Student activity: How much heat in a reusable hand warmer?

Purpose:
You will determine how much heat energy in joules is released by the hand warmer. You will also determine the heat of solidification (J/g) for sodium acetate based on the heat released by the hand warmer and calculate the % error in your heat of solidification data.

Background:
The hand warmers are filled with sodium acetate. Click the metal disc and you will notice the liquid changes state and becomes a solid. In the process, heat is released. The sodium acetate is a supersaturated solution. We will discuss these more in our next unit, but for now you need to understand that they are unstable solutions. As a result, the clicking of the metal disc disturbs the solution enough that if causes it to crystallize or change states from a liquid to a solid. You will also need to know that the combined mass of the metal disc and the plastic that holds the sodium acetate was determined to be 8.4 g. The specific heat of sodium acetate is reported to be 3.0 J/g ^{o}C.

Pre-lab questions:
1. When the hand warmer is submerged in water and activated, describe the transfer of heat that occurs by completing the following statement. Heat is released by the _____ and absorbed by the _____ and _____.
2. Write an equation that relates the heat lost by the hand warmer to the heat gained by the water in the calorimeter. Label the following variables. – H_{sol}m of the _____ = mCΔT of the _____ + mCΔT of the _____.
3. Does the temperature of the hand warmer remain constant, increase or decrease after it is activated?
4. The specific heat of sodium acetate is 3.0 J/g^{o}C. If the mass of sodium acetate is 21.4 g, how much heat was needed to increase the temperature of the sodium acetate from 21.0^{o}C to 29.8^{o}C? You may assume that all the heat is transferred to the sodium acetate.
5. Determine the heat required to convert 62.0 g of ice at -10.3 ^{o}C to water at 0.0^{o}C. The specific heat of ice is 2.09 J/g^{o}C.
6. Determine the mass of iron at 85.0^{o}C that would need to be added to 54.0 g of ice to produce water at 12.5^{o}C. The specific heat of iron is 0.45 J/g^{o}C.

Activities:
1. Brainstorm a way to determine the heat released by the hand warmer. Remember to review calorimetry
2. Write down your procedure and have it approved by your teacher.
3. Obtain a hand warmer from the teacher and perform your experiment. Be sure to record all experimental data.
4. Calculate the mass of sodium acetate used in your hand warmer package.
5. Calculate the heat released by the hand warmer. HINT: Where did the heat go when it left the hand warmer? Complete the following equation:

   q (released by the hand warmer) = q (_____) + q(_____).

6. Calculate the heat of solidification for sodium acetate. HINT: The heat released by the hand warmer was due to what process? Write the equation for this process: q = _____.
7. Once you have calculated the heat of solidification, ask your teacher for the known value so you can calculate the % error.

Grading rubric: Abbreviated report

Your final report must contain the following sections in this order:

1) Purpose (2 pts): One typed sentence that identifies the purpose of this activity.

2) Background (3 pts): Three or four typed sentences that explain calorimetry as it is used in this experiment.

3) Procedure (4 pts): Three or four sentences that describe the procedure used to perform the lab.

4) Calculations (11 pts): Neatly written work for the calculations of heat released by the hand warmer, heat of solidification for sodium acetate and % error (sodium acetate ΔH_{fus} = 264–289 kJ/kg) . Each calculation should include the following.

- Label to identify the calculation being performed.

Label each calculation so it is clearly identified. For example, the label "density" does not identify what substance is being investigated, but the label "density of water" does. The second label is much clearer to the reader.

- Formula used
- Data plugged into the formula
- Final answer circled
- Proper units and significant figures

5) Results (2 pts): One or two typed sentence that summarize the results of your experiment.

6) Conclusion (4 pts): Three or four typed sentences that explain one thing you learned in the experiment as well as two possible sources of error and the effect on your results.

7) Format (4 pts): One point is earned for each of the following. Typed, stapled together in the order of this rubric, paragraph format, and turned in on time.

Student activity: How Much Heat In A Reusable Hand Warmer?
Teacher Answer Key

Purpose:
You will determine how much heat energy in joules is released by the hand warmer. You will also determine the heat of solidification (J/g) for sodium acetate based on the heat released by the hand warmer and calculate the % error in your heat of solidification data.

Background:
The hand warmers are filled with sodium acetate. Click the metal disc and you will notice the liquid changes state and becomes a solid. In the process, heat is released. The sodium acetate is a supersaturated solution. We will discuss these more in our next unit, but for now you need to understand that they are unstable solutions. As a result, the clicking of the metal disc disturbs the solution enough that if causes it to crystallize or change states from a liquid to a solid. You will also need to know that the combined mass of the metal disc and the plastic that holds the sodium acetate was determined to be 8.4 g. The specific heat of sodium acetate is reported to be 3.0 J/g ^{o}C.

Pre-lab Questions:

1. When the hand warmer is submerged in water and activated, describe the transfer of heat that occurs by completing the following statement. Heat is released by the **hand warmer** and absorbed by the **water** and **sodium acetate in the hand warmer.**
2. Write an equation that relates the heat lost by the hand warmer to the heat gained by the water in the calorimeter. Label the following variables. – H_{sol}m of the _____ = mCΔT of the _____ + mCΔT of the _____.

Heat released by the heat of solidification of the sodium acetate = heat gained by the water + heat gained by the sodium acetate

$-q_{(hand\ warmer)} = q_{(water)} + q_{(sodium\ acetate)}$ or

$\Delta H_{sol}m_{(sodium\ acetate)} = mC\Delta T_{(water)} + mC\Delta T_{(sodium\ acetate)}$

3. Does the temperature of the hand warmer remain constant, increase or decrease after they are activated?

The temperature increases as heat is released by the solidification process. This heat is transferred to the water and the sodium acetate that is in the hand warmer.

4. The specific heat of sodium acetate is 3.0 J/g^{o}C. If the mass of sodium acetate is 21.4 g, how much heat was needed to increase the temperature of the sodium acetate from 21.0^{o}C to 29.8^{o}C. You may assume that all the heat is transferred to the sodium acetate.

$q = mC\Delta T \rightarrow q = (21.4\ g)(3.0\ J/g^{o}C)(29.8^{o}C - 21.0^{o}C) \rightarrow q = 565\ J$

5. Determine the heat required to convert 62.0 g of ice at -10.3 ^{o}C to water at 0.0^{o}C. The specific heat of ice is 2.09 J/g^{o}C.

Step 1: Heat the ice from -10.3^{o}C to 0^{o}C $C_{ice} = 2.09\ J/g^{o}C$

$q = mC\Delta T \rightarrow q = (62.0\ g)(2.09\ J/g^{o}C)(0.0^{o}C - (-10.3^{o}C)) \rightarrow q = 1334.67\ J$

Step 2: Melt the ice at 0^{o}C ΔH_{fus} (ice) = 334 J/g

$q = \Delta H_{fus} m \rightarrow q = (334\ J/g)(62.0\ g) \rightarrow q = 20708\ J$

Total Heat required = Heat in step 1 + heat in step = 2.07 kJ + 1.33 kJ → q = 22.0 kJ

6. Determine the mass of iron at 85.0°C that would need to be added to 54.0 g of ice to produce water at 12.5°C. The specific heat of iron is 0.45 J/g°C.

$-mC\Delta T(iron) = mC\Delta T(water) + \Delta H_{fus} m\ (ice)$

$-[m(0.45\ J/g^oC)(12.5^oC - 85.0^oC)] = [(54.0\ g)(4.184\ J/g^oC)(12.5^oC - 0.0^oC)] + [(334\ J/g)(54.0\ g)]$

m = 639 g of iron

Activities:

1. Brainstorm a way to determine the heat released by the hand warmer. Remember to review calorimetry.
2. Write down your procedure and have it approved by your teacher

The procedure should follow this general outline

- **Measure and record the volume and temperature of the water placed in the calorimeter.**
- **Measure and record the mass and temperature of the hand warmer,**
- **Activate and immediately put the hand warmer into the calorimeter.**
- **Record the final temperature of the water and hand warmer in the calorimeter.**

3. Obtain a hand warmer from the teacher and perform your experiment. Be sure to record all experimental data.
4. Calculate the mass of sodium acetate used in your hand warmer package.

Students must subtract the mass of the plastic that holds the sodium acetate. This mass is given in the background information for this lab.

5. Calculate the heat released by the hand warmer. HINT: Where did the heat go when it left the hand warmer? Complete the following equation:

q (released by the hand warmer) = q (**water**) + q(**sodium acetate**).

6. Calculate the heat of solidification for sodium acetate. HINT: The heat released by the hand warmer was due to what process? Write the equation for this process:

Students will use their data and solve for ΔH_{sol} in the following equation.

$\Delta H_{sol} m(sodium\ acetate) = mC\Delta T(water) + mC\Delta T(sodium\ acetate)$

7. Once you have calculated the heat of solidification, ask your teacher for the known value so you can calculate the % error.

ΔH_{fus} (sodium acetate) = 264–289 kJ/kg

Teacher notes:

Grading rubric: Abbreviated Report from every student

The final report must contain the following sections in this order:

2 pts 1) Purpose: One typed sentence that identifies the purpose of this activity.
During this lab we will determine the heat of solidification for sodium acetate used in the hand warmer as well as our % error.

3 pts 2) Background: Three or four typed sentences that explain calorimetry as it is used in this experiment.
Heat from the hand warmer will be absorbed by the water in the calorimeter and increase the temperature of the water. Using the formula $q=mC\Delta T$, we will calculate the heat absorbed by the water which is equal to the heat released by the hand warmer. The heat released by the hand warmer is due to the heat of solidification for sodium acetate ($q= \Delta H_{fus}m$)

4 pts 3) Procedure: Three or four sentences that describe the procedure used to perform the lab.
Determine the mass of the hand warmer and subtract the mass of the plastic and metal disc to determine the mass of the sodium acetate in the hand warmer. Record the temperature and volume of water in the calorimeter. Place the hand warmer into the calorimeter and activate the hand warmer. Record the highest temperature of the water in the calorimeter.

11 pts total 4) Calculations: Neatly written work for the calculations of heat, heat of fusion for sodium acetate and % error (sodium acetate ΔH_{fus} = 264–289 kJ/kg) . Each calculation should include the following.

2 pts Label to identify the calculation being performed

Label each calculation so it is clearly identified. For example, the label "density" does not identify what substance is being investigated, but the label "density of water" does. The second label is much clearer to the reader.

2 pts Formula used
3 pts Data plugged into the formula
2 pts Final answer circled
2 pts Calculations as always must include units and proper significant figures.

2 pts 5) Results: One or two typed sentences that summarize the results of your experiment.
We found that ___J of heat was released by the hand warmer, which meant that the heat of fusion was __ J/g. Our % error for the heat of fusion of sodium acetate is __ %

4 pts 6) Conclusion: Three or four typed sentences that explain one thing you learned in the experiment as well as two possible sources of error and the affect of those errors on your results.

One sentence stating that the method was successful or that the heat released by the hand warmer was significant. Two sources of error or improvements to the lab and a correct affect on the results.

4 pts 7) format: One point is earned for each of the following. Typed, stapled together in the order of this rubric, paragraph format, and turned in on time.