**Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Date \_\_\_\_\_\_\_\_\_\_\_Period \_\_\_\_\_**

**Investigating Hess’s Law**

The *net energy change* in a reaction or process does not depend on how the change occurs but only on the initial reactants and final products. This is the premise of Hess’s Law, which states that, “the change in energy is the same whether a reaction takes place in one step or in a series of steps” (Zumdahl, 2006). When a reaction takes place in a series of steps, the sum of the heat changes for all of the steps should equal the overall heat change.

An example of this is the reaction in which nitrogen gas and oxygen gas combine to form nitrogen dioxide:

N2(g) + 2O2(g) → 2NO2(g) ∆H = +68 kJ

This reaction can also be carried out in two steps:

Step 1: N2 (g) + O2 (g) → 2NO(g) ∆H = +180 kJ

Step 2: 2NO (g) + O2 (g) → 2NO2(g) ∆H = -112 kJ

If we add step 1 and step 2, we get the original reaction. Therefore, if we add ∆H 1 and ∆H 2 we get the original ∆H.

Step 1: N2 (g) + O2 (g) → 2NO(g) ∆H = +180 kJ

Step 2: 2NO (g) + O2 (g) → 2NO2(g) ∆H = -112 kJ

Sum of Step 1 and Step 2: N2 (g) + 2O2 (g) → 2NO2(g) Sum of ∆H 1 and ∆H 2 = +68 kJ

In this experiment, you will use a Styrofoam-cup calorimeter to measure the change in heat in three separate reactions. When two of these reactions are combined, the overall reaction is the same as the third reaction. Therefore, according to Hess’s Law, the sum of the heats of reaction for the two combined reactions should be equal to the heat of reaction for the third reaction*.* The primary objective of this experiment is to confirm or verify Hess’s Law.

**q = s • m • ∆T s water = 4.184 J/g ºC q rxn = - q H2O**

Pre-Lab Questions:

1). 25.0 g NaCl is dissolved in water. Calculate the moles of NaCl that dissolved in water. ***Show your work!***

2). 25.0 mL of 1.5 M NaCl solution is used in an experiment. Calculate the moles of NaCl used. ***Show your work!*** Hint: Write formula that includes volume and molarity!

3). Determine the heat of reaction, ∆H, that occurs in 50.0 mL water starting at 23.0°C an ending at 43.5°C.   
The density of water is 1.0 g/mL.

4). Combine the following two equations to determine the heat of this reaction: **H2O(l) → H2O(g)**

H2(g) + ½ O2(g)🡪H2O(l) ∆H = - 283 kJ

H2(g) + ½ O2(g) → H2O(g) ∆H = - 242 kJ

5). Do the same with the three reactions that will occur in the calorimeter today.   
 Show how to combine reactions A and B together to obtain reaction C:

***Reaction C: NaOH(s) + HCl(aq)  H2O(l) + NaCl(aq)***

Reaction A: NaOH(s)  NaOH(aq)

Reaction B: NaOH(aq) + HCl(aq) H2O(l) + NaCl(aq)

**Equipment and Materials:**

Balance thermometer 0.5M HCl solution Solid NaOH

Styrofoam cup calorimeter safety goggles 1.0M HCl solution 1.0M NaOH solution

Graduated cylinder – 100mL scoopula Deionized water

**Safety:**

Solid NaOH and concentrated aqueous solution of sodium hydroxide are highly corrosive to the skin and eyes. Wear safety goggles at all times. IF the solution makes contact with bare skin, rinse area with plenty of water.

**Procedure:**

**Part A**

1. Measure 100.0mL of deionized water using the graduated cylinder.
2. Measure the mass of the empty styrofoam cup, add the deionized water and measure the mass of the water and the cup.
3. Weigh a piece of weigh paper and record.
4. Using a spatula, measure 2.00g of solid NaOH pellets onto the weigh paper. Record the **exact mass** of paper and NaOH.
5. Measure the temperature of the water in the Styrofoam calorimeter and record as the initial temperature for Part A.
6. Add the solid NaOH pellets to the water in the cup. Close the lid of the calorimeter and stir to dissolve the NaOH. Monitor the temperature of the water inside the cup until the temperature stops rising. Record the highest temperature as the final temperature for Part A.
7. Discard the solution by washing it down the drain while running water and rinse the cup.

**Part B**

1. Measure 50.0mL of 1.0M HCl and pour it into the Styrofoam cup. Record the temperature of the acid as the initial temperature for Part B.
2. Add 50.0mL of 1.0M NaOH solution to the HCl solution. Close the lid of the calorimeter and stir. Record the highest temperature as final temperature of Part B
3. Measure the mass of the solutions and the cup.
4. Pour the solution down the sink while running water and rinse the cup.

**Part C**

1. Measure 100.0mL of 0.5M HCl using the graduated cylinder and pour the solution into the empty cup.
2. Measure the mass of the solution and the cup before starting the reaction and record.
3. Measure the temperature of the acid solution in the cup and record as initial temperature for Part C.
4. Measure 2.00g of solid NaOH pellets (steps 3 and 4 in Part A) and record.
5. Add the NaOH to the acid solution, close the lid to the calorimeter and stir.
6. Measure the highest temperature of the solution in the cup and record as final temperature for Part C.
7. Discard the solution by washing it down the drain while running water and rinse the cup.

**Data Table**: Temperatures and Masses for Parts A, B, C

|  |  |  |  |
| --- | --- | --- | --- |
| **Object measured** | **Reaction A**  NaOH(s) 🡪 NaOH (aq) | **Reaction B**  NaOH(aq) + HCl(aq) | **Reaction C**  NaOH(s) + HCl(aq) |
| **Mass of empty cup** |  |  |  |
| **Mass of water or solution and cup** |  |  |  |
| **Mass of weigh paper** |  | ----------------------------- |  |
| **Mass of NaOH and paper** |  | ----------------------------- |  |
| **Initial Temperature water or solution (Ti)** |  |  |  |
| **FinalTemperature of solutoin (Tf)** |  |  |  |
| **Volume of 1.0 M NaOH** | ---------------------------- |  | ------------------------------ |

**Calculations: Complete the following calculations for Parts A, B and C according to the LHS EDR:**

1. Write a balanced chemical equation for each reaction.
2. Determine the mass of water (or solution) used for each reaction.
3. Determine the mass of NaOH used in reactions A and C.
4. Determine the temperature change of the solution for each reaction.
5. Determine the heat released or absorbed by the aqueous solution (assume the specific heat of the solutions in the calorimeter is equal to the specific heat of water, 4.184J/g˚C) for each reaction.
6. Convert joules of heat released into kilojoules.
7. Calculate the number of **moles of NaOH** reacted (in reaction B, use M=mol/L).
8. Calculate the **kilojoules of heat per mole of NaOH** released, to determine the ∆H for each reaction.
9. Using Hess’s Law show how reactions A and B combine to form reaction C.
10. Combine the ∆H’s for reactions A and B and compare to the ∆H for reaction C.
11. Calculate the percent error using the sum of ∆H’s for **A and B as experimental** and the ∆H for reaction **C as accepted**.

**Analysis:**1. State the purpose of this lab.

2. Describe the reaction and the temperature change of the water for the three reactions you performed. (Support with numbers)

1. State whether these reactions are endothermic or exothermic and explain your reasoning.
2. Did your results verify Hess’s Law? Show with numbers whether or not the sum of ΔHs for reactions A and B equals the ΔH for reaction C.
3. State whether the ΔH for reaction C determined experimentally is greater or less than the accepted value

of -79.8 kJ/mol. Suggest an error that would cause this difference and explain how the error affected the value. Include numbers in answer.