

## **Problem #6: How Much Heat Can A Phase Change Produce? How A Reusable Hand Warmer Is Similar To Heating A House**

### **Introduction**

This lesson is designed to allow students to relate the heat energy involved in a phase change to useful applications. In the process students will perform calculations using  $q = mC\Delta T$  as well as  $q = \Delta H_{\text{solid}}m$ . This lesson also asks students to compare and contrast the phase change chemistry in a science fiction passage to an actual home heating application.

### **Learning outcomes**

The students will:

- Describe the energy in a change of state as endothermic or exothermic
- Write a thermochemical equation to represent the endothermic or exothermic change of state
- Explain how a house can “heat and cool itself”
- Read and interpret the phase change diagram for water
- Use calorimetry to determine the heat released by a reusable hand warmer.
- Relate and apply chemical principles to their life.

### **Curriculum alignment**

NC SCOS GOAL 4: The learner will build an understanding of energy changes in chemistry.  
4.02 Analyze the law of conservation of energy, energy transformation, and various forms of energy involved in chemical and physical processes.

- Analyze heating and cooling curves.
- Calorimetry, heat of fusion and heat of vaporization calculations.
- Endothermic and exothermic processes including interpretation of potential energy.

National Science Content Standard A: As a result of their activities in grades 9-12, all students should develop an understanding of

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

National Science Content Standard B: As a result of their activities in grades 9-12, all students should develop an understanding of

- Structure of atoms
- Structure and properties of matter
- Chemical reactions
- Motions and forces
- Conservation of energy and increase in disorder

### **Classroom time required**

3- 85 minute class periods

### **Materials needed**

- Sodium Acetate reusable hand warmers (1 for each group). These can be purchased from amazon.com or other on line sources. Simply search for reusable hand warmer. Purchase after winter for the best prices. They will cost about \$3.00 a piece. I purchased 16 for \$40.00.
- Cat's Cradle by Kurt Vonnegut.
- *Endothermic and Exothermic Reactions and Thermochemical Equations WS* (1 per student).
- Science Friday video clip <http://www.sciencefriday.com/videos/watch/10007>
- *How Much Heat In A Reusable Hand Warmer?* activity. (1 per student).
- 1 calorimeter for each lab group
- *What Do the House and Cat's Cradle Have in Common WS* (1 per student).

## Technology resources

1. A computer and projector to show video clip.

## Student Pre-activities

Students should have an understanding of types of reactions and dimensional analysis.

Students should distinguish between heat and temperature

Students should have an understanding of enthalpy and be able to solve for q using  $q = mC\Delta T$

## Teacher Pre-activities

Prepare the endothermic demo by gathering a 250 ml Erlenmeyer flask and placing 32 g of  $\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$  g in the flask. Have 11 g of  $\text{NH}_4\text{Cl}$  weighed on a piece of weigh paper. Have a piece of wood available to place the flask on.

## Activities

### Day 1:

1. Review the endothermic and exothermic reactions using a demonstration of each as follows. Add 11 g of ammonium chloride to an Erlenmeyer flask containing 32 g of barium hydroxide. Swirl to mix and have students touch the flask and comment on what they see and feel. As the flask gets cold set it on a wet piece of wood. The reaction is so endothermic that the water will freeze and the flask will be stuck to the wood. To demonstrate an exothermic reaction activate a Hot Hands and pass it around so students can feel the heat released.
2. Present slides 1 -12 from *Heat in changes of State power point*. These slides also cover thermochemical equations.
3. Practice some problems from the *Endothermic and Exothermic Reactions and Thermochemical Equations WS* in class. This can be completed for homework.
4. Present slides 13 – 20 and discuss heat during a phase change
5. Students should read chapters 19 – 23 from ***Cat's Cradle*** by Kurt Vonnegut prior to the next class. Provide a little background information to let students know that the story picks up with an interview of Dr. Breed who worked with Dr. Hoenikker. The narrator, John, is writing a book about the bombing of Hiroshima and he wants to include information about Dr. Hoenikker, a Nobel prize winning physicist and one of the fathers of the atomic bomb. Dr. Hoenikker is no longer alive, so John is talking with his coworker, Dr. Breed. Chapters 19-23 discuss a fictional substance called ice nine. You can check the SparkNotes web site for a summary of the book.

### Day 2 and 3:

6. Present the video clip <http://www.sciencefriday.com/videos/watch/10007> from the Science Friday web site. This clip shows how we can utilize the fact that heat is absorbed and released during phase changes.
7. Present slides 21 -25 to explain calorimetry as a technique used to measure heat released as a result of a chemical or physical change. Demonstrate the proper use of the equipment throughout the discussion.
8. Hand out and introduce the *How Much Heat In A Reusable Hand Warmer?* Activity by giving each lab group 1 reusable hand warmer. Show them how to activate the hand warmer by bending the metal disc. Allow them to observe the reaction so they will understand that heat is generated as the sodium acetate changes state. Purchasing information for these hand warmers is available in the materials section of this document.
9. Have each lab group explain their observations on a white board and in turn share these ideas with the class.
10. Students will work in their lab groups to answer all prelab questions and write a procedure so they are ready to perform and complete the lab during class tomorrow.
11. Students perform *How Much Heat In A Reusable Hand Warmer?* lab. The specific heat of sodium acetate ( $C = 2.5 \text{ J/g } ^\circ\text{C}$ ) and the heat of fusion for sodium acetate ( $H_f = 264 - 289 \text{ J/g}$ ) are included on the student sheet.
12. Students will complete the *What Do the House That Heats Itself and Cat's Cradle Have in Common* WS for homework as a way to once again relate change of state to heat.

### Assessment

1. Rubric is attached to the *How Much Heat In A Reusable Hand Warmer?* activity.
2. *What Do the House That Heats Itself and Cat's Cradle Have in Common* WS
3. Unit test

### Modifications

This lesson was designed and used with honors chemistry students. Academic chemistry students will require instruction on how to go about doing the calculations so they recognize that the heat released during the solidification of the sodium acetate is transferred to the water thereby increasing the temperature of the water and it is also increasing the temperature of the sodium acetate. We ignore the plastic casing of the hand warmer, although it could also be included. The final equation looks like this:  $-\Delta H_{\text{sol}}m (\text{sodium acetate}) = mC\Delta T (\text{water}) + mC\Delta T (\text{sodium acetate})$ .

### Supplemental information

1. The specific heat of sodium acetate is  $3.0 \text{ J/g } ^\circ\text{C}$ .
2. Heat of fusion and heat of solidification are the same amount of heat. Heat of fusion is a positive value because it requires the input of heat to melt a substance while heat of solidification is a negative value because heat is released when a substance solidifies. The known value for heat of fusion of sodium acetate is  $264-289 \text{ kJ/kg}$  which is the same as  $264-289 \text{ J/g}$ .
3. The heat of solidification values obtained in the lab tend to be low which allows for a discussion of where the heat may have gone or other possible errors. Remember that we did not include the plastic casing.

### Critical vocabulary

Calorie

calorie  
Joule  
Enzyme  
Energy  
Thermochemistry  
Calorimetry  
Calorimeter  
Heat of fusion  
Heat of solidification  
Endothermic  
Exothermic

### **Websites and Resources**

The House that Heats and Cools Itself video clip  
<http://www.sciencefriday.com/videos/watch/10007>

### **Comments**

In order for students to obtain decent result in the *Much Heat In A Reusable Hand Warmer?* Activity it is necessary to guide them to understand that the heat released when the hand warmers are activated is used to increase the temperature of the water in the calorimeter as well as to increase the temperature of the hand warmer itself.

These reusable hand warmers can be reactivated by putting them in boiling water. Watch then carefully and when they are liquid again allow them to remain in the water until it cools to room temperature for best results.

### **Author Info:**

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