The Heat of Reaction

When a reaction can be expressed as the algebraic sum of two or more simpler reactions, then its heat of reaction will also be the sum of the heats of these simpler reactions. This generalization has been found to be true for every reaction and is called **Hess's Law of Heat Summation**. In this experiment you will use this generalization to determine the heat of reaction for a reaction that is difficult to determine directly by measuring and comparing the quantity of heat involved in several chemical reactions. You will determine the heats of reaction using a simple nested Styrofoam cup calorimeter. Assume the specific heat capacity of each solution is 4.18 J/g°C and assume the density of any solution is 1.00 g/mL. Your accuracy (percent error) for your final answer will be marked so measure carefully! The reactions being used are as follows:

LAB SAFETY

Hazards:

Biohazardous:	
Compressed Gas:	
Corrosive:	$HCl_{(aq)}$, $NaOH_{(aq)}$, $NaOH_{(s)}$
Dangerously Reactive:	
Flammable/Combustible:	
Irritant:	
Oxidizer:	
Poisonous:	

Personal Protective Equipment Needed:
☐ Apron ☐ Gloves ■ Glasses

Rxn	Process	Equation	Enthalpy (kJ/mol)
1	Solid sodium hydroxide is dissolved in water to form aqueous ions.	$NaOH_{(s)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$	$\Delta H_1 = ?$
2	Solid sodium hydroxide reacts with aqueous hydrogen chloride.	$NaOH_{(s)} + H^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow H_2O_{(l)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)}$	$\Delta H_2 = ?$
3	Aqueous sodium hydroxide reacts with aqueous hydrogen chloride.	$Na^{+}_{(aq)} + OH^{-}_{(aq)} + H^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow H_2O_{(l)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)}$	$\Delta H_3 = ?$

<u>Procedure</u>:

1. Compete the following data table as you conduct the experiment and submit a copy when you are finished:

Your Name: _______________________ **Partner's Name:** _______________________

Measurement	Reaction		
	1. Dissolving NaOH	2. $NaOH_{(s)} + HCl_{(aq)}$	3. $NaOH_{(aq)} + HCl_{(aq)}$
Mass of Empty Cup Calorimeter (g)			
Mass of Cup Calorimeter and Solution (g)			
Mass of Solute Used (g)			X
Initial Solution Temperature °C			
Final Solution Temperature °C			

Reaction 1: Dissolving NaOH

1. Rinse to clean and gently dry a Styrofoam cup. Nest it inside another Styrofoam cup (one inside the other). Record the mass of your empty **<u>Styrofoam cup calorimeter</u>**.
2. Use a clean graduated cylinder to add about 100 mL of distilled water into the Styrofoam cup calorimeter. Record the mass of the water (identified as a solution in the table above) and the Styrofoam cup calorimeter.
3. Stir the water in the cup calorimeter carefully with a clean, dry thermometer until a constant temperature is reached. Record the initial temperature.
4. Mass precisely about 3.0 g of solid NaOH in a clean and dry weighing boat. Do this rapidly as NaOH is hygroscopic. Record this mass of solute used.
5. Quickly, pour the NaOH into the water of the Styrofoam cup calorimeter. Stir gently with the thermometer and record the maximum or minimum temperature obtained.
6. Discard the final solution in the Neutralization Waste Beaker and rinse with tap water.

Reaction 2: $NaOH_{(s)} + HCl_{(aq)}$

7. Repeat the steps for reaction 1, but substitute about 100 mL of 0.750 M $HCl_{(aq)}$ solution for distilled water.

Reaction 3: $NaOH_{(aq)} + HCl_{(aq)}$

8. Rinse to clean and gently dry a Styrofoam cup. Nest it inside another Styrofoam cup (one inside the other). Record the mass of your empty **Styrofoam cup calorimeter**.
9. Use a clean graduated cylinder to add about 50 mL of 1.50 M $HCl_{(aq)}$ into a Styrofoam cup calorimeter.
10. Stir the $HCl_{(aq)}$ solution in the cup calorimeter carefully with a clean, dry thermometer until a constant temperature is reached. Record the initial temperature.
11. Use a clean graduated cylinder to obtain about 50 mL of 1.50 M $NaOH_{(aq)}$.
12. Stir the $NaOH_{(aq)}$ solution in the graduated cylinder carefully with a clean, dry thermometer until a constant temperature is reached. Record the initial temperature. Each solution should be the same temperature or very close. Record the average temperature of these two solutions as the initial solution temperature.
13. Pour the $NaOH_{(aq)}$ solution into the Styrofoam cup calorimeter. Stir gently with a clean, dry thermometer and record the maximum or minimum temperature obtained.
14. Record the mass of the Styrofoam cup calorimeter containing the final solution.
15. Discard the final solution in the Neutralization Waste Beaker and rinse with tap water.

The Write-up: (show all your math in an **Appendix**)

1. Include an underlined title and underline date.

/10 2. Copy and complete the data table (using a ruler). Don't forget units and include a complete table title.

/3 3. Use chemical equations to show how reaction equation 2 is the sum of reactions equations 1 and 3.

/6 4. For each reaction, calculate the amount of heat absorbed or given off by the solution using the formula:

$$Q_{solution} = m_{solution}\, c_{solution}\, \Delta T_{solution}.$$

/6 5. For each reaction, calculate the heat released or absorbed per mole of NaOH used.

/4 6. Use your molar value of ΔH_2 as the expected result and your molar value of $(\Delta H_1 + \Delta H_3)$ as the observed result to determine your percent error for the experiment.

$$\textit{Percentage Error} = \left| \frac{\text{observed - expected}}{\text{expected}} \right| \times 100\%$$

/2 7. Explain why it is better to use ΔH_2 rather than a tabled value for this reaction as the expected result.

/3 8. Identify the source of error (not human) that had the most impact on your results and explain how it would affect your results.

$A \rightarrow C$
$C \rightarrow D$
$D \rightarrow B$
$A \rightarrow B$