Heats of Reaction Lab – NaOH and HCl Report

Purpose: To measure the heats of reaction for three related exothermic reactions and to verify Hess's Law of Heat Summation.

$NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$ $\Delta H = -10.6$kcal/mol
$NaOH_{(s)} + H^+_{(aq)} + Cl^-_{(aq)} \rightarrow H_2O + Na^+_{(aq)} + Cl^-_{(aq)}$ $\Delta H = -23.9$kcal/mol
$Na^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)} \rightarrow H_2O + Na^+_{(aq)} + Cl^-_{(aq)}$ $\Delta H = -13.3$kcal/mol

Background: Energy changes occur in all chemical reactions; energy is either absorbed or released. If energy is released in the form of heat, the reaction is called *exothermic*. If energy is absorbed, the reaction is called *endothermic*.

Materials:

- spatula
- 1 Styrofoam cup
- 1 100-mL graduated cylinder
- 1 400-mL beaker
- 1 50-mL beaker
- thermometer
- sodium hydroxide pellets (NaOH)
- 1.0 M sodium hydroxide (NaOH)
- 0.5M Hydrochloric acid (HCl)
- 1.0 M hydrochloric acid (HCl)
- distilled water
- digital balance

Procedures:

Reaction 1:

a. Measure 100mL of distilled water into a plastic-foam cup. Place the cup inside a 400mL beaker for support. This assembly, together with a thermometer, will serve as your calorimeter.

b. Measure and record the mass of a 50mL beaker to the nearest 0.01g. CAUTION: *NaOH is extremely corrosive*. Using a spatula, add as close to 2.00g as possible of sodium hydroxide pellets to the beaker. Measure and record the combined mass of the beaker and sodium hydroxide to the nearest 0.01g. (Do this operation as quickly as possible to avoid error due to absorption of water by the NaOH.)

c. Measure and record the temperature of the water in the foam cup to the nearest 0.5°C. Add the NaOH pellets to the water in the calorimeter. Stir the mixture gently with the thermometer until all the solid has dissolved. CAUTION: *Hold the thermometer with your hand at all times.* Record the highest temperature reached during the reaction.

Reaction 2:

a. CAUTION: *Low-concentration hydrochloric acid can irritate your skin.* Measure 100mL of 0.5MHCl into the plastic foam cup and place the cup inside a 400mL beaker.

b. Using a spatula measure out 2.00g of solid NaOH pellets. CAUTION: *NaOH is extremely corrosive*.

c. Measure and record the temperature of the HCl solution in the foam cup.

d. Add the NaOH pellets to the acid solution and stir *gently* until the solid is dissolved. Measure and record the highest temperature reached by the solution during the reaction.

Reaction 3:

a. Place the plastic foam cup inside a 400mL beaker. Measure 50mL of 1.0M HCl into the cup. Rinse the graduated cylinder and fill with 50mL of 1.0M NaOH.

b. Measure and record the temperature of the HCl solution (in the cup) and the NaOH solution (in the cylinder) to the nearest 0.5°C. Rinse the thermometer between measurements.

c. Pour the NaOH solution into the foam cup. Stirring the mixture gently, measure and record the highest temperature reached.

Data Table 1: Observations

	Reaction 1	Reaction 2		Reaction 3
Volume of Water (ml)		----------	Volume 1M HCl (ml)	
Volume 0.5M HCl (ml)	----------		Initial Temp HCl ˚C	
Mass of NaOH (g)			Volume 1M NaOH (ml)	
Initial Temp ˚C			Initial Temp NaOH ˚C	
Final Temp ˚C			Average Initial Temp	
			Final Temp ˚C	

Analysis:

1. Determine the **change in temperature** for each reaction. Show work here and record your answer in Data Table 2.

2. Calculate the **mass** of the reaction mixture in each reaction first by determining the volume of the *solution* and then assuming that the density of the solution is the same as pure water (1.0g/ml). Show work here and record your answer in Data Table 2.

3. Calculate the total **heat released** in each reaction. Assume that the specific heat of the solution is the same as for pure water (4.18J/gK). Use $q=mc\Delta T$. Show work here and record your answer in Data Table 2.

4. Calculate the number of **moles of NaOH** used in reactions one and two. Show work here and record your answer in Data Table 2.

5. In reaction three, the **number of moles of NaOH** can be calculated from the concentration of the solution (1.0M = 1.0mole/L) and the volume used. The calculation is below. Enter the result into Data Table 2.

$$\frac{50.0\text{ml NaOH}}{1} \times \frac{1\text{mol NaOH}}{1000\text{ml NaOH}} = 0.050\text{mol NaOH}$$

6. Calculate the **molar enthalpy in Joules per mole of NaOH** for each reaction. Show work here and record your answer in Data Table 2.

Data Table 2: Results of Analysis

Reaction	ΔT (˚C)	Mass (g)	Heat Released (J)	Moles NaOH	Molar Enthalpy (J/mol)
1					
2					
3					

Conclusion:

1. Using Hess's Law of Heat Summation, check to see how closely that the molar enthalpy of NaOH in reaction one and three add up and equal to the molar enthalpy of NaOH in reaction two.
2. If the molar enthalpy of NaOH in reaction one and three DO NOT add up to equal the molar enthalpy of NaOH in reaction two, what factors might account for any differences?
3. Calculate the percent difference between the molar enthalpy of reaction two and the sum of the molar enthalpies of reactions one and three. Assume that the molar enthalpy from reaction two is correct.

$$\text{Percent difference (in evolved heat)} = \frac{|\ \text{heat}_2 - (\text{heat}_1 + \text{heat}_3)\ |}{\text{heat}_2} \times 100$$

4. Would changing the amount of NaOH in reaction #1 affect the value obtained for the molar enthalpy of NaOH? EXPLAIN.
5. Taking into account your answer in question four of the ANALYSIS, **explain** why you were asked to use exactly 2.00g of NaOH in reactions one and two, and an equivalent number of moles of NaOH in reaction three.