The Chemistry of Heat Packs

Subject Area(s) Chemistry

Associated Unit Hillsborough County School District Chemistry
Units 12 & 13: Solutions & Thermochemistry

Figure 1
Sodium Acetate Crystallization
ADA Description: Sodium acetate crystals begin to rapidly form from a seed crystal.
Source/Rights: Copyright © http://giphy.com/gifs/sodium-acetate-crystallization-4UABFKJWRHx6g
Caption: Figure 1: Sodium Acetate Crystals

Grade Level 10 (10-12)

Time Required (4) 50 minute class periods

Summary

Students design and build a reusable heat pack. They are required to determine what chemical reaction generates heat and is reusable. A delivery package is designed and tested. Students are encouraged to redesign as needed in every stage of the process until they have a working heat pack. Students analyze their process to determine factors that must be considered in the design for effectiveness and safety of the chemical reaction, package, and ultimately the final product.

Engineering Connection

Students will become engineers as they apply standard solubility and thermodynamic concepts to design a functional heat pack (contents and container). Redesign is implicit at all stages and yet the product may fail. Like engineers, students will learn that their own initial failure can lead to final success for later teams. Explaining their process and collaborating with peers is just as valuable a lesson that will allow them to succeed even if their product doesn't.

Engineering Category =

2. Engineering analysis or partial design

Keywords

reusable, upcycle, crystallization, solutions, thermochemistry

Educational Standards **(List 2-4)**
State STEM Standard

CPALMS, 2008, SC.912.L.18.12.D - Discuss the special properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent

CPALMS, 2008, SC.912.P.10.7.C - Distinguish between endothermic and exothermic chemical processes.

ITEEA Standard

ITEEA, 2000, Standard 10, I (grades 9-12) Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace

NGSS Standard

Nextgenscience.org, 2013, HS-PS3-3 Energy - Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [*Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*] (9-12)

CCSS Standard

Corestandards.org, 2013, CCSS.MATH.CONTENT.HSN.Q.A.1 - Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

Pre-Requisite Knowledge
Stoichiometry, chemical reactions, basic fire safety

Safety:

- Students should have some prior experience working with open flames in the lab. Any students without the requisite skills, should be provided with an opportunity for remediation by instructor or (as a last resort) paired with a student who does have the skills and closely monitored by the instructor. (See 5E-Explain below)
- Safety glasses are required for all (students, teachers, observers, etc) as well as chemical resistant gloves for all active participants.

Learning Objectives

After this lesson, students should be able to:

- Determine 3 reactions to perform; what equipment will be necessary; determine the safety of each proposed reaction, and have a basic idea of what SHOULD happen on lab day. (Day 1)
- Record thermodynamic data for later use; Determine factors that affect solubility and recrystallization; Calculate molarity; (Day 2)
- Calculate enthalpy of reaction for all Day 2 reactions. Decide which reaction to use for their heat pack. Evaluate the properties of different plastics (Day 3)
- Heat seal and test the plastics of their choice. Make the pack. Test the properties of the pack. (Day 4)

Introduction / Motivation (5E – Engage)

Opening text to students:

"Ever been cold on your way to school? Even in Florida, winter mornings can be cold. How about those over air-conditioned classrooms? Wouldn't it be nice to have a little package of warm no further away than your book bag? What if you lost it? Wouldn't it be nice to have the ability to just make another one whenever you need? Well, the point of this lesson is to give you the skills to make your own reusable hot pack. You will determine what chemical reaction to use, what container to use, and how to reactivate it. Oh, and yes, you can safely make a hot pack from materials in the average household."

Discussion:

"In your groups, examine the commercial hot pack. Discuss how you might make a hot pack. Has anyone had experience making one or taking one apart? Does anyone know or have a suggestion as to how these might work?"

Lesson Background & Concepts for Teachers (5E – Explain)

1. Students will begin work on day 1 in groups of 4. On day 2, students will collect data from their chemical reactions in pairs. Analysis of the data will be done during homework. Day 3 will allow students (in pairs) to explore possible packaging options and collaborate on their prior data (whatever type of groups you like). Finally, on day 4, the students will individually build and test their product. Again, analysis is completed as homework.
2. This lesson is designed to allow the student as much independent learning as possible. There are some guided elements in place to keep the students on track.
3. Students will be working with open flames on days 3 & 4. If you are not already comfortable with this practice, substitute a simple Ziploc bag and shorten the lesson. The redesign element can be maintained if you chose different brands or types (i.e. freezer, zip, snap, etc)
4. For lower level chemistry sections (or that one class that just needs more hand holding), you can limit the number of reactions they can choose from but be sure to keep one that won't work.

Figure 2

ADA Description: 9 reusable hot packs shown in the following shapes and colors: blue crescent moon and circle, red heart, tear drop, and santa, yellow star, green Christmas tree, orange hot water bottle, and light blue rectangle

Source/Rights: Copyright © http://www.tradekorea.com/product/detail/P262224/Reusable-hand-warmer,-heat-pack,-hot-pack,-heat-pad.html

Caption: Figure 2. Reusable hot packs in fun shapes

Vocabulary / Definitions

Word	t
solvation	The process of surrounding solute particles with solvent particles to form a solution
saturated solution	Contains the maximum amount of dissolved solute for a given amount of solvent at a specific temperature and pressure
super saturated solution	Contains more dissolved solute than a saturated solution at the same temperature and pressure
heat of solution	The overall energy change that occurs during the solution formation process
specific heat	The amount of heat required to raise the temperature of one gram of that substance by one degree Celsius.
enthalphy	Heat content of a system at constant pressure

Associated Activities (5E – Explore)

What Is the Best Insulator: Air, Styrofoam, Foil or Cotton?

A short activity to investigate the insulating properties of different materials. As it's geared toward elementary, it is probably best used as a short introduction prior to the start of this lesson.

Assessment (5E – Evaluate)

Pre-Lesson Assessment
Descriptive Title: Prior knowledge quiz

Post-Introduction Assessment
Descriptive Title: 3-2-1 Summary

Lesson Summary Assessment
Descriptive Title: Hot Pack Lab Report (completed in stages as part of homework)

Homework
Descriptive Title:

Day 1. Create a list of the chemicals discussed today that are currently available to you at home. Did you find them as pure substances or listed in the ingredients of some product? Research one of them (you pick) and find the safety data sheet. Include all of this information in your final report under background.

Day 2: Begin work on the solutions section of analysis questions.

Day 3: Begin work on the thermochemistry section of the analysis questions. Examine the available plastic bags in your home. Bring any likely prospects in for further testing and consideration.

Day 4: Complete the Lab Report

Lesson Extension Activities (5E – Extension)
Pick one of the following scenarios for your future work section. Suggest an experimental design to test your hypothesis and submit it with your final lab report. (1.) Determine how long your heat pack will last. Hypothesize how many times the pack can be used and which component of the pack you would expect to fail first.

Additional Multimedia Support
Canadian Museum of Nature: dissolution of ionic compound in water animation. (https://www.youtube.com/watch?v=xdedxfhcpWo)

Method to seal their package. For instructor (or students as you decide)
https://www.youtube.com/watch?v=N4utVVGK3jc

References
College Board, AP Chemistry Guided Inquiry Experiments. New York, NY. College Board, 2013

Attachments

Prior knowledge quiz

Preliminary Experimental Outline

Hot Pack Lab Report (analysis questions)

Equipment and material lists

Contributors
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Attachments

Prior knowledge quiz

1. Define exothermic and endothermic.
2. How many moles are in 32.0 grams of oxygen gas.
3. Describe the 3 components of the fire triangle and the safety concerns of each.

Preliminary Experimental Outline

Write a short outline detailing the following:

1. Safety concerns
2. Which 3 chemicals did you choose to test? Rank them best to least and give a brief rationale for the choice
3. Equipment you'll need for the liquid phase
4. What preliminary plastics are you considering?
5. Possible tests to verify functionality.
6. Any obstacles you've considered in regards to the pack.

Hot Pack Lab Report

Follow the standard lab report format. (teachers will probably have their own preferences)

Solutions analysis:

1. Determine the molarity of your solutions.
2. What factors affected the solubility of solutes?
3. How did you know the solution was saturated? Supersaturated?
4. What evidence can you provide to support your final choice of solution for the pack? (Evidence must be organized and explained in relation to the question)

Thermochemistry analysis:

5. Watch the animation and describe the changes you observe, including changes in the bonds and particle attractions.
6. When NaCl is dissolved in water, the resulting solution is colder than the water prior to the dissolution of the salt. Why?
7. Some the solutes you dissolved in your experiments increased the temperature of the solution. Hypothesize what would cause the resulting solution to be higher or lower in temperature?
8. For all 3 reactions, calculate the enthalpy change for both the cold and then the hot water.
9. Why aren't the values for hot and cold equal in each equation?
10. How long did the pack last? What was the main factor in the length of functional time of the pack?

Lab Suggestions

Materials

- NaCl
- $CaCl_2$
- $NaC_2H_3O_2$
- Na_2CO_3
- LiCl
- NH_4Cl

Equipment

- Styrofoam cups
- Thermometers (probeware would be better)
- Source of flame (small light would be best but a cool flame on a Bunsen burner would be ok, if carefully controlled)
- Balance
- Weigh paper or boats
- scoopula

Solution preparation

Basic calorimetry experiments are readily available either in your textbook or online. Find one that suits your preferences. I am deliberately not providing step by step instructions to encourage you to allow the students to explore and find their own way.

Package testing

Depending on your level of comfort and students, you will either use Ziploc bags or follow the method detailed in the YouTube video I've included. I strongly suggest you allow the students to develop their own testing methods for how well the seal will hold. Use water as the liquid for seal tests obviously.

Final thoughts….

Just remember, you should never do any lab with students that you haven't run yourself first. That goes doubly so for guided or full inquiry labs. This lab is definitely guided but with a lot of independence. Good luck, and don't be afraid to learn with your students!