HESS'S LAW: ADDITIVITY OF HEATS OF REACTION

LAB THC 1.COMP
From *Chemistry with Computers***,** Vernier Software & Technology, 2000

INTRODUCTION

In this experiment, you will use a Styrofoam-cup calorimeter to measure the heat released by three reactions. The amount of heat released or absorbed by a reaction is referred to as the heat of reaction, q. The enthalpy of reaction, ΔH, is equal in magnitude, but opposite in sign to the heat of reaction, ΔH = -q. Of the three reactions conducted in this experiment, one is the same as the combination of the other two reactions. Therefore, according to Hess's law, the heat of reaction of the one reaction should be equal to the sum of the heats of reaction for the other two. This concept is sometimes referred to as the *additivity of heats of reaction.* The primary objective of this experiment is to confirm this law. The reactions conducted in this experiment are:

1) Solid sodium hydroxide dissolves in water to form an aqueous solution of ions.

$$NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq) \qquad \Delta H_1 = ?$$

2) Solid sodium hydroxide reacts with aqueous hydrochloric acid to form water and an aqueous solution of sodium chloride.

$$NaOH(s) + H^+(aq) + Cl^-(aq) \longrightarrow H_2O(l) + Na^+(aq) + Cl^-(aq) \qquad \Delta H_2 = ?$$

3) Solutions of aqueous sodium hydroxide and hydrochloric acid react to form water and aqueous sodium chloride.

$$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \longrightarrow H_2O(l) + Na^+(aq) + Cl^-(aq) \qquad \Delta H_3 = ?$$

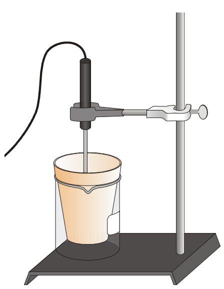

Figure 1

You will use a Styrofoam cup in a beaker as a calorimeter, as shown in Figure 1. For purposes of this experiment, you may assume that the heat loss to the calorimeter and the surrounding air is negligible. Even if heat is lost to either of these, it is a fairly constant factor in each part of the experiment, and has little effect on the final results.

PURPOSE

The purpose of this lab is to confirm Hess's Law, which states that heats of reactions are additive.

PRE-LAB EXERCISE

In the space below, combine two of the above equations algebraically to obtain the third equation. Indicate the number of each reaction on the shorter lines.

_____ ____

_____ ____

_____ ____

MATERIALS

Laptop computer with Logger*Pro*	100 mL of water
Lab*Pro* with AC adapter	4.00 g of solid NaOH
Lab*Pro* → computer cable	Ring stand
Stainless steel temperature probe	Utility clamp
50 mL of 1.0 M NaOH	Stirring rod
50 mL of 1.0 M HCl	Styrofoam cup
100 mL of 0.50 M HCl	250-mL beaker
2, 100 mL graduated cylinders	Balance (0.01 gram)

SAFETY

- Always wear goggles and an apron in the lab.
- Use caution handling solid NaOH and the resulting solutions.
- Use caution handling HCl solutions.

PROCEDURE

Reaction 1

1. Prepare the computer for data collection by opening the Experiment 18 folder from *Chemistry with Computers*. Select Exp 18 Stainless Steel Temp. The vertical axis has temperature scaled from 15°C to 40°C. The horizontal axis has time scaled from 0 to 200 seconds.

2. Place a Styrofoam cup into a 250-mL beaker as shown in Figure 1. Measure out 100.0 mL of water into the Styrofoam cup. Lower the Temperature Probe into the solution.

3. Use a utility clamp to suspend the Temperature Probe from a ring stand as shown in Figure 1.

4. Weigh out about 2 grams of solid sodium hydroxide, NaOH, and record the mass to the nearest 0.01 g in your Data Table. Since sodium hydroxide readily picks up moisture from the air, it is necessary to weigh it and proceed to the next step without delay.

5. Click on Collect to begin data collection and obtain the initial temperature, t_1. It may take several seconds for the Temperature Probe to equilibrate at the temperature of the solution.

6. After three or four readings at the same temperature have been obtained, add the solid NaOH to the Styrofoam cup.

7. Using the stirring rod, stir continuously for the remainder of the 200 seconds or until the temperature maximizes. **Note:** As soon as the temperature has begun to drop after reaching a maximum, you may terminate the trial by clicking Stop.

8. Examine the initial readings in the Table window to determine the initial temperature, t_1.

9. To determine the final temperature, t_2, click the Statistics button, . The maximum temperature is listed in the statistics box on the graph.

10. Record t_1 and t_2 in your data table.

11. Rinse and dry the Temperature Probe, Styrofoam cup, and stirring rod. Dispose of the solution as directed by your instructor.

Reaction 2

12. Repeat Steps 2-11 using 100.0 mL of 0.50 M hydrochloric acid, HCl, instead of water.

Reaction 3

13. Repeat Steps 2-11, initially measuring out 50.0 mL of 1.0 M HCl (instead of water) into the Styrofoam calorimeter. In Step 4, instead of solid NaOH, measure 50.0 mL of 1.0 M NaOH solution into a graduated cylinder.

DATA SHEET

Name ________________________
Name ________________________
Period _______ Class ___________
Date ___________

HESS'S LAW: ADDITIVITY OF HEATS OF REACTION

DATA TABLE

	Reaction 1	Reaction 2	Reaction 3
Mass of solid NaOH	g	g	(no solid NaOH mass)
Mass (total) of solution*	g	g	g
Final temperature, t_2	°C	°C	°C
Initial temperature, t_1	°C	°C	°C
Change in temperature, Δt	°C	°C	°C

*Assume the density of each solution is 1.00 g/mL.

CALCULATION TABLE

	Reaction 1	Reaction 2	Reaction 3
Heat, q	kJ	kJ	kJ
Enthalpy, ΔH	kJ	kJ	kJ
Moles of NaOH	mol	mol	mol
ΔH/mol	kJ/mol	kJ/mol	kJ/mol
Experimental value kJ/mol			
Accepted value kJ/mol			
Percent error %			

PROCESSING THE DATA

1. Determine the mass of 100 mL of solution for each reaction (assume the density of each solution is 1.00 g/mL).

2. Determine the temperature change, Δt, for each reaction.

3. Calculate the heat released by each reaction, q, using the formula:

$$q = C_p \cdot m \cdot \Delta t \quad (C_p = 4.18 \text{ J/g°C})$$

   Convert joules to kJ in your final answer.

4. Find ΔH ($\Delta H = -q$).

5. Calculate moles of NaOH used in each reaction. In Reactions 1 and 2, this can be found from the mass of the NaOH. In Reaction 3, it can be found using the molarity, M, of the NaOH and its volume, in L.

6. Use the results of the Step 4 and Step 5 calculations to determine ΔH/mol NaOH in each of the three reactions.

7. To verify the results of the experiment, combine the heat of reaction (ΔH/mol) for Reaction 1 and Reaction 3. This sum should be similar to the heat of reaction (ΔH/mol) for Reaction 2. Using the value in Reaction 2 as the accepted value and the sum of Reactions 1 and 3 as the experimental value, find the percent error for the experiment.