Chemical Differences in Emergency Energy Sources

Lesson 5: Engineering a Hot Pack

AUTHOR
Melody Childers, Unit Author, Susan Holveck and Berkeley Gabdaw, Activity Authors

DESCRIPTION
Through a series of inquiry activities, students will discover the properties of the chemical reaction of dissolving $CaCl_2$ in water, the effect of stirring, and of adding baking soda and sodium polyacrylate crystals. Once initial data is collected, students will share preliminary data through the collaborative inquiry gallery walk protocol practiced in Lesson 2, test a second iteration of their design, and propose an optimized design to meet specified criteria.

GRADE LEVEL(S)
7, 8

SUBJECT AREA(S)
Engineering Design, Chemical Reactions, Exothermic Reactions

ACTIVITY LENGTH
4 class periods (~80-minute class periods)

LEARNING GOAL(S)

1. Students will collect data to characterize a chemical reaction
2. Students will identify the criteria and constraints of an engineering challenge.
3. Students will design and build a hot pack that meets the criteria of the project.
4. Students will collect data to support their proposed design.

Expected Content Understanding

STUDENT BACKGROUND

Students participating in this lesson should be familiar with the following scientific concepts and practices:

- The engineering design process
- Data collection, organization, and presentation
- Claim, evidence, reasoning communication of scientific knowledge
- Exothermic reactions basics:
    - Chemical reactions conserve matter. Atoms in the reactants are rearranged to form the products.
    - Exothermic reactions result in lower energy products, so heat is released into the environment.

EDUCATOR BACKGROUND

Please see the final two pages of the activity handout for a discussion of exothermic reactions and why dissolving a salt is a chemical change, not a physical change. In short, the reactants ($CaCl_2$) are not present in the same compound after they dissolve, they are present as ions, making this a chemical rather than physical change.

REQUIRED MATERIALS

HANDOUTS/PAPER MATERIALS

- Inquiry and Engineering A Hot Pack Lab Packet
- Assessment Rubric

ACTIVITY SUPPLIES (PER GROUP OF 3-4 STUDENTS)

Day 1: Inquiry into Calcium Chloride Reactions

- (4) clear cups or small plastic beakers
- (1) thermometer
- (1) timer
- (40 g) $CaCl_2$ (Available as Driveway Heat or Damp Rid, also available from scientific supply companies)
- (20 g) $NaHCO_3$ (Baking soda)
- (6 g) Sodium Polyacrylate crystals (available less expensively as Miracle Gro water storing crystals than as other gimmicky science edutainment packaging)

Day 2: Engineering a Hot Pack

- (4) clear cups or 100 mL plastic beakers

- (1) thermometer
- (1) timer
- (5+) snack size ziplock bags
- (100+ g) $CaCl_2$
- (100+ g) $NaHCO_3$ (Baking soda)
- (10+ g) sodium polyacrylate crystals

LESSON PROGRESSION

PLANNING AND PREP

This lesson is designed to span 3-5 days. Students will need the inquiry and engineering packet each day.

Day 1: Discovering the properties of the reaction. Students conduct guided inquiry to observe and explain the exothermic reaction of dissolving calcium chloride in water, with and without baking soda and sodium polyacrylate crystals. In order to limit reactant waste, you may wish to pre-measure the total amount of each supply per group. Students would still practice measuring by measuring out reactants for each individual reaction. I find reusable plastic medicine cups (from cough syrup bottles, for example) to be very useful for this application. Be aware that both the calcium chloride and the sodium polyacrylate will absorb moisture from air, so they should be stored in airtight containers.

Days 2 - 4: Design, Test, and propose a hot pack design. Pre-measure or otherwise control access to reactants to avoid waste.

LESSON SEQUENCE

Day 1: Inquiry to Characterize the Reaction

(80 minutes) Students work in small groups to conduct four guided inquiry experiments found in the activity sheet. They characterize the heat generated by dissolving $CaCl_2$ in water and the impact of adding baking soda, sodium polyacrylate crystals, and/or stirring the mixture. Students document their work in a data table, graph, and a claim, evidence, reasoning analysis. They should spend no more than 15-20 minutes on each guided inquiry.

Days 2-4: Engineering Design, Testing and Proposing Solutions

Students identify the criteria and constraints of the engineering challenge, design and test the hot pack following through the process with exemplars provided in the activity guide. It is probably best to read through this together and decide as a class on the criteria and constraints for the activity, so that each team's designs are aligned to the same standards.

Wherever possible, relate back to the original phenomena of Hurricane Maria and disaster response in Puerto Rico in 2017. However, this can be modified to fit any number of engineering scenarios, such as hot packs for sports teams or other survival-type situations. After students test their first iteration and have their first set of data, have them complete a whiteboard gallery walk, just as they did in lesson two with the thermal energy inquiry in Lesson 1.

Recall that students elect one group member to stay at their table and present their preliminary data and other group members go listen to the rest of the class' data. With the collective results of the first round of design and testing, students pull successful ideas from peers to optimize their design proposal. Students repeat the design and test cycle, but rather than do a second gallery walk, they use their second round of testing data to compose a final design proposal.

Set up of the board:

<table>
<tr><td colspan="2">Challenge: Design a hot pack to meet the design criteria and constraints.</td></tr>
<tr><td colspan="2">Claim: (Students make a claim about the effectiveness of their hot pack design as it relates to the criteria and constraints) Ex: Our design performs within the guidelines but is too expensive because we use too much sodium polyacrylate.</td></tr>
<tr><td>Evidence:
(Students present initial design and data table and/ or graph)</td><td>Reasoning:
Students evaluate their data and explain why it is so based on their understanding of exothermic chemical reactions. Example:

Our data is consistently within the desired temperature range, and the reaction provides warmth for the specified length of time. This is likely due to using enough calcium chloride to release energy and enough sodium polyacrylate to retain the thermal energy, rather than quickly releasing it into the environment. Because we used so much, it costs too much for the constraints.</td></tr>
</table>

FORMATIVE ASSESSMENT

Teacher should circulate and take note of student understanding of the task during the inquiry phase of the project. Students will provide written claim, evidence, reasoning documentation of their understanding of the exothermic reaction and the effect of each addition to the system during the gallery walk, an excellent point to clarify content misunderstandings on a one-on-one or small group basis.

SUMMATIVE ASSESSMENT

Lab reports will be turned in and assessed on included rubric for proficiency in data collection, supporting claims with evidence and reasoning, the engineering design cycle, and communication a model to describe of conservation of mass in the reaction involved in the hot pack.

LESSON EXTENSIONS

It would be reasonable to expand the inquiry to include an endothermic reaction and the engineering challenge to include a choice between engineering an instant hot or cold pack. That is equally relevant to the context of increasing health, safety, and comfort in a natural disaster setting.