Companion Lesson

Designing Hot and Cold Packs

Overview

This hands-on activity builds on and reinforces students' understanding of temperature changes. Students are challenged to design a hot pack or a cold pack by mixing substances in a sealed plastic bag. First, students explore combinations of substances, observing the temperature changes that occur when different substances are mixed. As they discuss observations from this exploration, students are introduced to the idea that chemical reactions can absorb or release thermal energy. Students iterate on their cold or hot pack designs, attempting to optimize the absorption or release of thermal energy while minimizing the substances required. Finally, students write design proposals that describe how their optimal hot or cold pack design combination meets two criteria: (1) reaching the highest or lowest temperature possible and (2) minimizing the quantity of reactants. The purpose of this lesson is to extend students' understanding of thermal energy and to introduce them to the concept that chemical reactions can absorb or release thermal energy.

Recommended Placement: *Thermal Energy*, after Lesson 2.5
Suggested Time Frame: 105 minutes (can be spread across multiple class periods)

Crosscutting Concepts

- Cause and Effect
- Energy and Matter

Vocabulary

- energy
- kinetic energy
- molecule
- temperature
- transfer

Materials & Preparation

Materials

For the Class

- Designing Hot and Cold Packs copymaster
- 1 instant hot pack
- 1 instant cold pack
- 10 "baking soda" labels
- 10 "calcium chloride" labels
- 10 "citric acid" labels
- 6 waste containers (dish tub or similar-sized container)*

For Each Group of Four Students

- 1 plastic tray*
- 1 graduated cylinder, 50 mL
- 6 plastic bags with zip, quart size
- 3 measuring spoon sets
- 6 teaspoons of calcium chloride
- 6 teaspoons of baking soda
- 6 teaspoons of citric acid
- 2 squeeze bottles
- water*
- 5 plastic cups, 9 oz.
- 3 lids (for plastic cups)
- 2 thermometers**
- 1 permanent marker*

For Each Student

- safety goggles*
- Designing Hot and Cold Packs student sheets*

*teacher provided
**from *Thermal Energy* kit

Preparation

Safety Note: Using Chemicals

It is recommended that students wear safety goggles when handling all substances. The calcium chloride ($CaCl_2$), citric acid ($C_6H_8O_7$), sodium bicarbonate (Na_2CHO_3), and products of the different reactions present irritation risks. If these substances get on students' skin, rinse the exposed areas with water for several minutes. If these substances get in students' eyes, have them rinse with water for 15 minutes. Calcium chloride ($CaCl_2$)

Preparation (continued)

degrades plant-based plastics, so it is recommended that you use laboratory-grade glass or plastic containers for mixing substances. If that is not available, a beverage or milk container will also work.

1. **Print Designing Hot and Cold Packs copymaster.** Locate the Designing Hot and Cold Packs copymaster on the New York City Resources webpage: www.amplify.com/amplify-science-new-york-city-resources. Make one copy of all pages for each student.
2. **Prepare cups of substances.** Each group of four students will need three labeled cups: one cup for calcium chloride, one cup for baking soda, and one cup for citric acid. Affix the appropriate label to each cup and add 6 teaspoons of the corresponding substance to each. Place a lid on each cup and close it.
3. **Fill squeeze bottles with water.**
4. **Prepare trays of materials.** For each group of four, add the following items to a tray:
   - 3 lidded, labeled cups with substances
   - 2 squeeze bottles with water
   - 6 plastic bags
   - 2 empty cups (for Part 2)
   - 2 thermometers (for Part 2)
   - 3 measuring spoon sets
   - 1 graduated cylinder
   - 1 permanent marker for labeling bags
5. **Designate waste containers for reaction products.** Label each waste container with one of the six combinations that students will mix:
   - water + baking soda
   - water + calcium chloride
   - water + citric acid
   - water + baking soda + calcium chloride
   - water + baking soda + citric acid
   - water + calcium chloride + citric acid

   Place the waste containers in a central location in the classroom.
6. **Locate and review rubrics.** Review the Rubrics for Assessing Students' Hot and Cold Pack Design Proposals in the Assessment section of this lesson. These rubrics can help you plan ways to support students as they complete their design proposals and draw conclusions during the lesson. After the lesson, use the rubrics to formatively assess students' developing facility with science and engineering practices and their understanding of disciplinary core ideas.

7. **Immediately before the lesson, have on hand the following materials:**
   - student sheets
   - trays of materials
   - safety goggles
   - hot pack
   - cold pack
8. **After the lesson, properly dispose of reaction products.** Dispose of the reaction products according to any federal, state, and local regulations that apply. The products of the reactions are as follows:
   - baking soda ($NaHCO_3$) + calcium chloride ($CaCl_2$) = calcium carbonate ($CaCO_3$) + carbon dioxide (CO_2) + sodium chloride (NaCl)
   - baking soda ($NaHCO_3$) + citric acid ($C_6H_8O_7$) = sodium citrate ($Na_3C_6H_5O_7$) + carbon dioxide (CO_2)
   - calcium chloride ($CaCl_2$) + citric acid ($C_6H_8O_7$) = calcium citrate ($Ca_3(C_6H_5O_7)_2$) + hydrochloric acid (HCl)

Notes

Covering Substances

If you conduct this lesson over more than one day, you will need to make sure that all the plastic cups containing the substances are covered and sealed at the end of each day.

The Amounts of Substances

The amount of each substance suggested for this lesson is based on how much each group would need if they used the maximum amount of each substance for all five of their tests. It is unlikely that groups will need the full amount of each substance. If you think that you will have enough of each substance, you may want to have each group of four students make a hot and a cold pack. Consider having pairs of students within the group choose a hot or cold pack to design and then have them share their designs with their group.

Going Deeper

If you think your students are ready to go deeper with the science content in this lesson, circulate while they iterate on their hot or cold pack designs and ask them why they think that the changes they're making affect the temperature changes that they observe. For example:

(continued from previous page)

- If students reduce the amount of substances they're mixing and notice that the temperature change is less extreme, prompt them to consider why mixing a lesser quantity of the substances might lead to a smaller temperature change. [The temperature changes because the chemical reaction is absorbing or releasing thermal energy. When the amount of substances is reduced, there's less matter to react, so there's a smaller chemical reaction and therefore less thermal energy is absorbed or released.]

Science Background

Chemical reactions can either absorb or release thermal energy. To understand why this is, one must consider the chemical bonds that are broken and formed during chemical reactions. It takes energy to break the chemical bonds that hold a molecule together. That energy can be absorbed from the surroundings in the form of thermal energy. Conversely, when chemical bonds form, thermal energy is released. The stronger a chemical bond, the more energy it takes to break, and the greater the energy release when bonds form. Most chemical reactions release thermal energy. This is is because the reactants—the starting substances that are part of a chemical reaction—generally have weaker chemical bonds than the products—the ending substances that are made during a chemical reaction. Therefore, the amount of energy needed to break the reactants' bonds is less than the amount of energy released when the new products' bonds form, so overall, thermal energy is released to the surroundings. This causes the surroundings to increase in temperature. There are some chemical reactions that absorb thermal energy. In these reactions, the products have weaker bonds than the reactants, and the amount of energy needed to break the reactants' bonds is more than the amount of energy released when the new products' bonds form. Therefore, during these reactions, thermal energy is absorbed from the surroundings, and they decrease in temperature.

Dissolving ionic substances are similar to chemical reactions, but they are often not categorized as such. An ionic compound is a substance in which ions (atoms with net positive or negative charges) are held together by ionic bonds (the attraction between positive and negative charges). The process of dissolving an ionic compound in a solvent, such as water, is similar to a chemical reaction in that the bonds between ions break and form much as the bonds between atoms in molecules break and form during chemical reactions. When an ionic compound, such as table salt ($NaCl$) or calcium chloride ($CaCl_2$), dissolves in water, the ions separate, and ionic bonds between ions break. New types of bonds form between these ions and the water molecules. The resulting absorption or release of thermal energy is similar to the absorption or release of thermal energy when covalent bonds (the bonds due to shared electrons) between atoms break and form during a chemical reaction. In this activity, the dissolving of ionic substances is treated the same as a chemical reaction, and students are not asked to differentiate between the two. When students dissolve calcium chloride (an ionic compound) in water, they will observe a temperature increase. When they dissolve sodium bicarbonate (another ionic compound) in water, they will observe a temperature decrease. When students dissolve citric acid (which is not an ionic compound) in water, they will observe a temperature decrease. This is due to a chemical reaction: the citric acid molecules and water molecules react in an acid-base reaction.

Instructional Guide

Explore and Activate Prior Knowledge

1. **Review the idea that warmer objects transfer energy to cooler objects when they're in contact.**

   Imagine your friend comes inside after walking out in the snow, while you're inside and warm; you press your hands together. What happens to your hand and your friend's hand? What happens when a warmer object and a cooler object touch?
   [Energy transfers from the warmer object to the cooler object. The warmer object cools as its molecules lose kinetic energy. The cooler object warms as its molecules gain thermal energy.]

   Invite volunteers to share ideas.

2. **Introduce and activate hot and cold packs.** Hold up the hot pack and the cold pack, and explain that these are designed to be able to heat or cool by transferring energy to or away from a person's skin. Ask two volunteers to come to the front and demonstrate how they work.

   - Have the volunteers share what the packs feel like (their temperature) before activation. [Room temperature.]
   - Have the volunteers follow the directions for activating the packs and share what they feel happening.

3. **Pass hot and cold packs around the room and discuss thermal energy.** Have students pass the activated hot and cold packs around the room. As they pass the hot and cold packs, have them discuss the thermal energy in each pack.

   What happens to the thermal energy of the hot pack as it warms?
   [The thermal energy increases.]

   What happens to the thermal energy of the cold pack as it cools?
   [The thermal energy decreases.]

4. **Discuss energy transfer between hot and cold packs and skin.** Point out that hot packs and cold packs are useful because they transfer energy between a hot or cold pack and a person's skin.

   What happens with energy when a hot pack warms a person's skin?
   [The hot pack is hotter than the person's skin, which means its molecules are moving faster. When the hot pack is in contact with a person's skin, the molecules of the hot pack collide with the molecules of the person's skin and kinetic energy is transferred from the faster-moving molecules of the hot pack to the slower-moving molecules of the person's skin. This causes the temperature of the person's skin to increase.]

What happens with energy when a cold pack cools a person's skin?
[The opposite of what happens when a person touches a hot pack: energy transfers from the faster molecules in the person's skin to the slower molecules of the cold pack and the temperature of the person's skin decreases.]

5. **Discuss how hot and cold packs get hot or cold.** Invite students to share initial ideas about what causes a hot pack to get hot or a cold pack to get cold. Accept all responses, then let students know that they'll explore this during this lesson.
6. **Introduce the hot or cold pack design challenge.** Explain that students will design a hot pack or a cold pack. They will have a few substances to choose from for their designs. On the board, write "Criteria for Designing Hot or Cold Packs," and list the criteria underneath:
   - "Reach the highest or lowest temperature possible."
   - "Use as little of the substances as possible."
7. **Distribute the Designing Hot and Cold Packs student sheets and direct students to Part 1: Researching Substances.** Review safety precautions and directions, and point out that the criteria listed on the page are the same as what you wrote on the board. Let students know that they will work in groups of four during this research phase, and during the design phase, one pair from each group will design a hot pack and the other pair will design a cold pack. Emphasize that students should take turns handling the materials as they explore substances, and they should record observations for each mixture before moving on to the next one. Emphasize the maximum number of combinations to mix in a bag: there should be a maximum of two solid substances mixed with the water at a time.
8. **Show materials; model labeling, measuring, and combining substances.** Hold up a tray of materials and explain that each group will get one tray to share.
   - Point out how each cup has a label. Inform students that before mixing the substances in the bag, they should label the bag with the names of the substances that will be added.
   - Model how students should measure the substances, leveling each ¼ teaspoon of powder and looking closely at the graduated cylinder to squeeze a precise 45 mL of water from the squeeze bottle into the graduated cylinder.
   - Without actually adding substances to a bag, model quickly but carefully pressing the air out of a bag and sealing it. Then show how you would use your fingers outside the bag to mix substances inside the bag.
9. **Show students where to dispose of the substances.** Point out the waste containers in the classroom. Inform students that after they complete all the different combinations, they will dispose of each bag's contents in the corresponding waste container.
10. **Distribute trays of materials and give students time to explore substances.** Give students about 25 minutes to test different mixtures.

11. **Groups of four choose a hot or cold design challenge.** Have groups decide whether they will design a hot or cold pack. Then, instruct them to review the observations of different mixtures on the student sheet and decide which substances to use in their designs. Have them record and justify their choices in the space provided on the last page of Part 1.

Construct New Ideas

12. **Invite students to share observations from the exploration.** Accept all responses.
13. **Discuss temperature changes and thermal energy.** Highlight how students observed that mixing some substances resulted in a noticeable temperature increase or decrease.

    When you mixed certain substances, you felt the temperature of the bag increase. What does that tell you about the amount of thermal energy in the bag? [The amount of thermal energy increased.]

    When you mixed other substances, you felt the temperature of the bag decrease. What does that tell you about the amount of thermal energy in the bag? [The amount of thermal energy decreased.]
14. **Introduce the concept of chemical reactions.** Explain that the kinds of changes students observed, including temperature changes and the formation of a gas, can be evidence of chemical reactions. In a chemical reaction, starting substances react to form new substances.
15. **Introduce the idea of a chemical reaction releasing or absorbing thermal energy.**

    When a chemical reaction occurs and the temperature increases, scientists say that the reaction releases thermal energy.

    When a chemical reaction occurs and the temperature decreases, scientists say that the reaction absorbs thermal energy.

    Write "gets warmer—releases thermal energy" and "gets cooler—absorbs thermal energy" on the board.

    Note: If students ask where the thermal energy came from when it was released or where it goes when it is absorbed, you can explain that the energy was converted. In a reaction that releases thermal energy, energy is stored in the starting substances in a different form, and it is then converted and released as thermal energy. In a reaction that absorbs thermal energy, the ending substances store the thermal energy in a different form.
16. **Introduce the design cycle.** Direct students to the diagram on the first page of Part 2: Finding an Optimal Design.

    The design cycle is a process used by engineers to create solutions that address specific criteria, or goals for the design. There are four main steps in the design cycle: plan, build, test, and analyze.

Go through each step and ask students what they think happens.

- **Plan** [Brainstorm how to meet criteria and decide on how to make or change the design.]
- **Build** [Create the design.]
- **Test** [See how well the design works.]
- **Analyze** [Examine the test results and see how well that design meets the criteria. Once you have tested more than one design, you should compare your newest design to previous designs.]

17. **Emphasize that the process repeats.**

    After analyzing your design, you think about how you can change your design to better meet the criteria. You go through the cycle over and over, modifying your designs or combining parts of different designs, until you reach what you think is the optimal design.

18. **Review data sheets.** Have students look at the data design tables in Part 2: Finding an Optimal Design. Explain that these are set up to show all four steps of the design cycle. There is space for students to number their design versions as they iterate. Students will first describe a plan, then record how much of each substance they will use. They will test the design and record the highest or lowest temperature reached by the mixture. At that point, they will analyze the data by describing how well the criteria were met and what improvements might be made.

19. **Review constraints.** Remind students that the goal is to design a mixture that uses the least amount of substances possible, while providing the most heating or cooling. They cannot use more than 1 teaspoon of each substance in any design. For water, they should always use 45 mL.

20. **Point out the cups for combining substances.** Explain that students will test their designs in a cup. Mixing in a cup allows them to easily record the temperature. They should place their cups on the tray in case bubbles overflow the cup. Gently stirring a bubbling mixture with the thermometer can reduce overflow. Point out that groups of four will share materials. Inform students that they should dispose of the substances in the appropriate waste container and rinse their cups before moving on to their next design.

21. **Explain how to determine the highest or lowest temperature.**

    You will combine substances in a cup. You can use the thermometer to mix the substances and track the temperature. When the temperature stops increasing or decreasing, you will know that you have reached the highest or lowest temperature. This should take somewhere between 30 seconds and 2 minutes.

Apply New Ideas

22. **Students make and modify designs.** Give students about 30 minutes to work on their designs. Remind them to discuss and record their next steps between designs.
23. **Students choose optimal design.** Have students draw a star next to the design that they think best meets the criteria.
24. **Introduce writing a proposal.**

    An engineer's written proposal explains to others how and why a design solution works. To support their arguments for why the design is optimal, engineers use evidence from their data, and they use science concepts to explain the evidence.
25. **Review the parts of the proposal.** Direct students to the Part 3: Writing a Proposal student sheet. Point out that students will first describe what makes their design work. They should use science ideas to explain what causes the substances to get cold or hot. Next, they will make an argument to support the claim that their design addresses each criterion. For each criterion, they should describe the evidence from their measurements and observations that shows how the design meets the criterion.
26. **Students write proposals.** Give students about 20 minutes to write their proposals. Support students as needed.
27. **If time permits, have students present their optimal design to the class or to other groups.**

Rubrics for Assessing Students' Hot and Cold Pack Design Proposals

The rubrics below may be used when reviewing students' design proposals to formatively assess students' developing facility with science and engineering practices and their understanding of disciplinary core ideas.

Rubric 1: Assessing Students' Performance of the Practice of Constructing Design Arguments

Note that this rubric applies to the second question of the Part 3: Writing a Proposal student sheet. Rubric 1 is designed to monitor and support students as they develop dexterity with the practice of Engaging in Argument from Evidence. For each criterion, levels are described to monitor students' progress by indicating the degree to which students can independently demonstrate fluency with the science practice. This rubric may be used formatively to support students' facility with the practice of Engaging in Argument from Evidence. It features targeted questions that a teacher might use to assess students' design proposals, and it provides specific feedback for revisions and for future encounters with the practice.

Rubric 1: Assessing Students' Performance of the Practice of Constructing Design Arguments		
Criteria	**Description and possible feedback**	**Level**
Responsive Does the design proposal explain how the solution meets the design criteria?	The design proposal does not address the design criteria. Example: My cold pack design is the optimal design. That is because I mixed the substances really well. Possible feedback: *What are the design criteria for the hot or cold pack? Why do you think the substances and/or amounts of substances that you chose are best for meeting these criteria?*	0
	The design proposal explains why the design is the optimal design by addressing only one of two design criteria. Example: My cold pack design is the optimal design for a cold pack because it reaches a very low temperature. Possible feedback: *You explained how your design met one design criterion, but what about the other design criterion?*	1

(Table continues on the next page.)

Rubric 1: Assessing Students' Performance of the Practice of Constructing Design Arguments		
Criteria	**Description and possible feedback**	**Level**
(continued from previous page)	The design proposal explains why the design is the optimal design by addressing both design criteria. Example: My cold pack design is the optimal design for a cold pack because it reaches a very low temperature, and it uses a minimal amount of substances.	2
Supported Is evidence connected to each design criterion in a way that is likely to convince an audience that the proposed solution is the best one?	The design proposal does not provide evidence for how the design meets the design criteria. Possible feedback: *How could you convince your audience that your proposed solution meets the criteria?*	0
	The design proposal provides evidence for how the design meets only one of two design criteria. Example: My cold pack design reaches a lower temperature than other the designs I tested. It reached 13°C, which is lower than the 16°C and 18°C that other designs reached. My design also uses a minimal amount of substances. Possible feedback: *You included evidence that shows how your design meets one design criterion, but how can you convince your audience that your design meets the other criterion?*	1
	The design proposal provides evidence for how the design meets both design criteria. Example: My cold pack design reaches a lower temperature than other designs I tested. It reached 13°C, which is lower than the 16°C and 18°C that some other designs reached. My design also uses a minimal amount of the substances. I only used 3/4 of a teaspoon of baking soda, which is less than I used in some of my other designs.	2

Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit

Note that this rubric applies to the first question of the Part 3: Writing a Proposal student sheet. Rubric 2 considers whether students have constructed and applied ideas in a way that is consistent with accepted science ideas. This rubric is designed to be formative, and space is provided to note whether students are demonstrating understanding or struggling with the idea. If students are having difficulty, you might consider leading a focused exploration of what caused the temperature changes that students observed. You could return to a reaction that releases thermal energy (e.g., water, baking soda, and calcium chloride).

- Discuss evidence that a chemical reaction occurs when the substances are mixed (a gaseous substance is produced), AND
- Discuss evidence that the reaction releases thermal energy (the temperature rises as the substances are mixed and the gas is produced). There is no obvious alternate explanation for the temperature increase—i.e., no hot object has come in contact with the substances that could transfer energy.

You could also lead a similar investigation and discussion with a reaction that absorbs thermal energy (e.g., water, citric acid, and calcium chloride). Discussing these examples will help all students construct the understanding that chemical reactions can absorb or release thermal energy.

Rubric 2: Assessing Students' Understanding of Science Ideas Encountered in the Unit		
Criteria	**Description**	**Is there evidence of student understanding?**
Consistent with accepted science ideas. Are students' conclusions consistent with accepted science ideas?	Students demonstrate understanding of the idea that chemical reactions can absorb or release thermal energy. Example: My cold pack works because of a chemical reaction between baking soda, citric acid, and water. The reaction absorbs thermal energy, which means it gets colder.	

Designing Hot and Cold Packs

Part 1: Researching Substances

Safety Note: Using Chemicals

Do not taste or touch the substances in the investigation. Mix substances only when you are told to do so by your teacher. The substances present skin irritation risks. Wash exposed areas when finished. If a substance gets on your skin or clothes, tell your teacher and rinse the substance off with water. If you get a substance in your eyes, tell your teacher and rinse your eyes with water for 15 minutes. If a substance is inhaled, move to fresh air and seek medical help for any breathing difficulties.

Criteria:

- Reach the highest or lowest temperature possible.
- Use as little of the substances as possible.

Procedure:

1. Test what happens when you mix different combinations of substances in a plastic bag. Use these tests to explore substances that you might use in a hot or cold pack design.
2. In each test, mix no more than two solids with water. Clearly label your bag with the names of the substances and record them in the table below.
3. For solids, measure ¼ teaspoon (leveled), and add it to the plastic bag. For water, measure 45 mL. Add the water last.
4. Quickly and carefully press the air out of the bag and seal it. Mix the substances through the bag with your fingers.
5. Observe what happens and record the results.

Substances:

- baking soda ($NaCHO_3$)
- calcium chloride (CaCl)
- citric acid ($C_6H_8O_7$)
- water (H_2O)

Possible Student Responses

Designing Hot and Cold Packs (continued)

Answers will vary. Examples shown below.

Substances	Observations
Water, baking soda, calcium chloride	Hot for a second, then warm, then cold; very bubbly and loud; bag puffed up with gas; some, but not all the calcium chloride seemed to become liquid; baking soda seemed to become liquid or mix into the liquid; liquid turned cloudy
Water, baking soda, citric acid	Very cold, loud and bubbly; bag puffed up; baking soda and citric acid seemed to become liquid or mix into the liquid; liquid turned cloudy
Water, baking soda	Got cool; baking soda seemed to become liquid or mix into the liquid; liquid turned cloudy
Water, calcium chloride	Got hot; some, but not all the calcium chloride seemed to become liquid
Water, citric acid	Got cool; citric acid seemed to become liquid or mix into the liquid
Water, citric acid, calcium chloride	Got very hot; citric acid seemed to become liquid or mix into the liquid; some, but not all the calcium chloride seemed to become liquid

Designing Hot and Cold Packs (continued)

Designs will vary. Example:

1. Which type of pack will you design?

- [ ] a hot pack
- [x] a cold pack

2. Which substances will you use in your design? (Check all that apply.)

- [x] baking soda ($NaCHO_3$)
- [ ] calcium chloride (CaCl)
- [x] citric acid ($C_6H_8O_7$)
- [x] water (H_2O)

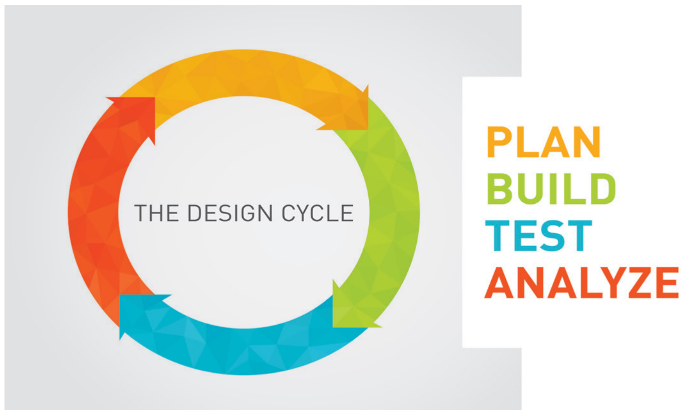
3. Why did you choose these substances?

When we mixed these substances, the bag got colder than when we mixed any other substances.

Possible Student Responses

Designing Hot and Cold Packs (continued)

Part 2: Finding an Optimal Design



Constraints:

- In any design, do not use more than 1 teaspoon of calcium chloride, baking soda, or citric acid.
- If using water, always use 45 mL.

Designs will vary. Example:

PLAN

VERSION

We will start with the same cold mixture from testing: water, baking soda, and citric acid.

BUILD

Substance	Amount
$C_6H_8O_7$	½ teaspoon
$NaCHO_3$	½ teaspoon
H_2O	45 mL

TEST

Highest or Lowest Temperature: 18°C (lowest)

Notes: This created a lot of bubbles and the water got really cloudy when I mixed in the baking soda and citric acid.

ANALYZE

This gets cold nicely, but maybe we can make it colder with more citric acid.

Designing Hot and Cold Packs (continued)

Designs will vary.

PLAN

VERSION

BUILD

Substance	Amount

TEST

Highest or Lowest Temperature:

Notes:

ANALYZE

PLAN

VERSION

BUILD

Substance	Amount

TEST

Highest or Lowest Temperature:

Notes:

ANALYZE

Possible Student Responses

Designing Hot and Cold Packs (continued)

Designs will vary.

PLAN

VERSION

BUILD

Substance	Amount

TEST

Highest or Lowest Temperature:

Notes:

ANALYZE

PLAN

VERSION

BUILD

Substance	Amount

TEST

Highest or Lowest Temperature:

Notes:

ANALYZE

Designing Hot and Cold Packs (continued)

Answers will vary. Examples shown below.

Part 3: Writing a Proposal

1. Explain how your hot or cold pack works.

My cold pack works because of a chemical reaction between baking soda, citric acid, and water. The reaction absorbs thermal energy which means it gets colder. After we mixed the substances, the molecules moved more slowly than before and the pack had less thermal energy.

2. Explain why your design is the optimal design. Be sure to address each criterion and provide evidence that shows how your design meets each criterion.

My cold pack design is the optimal design for a cold pack because it reaches a very low temperature and uses as little of the substances as possible. My cold pack design reaches a lower temperature than the other designs I tested. It reached 13°C, which is lower than the 16°C and 18°C that other designs reached. My design uses very little of the substances since it only uses 3/4 teaspoon of baking soda, which is less than I used in some of my other designs.