 9V batteries to provide a DC power supply. Do not use an AC power supply. AC will produce oxygen gas and hydrogen gas equally at both electrodes, which can be an explosive mixture.

Disposal

The magnesium sulfate solution may be disposed of down the drain. The stainless steel electrode wires should be rinsed with water. The wires and the alligator clips should be dried to prevent rusting and stored for future use.

Pre-Lab Preparation

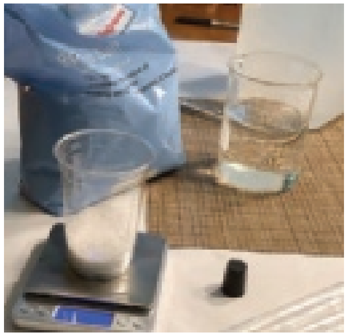
Electrolyte Solution Preparation

To prepare 500 mL of 1 M magnesium sulfate ($MgSO_4$) solution, add 60 g of magnesium sulfate (Epsom salts) to 400 mL of distilled or deionized water in a 600-mL beaker. Stir to dissolve and then dilute the solution to a final volume of 500 mL with distilled or deionized water. Use the video for help in setting up and running this lab. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)

Note: The concentration of magnesium sulfate is not critical. A 1 M concentration is the option outlined below; 0.5 M, 2 M, or 3 M will also work. The higher the concentration, the faster the reaction will proceed, because more current will be allowed to flow through the solution.

Setup A: Electrolysis apparatus with no test tubes

Pour 400 mL of 1 M magnesium sulfate electrolyte solution into a 600-mL beaker.

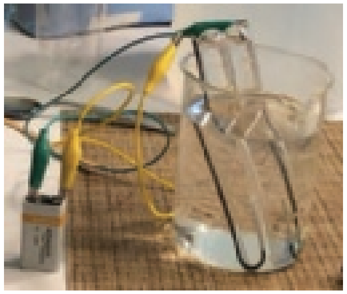


Place both stainless steel electrode wires in the beaker.

Attach an alligator clip to the end of each steel electrode wire sticking out of the beaker.

Attach three 9V batteries together in a series (as shown), if you want to produce the gases quickly (within 20 min). Alternatively, attach a single 9V battery if you have an hour available to produce the gases. If the batteries start losing charge, attaching three together as shown may help get one more use out of them.

Attach one alligator clip to the positive terminal that is exposed on one of the batteries. Attach the other alligator clip to the negative terminal that is exposed on the other battery. Do not use an AC power supply!



Bubbles should start forming on each wire.

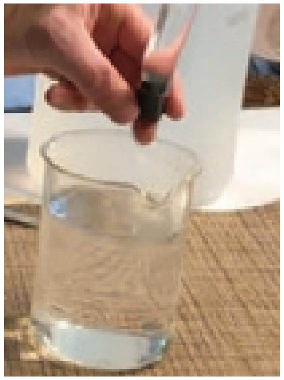
Setup B: Electrolysis apparatus with test tubes. Watch the video for additional guidance, if needed. (See the **Online Resources Guide** for a link to this resource. **www.coreknowledge.org/cksci-online-resources**)

You may want to make two to three separate setups to produce gas samples for more than one class. If so, repeat steps 1-11.

Pour 400 mL of 1 M magnesium sulfate electrolyte solution into a 600-mL beaker.

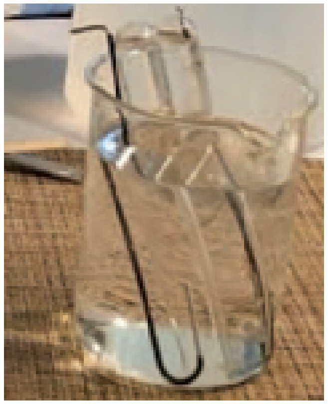
Dispensing from the beaker, completely fill one test tube with the solution. Cork it with a rubber stopper. Repeat this for the second test tube.

Turn the test tubes upside down over the 600-mL beaker, making sure the rubber stoppers do not come out. Lower them into the beaker.



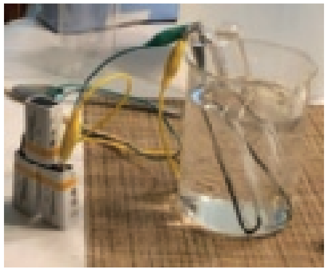
Remove the rubber stopper from the bottom of both test tubes while they are still submerged in the solution. The test tubes should remain nearly completely filled with liquid.

Place both stainless steel electrode wires in the beaker. Lift a test tube just enough to move it over an electrode wire. Do this for the second test tube and second wire as well. Don't lift the test tubes higher than the level of the solution in the beaker or the liquid will empty out of the test tube and you will have to go back to step 2.



Attach an alligator clip to the end of each steel electrode wire sticking out of the beaker.

Attach three 9V batteries together in a series (as shown), if you want to produce the gases quickly (within 20 min). Alternatively, attach a single 9V battery if you have an hour available to produce the gases. If the batteries start losing charge, attaching three together in series (as shown) may help get one more use out of them.



Attach one alligator clip to the positive terminal that is exposed on one of the batteries. Attach the other alligator clip to the negative terminal that is exposed on the other battery. Do not use an AC power supply!

Bubbles should start forming on each wire. Mark the one with more bubble formation as "A" using a piece of lab tape (this is hydrogen gas). Mark the one with less bubble formation as "B" using a piece of lab tape (this is oxygen gas).

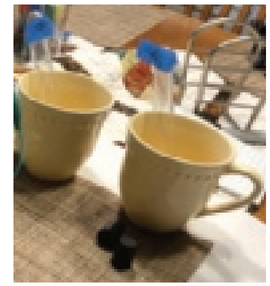
Unclip the alligator clips from the electrodes and the batteries when test tube A is three-fourths or more full of gas (hydrogen gas).

Capturing the gases in test tubes to test

Unclip the alligator clips from the electrodes and the batteries.

Lift test tube A just enough to move it off of an electrode wire. Use crucible tongs to carefully insert a rubber stopper into the opening of one of the test tubes. Make sure the rubber stopper is tightly sealed in the opening of the test tube by carefully, yet firmly, pushing the test tube down so that the rubber stopper presses against the bottom of the beaker. Don't lift the test tubes higher than the level of the solution in the beaker until the stopper is inserted or the gas inside the test tube may escape.

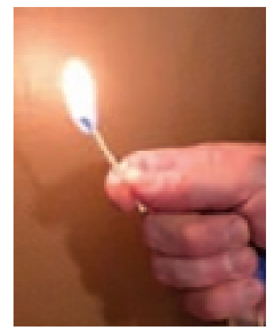
Once the rubber stopper is secure, remove the test tube and turn it right-side up. Dry the outside with a paper towel and place the test tube in the beaker or in a test tube rack. Repeat the last two steps for the other test tube. Do not place the test tubes immediately adjacent to each other in the test tube rack. Place each test tube you get in a separate cup or beaker or test tube rack.



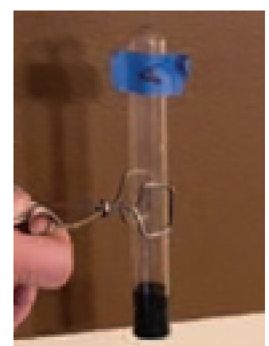
Testing the gases

Reduce the amount of light in the room for these steps so the effects are more visible.

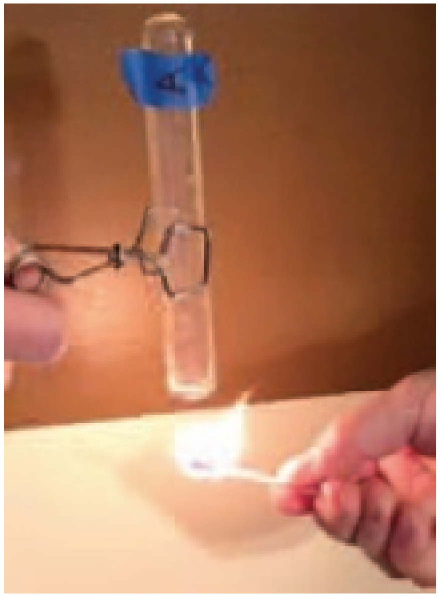
Use the long matches included in your kit. Light one of the matches. Let it burn until the tip has a small, steady flame.



Choose test tube A and secure it in place with a test tube holder so that the mouth of it is facing downward.

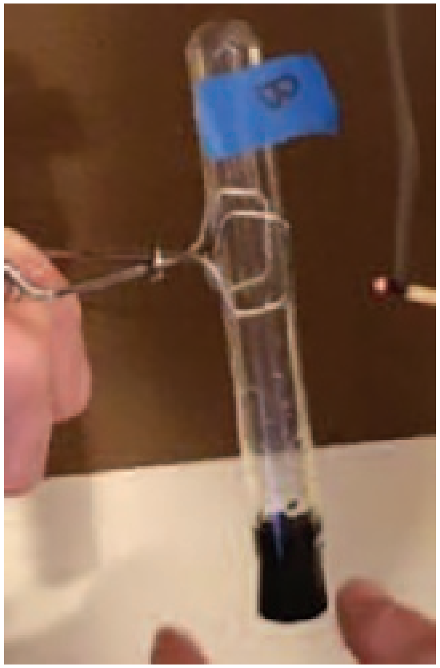


Place the flaming match near the stoppered opening. Quickly remove the rubber stopper and insert the match into the test tube opening.



Observe what happens. A pale blue flame and a loud “pop” or “bark” will occur. If the match is still lit, extinguish the match in a beaker of water.

Repeat the last five steps for the test tube labeled B. This time, the flame will glow brighter when placed into the test tube.



Instructions above were adapted from *Brownlee Electrolysis Apparatus Without Battery Jar Demonstration Kit Publication;* Flinn Scientific: Batavia, IL.

LESSON 10: ANSWER KEY

Sample Student Response for Written Explanation

At the end of the lesson, students were asked to construct an explanation to answer the lesson question: *When energy from a battery was added to water, were the gases produced by this made of the same particles as were produced from heating the water*? Their argument should include both of the following: (A) appropriate evidence and (B) reasoning connected to relevant key model ideas.

Up until Lesson 8 students have been constructing arguments for various claims, instead of developing explanations for how/why a phenomenon occurs. We made this distinction that students are writing explanations in this lesson and the last one now because they are accounting for a phenomenon by reasoning about changes occurring at a particle level (unseen mechanisms). This transition to explaining how and why these processes occur by using ideas about what is happening at a level we can't see is one distinction we are making between an explanation for *how and why* something happens vs. an argument for what happened.

This will be useful as a formative writing piece for your students so you can gauge how they grow in this practice (constructing explanations) and the use of the related crosscutting concept (micro-macro patterns) over time. In the last few lessons of this unit and in future units, students will have more experience in this type of writing. Their responses will allow you to see where they are with this practice and how much additional support they need across future lessons.

On the next page is guidance for what to look for in your students' explanations. Their wording may be different, but by this point in the unit, it should be expected that students will support their claim with an adequate amount of evidence and the use of key model ideas in their reasoning.

Example Claims:

- The particles in the gases made by adding energy to water by a battery are not the same as when energy is added to water by heating it.
- When energy is added to water by heating, the gas bubbles are made of different particles than the gas bubbles made from adding energy to water using a battery.

Evidence using observations from the investigations:

- When we heated the water it created gas bubbles. But when the heat was removed, the gas became a liquid again at room temperature.
- When we tested the flammability of the gas bubbles, the flame went out.
- When we tested the density of this liquid, it was the same as water, 1.0 g/mL.
- When we added energy to the water using a battery, it produced gases that stayed in gas form at room temperature.
- When we tested the flammability of the gases, one of them made the match glow brighter and the other made a small explosion.

Reasoning using these key model ideas:

- Properties don't change for substances; different substances have different properties.
- Flammability is a property.
- State of matter at room temperature is a property.
- When new substances are produced from old substances some of the particles that make up the original substances break apart and/or join together to make new types of particles.

Sample explanation

- Since we know we can use properties to figure out what different substances are and these properties don't change for substances, the gases made from adding energy from the battery are made of different particles than the gas made from energy added by heating. Flammability, a property, was different for all of the gases. The gas bubbles from the heated water made the match go out, while one of the gases produced from the battery caused the match to burn brighter and the other gas made a little explosion. All three of these gases had a different result for this property, so they are all different substances. And since they are different substances they must be made of a different type of particle. State of matter at room temperature is another property of substances. The gas bubbles that were produced by heating the water became a liquid again at room temperature and when we tested the density we figured out it was the same as the original water (1.0 g/mL). In this process the water went through a phase change but did not produce a different substance. The other two gases produced when the battery energy was added stayed a gas at room temperature. Since they were a different state of matter than the liquid water, these gases are new substances, which means they must be made of different types of particles than water.

Name: ____________________ Date: ____________________

Constructing a revised explanation

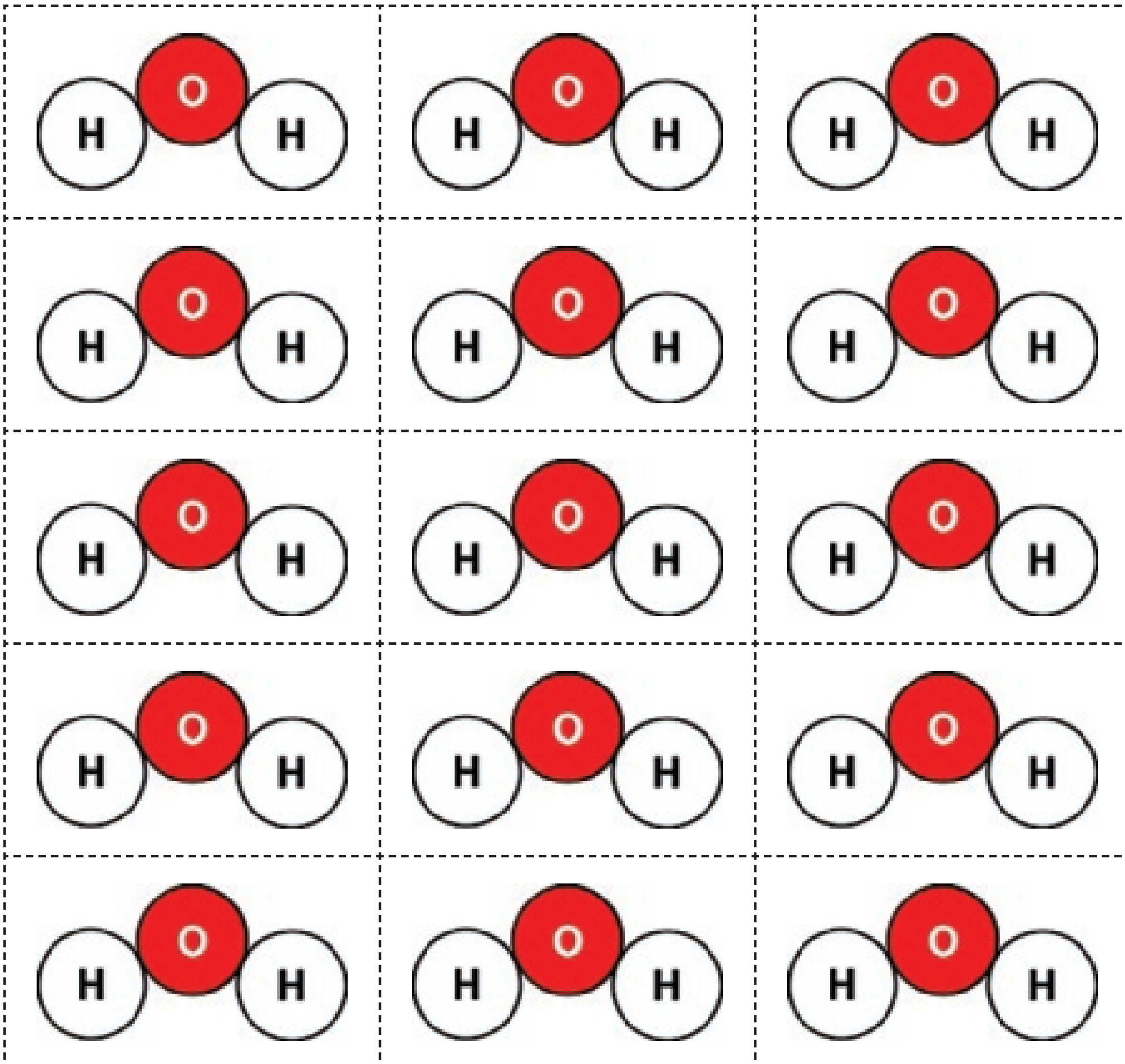
Use your new key model ideas to explain why the gas that was produced could only be one of the substances you circled and not the other two.

Draw and label a model showing where the matter came from at the particle level to produce this particular kind of gas.

Describe, in words, how the molecules of of baking soda, citric acid, and water interact in the chemical reaction that produces the gas:

How confident are you in your model and explanation above? What questions did your responses raise for you?

These 2-D molecule cutouts will be used by students as the class discusses what happens to water molecules in different chemical processes. It is advised to make a copy of these, cut them out before class, and store them in a baggie or bin to be used during the class discussion. In some cases, students may tear the atoms apart to represent one or more of the processes, so you will want to make a few pages per class to be sure to have enough for students as they make sense of these processes.



Name: ______________________ Date: ______________________

Explaining New Aspects of the Anchoring Phenomena

A group of students in another class investigated why bath bombs behave the way they do. They added baking soda to citric acid and water and collected evidence that a chemical reaction between these substances produced carbon dioxide gas from a chemical reaction. But this group of students wondered if the chemical reaction in the container produced other substances too. They wanted to test the liquid left in the container to figure this out.

Q1) To do this, they boiled the liquid left over in the container and captured the gas from this. As the gas they captured cooled back down, it became a clear liquid. They measured the density of the liquid they collected and determined that it is the same as water. They were surprised, however, to find that they had 4.3 grams more water now than they had at the start (before mixing everything together).

Explain how a chemical reaction between molecules of baking soda and molecules of citric acid could also have produced some new water molecules. Use the models below to support your explanation.

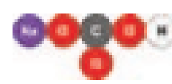
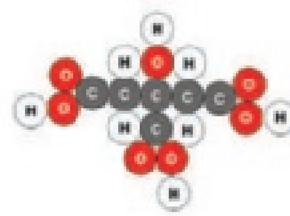
____

____

____

____

Atom symbol	Atom name
	Hydrogen
	Carbon
	Nitrogen
	Oxygen
	Calcium
	Sulfur

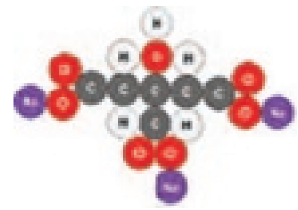
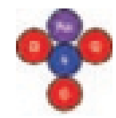
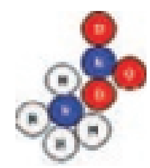
Substance	Molecular formula	2D model
Water	H_2O	
Baking soda	$NaHCO_3$	
Citric acid	$C_6H_8O_7$	

Q2) After boiling off the water, there was a whitish powder left in the bottom of the container. One group member claimed this is either citric acid or baking soda. Another group member disagreed and claimed that this might be a third new substance that was produced in the chemical reaction. They test the properties of the unknown powder left over and compare it to samples of citric acid and baking soda to try to determine which claim is correct.

Sample	State of matter at room temperature	Color	Density	Solubility In water	Solubility in rubbing alcohol
Baking soda	solid	white	2.20 g/cm^3	very soluble	slightly soluble
Citric acid	solid	white	1.66 g/cm^3	very soluble	very soluble
Unknown powder left over	solid	white	1.70 g/cm^3	very soluble	not soluble

Construct an argument to answer this question: **Is the unknown powder left over in the container a new substance?** Use evidence from the data above and related key model ideas to support your claim.

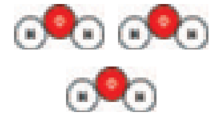
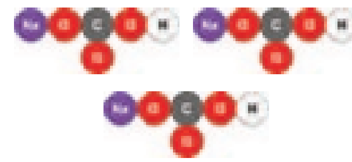
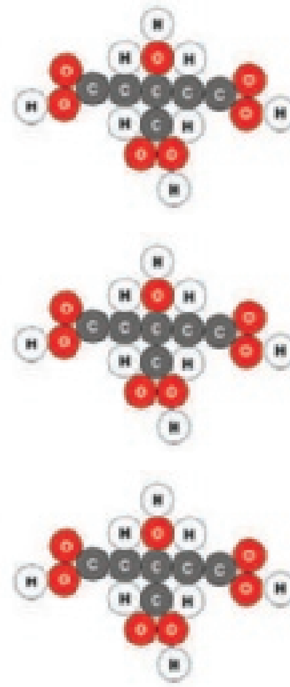
Q3) Another student claims that a chemical reaction can sometimes produce more than one new substance. Here are three substances that this student claims could also have been produced in a chemical reaction between molecules of baking soda, citric acid, and water:

Substance	Molecular formula	A single molecule of this substance
Sodium citrate	$Na_3C_6H_5O_7$	
Sodium nitrate	$NaNO_3$	
Ammonium nitrate	NH_4NO_3	

Refer to the molecular models for baking soda, citric acid, and water on the next page to support your answer to this question: **Explain why a chemical reaction between molecules of baking soda, citric acid, and water could produce <u>only</u> <u>one of the</u> substances shown above?**

- **In your explanation describe what substances are produced and what happens to molecules of the reactants in this process.**
- **Also explain why the other two substances are not possible products of this chemical reaction.**

Atom symbol	Atom name
	Hydrogen
	Carbon
	Nitrogen
	Oxygen
	Calcium
	Sulfur

Substance	Molecular formula	3 molecules of this substance
Water	H_2O	
Baking soda	$NaHCO_3$	
Citric acid	$C_6H_8O_7$	

Name: ______________________ Date: ______________

LESSON 12: ANSWER KEY 1

Explaining New Aspects of the Anchoring Phenomena

A group of students in another class investigated why bath bombs behave the way they do. They added baking soda to citric acid and water and collected evidence that a chemical reaction between these substances produced carbon dioxide gas from a chemical reaction. But this group of students wondered if the chemical reaction in the container produced other substances too. They wanted to test the liquid left in the container to figure this out.

Q1) To do this, they boiled the liquid left over in the container and captured the gas from this. As the gas they captured cooled back down, it became a clear liquid. They measured the density of the liquid they collected and determined that it is the same as water. They were surprised, however, to find that they had 4.3 grams more water now than they had at the start (before mixing everything together).

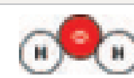
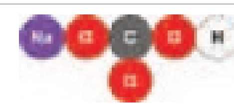
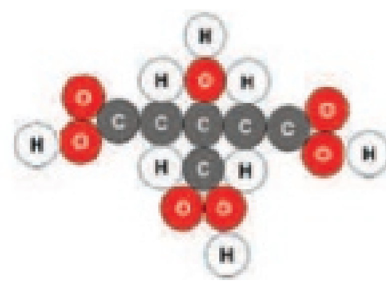
Explain how a chemical reaction between molecules of baking soda and molecules of citric acid could also have produced some new water molecules. Use the models below to support your explanation.

Student responses should include:

+ In a chemical reaction, new molecules (products) are made from the atoms that make up the old molecules (reactants).

+ Since two types of atoms, hydrogen and oxygen, are needed to make a water molecule, and both of these are found in the reactant molecules (citric acid and baking soda), new water molecules could have been produced in this chemical reaction.

Atom symbol	Atom name
	Hydrogen
	Carbon
	Nitrogen
	Oxygen
	Calcium
	Sulfur

Substance	Molecular formula	2D model
Water	H_2O	
Baking soda	$NaHCO_3$	
Citric acid	$C_6H_8O_7$	

Q2) After boiling off the water, there was a whitish powder left in the bottom of the container. One group member claimed this is either citric acid or baking soda. Another group member disagreed and claimed that this might be a third new substance that was produced in the chemical reaction. They test the properties of the unknown powder left over and compare it to samples of citric acid and baking soda to try to determine which claim is correct.

Sample	State of matter at room temperature	Color	Density	Solubility In water	Solubility in rubbing alcohol
Baking soda	solid	white	2.20 g/cm^3	very soluble	slightly soluble
Citric acid	solid	white	1.66 g/cm^3	very soluble	very soluble
Unknown powder left over	solid	white	1.70 g/cm^3	very soluble	not soluble

Construct an explanation to answer this question: **Is the unknown powder left over in the container a new substance?** Use evidence from the data above and related key model ideas to support your claim.

Look for a claim similar to the following:

+ The unknown powder left over in the container is a new substance.

Look for references to the data table that includes:

+ Reference to the data from at least one of these property differences:

- + The density of the unknown powder (1.70 g/cm^3) is different from citric acid (1.66 g/cm^3) and it is different from baking soda (2.20 g/cm^3).
- + The solubility of the unknown powder in alcohol (not soluble) is different from the solubility of citric acid in alcohol (very soluble) and it is different from the solubility of baking soda in alcohol (slightly soluble).

Look for the use of these key model ideas:

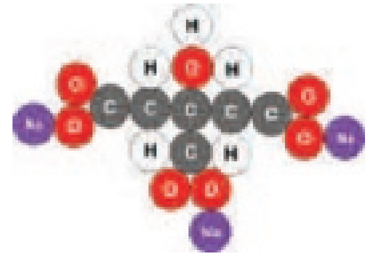
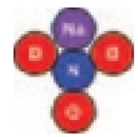
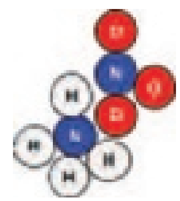
+ Different substances have different properties; two of these properties are density and solubility.

+ In a chemical reaction, new substances with new properties are formed from the old substances.

Look for these **connections** between the data collected and the scientific principles:

+ Since at least one of the properties of the white power (its density and/or its solubilty in alcohol) is different from citric acid and is different from baking soda, it is not the same substance as them, because different substances have different properties.

Q3) Another student claims that a chemical reaction can sometimes produce more than one new substance. Here are three substances that this student claims could also have been produced in a chemical reaction between baking soda, citric acid, and water:

Substance	Molecular formula	A single molecule of this substance
Sodium citrate	$Na_3C_6H_5O_7$	
Sodium nitrate	$NaNO_3$	
Ammonium nitrate	NH_4NO_3	

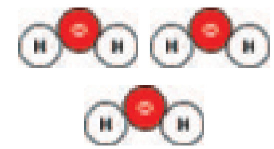
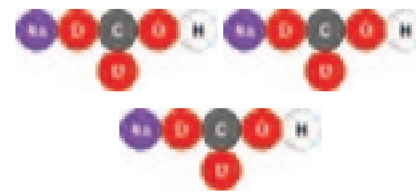
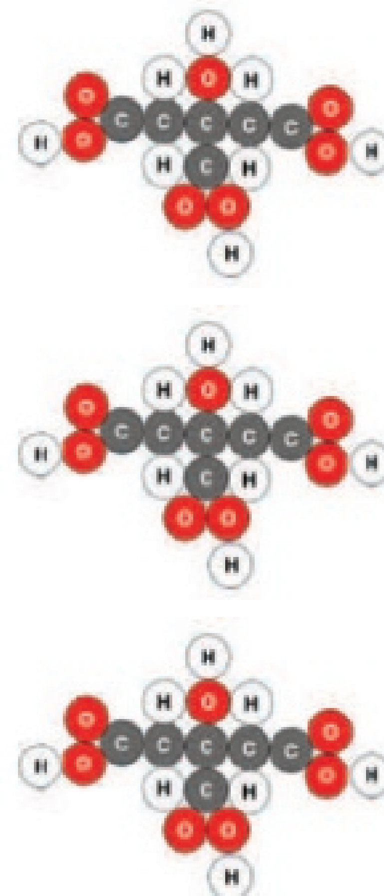
Refer to the molecular models for baking soda, citric acid, and water on the next page to support your answer to this question: **Explain why a chemical reaction between molecules of baking soda, citric acid, and water could produce <u>only one of the</u> substances shown above?**

- **In your explanation describe what substances are produced and what happens to molecules of the reactants in this process.**
- **Also explain why the other two substances are not possible products of this chemical reaction.**

This model or argument explanation should show that since there are no nitrogen atoms in citric acid, baking soda, or water, there is no way they can be the reactants in a chemical reaction that would be needed to produce sodium nitrate or ammonium nitrate molecules. This is because one type of atom is missing from these two reactant molecules—nitrogen.

Sodium citrate, however, is made of the same four types of atoms (sodium, carbon, oxygen, and hydrogen) that can all be found in the reactant molecules, so it should be a possible product.

Atom symbol	Atom name
	Hydrogen
	Carbon
	Nitrogen
	Oxygen
	Calcium
	Sulfur

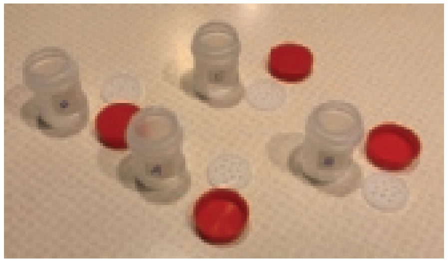
Substance	Molecular formula	2D model
Water	H_2O	
Baking soda	$NaHCO_3$	
Citric acid	$C_6H_8O_7$	

Setting up Odor Lab

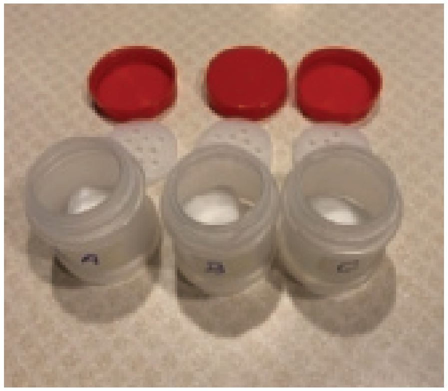
You will need:

- 4 travel spice containers per group
- one vial each of: vanilla oil, lavender oil, menthol crystals, limonene oil
- one cotton ball per spice container
- one copy of *Molecular Models of Different Substances* (a color copy is included in the student workbook)

1. Begin by labeling 6 containers on the side with the letter A, 6 containers with the letter B, 6 containers with the letter C, and 6 containers with the letter D. Then remove the caps and the sifter lids.



2. Place a cotton ball in all the containers labeled with the letter A, letter B and letter C.



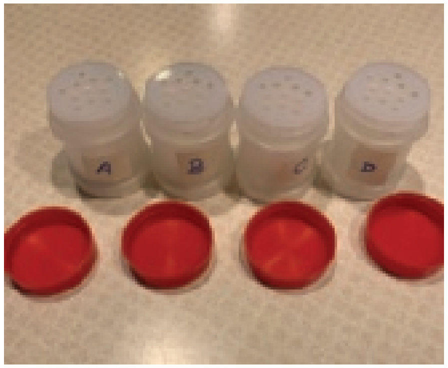
3. In all the containers labeled with the letter A, place 4-6 drops of the vanilla oil onto the cotton ball inside the container.

4. In all the containers labeled with the letter B, place 4-6 drops of the lavender oil onto the cotton ball inside the container.

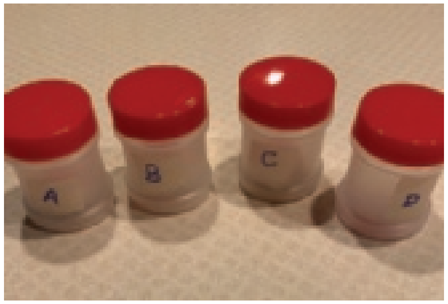
5. In all the containers labeled with the letter C, place 4-6 drops of the limonene oil onto the cotton ball inside the container.

6. In all the containers labeled with the letter D, place 1-2 crystals of menthol inside the container.

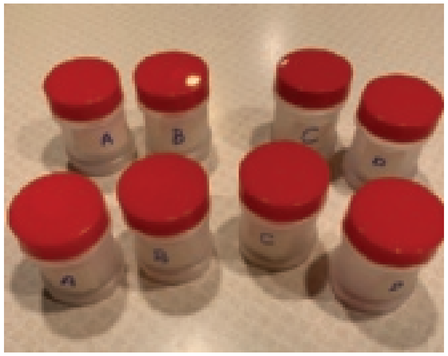
7. After you have filled each of the containers, put the sifter tops back onto the containers. Students should not remove these as they should be able to waft the odor through these.



8. Close each container with the cap until needed in class. If the cap is replaced after each use, these will last longer and you will not need to replace the oils and crystals in the containers.



9. You will need one set of 4 (one A, one B, one C, and one D) containers per group of students.



10. In addition you will need one copy of Molecular Models of Different Substances per group in color. You can either print these out and/or use the color copy included in the student workbook.

Sample Student Response for Written Explanation

Since students have a relatively short amount of time to write this explanation, look primarily for the chain of cause and effect, rather than citation of relevant evidence. The chain of cause and effect connects to the information gathered from the reading, which is the focus of this lesson level performance expectation. This chain of cause and effect should connect these ideas together:

- Odor is a property of substance, that is determined by the number, type, and arrangement of atoms that make up that substance.
- Molecules of substances must travel into our nose in order for us to detect an odor from them.
- Our nose has many different cells that each have different structures (sensory receptors for odor) that different shaped molecules can fit into, which will cause that cell to send a signal to other nerve cells that relay that signal to our brain.
- The perception of different scents is the result of the combination of signals that the brain receives from these different nerve cells.

Since students are asked to develop an explanation, this may cue some students into citing relevant evidence too. You may therefore see the following lines of evidence in some student explanations:

- We observed different odors when we smelled different substances in different containers.
- There were patterns in the type of atoms that made them up (C, H, and O), but differences in the number, type, and arrangement of those atoms.

What to do: If students don't develop this chain of cause and effect, provide structured prompts to ask students to respond to:

- What do the patterns in molecular models on *Molecular Models of Different* Substances help you explain about odors?
- What has to happen to particles of the matter that makes up a substance in order for it to reach your nose?
- What happens to those particles when they reach your nose that cause some (but not all of them) to be detected and recognized by you?
- How could some scents be the result of more than one type of particle being detected by more than one sensory receptor?

Part 1: Explaining Marble Changes in the Taj Mahal

The Taj Mahal was built in Agra, India by the emperor Shah Jahan as a memorial for his wife. It was completed around 1653. It is an impressive building created out of white marble. The Taj Mahal has been named a world heritage site by the United Nations Educational, Scientific, and Cultural Organization. Between 7 and 8 million people visit the Taj Mahal each year. However, in the last 50 years, people have started noticing that the building is turning from white to yellow and the marble is cracking and falling apart.

The marble used to build Taj Mahal is made mostly of one substance: calcium carbonate. Scientists suspect that chemical reactions between a substance that is coming into contact with the calcium carbonate in the marble might be causing it to break down. Here are two possible candidates for this process causing this cracking and falling apart:

Chemical reactions could be happening between the calcium carbonate and acid rain. The acid rain can form from certain pollutants in the air.

Two substances in this acid rain are sulfuric acid and nitric acid.

Chemical reactions could be happening between the calcium carbonate and substances released by algae. Algae is a single-celled organism growing on the surface of the marble.

One substance that algae releases as it is growing is malic acid.

1) Plan an Investigation: If you combined a sample of calcium carbonate with any of these five substances, how would that provide evidence to support or refute the scientists' idea that a chemical reaction is occurring between the calcium carbonate and any of them? What evidence would you look for?

[Based on data from Banerjee, D., and Sarkar S. *Chemical and Biochemical Onslaught of Anthropogenic Airborne Species on the Heritage Monument of the Taj Mahal,* Heritage (ISSN 2571-9408), doi:10.3390/heritage2030129, Published: 24 July 2019.]

We will now investigate some of these substances, starting first with the one of the acids that the algae releases, malic acid.

2) Plan Your Investigation: Procedure

- Wear goggles throughout this procedure.
- Get the following supplies from your teacher: ~1 g of calcium carbonate, ~20 mL container of water, 1 container with one capsule of malic acid in it, a spoon, a wooden stirrer, and 6 clear cups to transfer samples to and collect observations from.
- You also have access to a digital scale and thermometer.
- In the space provided, **make a data table below** to record your observations about:
    - Each of three substances you have before combining any of them (calcium carbonate, water, and the malic acid).
    - What happens when you combine two different substances at a time together.
    - What happens when you combine all three substances at a time together.
- Label the clear cups with the different substance(s) you plan to put in each of them.

3) Carry Out Your Investigation: Procedure

- Wear goggles throughout this procedure.
- The malic acid capsule will need to be opened to transfer it into a container. Pull both ends of the capsule apart above an empty container to do this.
- Carry out your investigation recording what you observe before, during, and after 1 minute.
- When you finish, follow the cleanup procedure.
- Wash your hands.

4) Data Table

5) Which claim does your data support? A or B? ___________

A. Malic acid that algae releases chemically reacts with the calcium carbonate in the marble surface of the Taj Mahal.

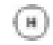
B. Malic acid that algae releases *does not* chemically react with calcium carbonate in the marble surface of the Taj Mahal.

Use the data from your investigation and your key model ideas to support your argument.

Name: ______________________ Date: ______________________

Part 2a: Explaining Marble Changes in the Taj Mahal

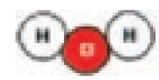
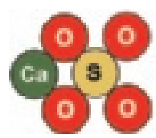
Now, we will also investigate what is going on with the marble in the Taj Mahal and the acid rain produced from pollution. Remember, one of the substances in acid rain is sulfuric acid.

Atom symbol	Atom name
	Hydrogen
	Carbon
	Nitrogen
	Oxygen
	Calcium
	Sulfur

A scientist claims that a chemical reaction between molecules of sulfuric acid (H_2SO_4) and molecules of calcium carbonate ($CaCO_3$) in the marble is happening and that this reaction produces these four new substances:

- calcium nitrate (CaN_2O_6)
- water (H_2O)
- calcium sulfate ($CaSO_4$)
- carbon dioxide (CO_2)

They provide the molecular models below to support this claim.

Proposed reactants	Proposed products	
 A molecule of sulfuric acid (H_2SO_4)	 A molecule of calcium nitrate (CaN_2O_6)	 A molecule of water (H_2O)
 A molecule of calcium carbonate ($CaCO_3$)	 A molecule of calcium sulfate ($CaSO_4$)	 A molecule of carbon dioxide (CO_2)

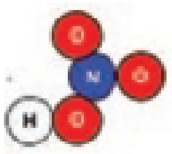
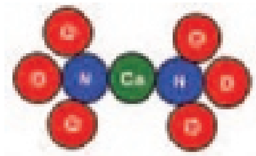
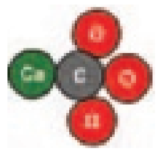
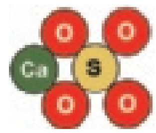
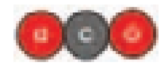
1) Use the models they provided to support an argument. Can the two substances listed as proposed reactants produce any of the four substances listed as proposed products? Explain why using what you know about what happens in a chemical reaction.

____

____

____

____

Proposed reactants	Proposed products	
 A molecule of nitric acid (HNO_3)	 A molecule of calcium nitrate (CaN_2O_6)	 A molecule of water (H_2O)
 A molecule of calcium carbonate ($CaCO_3$)	 A molecule of calcium sulfate ($CaSO_4$)	 A molecule of carbon dioxide (CO_2)

2) Use the above model to support a second argument. Another substance that is in acid rain is nitric acid. Explain whether a chemical reaction between molecules of nitric acid (HNO_3) and molecules of calcium carbonate ($CaCO_3$) could produce any of the four substances listed below. Explain whether it is possible for every proposed product in your response:

The marble in the Taj Mahal is falling apart. Now that we have analyzed some potential products from acid rain and algae interacting with the marble, we will look at the properties of these products to explain why the Taj Mahal is falling apart and what could be done to preserve it.

3) The original designer of the Taj Mahal expected the marble to last through all kinds of weather typical for the area 300 years ago, because the air was not polluted back then and the rain water back then would not have acids in it that break down marble. Use the data table below and data from your investigation to make an evidence-based argument to support the decision to use marble (calcium carbonate) for the building.

	Calcium carbonate	Calcium nitrate	Calcium sulfate
Chemical formula	$CaCO_3$	CaN_2O_6	$CaSO_4$
Color	white	white	white
Solubility in water	not soluble	very soluble	slightly soluble
Density (g/cm^3)	2.71	2.50	2.32
Melting point (°F)	1517	1042	2660

4) Use the property data table above to develop two arguments:

A. Calcium nitrate—make an evidence based argument for why acid rain would cause the calcium carbonate in the marble to slowly break down and wash away over time when calcium nitrate is produced.

B. Calcium sulfate—make an evidence based argument for why acid rain would cause the calcium carbonate in the marble to slowly break down and wash away over time when calcium sulfate is produced.

5) Construct a scientific explanation to advise the government of India.

These pollutants in the air produce the substances we find in acid rain:

- Sulfur dioxide is a pollutant that reacts with water to produce the sulfuric acid in acid rain.
- Nitrogen dioxide is a pollutant that reacts with water to produce the nitric acid in acid rain.

Which pollutant (nitrogen dioxide or sulfur dioxide) would you suggest the government try to limit in order to slow down the breakdown of the marble (calcium carbonate) on the Taj Mahal? In your explanation:

- Describe how that pollutant leads to changes in matter at a particle level.
- Explain why that results in the breakdown of the marble in the Taj Mahal.
- Explain how limiting that pollutant would slow down the breakdown of the marble.

Part 2b: Explaining Iron Changes in the Taj Mahal

The Taj Mahal was built in Agra, India as a tomb for the burial of Shah Jahan's wife. It was completed around 1653. It is an impressive building created out of white marble and held together with iron rods and clamps. The Taj Mahal is a UNESCO world heritage site. Between 7 and 8 million visitors visit the Taj Mahal each year. However, in the last 50 years, people started noticing that the building is cracking and falling apart.

One reason why this might be happening are changes occurring in the iron rods and clamps that hold the marble together.

Iron is a substance made of only one type of atom throughout (Fe). Iron objects weaken when they rust. When this happens, the rust that appears can come in many forms. An example of this is shown in the image to the right.

Non-commercial use only.

A) Plan an Investigation: If you scraped off a sample of the rust on these rods or clamps, what tests could you try to do on it to determine which substance it was (iron oxide or hydrated iron oxide)? How would the results help you determine whether it was one of these substances or not?

Property Table			
Substance name	**Iron**	**Iron oxide**	**Hydrated iron oxide**
Chemical formula	Fe	Fe_2O_3	$Fe(OH)_3$
Color	greyish	reddish-brown	dark orange
Solubility	not soluble in water	not soluble in water	not soluble in water
Density	7.87 g/cm^3	5.25 g/cm^3	4.25 g/cm^3
Melting point	2,800°F	2,849°F	275°F

Four students make different claims about how iron oxide (Fe_2O_3) and hydrated iron oxide $Fe(OH)_3$ might form from iron and other substances in the air. These are their different claims:

1. Iron (Fe) and nitrogen (N_2) could chemically react to form both iron oxide (Fe_2O_3) and iron oxide-hydroxide $Fe(OH)_3$.
2. Iron (Fe) and oxygen (O_2) could chemically react to form both iron oxide (Fe_2O_3) and iron oxide-hydroxide $Fe(OH)_3$.
3. Iron (Fe) and water vapor (H_2O) could chemically react to form both iron oxide (Fe_2O_3) and iron oxide-hydroxide $Fe(OH)_3$.
4. Iron (Fe), oxygen (O_2), and water vapor (H_2O) could chemically react to form both iron oxide (Fe_2O_3) and iron oxide-hydroxide $Fe(OH)_3$.

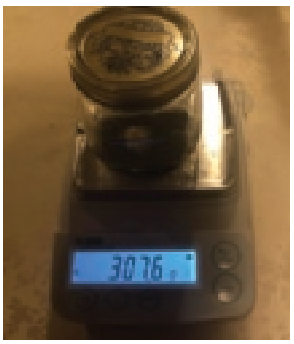
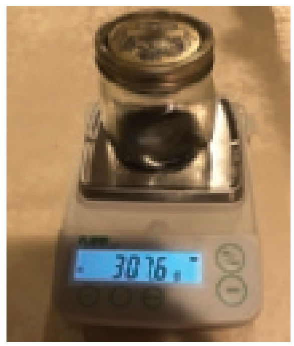
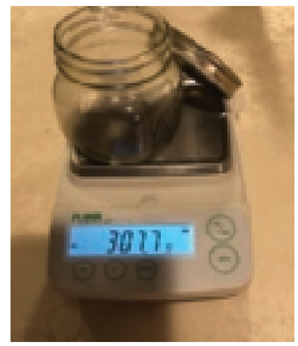
Types of atoms in these proposed models				
Atom name	**Iron**	**Nitrogen**	**Oxygen**	**Hydrogen**
Atom symbol	Fe	N	O	H

B) Develop and Use a Model to Support and Refute Each of the Claims: Which, if any, claims of the four claims listed above do you agree with? Support your argument by developing and using a model that shows what would happen to the different types of particles in the system.

In order to test these claims, another student conducts an investigation. This is the procedure they follow:

- They put a small amount of iron in a test tube and record what it looks like.
- They slide the test tube into a soda bottle with some water in the bottom of it so that the iron is not yet in contact with the water. They seal the top off the bottle with a cap.
- They weigh the entire system. The results are shown in image A.
- They tilt the soda bottle over to mix the iron and water together and let it sit overnight.
- The next day they reweigh the entire system again. The results are shown in image B.
- They remove the cap and reweigh the entire system again. The results are shown in image C.
- They remove the test tube from the soda bottle and record what the solid material in the bottle looks like.

These are their results:

Image A	Image B	Image C
		

Observations of the solid in the test tube before mixing it with water	Observations of the solid in the bottle one day after mixing it with water
shiny, greyish metal	reddish-brown powder

C) Make an Evidence-Based Argument to Answer this Question: Was there a new substance produced in the bottle that was not there before?

D) Make an Evidence-Based Argument to Answer this Question: Where did the matter that makes up the particles in the new substance come from? What evidence from the investigation supports this argument?

E) Explain why the mass of the system did not change from image A to image B but did change from image B to image C.

F) In the first part of the assessment you also learned that there are pollutants in the air that produce acid rain. Two of the substances in acid rain were sulfuric acid and nitric acid.

One Scientist Makes Claim A about Acid Rain

Claim A is that sulfuric acid in acid rain chemically reacts with the iron rods and clamps in the Taj Mahal to produce three substances: iron (II) sulfate, water, and hydrogen. They provide this model to explain how the atoms rearrange in this proposed chemical reaction to support their argument:

Fe	+	H_2SO_4	→	H_2	+	$2\ H_2O$	+	$FeSO_4$
iron		*sulfuric acid*		*hydrogen*		*water*		*iron(II) sulfate*

Another Scientist Makes Claim B about Acid Rain

Claim B is that nitric acid in acid rain chemically reacts with the iron rods and clamps in the Taj Mahal to produce two substances: nitrous oxide and iron (III) nitrate. They provide this model to explain how the atoms rearrange in this proposed chemical reaction to support their argument:

Fe	+	$4\ HNO_3$	→	NO	+	$Fe(NO_3)_3$
iron		*Nitric acid*		*Nitrous Oxide*		*Iron (III) Nitrate*

Types of atoms in these proposed models					
Atom name	**Iron**	**Nitrogen**	**Sulfur**	**Oxygen**	**Hydrogen**
Atom symbol	Fe	N	S	O	H

The properties of some of these different substances are listed below:

Substance	Chemical formula	State of matter at room temperature	Solubility	Odor
iron(II) sulfate	$FeSO_4$	solid	soluble in water; not soluble in alcohol	odorless
iron(III) nitrate	$Fe(NO_3)_3$	solid	soluble in water; soluble in alcohol	odorless

Substance	Chemical formula	State of matter at room temperature	Boiling point	Density (g/L)	Flammability
nitrous oxide	NO	gas	–127.3°F	1.3402 g/L	non- flammable
hydrogen	H_2	gas	–423.2°F	0.08988 g/L	explodes when exposed to a flame

* The density of air at sea level and 15°C is 1.160 (g/L).

To simulate acid rain, you could mix a small amount of nitric acid with water and you could also mix a small amount of sulfuric acid with water. You could take each of these mixtures and spray them on a sample of iron. If you had the materials to do this, along with additional lab and testing supplies, what investigations could you carry out and what data could you collect that could help you support or refute claim A and claim B?

Item alignment guide

Alignment between Lesson 14 assessment questions and related DCIs, SEPs, and CCCs	Part 1 Questions					Part 2a Questions					Part 2b Questions					
	1	2	3	4	5	1	2	3	4	5	A	B	C	D	E	F
SEPs																
Plan and carry out an investigation.	x	x	x	x												x
Analyze and interpret data.					x			x	x	x	x		x	x	x	
Develop and use models.						x	x			x		x				x
Argue from evidence.					x				x	x			x			
Construct an explanation/design a solution.										x				x	x	
DCIs/related key model ideas																
Every substance has characteristic properties that can be used to identify it.	x	x	x	x	x				x		x		x			x
Substances are made from different types of atoms, which combine with one another in various ways.						x	x			x		x				x
The number, type, and arrangement of atoms in the molecules that make up a substance are unique to that substance.						x	x			x		x				x
In a chemical reaction, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.						x	x			x				x	x	
In a chemical reaction, the total number of each type of atom is conserved, and thus the mass does not change.														x	x	
CCCs																
Patterns	x	x	x	x					x	x	x	x				x
Energy and Matter						x	x			x		x		x	x	
Systems and System Models														x	x	
Cause and Effect						x	x		x	x			x	x	x	x

LESSON 14: ANSWER KEY 1

Part 1 of the Assessment

1) **Plan an investigation:** If you combined a sample of calcium carbonate with any of these five substances, how would that provide evidence to support or refute the scientists' idea that a chemical reaction is occurring between the calcium carbonate and any of them? What evidence would you look for?
    - Combining calcium carbonate with each substance one at a time could provide evidence of whether a chemical reaction has occurred.
    - Evidence to look for:
        - One or more property changes.
    - If a property changes, then a new substance has been produced, which would support the scientists' claim that a chemical reaction is occurring between the calcium carbonate and that substance.

Let's investigate some of these substances, starting first with the one of the acids that the algae releases, malic acid.

2) **Plan Your Investigation: Procedure**
    - Wear goggles throughout this procedure.
    - Get the following supplies from your teacher: ~1 g of calcium carbonate, ~20 mL container of water, 1 container with one capsule of malic acid in it, a spoon, a wooden stirrer, and 6 clear cups to transfer samples to and collect observations from.
    - You also have access to a digital scale and thermometer.
    - In the space provided, **make a data table below** to record your observations about:
        - Each of three substances you have before combining any of them (calcium carbonate, water, and the malic acid).
        - What happens when you combine two different substances at a time together.
        - What happens when you combine all three substances at a time together.
    - Label the clear cups with the different substance(s) you plan to put in each of them.
3) **Carry Out Your Investigation: Procedure**
    - Wear goggles throughout this procedure.
    - The malic acid capsule will need to be opened to transfer it into a container. Pull both ends of the capsule apart above an empty container to do this.
    - Carry out your investigation recording what you observe before, during, and after 1 minute.
    - When you finish, follow the cleanup procedure.
    - Wash your hands.

4) Data Table Example of a data table students may set up:

Substance	Before combining
water	clear, liquid, odorless
calcium carbonate	white, solid powder, odorless
malic acid	white, solid powder, odorless

After combining

Water & malic acid	Water & calcium carbonate	Malic acid & calcium carbonate	Water, calcium carbonate & malic acid
+ soluble in water	*+ not soluble in water*	*+ no observable change*	*+ bubbles, a gas*
+ no odor	*+ no odor*	*+ no odor*	*+ an odor (floral/citrusy/soda)*

5) Which claim does your data support? A or B? ____A____

A. Malic acid that algae releases chemically reacts with the calcium carbonate in the marble surface of the Taj Mahal.

B. Malic acid that algae releases *does not* chemically react with calcium carbonate in the marble surface of the Taj Mahal.

Use the data from your investigation and your key model ideas to support your argument.

- Evidence:
  - Before these substances are combined, the malic acid and marble are solids and the water is a liquid.
  - After combining there is a gas that forms.
  - Before combining any substances, none of them have an odor.
  - Malic acid and water combined do not have an odor.
  - Calcium carbonate and water combined do not have an odor.
  - When malic acid, calcium carbonate, and water are combined there is a flowery/soda like odor.
- Use of key model ideas:
  - Different substances have different properties.
  - State of matter at room temperature is a property.
  - Odor is a property.
  - Chemical reactions produce new substances.
- Related reasoning:
  - Properties of substances in the container change.
  - Since properties have changed, a new substance was made.
  - Since a new substance was made, a chemical reaction has occurred.

Part 2a of the Assessment

1) Use the models they provided to support an argument. Can the two substances listed as proposed reactants produce any of the four substances listed as proposed products? Explain why using what you know about what happens in a chemical reaction.

+ Calcium nitrate (CaN_2O_6) is not a possible product. It contains nitrogen atoms (N). There are no nitrogen atoms in either of the proposed reactants.

+ Water (H_2O), calcium sulfate ($CaSO_4$), and carbon dioxide (CO_2) are all possible products. They all contain the same type of atoms (H, O, C, Ca, and S) as are found in the proposed reactants.

+ In a chemical reaction, the type of atoms that are in the reactant molecules break apart and rearrange to form new molecules made of the same atoms.

2) Use the model from the previous page to support an argument. Another substance that is in acid rain is nitric acid. Explain whether a chemical reaction between molecules of nitric acid (HNO_3) and molecules of calcium carbonate ($CaCO_3$) could produce any of the four substances listed below. Explain whether it is possible for every proposed product in your response:

+ Calcium sulfate ($CaSO_4$) is not a possible product. It contains sulfur atoms (S). There are no sulfur atoms in either of the proposed reactants.

+ Water (H_2O), calcium nitrate (CaN_2O_6), and carbon dioxide (CO_2) are all possible products. They all contain the same type of atoms (H, O, C, Ca, and N) as are found in the proposed reactants.

+ In a chemical reaction, the type of atoms that are in the reactant molecules break apart and rearrange to form new molecules made of the same atoms.

3) The original designer of the Taj Mahal expected the marble to last through all kinds of weather typical for the area 300 years ago, because the air wasn't polluted back then and the rain water back then wouldn't have acids in it that break down marble. Use the data table below and data from your investigation to make an evidence-based argument to support the decision to use marble (calcium carbonate) for the building.

+ Calcium carbonate is not soluble in water so the marble when it isn't exposed to pollution can withstand rain and won't break down.

+ We saw this too when we put the solid calcium carbonate (marble powder) in water alone and it didn't bubble, react, or dissolve.

4) Use the property data table above to develop two arguments:

a. Calcium nitrate—make an evidence based argument for why acid rain would cause the calcium carbonate in the marble to slowly break down and wash away over time when calcium nitrate is produced.

+ When nitric acid reacts with calcium carbonate and water it can produce calcium nitrate.

+ Calcium nitrate is very soluble in water, so when it rains that part of the marble will dissolve.

b. Calcium sulfate—make an evidence based argument for why acid rain would cause the calcium carbonate in the marble to slowly break down and wash away over time when calcium sulfate is produced.

+ When sulfuric acid reacts with calcium carbonate and water it can produce calcium sulfate.

+ Calcium sulfate is not very soluble in water but is still partially soluble in water, so when it rains, that part of the marble will dissolve more slowly.

5) Construct a scientific explanation to advise the government of India.

These pollutants in the air produce the substances we find in acid rain:

- Sulfur dioxide is a pollutant that reacts with water to produce the sulfuric acid in acid rain.
- Nitrogen dioxide is a pollutant that reacts with water to produce the nitric acid in acid rain.

Which pollutant (nitrogen dioxide or sulfur dioxide) would you suggest the government try to limit in order to slow down the breakdown of the marble (calcium carbonate) on the Taj Mahal? In your explanation:

- Describe how that pollutant leads to changes in matter at a particle level.
- Explain why that results in the breakdown of the marble in the Taj Mahal.
- Explain how limiting that pollutant would slow down the breakdown of the marble.

+ High concentrations of nitrogen dioxide in the air is potentially worse for the Taj Mahal than sulfur dioxide because the product it makes, calcium nitrate, is very soluble in water. Calcium carbonate is a substance that is not soluble in water. Nitrogen dioxide is one air pollution substance that is moved through the air. When it rains, this substance lands on the calcium carbonate of the Taj Mahal and reacts. When this reaction occurs, a new substance is made called calcium nitrate. Calcium carbonate is not soluble in water, but this new substance, calcium nitrate, is soluble in water. The more this pollutant, nitrogen dioxide, reacts with the calcium carbonate, the more it will crumble because the parts that react with the nitrogen dioxide will be dissolving. Therefore limiting the amount of nitrogen dioxide would help to slow down this process and help to preserve what is left of the Taj Mahal.

Part 2b of the Assessment

A) **Plan an Investigation:** If you scraped off a sample of the rust on these rods or clamps, what tests could you try to do on it to determine whether it was iron oxide or iron oxide-hydroxide? How would the results help you determine whether it was one of these substances or not?

- We could perform property tests on the substance, such as solubility, density, color, and odor.
- Using property data we could compare the properties of this substance to the properties of the iron oxide and iron oxide-hydroxide.
- Then we could match the properties to determine which substance is produced.

Four students make different claims about how iron oxide (Fe_2O_3) and hydrated iron oxide $Fe(OH)_3$ might form from iron and other substances in the air. These are their different claims:

1. Iron atoms (Fe) and nitrogen molecules (N_2) could chemically react to form both iron oxide molecules (Fe_2O_3) and iron oxide-hydroxide molecules ($Fe(OH)_3$).
2. Iron atoms (Fe) and oxygen (O_2) could chemically react to form both iron oxide (Fe_2O_3) and iron oxide-hydroxide $Fe(OH)_3$.
3. Iron (Fe) and water vapor (H_2O) could chemically react to form both iron oxide (Fe_2O_3) and iron oxide-hydroxide $Fe(OH)_3$.
4. Iron (Fe), oxygen (O_2), and water vapor (H_2O) could chemically react to form both iron oxide (Fe_2O_3) and iron oxide-hydroxide $Fe(OH)_3$.

B) **Develop and Use a Model To Support and Refute Each of the Claims:** Which, if any, claims of the four claims listed above do you agree with? Support your argument by developing and using a model that shows what would happen to the different types of particles in the system.

- Students should draw a model to represent the molecules of each of the substances using atoms.
- Then they should use this model to argue that they agree with claim #3 and/or #4 because in either of these cases there are the right kinds of atoms in the reactants to produce iron oxide and iron oxide-hydroxide.

In order to test these claims, another student conducts an investigation.

This is the procedure they follow:

- They put a small amount of iron in a test tube and record what it looks like.
- They slide the test tube into a soda bottle with some water in the bottom of it so that the iron is not yet in contact with the water. They seal the top off the bottle with a cap.
- They weigh the entire system. The results are shown in image A.
- They tilt the soda bottle over to mix the iron and water together and let it sit overnight.
- The next day they reweigh the entire system again. The results are shown in image B.

- They remove the cap and reweigh the entire system again. The results are shown in image C.
- They remove the test tube from the soda bottle and record what the solid material in the bottle looks like.

These are their results:

Image A	Image B	Image C
		

Observations of the solid in the test tube before mixing it with water	*Observations of the solid in the bottle one day after mixing it with water*
shiny, greyish metal	*reddish-brown powder*

C) Make an Evidence-Based Argument to Answer this Question: Was there a new substance produced in the bottle that wasn't there before?

- A new substance was produced when the iron was combined with water and oxygen. Before the substances were combined the iron was a shiny grey color and the iron was solid and hard. After the iron had been combined with the water and air a substance that was reddish-brown in color and powdery was produced. Color and hardness are properties and properties are used to identify substances. So if properties change, then a new substance has formed.

D) Construct an Explanation to Answer this Question: Where did the matter that makes up the particle in the new substance come from? What evidence from the investigation supports this argument?

- The matter that makes up the particles in the new substance come from the water and the oxygen that it interacts with. The investigation was done in a closed system, so nothing could get in or out of the bottle. Because of this, the matter that made up the new substance had to come from whatever was in the bottle, which was water and air. So the new substance was formed when the iron was combined with the water and the air.

E) Explain why the mass of the system didn't change from image A to image B but did change from image B to image C.

- Though a chemical reaction occurred between A and B, no matter exited or entered the system. All the particles (atoms) that made up the matter in the system simply rearranged to make new types of molecules.
- The system was opened between B and C. This allows matter to exit or enter the system. Since the mass increased, matter must have entered the system. (This matter could have been a gas.)

F) In the first part of the assessment you also learned that there are pollutants in the air that produce acid rain. Two of the substances in acid rain were sulfuric acid and nitric acid.

One Scientist Makes Claim A about Acid Rain

Claim A is that sulfuric acid in acid rain chemically reacts with the iron rods and clamps in the Taj Mahal to produce three substances: iron (II) sulfate, water, and hydrogen. They provide this model to explain how the atoms rearrange in this proposed chemical reaction to support their argument.

Fe	+	H_2SO_4	$\rightarrow$	H_2	+	$2H_2O$	+	$FeSO_4$
iron		*sulfuric acid*		*hydrogen*		*water*		*iron (II) sulfate*

Another Scientist Makes Claim B about Acid Rain

Claim B is that nitric acid in acid rain chemically reacts with the iron rods and clamps in the Taj Mahal to produce two substances: nitrous oxide and iron (III) nitrate. They provide this model to explain how the atoms rearrange in this proposed chemical reaction to support their argument:

Fe	+	$4HNO_3$	$\rightarrow$	NO	+	$Fe(NO_3)_3$
iron		*nitric acid*		*nitrous oxide*		*iron (III) nitrate*

The properties of some of these different substances are listed below:

Substance	Chemical formula	State of matter at room temperature	Solubility	Odor
Iron (II) sulfate	$FeSO_4$	solid	soluble in water; not soluble in alcohol	Odorless
Iron (III) nitrate	$Fe(NO_3)_3$	solid	soluble in water; soluble in alcohol	Odorless

Substance	Chemical formula	State of matter at room temperature	Boiling point	Density (g/L)	Flammability
nitrous oxide	NO	gas	–127.3°F	1.3402 g/L	non-flammable
hydrogen	H_2	gas	–423.2°F	0.08988 g/L	explodes when exposed to a flame

* The density of air at sea level and 15°C is 1.160 (g/L).

To simulate acid rain, you could mix a small amount of nitric acid with water and you could also mix a small amount of sulfuric acid with water. You could take each of these mixtures and spray them on a sample of iron. If you had the materials to do this, along with additional lab and testing supplies, what investigations could you carry out and what data could you collect that could help you support or refute claim A and claim B?

Students should be able to describe ways to test a) whether a gas forms and b) whether the gas that forms has one or more properties that match those listed here.

+ a) Collecting evidence of whether a gas forms in each case. Such plans could include any of the following, any of which helps support the argument that a gas formed:

- Watching for bubbles after mixing.
- Mixing the substances in something like a baggy (closed system) and seeing if the volume of the baggy increases.
- Mixing the substances in a closed system and seeing if the mass of the system goes down after opening it.
- Mixing the substances in an open system and seeing if the mass of the system decreases.

+ b) If a gas forms, collecting additional evidence for the properties of the gas. Such properties could include:

- Putting a flame near the gas collected and seeing:
  - If it goes out, in which case it is non-flammable, which supports the argument that it could be nitrous oxide.
  - If it explodes, in which case it would support the argument that it could be hydrogen.
- Determining if it interacts with a flame, above or below the container it was collected in.
  - If it explodes in the presence of a flame above the container it was collected in, but not below it, then it is less dense than air, which supports the argument that it could be hydrogen.
  - If it goes out in the presence of a flame below the container it was collected in, but not above it, then it is less than air, which supports the argument that it could be nitrous oxide.

Students may be able to describe ways to test whether a new solid forms, though this will be something they are less familiar with, particularly because the solid that forms might be dissolved in the water that is sprayed on the iron. The following sources of evidence may be ones that you see some students suggest:

- Look for a solid on the surface of the iron that is a different color than the original iron.
- Scrape the solid off the iron and add some of it to water and some of it to rubbing alcohol and see if some or all it dissolves in either case.

Students may also suggest a way to collect and/or separate the liquid in the system that is left over to figure out what that liquid is and how much of it there is to determine if extra water was produced when a mixture of water and sulfuric acid is sprayed on iron. This may include:

- Separating the liquid in the system after the acid and iron interact for a bit. This separation could include boiling the liquid and capturing all of the gas produced, like in water and then calculating the density of the liquid (by its mass and its volume and dividing one by the other) and comparing this to water's known density. This would be similar to what they did in Lesson 9.
- Measuring the mass of the liquid collected and seeing if this is greater than the mass of water used in the acid rain sprayed on the iron. This would be similar to the idea that was introduced in the individual assessment in Lesson 12.

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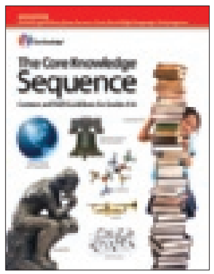

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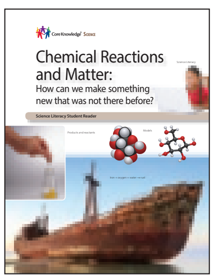

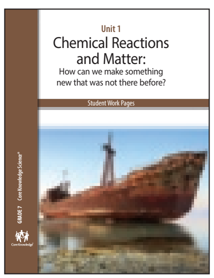

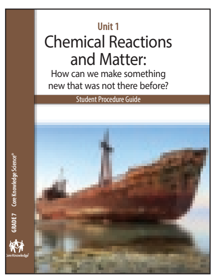

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