Unit 2

Chemical Reactions and Energy:

How can we use chemical reactions to design a solution to a problem?

Student Procedure Guide

GRADE 7 Core Knowledge Science®

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Core Knowledge Science®

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Chemical Reactions and Energy

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Lesson 1: How can we heat up food when we don't have our typical methods available?

Turn and talk about how we heat food.

Turn and talk

1. Think about all the ways in which people can heat up food inside and outside of their homes. Turn to an elbow partner and start listing ways you know of that we can heat our food.
2. Share your ideas with the class.
3. Think: But what if people did not have those ways to heat food? What would they do instead?

What are some situations where people cannot heat food in the usual ways?

With your class

4. Your teacher will show you some images of a situation where there had been a severe storm and people were distributing Meals, Ready-to-Eat. These prepackaged meals include a "flameless heater" that is able to warm food without using electricity, gas, or fire. But how does it do that? Let's try one and see.

Watch an MRE demonstration.

In your notebook

5. Make a T-chart in your science notebook where you can record your noticings and wonderings as your teacher demonstrates how to use an MRE. Your teacher will also pass around the various parts of the MRE, including the heater itself.

With your class

6. Watch a video of a person eating an MRE and continue to add ideas to the Notice and Wonder chart in your notebook.
7. Share your noticings and wonderings with the class.

Develop an initial model.

On your own

8. On your *Initial Model* handout, develop an initial model to explain how you think a flameless heater works, including at a scale too small to see. You can use pictures, words, symbols, and labels to explain your thinking.

Compare initial models.

With a partner

9. Share your model with a partner or partners, as your teacher directs.
    - Look for similarities and differences between your models.
    - Make a T-chart in your science notebook like the one below. Keep track of the similarities and differences in this chart.

Similarities between our models	Differences between our models

    - Be prepared to share your thinking with the whole class.

Review norms.

With a partner

10. Review your classroom norms. Consider which one(s) we need to intentionally work on to get better at.
11. Choose one norm that you personally will work on for the rest of today's class. Share the norm you decided to work on with a partner and tell them why it is important for you. Tell your partner what strategy(ies) you will use to work on your focal norm.

Consensus Discussion

Scientists Circle

12. Develop a whole-group record of what we agree on and where we have competing ideas across our initial models around the question: "How does a flameless heater heat up food just by adding room-temperature water?"
    - What do we all seem to agree on?
    - What do we disagree on?
    - Are there some new ideas that we may want to consider?

Reflect on your focal norm.

On your own

13. Reflect silently on the following questions:
    - How did you do with practicing the norm you selected to work on?
    - How did the class do as a learning community?

- What did we do well?
- What could we improve on?

14. Share your ideas with the class.

Home Learning

Home learning

15. What are we wondering now? What questions do you have about MREs and flameless heaters? Write down in your science notebook some initial questions that you have.

16. Survey family and friends using the link to the electronic survey provided by your teacher.

Review community survey results.

In your notebook

17. Make a T-chart in your science notebook where you can record your noticings and wonderings as your teacher projects the results from our community survey of our family and friends.

Brainstorm related situations.

In your notebook

18. So far in this lesson we have observed some different examples of MREs being used in different situations. What are all the different situations in which an MRE could be useful? Use the next clean page in your science notebook to list any situations—related to the ones we have already seen or other situations—in which you think it would be helpful to have an MRE.

19. Share your ideas with the class. Your teacher will scribe a list of related situations.

Where have MREs been used?

In your notebook

20. Find the Notice and Wonder chart you started in your notebook for the survey results. Draw a horizontal line underneath your previous noticings and wonderings. Then record additional noticings and wonderings as you observe the photos that your teacher shows you of when and where MREs with flameless heaters are typically used.

21. Draw connecting lines between these new noticing and wonderings and similar ones you wrote when observing the survey results.

22. Be ready to share your thinking with the class.

Share noticings and wonderings.

With your class

23. After observing the prices of MREs, share what you notice and wonder about how and where MREs are typically used.

Define problems.

On your own

24. These flameless heaters and MREs are pretty useful, but they are not perfect. What problems or issues do you see with using MREs with flameless heaters to get hot food to people when they do not have their typical methods available? Take a minute to jot down your ideas on the next clean page of your notebook.

Collect problem ideas.

Scientists Circle

25. Your teacher will distribute several pieces of loose-leaf paper.

- When you get a piece of paper, write one of your problems with getting hot food to people when they do not have their typical methods available.
- Also, if one of your ideas (or a very similar one) is already listed on a paper you get, put a check mark near it. We want to keep an informal tally of how many people thought of similar problems.
- If you think an idea that someone else has written is very important (even if you had not thought of it yet yourself), put a star near it, also.
- After you have written an idea and checked any others as needed, pass the paper along to someone else.

26. Your teacher will share and post the most frequently mentioned problem ideas from the paper-passing activity.

Why do MREs include a flameless heater?

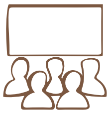
Scientists Circle

27. Why do you think a heater is included with these meals? Why not just have people eat the food cold? Consider these questions individually.

28. Be ready to share your ideas with the class.

Consider solutions to these problems.

Engineers Circle



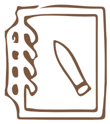
29. Turn and talk with a partner about the following questions:

- What if, during an emergency situation, all the MREs and flameless heaters were sold out? How could people be prepared if that happened?
- What if people could not buy the premade MREs and flameless heaters? What could they do?

30. Work with your class to propose a solution to these problems, which your teacher will post in the classroom.

Start Progress Trackers.

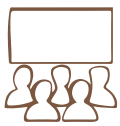
In your notebook



31. Find the section of your science notebook that you have set aside for this unit's Progress Tracker. Set up a chart like the one shown here to be your Progress Tracker for this unit.

What did we do as engineers?	What did we figure out that can help us with our designs?

With your class

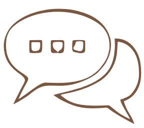


32. Work with your class to fill out two entries in this Progress Tracker.

33. Your teacher will also use big sticky notes to create a What We Do as Engineers board.

Consider criteria and constraints.

Turn and talk



34. In the Natural Hazards Unit we learned that whenever we want to solve a problem, we need to first define the criteria and constraints of the solution. Turn and talk with a partner about what "criteria" and "constraints" mean.

35. Turn and talk with a different partner about the following questions and be ready to share your ideas with the whole class.

- What criteria should we have for our homemade flameless heater? What does our design need to do?
- What constraints should we have? What are the limitations of our design?

36. Share your ideas for criteria and constraints with the class. Your teacher will record these ideas on a chart for reference later.

Update Progress Trackers.

In your notebook

37. Add to your Progress Tracker now that we have identified criteria and constraints.

What did we do as engineers?	What did we figure out that can help us with our designs?
We identified our criteria and constraints.	

Develop an initial design solution.

On your own

38. How can we design a homemade flameless heater to help people prepare for different situations? Use a blank piece of paper to plan a design that will fit our criteria and constraints. Be sure your model shows how your heater design will cause food to be heated up.

Share initial design solution.

With your group

39. Use the *Talking Sticks* protocol to share your design with your group and listen when others share theirs with you. To begin each round, everyone puts their writing utensil ("talking stick") in the middle of the group. Track who has had a turn by picking up your writing utensil after you speak.

- Round 1: Everyone shares their design solutions. No interruptions, no questions.
- Round 2: Ask a question or make a connection or comment about someone else's idea.

Reflect on your design.

Home learning

40. Use *Initial Design Reflection* to answer the following questions:

- What went well when creating or sharing your initial design?
- What was difficult about creating or sharing your initial design?

Discuss our initial design solutions.

Engineers Circle

41. Discuss the following questions with your class:

- Recall the problems that we identified most frequently about MREs. How would making a homemade flameless heater help solve these problems?

- What went well when creating or sharing your initial design?
- What was difficult about creating or sharing your initial design?

Generate design questions.

On your own

42. Brainstorm questions you have by looking back at these resources:

- your Notice and Wonder chart
- your initial model and/or the classroom consensus model
- our chart of related situations
- your initial design

43. Write down any questions you have about this idea: How can we help people build a flameless heater?

- Write your questions on sticky notes—one question per sticky note.
- Write in marker—big and bold.
- Put your initials on the back of the sticky note in pencil.
- Try using these sentence starters: Why. . .? How. . .? What causes. . .?

Create our Design Questions Board.

Engineers Circle

44. Bring your sticky notes with questions to our Engineers Circle. We will work together as a class to organize our questions on our Design Questions Board (DQB).

Generate ideas for investigations.

With a partner

45. Title the next page in your science notebook "Ideas for Investigations." Choose one question or category of questions from our Design Questions Board and talk with one or two partners near you to consider how we might find the answer for the question: "What investigation could we design, what data should we gather, and how could we figure this out in our classroom?" Keep track of your ideas in your notebook. After you have discussed one question, move on to another.

Share ideas for investigations.

With your class

46. As you share your ideas for investigations with the class and listen as others share theirs, we will record them on a chart to refer to later.

Lesson 2: How do heaters get warm without a flame?

Discuss with your class.

With your class

1. What did we need to do to make the MRE heater get hot?
2. What could we do to investigate this MRE heater to help explain what is happening?

Prepare for flameless heater and hand warmer investigations.

In your notebook

3. Open your notebook to the first section with two blank pages and begin creating the data table.
4. Add a table on the opposite page to collect data for the hand warmer.

Plan and carry out the flameless heater investigation as a class.

With your class

5. Decide what data you will collect as evidence that a chemical reaction is happening.
   - What specific evidence should we collect to support the idea that a chemical reaction is happening?
   - What specific things could we measure or observe?

In your notebook

6. Update your data collection tables to reflect the new data you decide to collect.
7. Record the starting mass and any other observations of the MRE heater. Watch the time-lapse video of the substances inside the MRE heater after they are activated and get hot.
8. Write down any observations you notice throughout the video.
9. Record the temperature of the MRE heater investigation every 5 minutes.
10. Record any observations you have about the appearance of the substance inside the MRE heater before and after it was activated.

With a partner

11. Look at the flameless heater ingredient list.
    - Do you recognize any ingredients?
    - Based on the ingredient descriptions, which substances could be responsible for making the device warm up?
12. After 15 minutes, record the final temperature and final mass of the flameless heater.

Carry out the hand warmer investigation in small groups.

Safety Precautions

13. Read and follow the following safety guidelines:

- Do not cut or tear open your hand warmer. Notify an adult immediately if your hand warmer is torn or breaks open.
- Wear goggles, nonlatex gloves, and an apron during setup, investigation, and cleanup.
- Secure loose clothing, remove loose jewelry, tie back long hair, and wear close-toed shoes.
- Avoid touching your face (so substances do not get near your nose or mouth). Never taste any substance in the lab.
- Move carefully so that we do not spill anything and immediately wipe up any spills that do happen.
- Follow instructions for cleanup and wash your hands with soap and water after cleanup is complete.
- Use caution when working with heated liquids—they can burn skin.

With your group

14. Obtain your materials and prepare your investigation.

15. Discuss the investigation with your group.

- What data will you collect first and how?
- Do you have any other questions about the investigation before we start?

In your notebook

16. Record the starting mass and any other observations of the hand warmer. Watch the time-lapse video of the substances inside the hand warmer after they are activated and get hot.

17. Write down any observations you notice throughout the video.

18. Record the temperature of the hand warmer investigation every 5 minutes.

19. Record any observations you have about the appearance of the substance inside the hand warmer before and after it was activated.

With your group

20. Look at the hand warmer ingredient list.

- Do you recognize any ingredients?
- Based on the ingredient descriptions, which substances could be responsible for making the device warm up?
- What do you notice when you compare the ingredients in each device?

21. After 15 minutes, record the final temperature and final mass of the hand warmer.

Discuss results of the investigations with your class.

With your class

22. Be prepared to share data that are evidence to support whether or not a chemical reaction happened in each device.

- What did we figure out from our investigations in this lesson?

How do we move forward with our designs?

In your notebook

23. Add to your Progress Tracker:

- In this lesson, we researched existing solutions. How did this help us with our designs?

With your class

24. Share your thoughts with the class—What are you wondering now?

Lesson 3: What other chemical reactions could we use to heat up food?

Navigation

We ended up with a lot of questions last class! Let's look at the Criteria and Constraints chart to help us.

Turn and talk

1. Turn and talk with a partner about the following questions:
   - What did we figure out last time about using the materials in the MRE flameless heater in our own designs?
   - For our homemade heater, what do we need the chemical process to do? What are our criteria for it?
   - Your teacher gathered some things from local places, like the grocery store and the hardware store. How can we figure out if some of these might work for our homemade flameless heater?

Explore substances we will try in our investigation.

With your class

2. Your teacher will show you images of the following substances we are going to use in our investigations.
   - Baking soda and vinegar
   - Root killer and aluminum foil in saltwater
   - Cabbage juice and vinegar
   - Vinegar-dipped steel wool and air

Review safety protocols.

Safety Precautions

3. Before we combine chemicals, let's review how we can stay safe:
   - Wear indirectly vented chemical splash goggles, a nonlatex apron, and nitrile gloves during the setup, hands-on, and take-down segments of the activity.
   - Immediately wipe up any spilled water on the floor—it is a slip and fall hazard.
   - Follow your teacher's instructions for disposing of waste materials.
   - Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
   - Wash your hands with soap and water immediately after completing this activity.

- Never eat any food items used in a lab activity.
- Never taste any substance or chemical in the lab.
- Use caution when working with heated liquids—this can burn skin!
- Safety guidelines need to be in place for the hydrogen gas that is generated by these reactions (root killer). Guidelines should include the use of vented containers to avoid the build up of pressure and the elimination of potential ignition sources like sparks and flames. The amounts of hydrogen generated by these reactions do not pose an inhalation hazard. Use appropriate lab ventilation.

Plan to conduct our investigation.

With your class

4. Think about how we want to conduct our investigation:

- What is the goal of investigating these chemical processes?
- Does the amount of the substance we use matter?

Turn and talk

5. Turn and talk with a partner.

- How could we test your ideas in our investigations?

Make a prediction.

In your notebook

6. Write a prediction in your notebook.

- For a reaction that heats up, if we used more substances, would we get more heat, less heat, or the same amount of heat produced?

Plan to collect data.

With your class

7. We have a lot of things to test, so we are going to use a jigsaw strategy for our investigations. Since we want to share our results, we need to follow the same protocols.

- What types of data should we collect in our investigations?

Prepare small-group data tables.

In your notebook

8. Tape *Data Table for Chemical Reactions Lab* into your science notebook.

- Fill in the group letter for which reaction you are testing (see the table on the slide).
- Fill in the substances you are going to be investigating. (It may not be necessary to complete all the "Substances Used" lines A, B, and C.)

Take on a group role as you conduct the investigation.

With your group

9. With your assigned group, see *Chemical Reactions Lab Instructions* and find your group's assigned investigation. Notice that there are different roles, and each role is responsible for a task at different times.

Carry out the chemical reactions lab.

With your team

10. Follow *Chemical Reactions Lab Instructions* for instructions about which substances you are using and how to carry out the investigation.

11. Conduct the investigation with your group.

- Make sure you are following the safety protocols.
- Use free time to copy the temperature data collected by the Data Recorder into *Data Table for Chemical Reactions Lab* in your science notebook.

Cleanup Procedures

With your team

12. Follow these procedures and your teacher's instructions for cleaning up:

- Keep your gloves, goggles, and apron on until you are finished cleaning up.
- Save and rinse your Styrofoam cups for future use.
- Collect liquid leftovers in the container provided by your teacher.
- Put copper and used aluminum in the trash can.

Share data for whole-class data table.

With your team

13. Follow the directions on *Class Data for Chemical Reactions Lab* and fill in your group's row. Be prepared to share your results with the class.

With your class

14. As other groups share, add their data to your copy of *Class Data for Chemical Reactions Lab.*

Find patterns in the data and track energy transfer from our investigations.

On your own

15. Answer the questions on *Class Data for Chemical Reactions Lab* using the whole-class data table.

Home learning

16. If you do not complete these questions in class, answer them for home learning.

Building Understandings Discussion

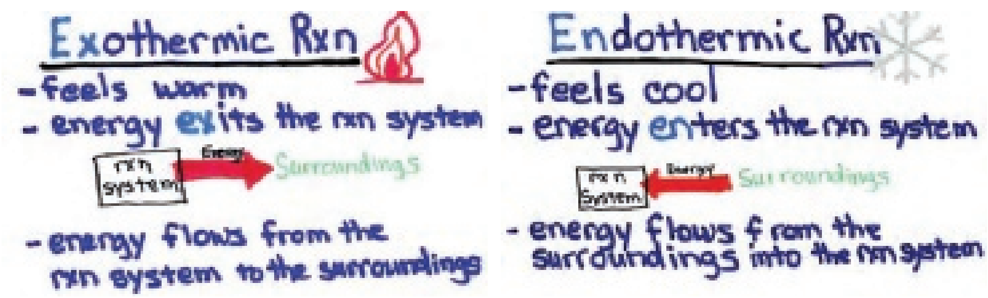
Engineers Circle

17. Using your answers from *Class Data for Chemical Reactions Lab,* discuss the following questions with your class:

- Which chemical reactions caused an increase in temperature?
- Which chemical reaction do you think is the best candidate for trying in our homemade flameless heater? Why do you think that?
- Think back to what we learned in the *Cup Design* unit. What happens to particles when the temperature increases? You can use words and/or pictures to explain your thinking.
- Think about which way the energy is flowing in this reaction. What direction did the energy flow when the temperature increased?
- What direction did the energy flow when the temperature decreased?
- What happened to the temperature when we added *more* reactants?

In your notebook

18. Add the following vocabulary to your notebook as your teacher puts the terms on the Word Wall.



Add to your Progress Tracker.

In your notebook

19. We just did something else that engineers do! Add a new row to your Progress Tracker. Update your Progress Tracker individually to capture what we have figured out that can help us with our designs.

Co-construct a particle-level model.

Engineers Circle

20. Build a particle-level model of the exothermic reaction with your class as you discuss the following:

- whether the products are hazardous

- how to represent the particles in the reaction
- what happens to the reactants when they become the products
- how to show energy transfer from the exothermic chemical reaction

Why do more reactants transfer more energy?

With your class

21. Discuss with your class:

- What was different about the three amounts of reactants you used in the investigation?
- If they started at the same temperature, why did the amount of temperature change differ?
- How can you explain this difference in the change in temperature?

Create a new Energy Transfer Model with different amounts of reactants.

With your class

With a partner

22. Construct an Energy Transfer Model with your class by focusing on the reaction system as a whole and the food system. We will construct our model for how energy flows and predict how the temperature of the food will change based on evidence from our investigation.

- Get *Energy Transfer Models* from your teacher.
- Work with your class to complete the model for the first row.
- Work with a partner to create an Energy Transfer Model for the second row.
- Be ready to share your model if asked to do so.
- Come to an agreement with your class on the best way to represent the 2X reaction system and 1X food system.
- Revise *Energy Transfer Models* with the class model.

Consider doubling the food system.

With your class

On your own

23. Discuss with your class how the temperature of the food would change if you had 2X the food and 1X the reaction.

- Make a prediction of how the temperature of the food would compare to the 1X reaction and 1X food system.
- Complete the Energy Transfer Model for the third row of the table. Use a pencil to complete the row.

Watch video of doubling systems investigations.

On your own

24. As you watch the video with your class

- record in the first column of *Energy Transfer Models* the change in temperature of each test, and
- record any observations that will help you revise your model or compare the evidence with your predictions.

Complete the class models with captions.

With your class

25. Participate in a class discussion about the evidence you gathered from the video of the investigation. Use what the class figures out about the different combinations of reactant amounts and food amounts to do the following:

On your own

- Revise models based on what you figure out.
- Complete the captions to explain in words what your models show.

Update Progress Trackers.

On your own

26. You have just developed and used models as engineers do. Enter this into your Progress Tracker as shown below and complete the right column, listing what you have figured out.

What did we do as engineers?	What did we figure out that can help us with our designs?
We developed and used models to predict and explain what we could not see.	• In an exothermic reaction, energy is transferred from the reaction particles to other particles. • In an endothermic reaction, energy is transferred from the surroundings to the reaction particles. • The energy from an exothermic reaction is transferred to the surroundings. • We want to maximize the energy transferred to the food (surroundings).

27. Tape your completed *Energy Transfer Models* into your Progress Tracker below your last entry as your teacher directs.

Navigation

With your class

28. How might we apply what we have figured out to our homemade heater designs? We will continue this work next time!

Lesson 4: How much of each reactant should we include in our homemade flameless heater?

Share what we have learned about our reaction.

Turn and talk

1. What is something we learned about our chemical reaction last class?
2. What else do we need to figure out about the reaction system in order to create a homemade flameless heater?
3. Are equal proportions of reactants the best combination to use?

Create a plan to investigate the reaction further.

Turn and talk

4. How can we systematically test what amount of each reactant will work best?

On your own

5. How do we know what total amount of reactants we should use?

With your class

6. How should we conduct our investigation so that we can have credible data to explore later?

With a partner

7. Read through the procedure on your own.
8. After each part, pause and share your ideas about the following:
   - Why are these methods important for answering our question?
   - In what ways do the methods support accurate data collection?
   - What suggestions do you have for improving the accuracy of our data collection?

With your class

9. How should we conduct our investigation so that we can have credible data to explore later?

Conduct the investigation in small groups.

In your notebook

10. Tape the *Small-Group Data Table* into your science notebook.
11. Record your assigned group and which amounts of reactants you will be using.

With your group

12. Gather data from your investigation.

With your class

13. Add your small-group data to the class data table.

On your own

14. Revise or add new suggestions for improving accuracy of data collection.

Reflect on types of instructions.

On your own

15. On the next blank page of your science notebook, add the heading "Instructions Reflection".

16. Respond to the following prompts:

- What parts of the instructions were the most helpful?
- Why is it important to have instructions that are clear and easy to follow?
- What makes instructions clear and easy to follow?

Discuss your investigation results with the class.

Scientists Circle

17. Discuss the following with your class:

- Which combination of reactants worked the best?
- What evidence supports this claim?
- What does this mean for our design solutions?

Update your Progress Tracker.

In your notebook

18. Record in your Progress Tracker what we did and what we figured out that can help with our designs.

Reflect on the instructions you will create.

Turn and talk

19. Turn to your Instructions Reflection in your science notebook.

20. Discuss your reflection with a partner.

21. Share your ideas with the class.

In your notebook

22. Discuss as a class what to add to the What We Do as Engineers board and your Progress Tracker.

23. Update your Progress Tracker.

Plan to determine ways to inform homemade heater designs.

Turn and talk

24. Discuss with a partner:

- What questions would you ask a stakeholder to figure out what is most important to them?
- What aspects of your design would you want stakeholder feedback on?

25. Share your ideas with the class.

Home learning

26. Create a stakeholder survey to help inform your homemade heater design.

27. As home learning, give the survey to friends, family, household members, neighbors, and others you identify as stakeholders.

Lesson 5: How can we refine our criteria and constraints?

Turn and talk with a partner.

Turn and talk

1. According to our survey, what do stakeholders say is most important to them?

Read to learn about food temperature.

On your own

2. Read the text your teacher assigns you. Find, underline, and tag information that will help us define a target temperature range for our food. Use the following questions to guide your reading:

- What temperature is too hot?
- Does food need to get to a certain temperature to avoid illness?
- How warm does food need to get for people to enjoy the taste?

Share information about food temperature.

With your group

3. Work with your group to discuss each of the focal questions from your reading, with each of you sharing evidence from the text you read.

- Discuss the first question. Take turns adding any information you found in your reading that helped answer the first question.
- Repeat the same procedure for the next two questions.
- Record in your notebook the information that helps answer the focal questions.

Define a target temperature for our homemade heaters.

Engineers Circle

4. Discuss with your class: Can we use this information to define the temperature range to which we need our homemade heater to warm our food?

Define a cost constraint for our homemade heaters.

With your class

5. Investigate the cost of prepackaged MREs. Discuss with your class what a good target cost would be for the materials we will use in our own homemade flameless heaters. Update the Criteria and Constraints chart with this information.

Decide how to limit the weight of our homemade MREs.

Turn and talk

6. Turn and talk with a partner about the following questions:

- How is the weight of our MRE going to affect our stakeholders?
- How could we figure out how much a prepackaged heater weighs?

7. Weigh the premade MRE and decide on the weight limit for the homemade heater designs.

8. Update the Criteria and Constraints chart with the characteristics we want our designs to have.

Discuss a trade-off: weight.

Engineers Circle

9. How much of our 400 grams do we need to use for the reactants, and how much food can we include?

Update our Progress Trackers.

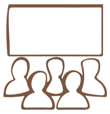
In your notebook

10. Add an entry to your Progress Tracker to show what we just figured out: we refined what our solution needs to do. How did that help us with our designs?

Lesson 6: How can we redesign our homemade flameless heater?

Revisit our What We Do as Engineers board and Progress Tracker.

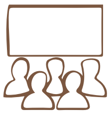
Engineers Circle



1. Bring your science notebook to the circle and look back at the Progress Tracker entry as well as the What We Do as Engineers board that we updated last time. Discuss with your class why we feel we are ready to design a solution.

Revisit our DQB and Ideas for Investigations.

Engineers Circle



2. Write a check mark on a sticky note and place it on our DQB or Ideas for Investigations chart near an idea that we have completed.
3. Look at the ideas that we have not checked off yet and compare them to our Criteria and Constraints chart. Turn and talk with a neighbor about what information we still need before we are ready for a redesign. Then, share your thinking with the class.

Consider materials we can use.

Engineers Circle

4. Your teacher will share examples of the containers and other materials you can use to construct your heater. The materials list and costs for each item can also be found in *Materials Cost List*.
5. Discuss how different mass measurements are important in the design solution.

Discuss safety while considering available materials.

Safety Precautions

6. Consider why "water bead soup" will be used instead of real food during testing.
7. Plan for how you will let hydrogen gas out of your heater. The container holding your reactants cannot be fully sealed, or it could pop open and splash out. You must leave the bag or container open slightly or cut a hole in it to let the gases escape.

Set an expected time for the heaters.

Engineers Circle

8. Discuss with your class how long it should take our heaters to work and add that time to our Criteria and Constraints chart.

Turn and talk about teamwork.

Turn and talk

9. The last time you modeled a design for a flameless heater, you worked on your own. This time, you will work with a team. Turn and talk with a neighbor about these questions:

- What will be good about working with a team rather than on your own?
- What might be challenging about working with a team?

10. Be ready to share your ideas with the class.

11. Your teacher will give you *Teamwork Self-Assessment* to add to your notebook and use at the end of this lesson to rate your own teamwork.

Why are different kinds of models helpful?

With your team

12. Talk with your class about the following questions:

- Why is it a good idea to model on paper before building something?
- What are the benefits of constructing a physical model?

Model your design on paper.

With your team

13. After you get together with your team members, decide on a team name and write it on the chart that your teacher has set up.

14. Use chart paper to create your design, using the checklist of *Design Must-Haves* to be sure that your design is complete.

15. Have your teacher check your design for safety.

Whole-Group Discussion About Writing Instructions

With your class

16. Discuss with your class the important features of good instructions.

With your team

17. Use the checklist of *How-to Instructions Must-Haves* to craft a set of instructions for your design on the handout.

Safety Reminders Before You Begin Building

Safety Precautions

18. Before you assemble your prototype, plan to stay safe by following the safety guidelines:

- Wear indirectly vented chemical splash goggles, a nonlatex apron, and nitrile gloves during the setup, hands-on, and take-down segments of the activity.
- Immediately wipe up any spilled water on the floor—this is a slip and fall hazard.
- Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
- Wash your hands with soap and water immediately after completing this activity.
- Never eat any food items used in a lab activity.
- Never taste any substance or chemical in the lab.
- Use caution when working with heated liquids—this can burn skin!
- Safety guidelines need to be in place for the hydrogen gas that is generated by these reactions (root killer). Guidelines should include the use of vented containers to avoid the build up of pressure and the elimination of potential ignition sources like sparks and flames. The amounts of hydrogen generated by these reactions do not pose an inhalation hazard. Use appropriate lab ventilation.

Scale down design.

With your team

19. Scale down your design to ¼ using *Scaling Down Design*. These scaled-down measurements will be used to build your prototype.

Assemble your prototype.

With your team

20. Keep *Scaling Down Design* out and place your drawn design and instructions off to the side while you start to assemble your prototype.

21. Double-check that measurements are for the scaled-down design.

22. You will not have saltwater yet, but you can begin building your prototype by

- measuring and packaging your “water bead soup”—1 part hydrated water beads and 3 parts plain water,
- measuring out your copper sulfate and aluminum, and
- preparing a vent in your reactant container.

Plan for testing our designs.

Turn and talk

23. Turn and talk about the following question:

- We know that engineers rely on systematic testing to help improve their designs. What do we need to do when we test our prototypes to be sure that our results can help inform our future designs?

24. Share your ideas with your class and work together to decide how you will systematically test your designs.

25. Set up a table in your science notebook to record data during testing. An example is shown here. The third column is space to record your observations about what components or systems of your group’s design are causing the temperature change patterns that you see in the data.

Time	Temperature	Why?

26. Your teacher will give you a copy of the *Design Testing Matrix* to add to your science notebook. This is where you will record your results.

Safety Reminders Before Testing

Safety Precautions

27. Before you assemble your prototype, plan to stay safe by following the safety guidelines:

- Wear safety goggles, nitrile gloves, and an apron during setup, investigation, and cleanup.
- Secure loose clothing, remove loose jewelry, tie back long hair, and wear closed-toe shoes.
- Avoid touching your face (so substances do not get near your nose or mouth). Never taste any substance in the lab.

- Move carefully so that we do not spill anything. Immediately wipe up any spills that do happen.
- Follow instructions for cleanup and wash your hands with soap and water after cleanup is complete.
- Use caution when working with heated liquids—they can burn skin.
- Make sure your design is properly vented.

Test your design.

With your team

28. Test your design following these procedures and any others that your teacher has set up:

a. Record the mass of your entire heater with food, reactants, and packaging.
b. Test your heater on a tray.
c. Be sure that your reactant container is vented.
d. Start watching the clock as soon as the reactants are combined.
e. Do your instructions say to swirl or stir?
f. Measure the food temperature regularly and record it in your notebook.
g. Follow instructions for cleaning up.

29. While you are waiting between temperature measurements, your teacher will distribute *Engineering Design Rubric* for you to read. You will not fill this out until after testing is complete.

Cleanup Procedures

With your team

30. Clean up your materials following these procedures and any others that your teacher has set up:

a. Follow all safety guidelines:
   i. Wear goggles, nitrile gloves, and an apron during setup, investigation, and cleanup.
   ii. Secure loose clothing, remove loose jewelry, tie back long hair, and wear closed-toe shoes.
   iii. Avoid touching your face (so substances do not get near your nose or mouth). Never taste any substance in the lab.
   iv. Move carefully so that we do not spill anything. Immediately wipe up any spills that do happen.
   v. Follow instructions for cleanup and wash your hands with soap and water after cleanup is complete.

b. Save your Styrofoam cups and unused reactants for future use.

c. Collect liquid leftovers in the container provided by your teacher.

d. Put copper and used aluminum in the trash can.

e. Rinse your containers for use next time.

f. Return your water beads to the container provided by your teacher.

Complete the engineering self-assessment.

With your team

31. Work together with your teammates and use *Engineering Design Rubric* to assess the work you did as engineers on this design. Turn it in to your teacher when you are finished.

Complete the Teamwork Self-Assessment.

On your own

32. Work independently to complete the *Teamwork Self-Assessment* that you already have in your notebook.

Update our Progress Trackers.

In your notebook

33. Work with your class to add to our Progress Trackers based on today's work. See the example entries started for you here.

What did we do as engineers?	What did we figure out that can help us with our designs?
We systematically tested parts of our design solution.	
We developed different types of models to help us plan for how we can improve our design.	

Exit Ticket

On your own

34. Using the *Exit Ticket* handout, consider how your design connects to the Energy Transfer Model.

Lesson 7: How did our design compare to others in the class?

Get ready to share.

In our last lesson, we tested our prototype designs. It might be helpful to share our designs with other teams as we think about changes to our designs.

On your own

1. Think of one component of your team's design that you want to improve.

- Do you have some ideas about changes that will improve performance?
- How might learning about other teams' designs be helpful?

Review norms.

With your class

2. Discuss these questions with your classmates:

- Which norms should we keep in mind as we share our designs with other teams?
- What does it look like to give feedback?
- What does it look like to receive feedback?

Share your team's design with two other teams.

With your group

3. Work with a partner team.

- 2 min: Exchange instructions and give written feedback on the instructions.
- 3 min: One team shares their design. The partner team records information about how the presenting team's design performed in their *Design Testing Matrix*.
- 3 min: Switch roles with partner team.
- 4 min: Individually give written feedback to the partner team using the guiding questions in *Peer Feedback on Designs*.

4. Pair with another team as your teacher assigns. Repeat step 3 with your new partner team.

Share the most promising design components.

Scientists Circle

5. Discuss these questions with your classmates:

- What promising design characteristics did you see or hear from other teams that could improve everyone's designs?
- What was promising?
- What were the trade-offs?
- What caused it to be effective?

Update your Progress Tracker.

In your notebook

6. Update your Progress Tracker by recording what we did as engineers and what we figured out that can help us in our designs.

Rank design components.

On your own

7. Use your *Design Testing Matrix* to rank the design components by order of importance to change in your next design.

Think about the effects of changes.

In your notebook

8. Make some notes in your notebook about the following questions:

- What is your justification for your top two rankings?
- How might comparing your rankings and reasoning with those of your team members better inform changes to your design?

Be prepared to share your thinking with your team in the next lesson.

Lesson 8: What effects might result from our design changes?

Navigation

On your own

1. Check your notebook to remember your rankings and to be sure that you have used specific data from the investigations to justify your choices.

In your notebook

2. Use the following sentence starter to make sure that you have included a justification for each of your top two criteria. ***Our design could be improved if we change*** (which criterion/constraint) ***to*** (how you will change the criterion/constraint) ***because*** (how the change you propose will help your design meet the optimal criterion and fit within our constraint better).

Brainstorm ways to change your design.

With your group

3. Share justifications for rankings with your team. To begin, each group member chooses a corner of the Discussion Diamond and writes
   - their name and
   - the top two criteria or constraints that they personally think the group should change.
4. Use the Discussion Diamond to equitably share ideas.

   Round 1
   - Each person gets one minute to share their rankings and to talk about the justification for why they ranked the proposed change the way they did.
   - No interruptions, no questions

   Round 2
   - Open discussion
   - Come to a consensus as a team about which 2-3 changes you think are important to investigate further.
   - Write these in the center of the diamond.

Turn and talk

5. Debrief the consensus process. Turn and talk to discuss the following prompts with an elbow partner.
   - How did you feel about the consensus process?
   - Were there any disagreements about which of the criteria to change or how to change them?

- Are you sure you are making the best decision?
- What would we need to do to be confident we were making the decisions that would optimize our design?

Begin to construct a cascading consequences chart as a class.

With your class

6. Reflect on how to be confident about the decisions we make.

7. Work as a class to construct the first "arm" of the Consequences Chart.

8. Add "cascading consequences" to the Word Wall.

Construct a cascading consequences chart with your team.

With your group

9. Work to complete the Consequences Chart(s). If your team's members are still in strong disagreement about which changes to make, split the team and have each subgroup make a Consequences Chart for the proposed changes they support. This will help the whole team decide on a final design using the charts as evidence.

10. To get started, assign each criterion a color.

11. Create the arms of your Consequences Chart using the colors that correspond to the criteria.

12. Annotate the chart by adding "+" and "–" signs to consequences that are generally positive or negative.

Navigation

In your notebook

13. Jot down your individual ideas about how to know if we are making the best design decisions. Use the following prompts to guide your answer:

- Are all consequences equal?
- Even if there are some negative consequences, can we still live with them if they make our design that much better?
- How can we be confident about our decision?

With your class

14. Discuss ideas with the class about how to know if we are making the best design decisions. Use the following prompts to guide your answer:

- Are all consequences equal?
- Even if there are some negative consequences, can we still live with them if they make our design that much better?
- How can we be confident about our decision?

Use stakeholders impact chart to make final design decisions.

With your group

15. Share stakeholder impact charts with team members and weigh impacts on stakeholders to decide which changes your team will make for the heater redesign. Use the following questions in team discussions to help decide on which changes to ultimately implement in the final design:

- How important to you are the interests of this stakeholder?
- If the effect on this stakeholder is negative, do you feel that it is directly offset by greater good elsewhere?

Update the Progress Tracker and What We Do as Engineers board.

In your notebook

16. Complete the Progress Tracker for the three things that we did in this lesson that engineers also do:

- We predicted consequences of making changes to design components.
- We collected and used stakeholder feedback.
- We considered the impact on stakeholders for different potential design solutions.
- We decided which design characteristics to implement.

Justify proposed design changes.

Writing in Science

17. Discuss the following with your class:

a. Which criteria and constraints are we going to change?

b. What are the potential impacts of this choice on stakeholders?

c. How are those impacts on stakeholders considered in the decision-making process?

18. Write in your science notebook an individual justification for these choices that addresses both positive and negative effects on stakeholders and explains how the effects were weighed to make a decision.

Lesson 9: What is our optimal design for a homemade flameless heater?

Navigation

Turn and talk

1. Review our updated What We Do as Engineers board. Turn and talk about the following questions:
    - What did we figure out last time?
    - What else did we consider when deciding on what changes to make?

Teamwork Self-Assessment

In your notebook

2. Review your *Teamwork Self-Assessment* that is already in your notebook.
3. Independently reflect on this question:
    - What is something you want to improve?
    - Write a goal in your science notebook.

Plan your redesign on paper.

With your group

4. Review *Design Must-Haves* with your team.
5. Your team will create a new model on chart paper or butcher paper. Use *Design Must-Haves* to be sure your model is complete.
6. Have your teacher check when you have calculated the amounts of reactants.
7. Explain how you combined parts of other designs to improve your flameless heater.
8. Practice good teamwork.

Update your how-to instructions.

With your group

9. Remember to update your how-to instructions to reflect any changes that your team has made to your design. Make sure your instructions are clear and complete because another team will follow them to build and test your heater. Use the checklist on *How-To Instructions Must-Haves* to be sure you've included all important points.

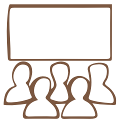
Remember to vent your heater for safety.

Safety Precautions

10. Remember that your team needs a plan for how you will let hydrogen gas and hot air out of your heater. The container holding your reactants cannot be fully sealed, or it could pop open and splash out. You must leave the bag or container open slightly or cut a hole in it to let the gases escape. Your teacher will check for this when they approve your model.

Review directions for building prototypes.

With your class



11. Review the directions for building prototypes with your class. Your team will build a prototype by

- measuring out your copper sulfate and aluminum,
- measuring and packaging water beads for your "food"—1 part water beads and 3 parts plain water,
- gathering and putting together your packaging,
- preparing a vent in your reactant container, and
- holding off on getting saltwater until you are ready to test.

Create an entry in your Design Testing Matrix.

In your notebook

12. Turn to *Design Testing Matrix* in your science notebook and write "My team's second design" in the first column of the next blank row. Be ready to record today's test data in that row.

13. Set up a table in your science notebook to record data during testing. An example is shown here. The third column is space to record any observations you make during testing.

Time	Temperature	Observations

Review steps for testing designs.

With your class

14. Review the procedures for testing prototypes with your class that you followed in Lesson 6:

- Record the mass of your entire heater with food, reactants, and packaging.
- Test your heater on a tray.
- Be sure your reactant container is vented.
- Start watching the clock as soon as the reactants are combined.
- Follow your instructions for mixing reactants.
- Measure the "food" temperature regularly and record it in your notebook.
- Follow instructions for cleaning up.

Your team should record the temperature at least every 5 minutes if you are opening a lid to place the thermometer in the "food." If your team chooses to leave the thermometer in the "food" for the entire time, you can collect temperature data more frequently.

Review safety guidelines.

Safety Precautions

15. In addition to testing your prototype on a tray, you should stay safe by doing the following things:

- Wear indirectly vented chemical splash goggles, a nonlatex apron, and nitrile gloves during the setup, hands-on, and take-down segments of the activity.
- Immediately wipe up any spilled water on the floor—it is a slip and fall hazard.
- Follow your teacher's instructions for disposing of waste materials.
- Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
- Wash your hands with soap and water immediately after completing this activity.
- Never eat any food items used in a lab activity.
- Never taste any substance or chemical in the lab.
- Use caution when working with heated liquids—this can burn skin!

- Safety guidelines need to be in place for the hydrogen gas that is generated by these reactions (root killer). Guidelines should include the use of vented containers to avoid the build up of pressure and the elimination of potential ignition sources like sparks and flames. The amounts of hydrogen generated by these reactions do not pose an inhalation hazard. Use appropriate lab ventilation.

Build and test your version 2 prototypes.

With your group

16. Work with your team to build and test your prototype by assembling and using your design as indicated in your model and how-to instructions. Look for places where you find your own how-to instructions to be confusing. Remember to record data in your science notebook.

Review and follow cleanup procedures.

Safety Precautions

17. You should stay while cleaning up your area by doing the following things:

- Keep your apron, gloves, and goggles on until you are finished cleaning up.
- Save and return your Styrofoam cups and unused reactants for future use.
- Collect liquid leftovers in the container provided by your teacher.
- Put copper and used aluminum in the trash can.
- Rinse your containers for future use.
- Return your water beads to the container provided by your teacher.

Prepare to exchange how-to instructions.

With your group

18. Remember to update your how-to instructions to reflect any changes that your team has made to your design. Make sure your instructions are clear and complete because another team will follow them to build and test your heater.

Prepare for another team to test your instructions.

With your group

19. As a team, fill in your design team name, class period, and the total cost of your version 2 design (this should be in the *Design Testing Matrix* in your science notebook under “My team’s second design”) on the *Partner Info Sheet for Final Design* half-sheet.

20. Take 5 minutes to make quick revisions to your how-to instructions. Focus on areas where you thought your own instructions were confusing and clarify them for a partner team. Ideally, your instructions should be clear enough for a partner team to meet or exceed the test results that you obtained. The revised instructions must still follow the design that was approved at the end of day 1 of this lesson.

Exchange designs with another team.

With your group

21. After your teacher assigns you a partner team to exchange how-to instructions with, your team should trade your partially filled-out *Partner Info Sheet for Final Design* half-sheet and your revised design how-to instructions with your partner team.

22. Fill in your team name as the testing team on the *Partner Info Sheet for Final Design* that you received from your partner team.

Begin assembling your partner team's heater.

With your group

23. Read through your partner team's how-to instructions and begin assembling their heater. There will not be enough time for you to test designs today, so you will not have access to saltwater until the next class.

24. Label and store your unfinished heater in the classroom according to your teacher's directions. You will run your test next time.

Finish building and test partner design.

With your group

25. Work together with your teammates to finish building your partner team's design.

- Make sure to follow all previous testing and safety procedures, including verifying that the device is vented properly.

Review and follow cleanup procedures.

With your group

26. As your team finishes testing your partner team's design, follow the cleanup procedures listed below:

- Keep your apron, gloves, and goggles on until you are finished cleaning up.
- Save and return your Styrofoam cups and unused reactants for future use.

- Collect liquid leftovers in the container provided by your teacher.
- Put copper and used aluminum in the trash can.
- Rinse your containers for future use.
- Return your water beads to the container provided by your teacher.

Exchange testing data between teams.

With your team

27. With your partner team, exchange information from the *Partner Info Sheet for Final Design.*

- Record this information in your *Design Testing Matrix* in your notebook.
- Ask your partner group members clarifying questions about the data collected on the *Partner Info Sheet for Final Design.*

28. Compare your version 2 testing results to your partner teams' test results.

Complete the Engineering Design Rubric with your team.

With your team

29. Work together with your teammates and use the *Engineering Design Rubric* to assess the work you did as engineers on this design. Turn it in to your teacher when you are finished.

Complete the Teamwork Self-Assessment.

On your own

30. Work independently to complete the *Teamwork Self-Assessment.* Add it to your notebook near your other self-assessment from Lesson 6. You may use a single piece of tape at the top of this sheet to attach this self-assessment over the one from Lesson 6, which will allow you to easily see both by just lifting and lowering the top sheet.

Evaluate our DQB questions.

With a partner

31. Evaluate how you think we have answered the questions on our DQB. Record on *Questions from Our DQB* any additional questions that come to mind. Use the following symbols to mark your questions:

- We did not answer this question or any parts of it yet: **O**
- Our class answered *some parts* of this question, or I think I could answer *some parts* of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓ +

32. Then choose three questions that you think we have made good progress on and write an answer with supporting evidence on your handout. Work with your partner to refine your answers with evidence.

What questions have we made progress on?

On your own

33. Take your handout and 5 sticky dots over to the Design Questions Board. Place your sticky dots on the sticky notes that match the questions that you think we have made progress on. Once you have placed your 5 dots, move to the Engineers Circle. As you are waiting for others to place their sticky dots,
    - be prepared to share your evidence for what the answers to the questions might be and
    - look for patterns to identify which questions have the most sticky dots.

Revisit our Design Questions Board.

Engineers Circle

34. In your Engineers Circle, discuss the following questions as a class:
    - Which questions have we made the most progress on?
    - What have we figured out?
    - What questions do you have about any of the ideas that have been shared?

Navigation

On your own

35. Look over the home learning survey.
36. If directed by your teacher, take a photo of your group's instructions so people taking the survey will have easy access to look at them.

Survey stakeholders.

Home learning

37. Use the Google Form your teacher provided to survey two or more friends or family members.
    - Describe your group's flameless heater and share your how-to instructions.
    - Make sure one person you survey is your age and the other person is an adult.
38. We will look at class data next time.

Lesson 10: How can we decide between competing designs?

Review survey results with your class.

Last class we spent time celebrating and reviewing the progress we have made. For home learning, you should have recorded any new insights we had during our DQB review.

With your class

1. Be prepared to discuss the responses to the stakeholder survey questions as a class:

- Do you think most people would be able to follow these instructions to build a flameless heater to successfully heat food?
- What suggestions for improvement do you have for these instructions?
- Do you think you could use this heater to do other things? List your ideas.

Review Progress Trackers.

Last class we spent time celebrating and reviewing the progress we have made. For home learning, you should have recorded any new insights we had during our DQB review.

With a partner

2. Discuss the following questions with a partner:

- What new ideas or insights did you add to your Progress Tracker?
- What remaining questions do you have?

Demonstrate understanding on an assessment task.

On your own

3. Individually show your understanding on the *Form A: Sea Turtle Assessment.*

Reflect on heater application in the assessment.

With your class

4. The heaters we made could be used for other applications.

- We just completed a task that used a chemical reaction for another purpose. What was it used to do?

Other Homemade Heater Applications

Quickwrite

5. We also surveyed people in our community about other possible uses of our homemade heater designs. Use ideas from the survey, the assessment, and any new ideas you can come up with to brainstorm in your notebook:
    - What are some of the best ideas?
    - How else could our homemade heaters be useful besides just heating up food?
    - Do you have any other ideas for how someone might use chemical reactions to solve other problems?

Graffiti Board

On your own

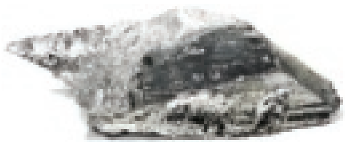
6. Share your ideas with your class by writing them on "graffiti boards" around the classroom.
    - Take a marker and find your assigned graffiti board around the classroom.
    - Write at least one idea you came up with for how our homemade heaters might be applied in a new context.
    - Then, go to another graffiti board to view ideas that your classmates wrote.
    - Write additional ideas on other boards if you get inspired by someone else's writing.

Discuss your homemade heater applications.

With your class

7. Discuss and celebrate the ideas shared on the graffiti boards as a class!

Ingredient List for MRE Heater

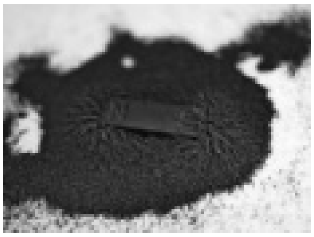
Ingredients in the MRE heater	Description
Iron 	A shiny solid that ranges from metallic grey to black in color. It is a metal with the atomic symbol Fe. It can be flammable in powder form. Pure iron is different from an iron supplement taken as a vitamin. Typically, iron supplements are sold as iron II fumarate with the chemical formula $C_4H_2FeO_4$. The iron powder in the MRE can be hazardous if ingested* or inhaled**.
Magnesium 	A shiny, gray solid. It is a metal with the atomic symbol Mg. Pure magnesium is highly flammable, especially in powdered form. Magnesium in vitamins is usually in the form of magnesium oxide with the chemical formula MgO. The magnesium powder in the MRE is hazardous if ingested* or inhaled**.
Sodium chloride 	A colorless crystalline substance commonly known as table salt. It can also be represented as NaCl.
Silicon dioxide 	A substance added to food to prevent other substances from clumping (sticking together), also called an anticaking agent. It is hazardous if ingested* or inhaled**. The formula for this compound is SiO_2.

Sodium tripolyphosphate 	A substance added to food that can be used to increase how much water other substances can hold. The formula for this compound is $Na_5P_3O_{10}$.
Wetting agent 	A substance used to increase how quickly and easily a liquid spreads through other materials. The specific wetting agent used in the MRE is privately owned; detergents are common wetting agents (the example shown here is Borax).

*ingested = to be eaten

**inhaled = breathed in

Ingredient List for Hand Warmer

Ingredients in the hand warmer	Description
Iron powder 	A shiny solid that ranges from metallic grey to black in color. It is a metal with the atomic symbol Fe. It can be flammable in powder form. Pure iron is different from an iron supplement taken as a vitamin. Typically, iron supplements are sold as iron II fumarate with the chemical formula $C_4H_2FeO_4$. The iron powder in the hand warmer can be hazardous if ingested* or inhaled**.
Water 	A tasteless and odorless compound represented as H_2O. It is a liquid at room temperature. It has the important ability to dissolve many other substances.
Salt 	A colorless crystalline substance also known as sodium chloride.
Activated charcoal 	A lightweight, black carbon residue produced by strongly heating wood (or other animal and plant materials) in minimal oxygen to remove all water and volatile constituents.
Vermiculite 	A common use of vermiculite is to combine it with other materials such as peat or composted pine bark to produce soilless growing medium for the professional and home gardeners. Vermiculite is able to absorb and hold a lot of water, which is helpful as it can be released as the plant needs it.

Chemical Reactions Lab Instructions

Part 1: Our Experimental Setup

In this investigation, each group will gather data on temperature changes during a specific chemical process. A picture of the experimental setup that you will use is shown here.

You will wrap a rubber band on the probe of the thermometer between the body and the lid. This will hold the tip of the thermometer in a constant position (as shown above). When the lid is placed on the cup, the tip of the thermometer should be roughly in the center of the liquid and other materials and should not touch the side or bottom of the cup.

Part 2: Data Collection

Your group will investigate only one type of chemical process but with three different amounts of substances: low, medium, and high. For each amount of substances, groups will record temperature data every 30 seconds for 5 minutes.

Wear indirectly vented chemical splash goggles, nitrile gloves, and non-latex aprons during set-up, activity, and take down portions.

Groups A and B: Baking Soda and Vinegar

Your group will gather data on temperature changes when baking soda is added to vinegar. Your group will be provided with a container of baking soda and 3 Styrofoam cups that each contain 50 mL of vinegar.

1. Decide which role each group member will be responsible for. When you are not actively engaged in your role, you should copy the data into your own science notebook and help clean up. The roles are listed here:

Role	Duties
Timer	Calls out time intervals and reads out temperature every 30 seconds for 5 minutes per cup (**Low, Medium, and High cups**).
Data Recorder	Writes down the temperature readings in the appropriate data table (for **Low, Medium, and High cups**) in their science notebook.
Low- and High-Cup Monitor	Opens and closes the cup lid for the **Low and High cups** so that substances can be added; gently swirls the cup for the 5 minutes that temperature is being monitored.
Medium-Cup Monitor	Opens and closes the cup lid for the **Medium cup** so that substances can be added; gently swirls the cup for the 5 minutes that temperature is being monitored.
Weigher	Weighs out different amounts (for **Low, Medium, and High cups**) of baking soda and adds them to the cup when the Cup Monitor removes the lid.

2. Wrap a rubber band around the thermometer and insert the thermometer through the center of the Low cup lid so that, as the rubber band rests on the lid, the thermometer is suspended in the liquid and is not touching the sides of the cup. Place the lid and thermometer on the Low cup and record in your science notebook the temperature of the vinegar after 30 seconds as the starting temperature.
3. Use a plastic spoon to weigh 1.0 g of baking soda onto parchment paper on the scale.
4. Lift the lid with the thermometer off of the Low cup and add the baking soda. Firmly replace the lid and thermometer and begin to gently swirl the contents of the cup. Be sure to keep swirling the cup for the entire 5 minutes that you are monitoring the temperature.
5. Timing should be started as soon as the baking soda is added to the cup. Record the temperature reading every half minute (30 s) for a total of 5 minutes.
6. Once the Low cup has been started, repeat step 3 for the Medium cup using 2.0 g of baking soda.
7. After you have recorded temperature data from the Low cup for 5 minutes, remove the thermometer and wipe it off with a damp paper towel. Immediately insert the thermometer into a new lid, place it on the Medium cup, and record the starting temperature after 30 seconds.

8. Repeat steps 4–5 with the Medium cup.
9. Once the Medium cup has been started, repeat step 3 for the High cup using 3.0 g of baking soda.
10. After you have recorded temperature data from the Medium cup for 5 minutes, remove the thermometer and wipe it off with a damp paper towel. Immediately insert the thermometer into a new lid, place it on the High cup, and record the starting temperature after 30 seconds.
11. Repeat steps 4–5 with the High cup.
12. Follow your teacher's directions for safe cleanup.

Group C: Vinegar-Dipped Steel Wool and Air

Your group will gather data on temperature changes as steel wool, freshly removed from vinegar, is exposed to air. Your group will be provided 3 containers of vinegar containing 3 different-sized pieces of steel wool and 3 air-filled Styrofoam cups with lids. The steel fibers are covered in a thin layer of oil that is used to make them. Vinegar is able to remove this oil to expose fresh steel wool.

1. Decide which role each group member will be responsible for. When you are not actively engaged in your role, you should copy the data into your own science notebook and help clean up. The roles are listed here:

Role	Duties
Timer	Calls out time intervals and reads out temperature every half minute for a total of 5 minutes per cup (**Low, Medium, and High cups**).
Data Recorder	Writes down the temperature readings in the appropriate data table (for **Low, Medium, and High cups**) in their science notebook.
Low- and High-Cup Monitor	Opens and closes the cup lid for the **Low and High cups** so that substances can be added; holds the cup for the 5 minutes that temperature is being monitored.
Medium-Cup Monitor	Opens and closes the cup lid for the **Medium cup** so that substances can be added; holds the cup for the 5 minutes that temperature is being monitored.
Weigher	Weighs the different-sized pieces of steel wool (for **Low, Medium, and High cups**) and adds them to the cup when the Cup Monitor removes the lid.

2. Place the digital thermometer into the Low container of vinegar containing the steel wool and record in your science notebook the temperature after 0.5 minutes as the starting temperature. You will use this starting temperature for all 3 cups.
3. After removing the thermometer from the Low container of vinegar and steel wool, insert it through the center of a cup lid so that it is suspended in the middle of the cup and is not touching the sides of the cup.
4. Using 2 plastic spoons, remove the piece of steel wool from the Low container of vinegar and place it on a paper towel on the scale. Record the weight in the data table in your science notebook.
5. Use your gloved hand to place the piece of steel wool around the tip of the thermometer and place it inside the cup. Firmly seal the lid on the cup.
6. Timing should be started as soon as the lid is placed on the cup containing the steel wool. Record the temperature reading every half minute (30 s) for a total of 5 minutes.
7. As the Low cup is approaching 5 minutes, get ready to repeat steps 4-6 for the Medium cup. As soon as the 5-minute temperature is recorded for the Low cup, remove the thermometer and wipe it off with a damp paper towel.
8. Repeat steps 4-6 for the Medium cup using the piece of steel wool from the Medium container.
9. After you have recorded data from the Medium cup for 5 minutes, remove the thermometer and wipe it off with a damp paper towel.
10. Repeat steps 4-6 for the High cup using the piece of steel wool from the High container.
11. Follow your teacher's directions for safe cleanup.

Groups D and E: Root Killer, Aluminum Foil, and Saltwater

Your group will gather data on temperature changes as pieces of aluminum foil react with root killer in saltwater. Your group will be provided with a container of root killer crystals, a bag of aluminum foil that has been shredded, and 3 Styrofoam cups that each contain 60 mL of saltwater. Pure aluminum reacts quickly with air to form a thin layer of a different substance on its surface. Salt in the water disrupts this layer to expose fresh aluminum.

1. Decide which role each group member will be responsible for. When you are not actively engaged in your role, you should copy the data into your own science notebook and help clean up. The roles are listed here:

Role	Duties
Timer	Calls out time intervals and reads out temperature every half minute for a total of 5 minutes per cup (**Low, Medium, and High cups**).
Data Recorder	Writes down the temperature readings in the appropriate data table (for **Low, Medium, and High cups**) in their science notebook.
Low- and High-Cup Monitor	Opens and closes the cup lid for the **Low and High cups** so that substances can be added; gently swirls the cup for the 5 minutes that temperature is being monitored.
Medium-Cup Monitor	Opens and closes the cup lid for the **Medium cup** so that substances can be added; gently swirls the cup for the 5 minutes that temperature is being monitored.
Weigher	Weighs out different amounts (for **Low, Medium, and High cups**) of aluminum and root killer and adds them to the cup when the Cup Monitor removes the lid.

2. Wrap a rubber band around the thermometer and insert the thermometer through the center of the Low cup lid so that, as the rubber band rests on the lid, the thermometer is suspended in the liquid and is not touching the sides of the cup. Place the lid and thermometer on the Low cup. Record in your science notebook the temperature of the saltwater after 0.5 minutes as the starting temperature.

3. Use your fingers to transfer aluminum foil pieces onto parchment paper on the scale to weigh 1.0 g of aluminum.

4. Use a plastic spoon to transfer root killer onto parchment paper on the scale to weigh 1.0 g of root killer.

5. Lift the lid with the thermometer off of the Low cup and add the root killer followed by the aluminum foil. Gently push the aluminum pieces down into the saltwater. Firmly replace the lid and thermometer and begin to gently swirl the contents of the cup. Be sure to keep swirling the cup for the entire 5 minutes that you are monitoring the temperature.

6. Timing should be started as soon as the root killer and aluminum are added to the cup. Record the temperature reading every half minute (30 s) for a total of 5 minutes.

7. Once the Low cup has been started, repeat steps 3-4 for the Medium cup using 2.0 g of root killer and 2.0 g of aluminum foil pieces.

8. After you have recorded data from the Low cup for 5 minutes, you can remove the thermometer and wipe it off with a damp paper towel. Immediately insert the thermometer into a new lid and place it on the Medium cup. Record the starting temperature after 0.5 minutes.

9. Repeat steps 5-6 with the Medium cup.
10. Once the Medium cup has been started, repeat steps 3-4 for the High cup using 3.0 g of root killer and 3.0 g of aluminum foil pieces.
11. After you have recorded data from the Medium cup for 5 minutes, you can remove the thermometer and wipe it off with a damp paper towel. Immediately insert the thermometer into a new lid and place it on the High cup. Record the starting temperature after 0.5 minutes.
12. Repeat steps 5-6 with the High cup.
13. Follow your teacher's directions for safe cleanup.

Group F: Cabbage Juice and Vinegar

Your group will gather data on temperature changes as different amounts of cabbage juice and vinegar react. Your group will be provided with containers of cabbage juice and vinegar as well as 3 Styrofoam cups containing different amounts of water: 50 mL in the Low cup, 40 mL in the Medium cup, and 20 mL in the High cup.

1. Decide which role each group member will be responsible for. When you are not actively engaged in your role, you should copy the data into your own science notebook and help clean up. The roles are listed here:

Role	Duties
Timer	Calls out time intervals and reads out temperature every half minute for a total of 5 minutes per cup (**Low, Medium, and High cups**).
Data Recorder	Writes down the temperature readings in the appropriate data table (for **Low, Medium, and High cups**) in their science notebook.
Low- and High-Cup Monitor	Opens and closes the cup lid for the **Low and High cups** so that substances can be added; gently swirls the cup for the 5 minutes that temperature is being monitored.
Medium-Cup Monitor	Opens and closes the cup lid for the **Medium cup** so that substances can be added; gently swirls the cup for the 5 minutes that temperature is being monitored.
Weigher	Weighs out amounts of cabbage juice and vinegar and adds them to the cup when the Cup Monitor removes the lid.

2. Wrap a rubber band around the thermometer and insert the thermometer through the center of the Low cup lid so that, as the rubber band rests on the lid, the thermometer is suspended in the liquid and is not touching the sides of the cup. Place the lid and thermometer on the Low cup and record in your science notebook the temperature of the water after 0.5 minutes as the starting temperature.
3. Weigh 5.0 g of cabbage juice into an unlabeled Styrofoam cup. Weigh 5.0 g of vinegar into a different unlabeled Styrofoam cup.
4. Lift the lid with the thermometer off the Low cup and add the cabbage juice and vinegar. Firmly replace the lid and thermometer and begin to gently swirl the contents of the cup. Be sure to keep swirling the cup for the entire 5 minutes that you are monitoring the temperature.
5. Timing should be started as soon as the two liquids are added to the cup. Record the temperature reading every half minute (30 s) for a total of 5 minutes.
6. Once the Low cup has been started, repeat step 3 for the Medium cup using 10.0 g of cabbage juice and 10.0 g of vinegar.
7. After you have recorded data from the Low cup for 5 minutes, remove the thermometer and wipe it off with a damp paper towel. Immediately insert the thermometer into a new lid, place it on the Medium cup. Record the starting temperature after 0.5 minutes.
8. Repeat steps 4–5 with the Medium cup.
9. Once the Medium cup has been started, repeat step 3 for the High cup using 20.0 g of cabbage juice and 20.0 g of vinegar.
10. After you have recorded data from the Medium cup for 5 minutes, remove the thermometer and wipe it off with a damp paper towel. Immediately insert the thermometer into a new lid and place it on the High cup. Record the starting temperature after 0.5 minutes.
11. Repeat steps 4–5 with the High cup.
12. Follow your teacher's directions for safe cleanup.

Some Common Gases

All data reported are measured at sea-level elevation.				
Substances	***Approximate % of gas in the air outside***	***Boiling point(°C)***	***Density measured at 0°C (g/L)***	***Flammability*** *Notes on how the gas interacts with a flame*
Nitrogen	78	–196	1.250	Will extinguish a flame.
Oxygen	21	–183	1.430	Will increase a flame or cause a glowing ember to burst into flame.
Argon	1	–186	1.780	Will extinguish a flame.
Carbon dioxide	0.04	N/A*	1.960	Will extinguish a flame.
Neon	0.0018	–246	0.900	Will extinguish a flame.
Helium	0.0005*	–268	0.179	Will extinguish a flame.
Methane (natural gas)	0.0002*	–161.5	0.714	Will increase a flame. Can create an explosion.
Hydrogen	0.0001	–252	0.090	Will increase a flame. Can create an explosion.
Propane	<0.0001	–42	2.000	Will increase a flame. Can create an explosion.
Carbon monoxide	<0.0001	–191.5	1.140	Flammable gas
Air with 5% humidity	*N/A*	*N/A (mixture)*	1.160	Can maintain an open flame.

* Changes straight from solid to gas with no liquid phase. This occurs at –78.4°C.

Investigation Procedure for Proportion of Reactants

Part 1: Measuring Reactants

In this investigation, groups will gather data on the temperature increases caused by the reaction of different amounts of aluminum (Al) and copper sulfate ($CuSO_4$) in a fixed amount of saltwater. For specific amounts of substances, each group will record temperature data every 30 seconds for a total of 5 minutes. The experimental setup is similar to what you used earlier in the unit and consists of a Styrofoam cup with a lid and a digital thermometer.

Your group will investigate only one of the following combinations of amounts of aluminum and copper sulfate. You will be provided with all the materials you will need to measure the amounts of substances assigned to your group using an electronic scale.

Safety Reminder

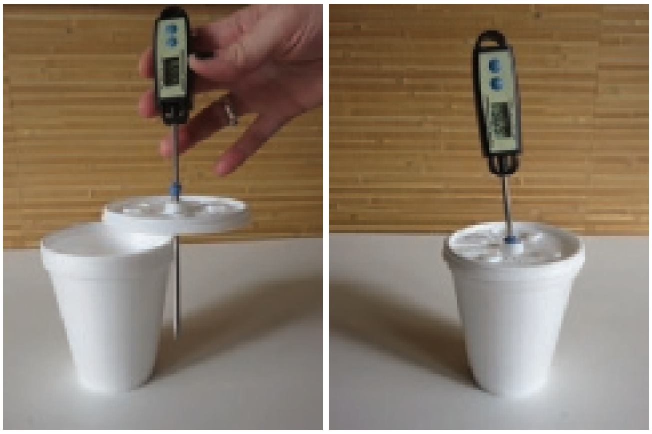
Ensure that the lab has engineering controls (eyewash station and shower) available.

1. Wear safety goggles (indirectly vented chemical splash goggles), a nonlatex apron, and nitrile gloves during the setup, hands-on, and take-down segments of the activity.
2. Immediately wipe up any spilled water on the floor—this is a slip and fall hazard.
3. Follow your teacher's instructions for disposing of waste 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.
8. Use caution when working with heated liquids—this can burn skin!
9. Safety guidelines need to be in place for the hydrogen gas that is generated by these reactions (root killer). Guidelines should include the use of vented containers to avoid the build up of pressure and the elimination of potential ignition sources like sparks and flames. The amounts of hydrogen generated by these reactions do not pose an inhalation hazard. Use appropriate lab ventilation.

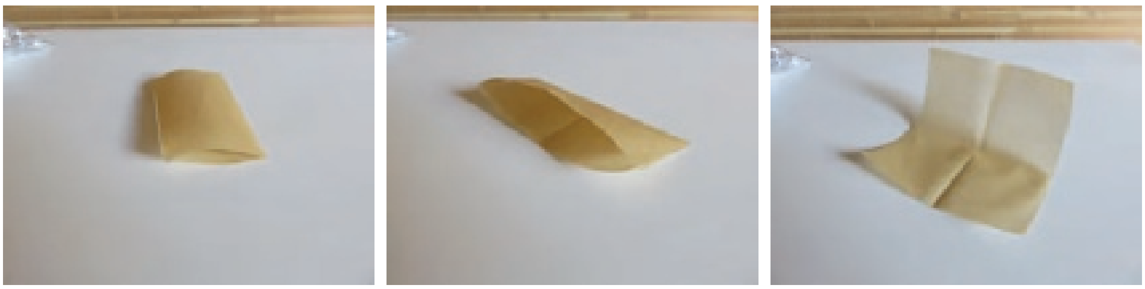
Groups	Amount of Al (g)	Amount of $CuSO_4$ (g)	Amount of saltwater (g)
A and B	0.1	5.9	60.0
C and D	0.5	5.5	60.0
E and F	4.5	1.5	60.0

General procedure

1. Read through all steps before you start to carry them out and decide who will be responsible for each step.
2. Measure 60.0 g of saltwater into a Styrofoam cup. Do not use your cleanest cup; save that cup for Part 3.
3. Wrap a rubber band around the thermometer and insert the thermometer through the center of the cup lid so that, as the rubber band rests on the lid, the thermometer is suspended in the liquid and is not touching the sides or bottom of the cup. When the lid is placed on the cup, the tip of the thermometer should be roughly in the center of the liquid.
4. Place the lid and thermometer on the cup and record on your *Small-Group Data Table the* temperature after at least 30 seconds. This will be your starting temperature, time = 0 minutes.



5. To make it easier to measure and handle substances, fold the pieces of parchment paper in one direction, open it, and then fold it in the other direction (as shown below). This will make the piece of parchment paper easier to pick up and pour from after measuring out substances.



6. Measure your group's amount of Al onto a piece of parchment paper.
7. Measure your group's amount of $CuSO_4$ onto the other piece of parchment paper using a plastic spoon.

Part 2: Collecting Temperature Data

General procedure

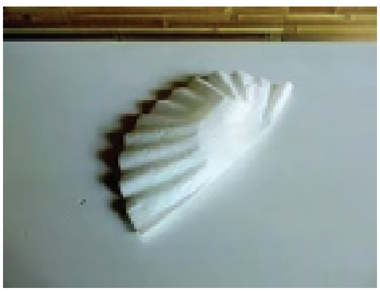
1. Read through all steps before you start to carry them out and decide who will be responsible for each step.
2. Lift the lid with the thermometer off the cup and add to the saltwater the $CuSO_4$ followed by the Al. Note: Groups E and F will be working with a lot of Al and will probably need to push it down into the cup so that you can get as much as possible in the liquid.
3. Firmly replace the lid and thermometer and begin to gently swirl the contents of the cup. Make sure the thermometer is not touching the cup sides or bottom. Be sure to keep swirling the cup for the entire 5 minutes that you are monitoring the temperature.
4. Timing should be started as soon as the lid is placed on the cup containing Al and $CuSO_4$ in saltwater. Record the temperature reading every 30 seconds for a total of 5 minutes.
5. Make sure all group members have recorded the temperature data on their *Small-Group Data Table* in their science notebook.

Part 3: Examining the Solids and Liquids after 5 Minutes

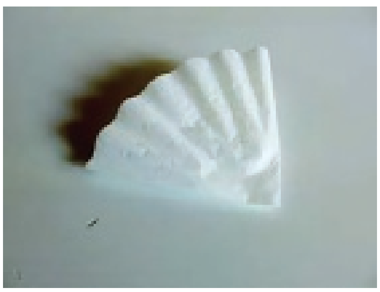
Once your group has finished collecting temperature data for 5 minutes, you will examine the remaining solids and liquids by passing the mixture through a coffee filter in a plastic funnel. The solids will be retained by the filter and the liquids will pass into a clean Styrofoam cup under the funnel, as shown here.

Refer to the images below to fold the coffee filter so that it will fit in the funnel: (1) flatten the coffee filter and fold it in half, (2) fold it in half a second time, and (3) place it in the funnel and open it so that 3 layers are to the left and only 1 layer is to the right.

1.



2.



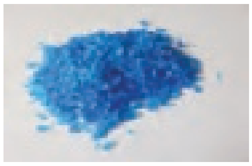
3.

General procedure

1. Read through all steps before you start to carry them out and decide who will be responsible for each step.
2. Fold the coffee filter, label it with your group's letter using a pencil, and place it in the funnel. Place the funnel above a clean Styrofoam cup.
3. Remove the lid and thermometer from the cup containing the amount of Al, $CuSO_4$, and saltwater for which your group just finished collecting temperature data.
4. Gently swirl the contents of the cup and immediately pour them into the coffee filter.
5. Use your plastic spoon to transfer any solids remaining in the cup into the coffee filter.
6. If there is still some solid material in the cup that you cannot remove with the plastic spoon, you can pour a small amount of liquid from the cup under the funnel back into the original cup and swirl it around to wash any remaining solid into the coffee filter. Only do this when the liquid has stopped dripping from the bottom of the funnel! Try to transfer as much of the solid as you can to the coffee filter, but it is OK if you do not get absolutely all of it.
7. Once liquid has stopped dripping from the funnel, you can remove the coffee filter from the funnel, place it on a paper towel, and carefully unfold it without losing any of the contents. An example is shown here.

8. Measure 20.0 g of liquid you collected in the cup under the funnel into a clean cup labeled with your group's letter.
9. Record in your *Small-Group Data Table* your observations of the solid you collected on the coffee filter and the liquid you collected in the cup under the coffee filter.
10. Follow your teacher's directions for safe cleanup.

Materials Cost List

Item	Image	Quantity	Cost
copper sulfate ($CuSO_4$)		1 gram	1.4 cents
aluminum foil, shredded		1 gram	1.3 cents
saltwater		100 mL	1 cent
12 oz. round plastic container		1 plus lid	10 cents
4 oz. round plastic container		1 plus lid	32 cents
ziplock freezer bag, quart size		1 bag	12 cents
ziplock freezer bag, gallon size		1 bag	14 cents

Reading: How hot does food need to get so that people do not get sick?

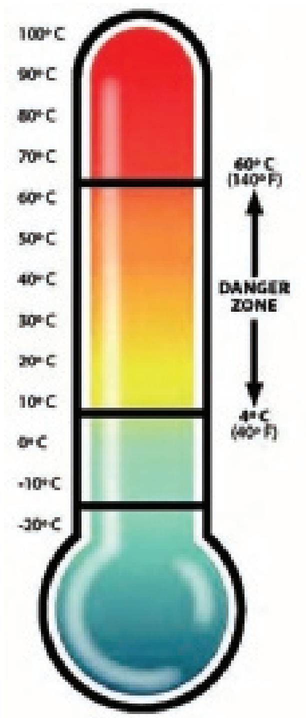
Directions: Read through the text and look at the picture below. Determine what information will help us define criteria about the temperature range of our homemade heaters. Underline important text to highlight the areas you think will help us define our temperature range criteria.

Foodborne Germs and Illnesses

Many different disease-causing germs can contaminate foods, so there are many different foodborne infections. These are also called foodborne diseases or food poisoning.

Researchers have found more than 250 foodborne diseases. Most of them are infections caused by different bacteria, viruses, and parasites. Harmful toxins and chemicals can also contaminate foods and cause foodborne illnesses.

Foods That Can Cause Food Poisoning



Some foods are more likely to cause foodborne illnesses and food poisoning than others. These foods can carry harmful germs that can make you very sick if the food is contaminated:

- chicken, beef, pork, and turkey
- fruits and vegetables
- raw milk and products made from it
- raw eggs
- seafood and raw shellfish
- sprouts
- raw flour

While certain foods are more likely to make you sick, any food can get contaminated. This can happen in the field, during processing, or during other stages of food production. For example, raw meat touching kitchen surfaces can contaminate other foods in the kitchen.

Many of the bacteria that cause foodborne illnesses grow fastest in the temperature range between 5°C and 57°C (41°F and 135°F). This range is known as the "Danger Zone." To be safe, the internal temperature of potentially hazardous foods must be below 5°C (41°F) when being stored and above 57°C (135°F) when being cooked or held in places like heated buffets or cafeteria lines.

Keeping Prepared Food Safe to Eat

Ever since humans were hunter-gatherers, we have looked for ways to preserve food safely. People living in cold climates learned to freeze food for future use. Since electricity was invented, freezers and refrigerators have been used to keep food safe. But except for drying, packing in sugar syrup, or salting food, keeping perishable food safe without refrigeration is a truly modern invention.

Commercially Processed Foods

Some foods are cooked and packaged at factories to be "Ready to eat." These foods may have been potentially hazardous, but processing them at the factory makes them safe to eat at any temperature. Foods labeled "ready to eat" or "shelf-stable" do not have to be heated to be served.

What does "shelf-stable" mean?

Foods that can safely be stored at room temperature, or "on the shelf," are called "shelf-stable." These nonperishable products include jerky, country hams, canned and bottled foods, rice, pasta, flour, sugar, spices, oils, foods processed in sealed, sterile packages, and other products that do not need refrigeration until after opening. Not all canned goods are shelf-stable. Some canned foods, such as some canned ham and seafood, are not safe at room temperature. These are labeled "keep refrigerated."

How are foods made shelf-stable?

In order to be shelf-stable, perishable foods must be treated by heat and/or dried to destroy foodborne germs or toxins that can cause illness or spoil food. Food can also be packaged in sterile, airtight containers. All foods eventually spoil if not preserved.

Heating and Using Shelf-Stable Foods

Shelf-stable foods are safe to open and eat at any temperature. However, once they are opened, they can be contaminated. Never leave food out of refrigeration for over 2 hours. If the air temperature is above 32°C (90°F), food should not be left out for more than 1 hour.

Sources:

- US Centers for Disease Control (2020). *Foodborne germs and illnesses*. Retrieved from https://www. cdc.gov/foodsafety/foodborne-germs.html
- FoodSafety.gov. (2019). *Safe minimum cooking temperatures*. Retrieved from https://www. foodsafe ty.gov/food-safety-charts/safe-minimum-cooking-temperature
- US Department of Agriculture. (nd). Food Safety and Inspection Service. Retrieved from https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/shelf-stable-food-safety
- Division of Food Safety, Florida Department of Agriculture and Consumer Services. (2016). *Cooking and hot holding food*. Retrieved from https://www.fdacs.gov/content/download/67385/file/Cookingand-Hot-Holding-Food.pdf

Reading: What temperatures cause scald burn injuries?

Directions: Use the text and chart below. Determine if any of this information can help us define the criteria for the temperature range of our homemade heaters. Underline important text and draw arrows to parts of the chart to show the information you think will help us define our temperature range criteria.

General Background Information on Scald Burns

Scald burns are burns caused by something wet. Scald burns can happen to anyone, but young children, older adults, and people with disabilities are the most likely to suffer scald burns. Most scald burn injuries happen in the home, when people prepare or serve hot food or beverages. They can also happen when a person is exposed to hot tap water in bathtubs or showers.

The temperature to which skin is exposed and how long it is exposed determines how bad a scald injury is. To help avoid these injuries, most home water heaters have a maximum water temperature of 48°C (120°F). The skin of adults can be exposed to this temperature for an average of five minutes before a serious burn happens.

If a hot liquid has a temperature of 60°C (140°F), it takes only five seconds or less for a serious burn to occur. Coffee, tea, hot chocolate, and other hot beverages are usually served at 71–82°C (160–180°F). Spilling one of these on human skin almost instantly causes burns that need surgery.

Time and Temperature Relationship to Severe Burns

Water Temperature		*Time for a third degree burn to occur*
155°F	68°C	1 second
148°F	64°C	2 seconds
140°F	60°C	5 seconds
133°F	56°C	15 seconds
127°F	52°C	1 minute
124°F	51°C	3 minutes
120°F	48°C	5 minutes
100°F	37°C	safe temperature for bathing

Source: American Burn Association. (nd). *Scald Injury Prevention Guide*. Retrieved from http://ameriburn.org/wp-content/uploads/2017/04/scaldinjuryeducatorsguide.pdf

Reading: What temperature range makes food enjoyable to eat?

Directions: Use the chart and text below. Determine if we can use any of this information to help us define the criteria for the temperature range of our homemade heaters. Draw arrows to parts of the chart and underline important text in the reading to show the areas that you think will help us define our temperature range criteria.

Survey: Rating of Food Enjoyment Tasted at Varying Temperatures

Tester	Food temperature in degrees Celsius (degrees Fahrenheit)					
	25°C (77°F)	30°C (86°F)	35°C (95°F)	40°C (104°F)	45°C (113°F)	50°C (122°F)
A	–	–	–	+	+	+
B	–	+	+	+	+	+
C	–	–	–	+	+	!
D	–	–	+	+	!	!
E	–	+	+	+	!	!
F	–	–	+	+	!	!
G	–	+	+	+	+	+
H	–	+	+	+	+	+
I	–	+	+	+	!	!
J	+	+	+	+	+	!
K	–	–	+	+	+	!
L	–	+	+	+	+	+
M	–	+	+	+	!	!

This chart shows the results of taste tests of food items at different temperatures. These tests were done to see at what temperature people liked the taste of food the most. Tasters recorded a "–" if the food was too cold, a "+" if the food was just right, and a "!" if the food was too hot to enjoy.

Why does temperature make that much of a difference when it comes to the flavor of food?

Human beings prefer hot food more than cold food. Eating hot food allows us to get more nutrients and protects us from some illnesses. Humans also perceive more tastes when eating warm foods than cold ones. This is because food that is warmer causes more activity in the small channels in the taste buds on our tongue.

From Cold Eaters to Hot Foodies

A few million years ago, before human beings discovered fire, the only available food was cold. Just like every other animal on the planet, eating our food raw was the only option. However, around 2 million years ago, early humans discovered fire. As a result, they were able to build fires to cook their food and ward off predators.

Applying heat to food causes chemical reactions and changes in the food. This makes food much easier for our body to use. Less time spent chewing and digesting cold food freed up a huge amount of time. It takes a lot of work for the body to digest cold food. Learning to heat up our food has allowed us to spend our mental and physical energy on the pursuit of greater things. In fact, our body cannot even handle a diet of only raw meat anymore. We do not have strong enough stomach acids to digest it.

Aside from being easier to digest, cooking food can eliminate many of the foodborne illnesses found in raw food. Cooked food is also more pleasant to our senses. When you heat up food, the food molecules become more volatile. These molecules fly off the food in the form of aromas, which keep us coming back for more. Our sense of smell evolved to encourage us to eat foods that are healthier for us. This is particularly true with foods that smell and taste better when they are cooked, such as meats, vegetables, beans, and so forth. However, these things do not fully explain our sense of taste or why people tend to think cooked foods taste better than cold foods.

Our Talented Tongues

A lot of research has been done about taste and smell. This is because food manufacturers want to understand everything they can about what flavors and tastes consumers enjoy. Manufacturers also want to find ways to mask unpleasant flavors. All this comes down to understanding the taste receptors in the tongue.

The tiny channels in our taste buds send electrical signals related to taste to the brain. These channels tend to work at a higher level when temperatures are higher. Foods and fluids have stronger bitter, savory, sour, and sweet flavors when they are warm. This can work both ways—with flavors that are both good and bad. The main exception to this is bitterness, which appears to be more powerful when something is cold.

For example, people mostly prefer their coffee hot. This is because the beverage's bitter flavor can be better masked when the coffee is warmed up. On the other hand, the sweet taste of ice cream is only activated when it begins to melt in our mouth. The tiny receptor channels in our tongue that pass messages to our brain about flavor do not function as well with cold substances.

On average, there are more than 10,000 taste buds on the human tongue. Each bud consists of between 50 and 100 cells. These taste buds can detect every type of taste–salty, sour, sweet, bitter, and umami. Some foods are preferred cold, such as soda, while others are preferred hot, such as tea and cocoa. Hot food does not necessarily mean that it is better; it just means that certain flavors will be more intense.

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