Hess's Law

Hess's Law is based on the conservation of energy. The conservation of energy states that energy is not lost or gained but only changed in form. Hess's Law demonstrates this through the following explanation. If a reaction is the sum of two or more reactions then the sum of their enthalpies are equal to the enthalpy of the reaction. This can be demonstrated by the following set of reactions.

(eq 1)	$H_2O(l) \rightarrow H_2(g) + 1/2O_2(g)$	$\Delta H = ?$
(eq 2)	$H_2O(l) \rightarrow (H)_2O(g)$	$\Delta H = +44.0$ kJ
(eq 3)	$H_2O(g) \rightarrow H_2(g) + 1/2\ O_2(g)$	$\Delta H = +241.8$ kJ

By adding equation 2 and 3 together and canceling any substances that are the same on opposite sides of the equation equation one is produced.

(eq 4)	$H_2O(l) + H_2O(g) \rightarrow H_2O(g) + H_2(g) + 1/2\ O_2(g)$	$\Delta H = 44.0$ kJ + 241.8 kJ
(eq 5)	$H_2O(l) \rightarrow H_2(g) + 1/2\ O_2(g)$	$\Delta H = +285.8$ kJ

When equation 2 and 3 are added equation 4 is generated. By canceling the substances that are the same on opposite sides the final equation (5) is equal generated and is equal to equation 1. Therefore the change in enthalpy for equation 1 would be 285.8 kJ.

Objective: Use Hess's Law to determine the enthalpy of reaction.

Material:

CBL	2 - 100 mL Beakers	1.0 M NaOH
2 Temperature Probes	100 mL Graduated cylinder	1.0 M NH_3
Graph-Link Cable	1.0 M NH_4Cl	1.0 M HCl
Coffee Cup Calorimeter		

Procedure:

1. Wear Goggles and Apron. **All materials can cause chemical burns.**
2. Connect the Graph-Link Cable to the CBL.
3. Connect a temperature probe to the CBL.

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Part 1:

1. Acquire 50 mL of 1.0 M NaOH and place in a 100 mL beaker.
2. Acquire 50 mL of 1.0 M HCl and place in a second 100 mL beaker.
3. Place the temperature probe into the calorimeter
4. Pour the NaOH into the calorimeter
5. Double click on the data table below.
6. Click on the Quick Data icon  .
7. Set up the Quick Data window.

Probe	**Temperature**
Samples	**300**
Collection Interval	**0.25**
x-List	**Time**
y-List	**Temp**
Collection Style	**Real Time**
Units	**C**

8. Click on Run and pour the HCl into the calorimeter.

	Trial 1 NaOH+ HCl	Units	Trial 2 NH3+HCl	Units	Trial 3 NaOH+NH4Cl	Units
Mass						
Initial Temp						
Final Temp						
DT						
Specific Heat	4.18	J/gC	4.18	J/gC	4.18	J/gC
Energy						

Sum of heats	
T2 + T3	
Energy T1	
% Error	

Part 2:

Repeat part one by replacing NaOH with NH_4OH. Change the List Names to Time2 and Temp2

Part 3:

Repeat part one replace HCl with NH_4Cl. Change the List Names to Time3 and Temp3

Analysis:

1. Determine the Initial Temperature for trial one. In cell B4 type **= min(I2:I301)** and press Enter.

2. Determine the Final or Maximum temperture for trial one. In cell B5 type **= max(I2:I302)** and press Enter.

3. Calculate the change in temperature for reaction one. In Cell B6 type **= B5-B4** and press Enter.

4. Calculate the Energy given off by reaction one by using the equation $E=m\,C_q\,\Delta T$. In Cell B8 type **= B2*B7*B6** and press Enter.

5. Write balanced chemical equation for the reactions that took place in your experiment.
   Part 1. $NaOH(aq) + HCl(aq) \rightarrow$
   Part 2. $NH_4OH(aq) + HCl(aq) \rightarrow$
   Part 3. $NaOH(aq) + NH_4Cl(aq) \rightarrow$

6. Repeat the procedure for calculating the initial temperture, final temperature, change in temperature for all other reactions. The Temperature data for reaction two and three are in different columns.

7. In the data table calculate the sum of the heats for trial 2 and 3. In cell B11 type **= D8+F8.**

8. Calculate the Percent error using the following equation.

$$\frac{\text{Theoretical - Experimental}}{\text{Theoretical}} \text{ x } 100\% = \%\text{ Error}$$

Theoretical is the sum of trial 2 and 3. Experimental is the enthalpy of reaction for trial 1.

Questions:

1. Explain why Hess's Law works for this reaction using the First Law of Thermodynamics.
2. Why did we use a specific heat of the system to be 4.18 J/g^{o}C?
3. Define the following terms as they relate to the Hess's Law experiment performed.
   A. Enthalpy
   B. Heat of formation
   C. Heat of reaction
   D. Exothermic
   E. Endothermic
   F. System
   G. Surroundings
4. Where these reactions enothermic or exothermic? What evidence demonstrates this?