Lab: Determining Heat of Reaction using Calorimetry and Hess's Law

Purpose:

To measure and compare the amount of heat involved in three separate but related reactions.
To provide experimental verification of Hess's Law.

Background:

The foundation of the study of thermochemistry was laid by the chemist Germain Hess, who investigated heat in chemical reactions during the last century. One statement of the law that bears Hess's name says:

The enthalpy change for any reaction depends on the products and reactants and is independent of the pathway or the number of steps between the reactant and product.

In this experiment, the quantity of heat involved in three reactions will be measured and compared. These heats of reaction will be measured using a coffee cup calorimeter. The three reactions are shown below.

Reaction 1: The dissolving of solid sodium hydroxide in water.

$$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$$

Reaction 2: The reaction of solid sodium hydroxide with dilute hydrochloric acid.

$$NaOH(s) + H^+(aq) \rightarrow Na^+(aq) + H_2O(l)$$

Reaction 3: The reaction of sodium hydroxide solution with dilute hydrochloric acid solution.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Safety:

Hydrochloric acid and sodium hydroxide are corrosive. Avoid direct contact. If any touches your skin, wash it off immediately. Solid sodium hydroxide is especially dangerous because it absorbs moisture rapidly from the air, forming an extremely corrosive liquid. Avoid spilling this solid, and if a spill occurs, clean it up immediately. Be sure to close the lids of bottles of sodium hydroxide securely, immediately after using.

Dispose of solutions according to your teacher's instructions. A lab coat or apron is strongly recommended.

Procedure:

Part One and Part Two: ***The Dissolving of Solid Sodium Hydroxide***

The procedure for Parts One and Two are the same except that Part One will use 200 mL of water and Part Two will use 200 mL of 0.25 M hydrochloric acid.

1. Measure 200 mL of liquid (water or hydrochloric acid) into the nested coffee cup calorimeter. Stir carefully with the temperature probe until a constant temperature is reached. Measure and record this temperature.
2. Measure and record the mass of about 2 grams of solid sodium hydroxide. Perform this operation as quickly as possible since the solid absorbs moisture from the air very rapidly and forms a very corrosive liquid.
3. Place the solid sodium hydroxide into the liquid in the cups. Stir gently with the temperature probe until the solid is completely dissolved and record the highest temperature reached.
4. Discard the solution as directed and rinse the cup thoroughly with water.

Part Three: ***The Reaction of Sodium Hydroxide Solution with Hydrochloric Acid***

1. Accurately measure 100 mL of 0.50 M hydrochloric acid solution into the calorimeter.
2. Accurately measure 100 mL of 0.50 M sodium hydroxide into a 250 mL beaker.
3. Record the temperatures and volumes of each solution.
4. Add the sodium hydroxide solution to the acid solution in the Styrofoam cup. Stir the mixture with the temperature probe and record the highest temperature reached.
5. Discard the solution as directed and rinse the cup thoroughly with water.

Data:

Part 1		**Part 2**	
Volume of H_2O		Volume of 0.25 M HCl	
Mass of NaOH(s)		Mass of NaOH(s)	
Initial temperature		Initial temperature	
Final temperature		Final temperature	

Part 3	
Volume of 0.50 M HCl	
Volume of 0.50 M NaOH	
Initial temperature of HCl	
Initial temperature of NaOH	
Final temperature	

Post-lab and Data Analysis:

1. For Reaction 1, calculate each of the following.
    a. The heat flow, q_{sys}, in kilojoules. Assume that the solution has the same density and specific heat of water.

    b. The number of moles of sodium hydroxide used.

    c. The heat of reaction, ΔH, in kJ/mol.

2. For Reaction 2, calculate each of the following.
    a. The heat flow, q_{sys}, in kilojoules. Assume that the solution has the same density and specific heat of water.

    b. The number of moles of sodium hydroxide used.

    c. The heat of reaction, ΔH, in kJ/mol.

3. For Reaction 3, calculate each of the following.
    a. The heat flow, q_{sys}, in kilojoules. Assume that the solution has the same density and specific heat of water.

    b. The number of moles of sodium hydroxide used.

c. The heat of reaction, ΔH, in kJ/mol.

4. Reaction 2 could take place in one step as it was performed in Part 2. Or Reaction 2 could be obtained by combining Reactions 1 and 3. Add the balanced equations of Reactions 1 and 3 to show that their sum would yield the balanced equation of Reaction 2.

5. In light of your answer to Question 4, Hess's Law and the ΔH values calculated for Reactions 1 and 3, calculate ΔH for Reaction 2.

6. Compare the ΔH for Reaction 2 obtained in Question 5 to that of Question 2. Would you expect the values to be the same? Explain your reasoning.

7. Suppose 8 g of sodium hydroxide had been used in Part One instead of 2 g. Would ΔH be greater than, less than or equal to that obtained in Question 1? Explain your reasoning.

8. Would ΔH of Reaction 3 become more positive, more negative or remain the same if the concentration of NaOH was actually greater than 0.50 M. Explain your reasoning.