**Designing a Hand Warmer**

Experiment Overview

The purpose of this advanced inquiry lab is to design an effective hand warmer that is inexpensive, nontoxic, and safe for the environment. The investigation begins with an introductory activity to become familiar with the principles of calorimetry and heat of solution calculations.

Materials

Ammonium nitrate calcium chloride sodium acetate

sodium chloride lithium chloride sodium carbonate

water beaker – 250 ml

Calorimeter grad cylinder 100 ml Hot plate Stirring plate

Magnetic stir bar ring stand and clamp Thermometer

Safety Precautions

Ammonium nitrate is a strong oxidizer and may explode if heated under confinement. It is also slightly toxic by ingestion and body tissue irritant. Calcium chloride is slightly toxic. Lithium chloride is moderately toxic by ingestion. Magnesium sulfate is a body tissue irritant. Sodium acetate is a body tissue and respiratory tract irritant. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical resistant gloves, and a chemical resistant apron. Wash hand thoroughly with soap and water before leaving the laboratory.

Part A. Heat Capacity of the Calorimeter – Construct your Own Data Table

1. Working in pairs, set up a calorimeter consisting of two nested polystyrene cups in a ring clamp attached to a support stand.

2. Place a magnetic stirrer below the calorimeter, then lower the ring clamp until the bottom of the cup just



sits on the magnetic stirrer. See Figure 1.

3. Measure 100.0 ml of distilled water in a 100 ml graduated cylinder and transfer the water into the calorimeter.

4. Add a magnetic stirring bar to the calorimeter, and set the bar spinning slowly. Do not remove the stirring rod from the calorimeter.

5. Measure and record the initial temperature of the water.

6. Heat approximately 125 ml of distilled water to about 50˚C in a 250 ml beaker.

7. Using heat resistant protection, measure 100.0 ml of the 50˚C distilled water in a 100 ml graduated cylinder.

8. Measure and record the temperature of the hot water.

9. Immediately pour the hot water into the room temperature water in the calorimeter.

10. Insert the thermometer, and stir the water.

11. Record the mixing temperature Tmix after 20 seconds.

12. Empty the calorimeter and dry the inside.

13. Calculate the calorimeter constant, Ccal using the equations below.

USE THIS DATA TO CALCULATE THE HEAT CAPACITY OF THE CALORIMETER (qcal)

Data Table Part A

|  |  |
| --- | --- |
| Volume of Deionized Water, Cold |  |
| Temperature, Cold Water |  |
| Volume of Deionized Water, Hot |  |
| Temperature, Hot Water |  |
| Final Temperature of mixed water |  |
| Average Temperature (Temphot + Tempcold)/2 |  |
| ΔTemperature (Tempmix - Tempavg) |  |
| q water |  |
| q calorimeter |  |
| Calorimeter Constant, (J/◦C) |  |

Calculation:

Mass of water = density of water X volume water

q water = (mass of hot water + mass of cold water) X (4.18) X (Tempmix – Temp avg)

qcal =-qwater

Ccal = \_\_\_\_\_\_qcal\_\_\_\_

(Tmix - Tinitial)

To correct your heat of solution in Part B use the following equation:

**qcal = [ΔT]Experiment  X [Ccal]**

your experiment heat of solution corrected for the amount of heat absorbed by the calorimeter is:

q solution = q aqueous solution of ionic solid and water + q cal

Part B Calorimetry Procedure- Working in groups, examine the heat energy change for the following your solution.

NH4NO3 (s) + H2O(l) 🡪 NH4+(aq) + NO3-(aq)

CaCl2(s) + H2O(l) 🡪 Ca+2(aq) + 2Cl-1(aq)

NaC2H3O2(s) + H2O(l) 🡪 Na+1(aq) + C2H3O2-1(aq)

NaCl(s) + H2O(l) 🡪 Na+1(aq) + Cl-1(aq)

KCl(s) + H2O(l) 🡪 K+1(aq) + Cl-1(aq)

Na2CO3(s) + H2O(l) 🡪 2Na+1(aq) + CO3-2(aq)

1. Measure 45.0 ml of distilled water in a 100 ml graduated cylinder and transfer to the calorimeter.

2. Measure and record the initial temperature of the water.

3. Measure 5.00 g of your solid onto weighing paper.

4. Put a magnetic stir bar or stirring rod into the calorimeter and slowly stir the water.

5. Quickly add the 5.00 gr of your solid to the calorimeter and insert the thermometer.

6. Monitor the temperature and record the highest or lowest temperature reading.

7. Calculate the molar heat of solution of your solid. Include the correction due to the heat capacity of the calorimeter.

Data Table

|  |  |
| --- | --- |
| Solid Name |  |
| Volume of deionized water |  |
| Mass of solid |  |
| Initial Temperature |  |
| Final Temperature |  |
| Temperature Change |  |
| Molar Heat of Solution (J) |  |

Class Data:

|  |  |
| --- | --- |
| Solid | Molar Heat of Solution (J) |
| NaCl |  |
| CaCl2 |  |
| NaC2H3O2 |  |
| Na2CO3 |  |
| KCl |  |
| NH4NO3 |  |

Calculations: Heat capacity of the calorimeter (qcal), Heat of solution (qsolution = -(qaq + qcal) see equation 1 , moles of solid, molar heat of solution.

Discussion:

Review the following data from a calorimetry experiment to determine the heat of fusion of ice. After shaking off any excess water, several ice cubes were added to 99 g of warm water contained in a calorimeter. The initial temperature of the warm water was 46.8˚C. The ice-water mixture was stirred until the temperature reached a stable, minimum value, which was 1.1˚C. Any unmelted ice remaining at this point was immediately and carefully removed using tongs and the mass of the waterof the calorimeter was measured = 154 g.

1. Use the heat energy equation to calculate the amount of heat in joules released by the warm water as it cooled.

2. Based on the law of conservation of energy, what amount of heat was absorbed by the ice as it melted?

3. Determine the amount of energy absorbed per gram of ice as it melted.

4. Calculate the heat of fusion (the heat required to melt ice) in units of kilojoule/mole.

5. The literature value for the heat of fusion of ice is 6.02 kJ/mole. What is the percent error for the experimentally determined heat of fusion?

6. When a mixture of ice and water originally at 0˚C is heated, the temperature remains constant (within experimental error) until all of the ice melts. Explain what happens to the heat energy that is absorbed during this time while the temperature does not change.

Conclusion: Include results, sources of error and the effect upon the result, brief recap of procedure and do the following:

Extrapolating from the information below, predict which solid(s) could be used in an effective hand warmer meeting the following requirements:

a. the hand warmer must contain 10g of an ionic solid and an inner pouch filled with 40 ml of water.

b. Activating the hand warmer must increase the temperature of the resulting solution by at least 20˚C.

c. Include statements outlining why you chose the ionic solid. Must include effectiveness and cost.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Solid | Cost ($/g) | ∆T, ◦C (40 ml) | ∆T, ◦C 10g/40 ml | Total Cost of Solid |
| NaCl | .0079 | -1.6 | NA | NA |
| CaCl2 | .0131 | 16.2 | 31.9 | .131 |
| NaC2H3O2 | .0258 | 5.3 | 10.3 | .258 |
| Na2CO3 | .0123 | 5.6 | 13.9 | .123 |
| LiCl | .0655 | 21.6 | 43.2 | .655 |
| NH4NO3 | .0181 | -9.0 | NA | NA |