LABORATORY SAFETY AND ASSESSMENT FORM

SECTION: GENERAL CHEMISTRY	LABORATORY: 9	EXPERIMENT TITLE:	
PERSONEL INVOLVED: Undergraduates, laboratory staff and Instructor			
SUBSTANCES INVOLVED*	QUANTITY USED IN EXPRIMENT	HAZARD (FROM MSDS)	PRECAUTIONS AND FIRST AID

*Identify all chemical reagents that you will use in the experiment.

Signed (Instructor): _____
Date:_____

CALORIMETRY

Heat is a form of energy, sometimes called thermal energy, which can pass spontaneously from an object at high temperature to an object at a lower temperature. If the two objects are in contact, given sufficient time, they will reach the same temperature.

Heat flow is ordinarily measured in a device called calorimeter. A calorimeter is simply a container with insulating walls, made so that essentially no heat is exchanged between the contents and the surroundings. Within the calorimeter, reactions may occur or heat may flow from one part of the contents to another, but no heat transfers into or out of the calorimeter.

In this experiment, the heat capacity of a calorimeter and the heat involved in the following reactions will be determined and compared.

Reaction 1: Solid sodium hydroxide dissolves in water to form an aqueous solution of ions:

$NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq) + X_1J$ $\Delta H_1 = -X_1$ J

Reaction 2: Solid sodium hydroxide reacts with an aqueous solution of hydrogen chloride to form water and an aqueous solution of sodium chloride.

$NaOH(s) + H^+(aq) + Cl^-(aq) \longrightarrow H_2O + Na^+(aq) + Cl^-(aq) + X_2J$ $\Delta H_2 = -X_2$ J

Reaction 3: An aqueous solution of sodium hydroxide reacts with an aqueous solution of hydrogen chloride to form water and an aqueous solution of sodium chloride.

$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \longrightarrow H_2O + Na^+(aq) + Cl^-(aq) + X_3J$ $\Delta H_3 = -X_3$ J

Objectives

1. To determine the amount of heat absorbed or released when solid dissolves in water to form a solution.
2. To determine and compare the amount of heat involved in the three related reactions.
3. To verify Hess's Law using the amount of heat involved in the three reactions.

Materials and Apparatus

Three Styrofoam cups (group assignment)*	Ice
Glass stirring rod	NaOH
50 °C thermometer (0.1 deg. calibration)	HCl
Filter paper	
250-mL beaker	

*Insulated cover (Use the third Styrofoam cup as cover)

Procedure

A. Determination of the Heat Capacity of the Calorimeter, Cs

1. Put 100 mL of water into the Styrofoam cup. Allow the cup and the water to come to thermal equilibrium for about 5 minutes. Note the temperature (t_1). See Fig. 1.1.

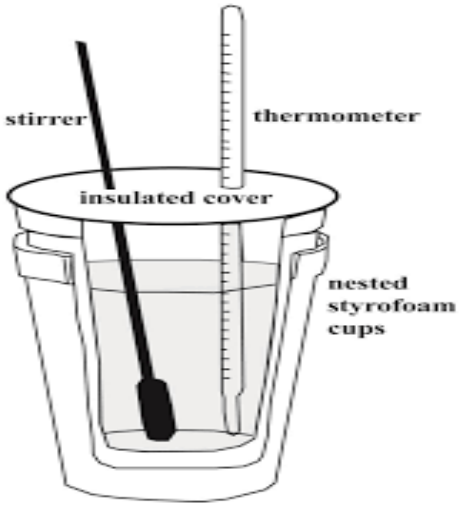

Figure 5.1 Coffee-cup Calorimeter Set-up

2. Place a piece of filter paper into a 250-mL beaker to serve as a lining. Place a 15.0–20.0 g of ice, cover with another filter paper, and weigh together (w_1).

3. Drop the ice into the Styrofoam cup with water. Stir the mixture and record the temperature at 30-seconds intervals for about 15 minutes or until thermal equilibrium is attained. While doing this, another member of the group may weigh the empty

beaker with filter paper (w_2). Note the constant temperature reached by the mixture in the Styrofoam cup (t_2).

B. Determination of the Heat of Reaction 1 (ΔH_1)

CAUTION: Sodium hydroxide (NaOH) is extremely corrosive to the skin and causes blindness.

1. Put 100 mL of water into the Styrofoam cup. Allow the cup and the water to come to thermal equilibrium. Note the temperature (t_1).

2. Weigh about 1.0 g (± 0.1) of solid NaOH as precisely and as quickly as possible. Use watch glass to contain the NaOH.

3. Pour the weighed NaOH into the water in the Styrofoam cup. Stir the mixture and record the highest temperature obtained (t_2). Before proceeding to Reaction 2, discard the solution and rinse the cup thoroughly with water. Dry the cup with tissue paper.

C. Determination of the Heat of Reaction 2 (ΔH_2)

1. Repeat steps 1, 2, and 3 of Part B, but substitute 100 mL of 0.25 M HCl instead of water in step 1. Assume that 100 mL of HCl solution weighs 100 g.

D. Determination of the Heat of Reaction 3 (ΔH_3)

1. Measure 50 mL of 0.5 M HCl into the Styrofoam cup and 50 mL of 0.50 M NaOH into a 250-mL beaker. Both solutions should be at, or slightly below, room temperature (t_1). Check this with the thermometer (rinse and dry the thermometer before changing from one solution to the other). Record the temperature (^oC).

2. Add the NaOH solution to the HCl solution in the Styrofoam cup. Mix quickly and note the highest temperature reached (t_2).

Treatment of Results

1. Solve for C_S, ΔH_1, ΔH_2 and ΔH_3

Determination of the Heat Capacity of Calorimeter, C_s

Using the relation: Heat lost = Heat gained

Heat lost by water + Heat lost by calorimeter = Heat gained by ice in melting + Heat gained by ice-water

$$m_w C_p \left(t_1 - t_2\right) + C_s \left(t_1 - t_2\right) = m_i H_f + m_i C_p \left(t_2 - t_{ice}\right)$$

where: m_w − mass of water (g)
C_p − specific heat of water (4.184 J/g-°C)
t_1 − initial temperature of water (°C)
t_2 – final temperature of water and ice mixture (°C)
t_{ice} – temperature of ice (0 °C)
C_s – heat capacity of calorimeter or calorimeter constant (J/ °C)
m_i – mass of ice (g)
H_f – heat of fusion of ice (333.5 J/g)

Determination of the Heat of Reaction

$$\Delta H_{Reaction} = \left(mC_p + C_S\right)\left(t_1 - t_2\right)$$

where: C_p − specific heat of water (4.184 J/g-°C)
m – for reaction 1, 100 g of water
for reaction 2, 100 g of HCl
for reaction 3, 100 g of HCl + NaOH
C_s – heat capacity of calorimeter or calorimeter constant from Part A
t_1 − initial temperature of water (°C)
t_2 – highest temperature obtained after mixing (°C)

2. Write the thermochemical equation of each reaction.
3. Compare ΔH_2 with (ΔH_1 + ΔH_3)
4. Calculate the percentage difference between ΔH_2 and (ΔH_1 + ΔH_3)

Questions

Suppose you used 4.0 g of NaOH in reaction 1,
(a) what would have been the number of Joules evolved in your experiment?
(b) what effect would this have on your calculations of ΔH_1, the heat evolved per mole?

DATA SHEET

EXPERIMENT 5
CALORIMETRY

Name: _____ **Instructor:** _____
Sec.: _____ **Group No.:** _____ **Date:** _____

A. Determination of the Heat Capacity of the Calorimeter

Volume of water used _____
Weight of beaker, filter paper, ice (m_1) _____
Weight of beaker, filter paper (m_2) _____
Weight of ice (m_1 - m_2) _____
Initial temperature (t_1) _____
Heat Capacity of Calorimeter (C_s) _____

Time Elapsed (min)	Temperature (°C)	Time Elapsed (min)	Temperature (°C)
0.5		4.5	
1.0		5.0	
1.5		5.5	
2.0		6.0	
2.5		6.5	
3.0		7.0	
3.5		7.5	
4.0		8.0	

Calculation:

B. Determination of the Heat of Reaction 1 (ΔH_1)

Volume of water used _____
Initial temperature of water (t1) _____
Highest temperature of NaOH solution (t2) _____
Weight of NaOH _____
Heat of Reaction 1 (ΔH1) _____

Calculation:

C. Determination of the Heat of Reaction 2 (ΔH_2)

Volume of HCl used _____
Initial temperature of HCl (t_1) _____
Highest temperature of HCl + NaOH (t_2) _____
Weight of HCl solution _____
Weight of NaOH _____
Heat of Reaction 2 (ΔH_2) _____

Calculation:

D. Determination of the Heat of Reaction 3 (ΔH_3)

Volume of 0.5M HCl used _____
Volume of 0.5M NaOH used _____
Initial temperature of HCl (t_1) _____
Initial temperature of NaOH (t_1) _____
Highest temperature of HCl + NaOH (t_2) _____
Heat of Reaction 3 (ΔH_3) _____

Calculation: