LABORATORY 6: Approximating Various Enthalpies using Calorimetry

PRELAB

Read the following procedure completely in order to prepare for lab.

Answer the following questions in your laboratory notebook:

1. In your own words, write the purpose of this experiment.
2. Acetic acid ($HC_2H_3O_2$) can be neutralized with sodium hydroxide, as you saw in laboratory 4. The temperature of the surroundings (the water) increased in value, meaning that the reaction was exothermic. Use your maximum temperature change from lab 4 to calculate q_{rxn}* (in kJ) for acetic acid and sodium hydroxide (assume the density of the final solution is 1.00 g/mL and the specific heat is 4.184 J/g °C).
3. Calculate the number of moles of NaOH in 30 mL of a 1 M solution, and use the number to calculate ΔH_{rxn} in kJ/mol.
4. The reported value of ΔH_{rxn} for the neutralization of $HC_2H_3O_2$ with NaOH is -54.3 kJ/mol. Calculate the percent error in your measurements to the nearest 0.1 %.

**Note: If you have not yet discussed enthalpies of reaction in lecture, the information can be found in Chapter 5 of your textbook, beginning on pp. 222.*

Before beginning in lab, update the Table of Contents with the title of the experiment and corresponding page number. You will be working with computers, so be aware of aqueous solutions at all times. You will be working with glassware at extreme temperatures, and cold glass looks exactly like hot glass. Do not touch any glassware unless you are sure it is safe.

PURPOSE

In this procedure, you will use calorimetry to determine the specific heat of a metal, the enthalpy of sublimation (ΔH_{sub}) of dry ice (solid CO_2), and enthalpy of solution (ΔH_{sol}) for ammonium nitrate. You will do so by measuring the heat exchanged with water (the "surroundings") to calculate the enthalpy of the "system" in each part of the procedure below.

INTRODUCTION

The basic assumption of all calorimetry experiments is that no heat is released to or absorbed from the surroundings outside the calorimeter. The contents within the calorimeter are contained in a closed system that is as isolated as possible. For this reason, any energy that is released to or absorbed from the solvent is assumed to be a direct result of either an exothermic or endothermic reaction. During an exothermic reaction, the temperature of the surroundings increases, and during an endothermic reaction, the temperature of the surroundings decreases. Specific heat is the amount of heat energy needed to raise the temperature of 1 gram of a material by 1 °C. The value of the specific heat is unique to the material; for instance, the specific heat of water is 4.184 J/g °C.

EXPERIMENTAL PROCEDURE: PART 1

Necessary Materials:

- digital thermometer
- 250 mL beaker
- unknown metal cylinder
- test tube clamp
- styrofoam cup
- 100 mL graduated cylinder

1. Obtain a digital thermometer.
2. Obtain a 250 mL beaker and fill it to the 200 mL mark with tap water. Place the beaker on a hot plate and bring the beaker to a rolling boil. Record the temperature of the boiling water.
3. Obtain a metal cylinder. Record its color and mass to the nearest 0.1 g.
4. Using a test tube clamp, carefully place the metal cylinder in the boiling water. Leave the metal in the water for at least 2 minutes.
5. Obtain a clean, dry styrofoam cup and record its mass to the nearest 0.1 g.
6. Measure 40.0 mL of distilled water and record the volume to the nearest 0.01 mL. Pour the water into the styrofoam cup and record its combined mass. Also, record the temperature of the water.

7. Using a test tube clamp, carefully remove the metal cylinder from the boiling water. Quickly transfer the hot metal to the room temperature water in the styrofoam cup. Gently stir the water with the thermometer and record the final (highest) temperature once it has stabilized.

8. Write your ΔT for water on the board corresponding to your metal cylinder. Once everyone's ΔT's have been written for your metal cylinder, record the class average in your lab notebook.

EXPERIMENTAL PROCEDURE: PART 2

Necessary Materials:

- digital thermometer
- thermos calorimeter
- 100 mL graduated cylinder
- dry ice

1. Obtain a small thermos and record its mass to the nearest 0.1 g.

2. Measure 80.0 mL of distilled water and record the volume to the nearest 0.01 mL. Pour the water into the thermos and record its combined mass. Also, record the temp. of the water.

3. Obtain 7.0 g of dry ice with the help of your instructor or TA and record its mass to the nearest 0.1 g. ***CAUTION:*** *The sublimation of dry ice occurs at -78 °C and should not be touched directly. Gloves will be available to you if you prefer, but are not required.*

4. Carefully add the dry ice to the thermos and cover with a lid. Occasionally stir the water with the thermometer and record the final (lowest) temperature once it has stabilized. This could take up to 5 minutes.

5. Write your mass of dry ice and ΔT for water on the board. Once everyone's data has been written, record the class averages in your lab notebook.

EXPERIMENTAL PROCEDURE: PART 3

Necessary Materials:

- digital thermometer

- 1 - large test tube w/ rubber stopper
- 100 mL graduated cylinder
- KNO_3

1. Obtain a large test tube and record its mass to the nearest 0.1 g.

2. Measure 25.0 mL of distilled water and record the volume to the nearest 0.01 mL. Pour the water into the test tube and record its combined mass. Also, record the temp. of the water.

3. Obtain 5.0 g of potassium nitrate in a weigh boat and record its mass to the nearest 0.1 g.

4. Quickly and carefully add the potassium nitrate to the test tube without losing material. Immediately seal the test tube with a rubber stopper and vigorously shake the contents completely dissolve. Quickly remove the stopper and record the final (lowest) temperature once it has stabilized.

5. Write your mass of KNO_3 and ΔT for water on the board. Once everyone's data has been written, record the class averages in your lab notebook.

WASTE MANAGEMENT

Once you have completed the experimental procedure and calculations, dispose of the solutions down the drain with running water. Rinse and return the metal cylinder as directed. Thoroughly rinse the beakers and test tubes once emptied in the sink. Return all glassware to your drawer. Thoroughly wipe down the bench top with a wet paper towel.

LABORATORY 6: REPORT SHEET

NAME:

LAB PARTNER:

LAB DATE AND TIME:

The report sheet should be completed and turned in before you leave lab today.

1. Complete the tables and fill in the blanks below using the observations you gathered in lab.

	Mass (g)	**Initial Temperature (°C)**	**Final Temperature (°C)**
Metal Cylinder			
Water in Styrofoam			
Class avg. Metal			
Class avg. H_2O			

	Mass (g)	**Initial Temperature (°C)**	**Final Temperature (°C)**
Dry Ice		--	--
Water in Thermos			
Class avg. dry ice			
Class avg. H_2O			

	Mass (g)	**Initial Temperature (°C)**	**Final Temperature (°C)**
Potassium Nitrate		--	--
Water in Test Tube			
Class avg. KNO_3			
Class avg. H_2O			

2. Calculate the heat absorbed by the water in the styrofoam cup using the class average of ΔT, then the heat released by, and the specific heat (in J/g °C) of, the metal cylinder.

3. The following table contains reported specific heats for a number of metals. Identify the metal based on the specific heat that you calculated and the color of the cylinder.

	Aluminum	**Brass**	**Copper**	**Iron**	**Silver**	**Zinc**
Specific heat (J/g °C)	0.900	0.386	0.385	0.450	0.230	0.387

Calculate the percent error in your measurements relative to the reported specific heat above to the nearest 0.1 %.

$$\%\ error = \left(\frac{Accepted - Experimental}{Accepted}\right) x100$$

4. Calculate the heat taken from the water in the thermos using the class average of ΔT, then the heat absorbed by, and the enthalpy of sublimation (in kJ/mol) of, the dry ice. Calculate percent error.

5. Calculate the heat exchanged with the water in the test tube using the class average of ΔT, then the heat exchanged with, and the enthalpy of solvation (in kJ/mol) of, KNO_3. Did the heat exchange between KNO_3 and water signify an exothermic or endothermic reaction? Calculate percent error.

6. A shiny silver-grey metal object was heated to 99.5 °C, and then dropped into 50.0 g of 23.0 °C water. The final temperature is 26.2 °C. If the weight of the metal was 20.3 g, calculate the specific heat of the metal. Identify the metal from the table of heat capacities above. Calculate percent error.

7. A 50.0 g sample of ethanol at 20.0 °C is mixed with a 50.0 g sample of water at 60.0 °C. The final mixture temperature is 45.2 °C. What is the specific heat of ethanol?

LABORATORY 6: RUBRIC

PRELAB

1. Purpose in notebook...______/2 points
2. Heat exchanged in lab 4...______/1 point
3. Enthalpy of reaction...______/2 points
4. Percent error..______/1 point

LAB NOTEBOOK

Proper header information on every page..______/1 point

Procedure recorded clearly...______/2 points

Mass of metal cylinder...______/1 point

Mass of dry ice..______/1 point

Mass of KNO_3..______/1 point

For all three parts:

Mass of water..______/2 points

Group's ΔT..______/2 points

Class average ΔT..______/2 points

POSTLAB

1. Tables filled in completely...______/1 point
2. Specific heat of the metal cylinder..______/2 points
3. Consistent identification of the metal cylinder..______/2 points

   Percent error..______/1 point
4. Enthalpy of sublimation of dry ice...______/2 points
5. Enthalpy of solvation of KNO_3...______/2 points
6. Specific heat of a hypothetical metal...______/1 point
7. Specific heat of ethanol..______/1 point

TOTAL..______/**30 points**