10. Additivity of Heats: Hess's Law

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10. Additivity of Heats of Reaction: Hess's Law

Purpose:

To practice applying Hess's Law using a coffee cup calorimeter and confirming that the heat of one reaction should be equal to the sum of the heats for the other reactions.

Pre-Lab:

(1) $Na^{+}_{(aq)} + OH^{-}_{(aq)}$ --> $NaOH_{(s)}$ $-\Delta H_1$

(2) $NaOH_{(s)} + H^{+}_{(aq)} + Cl^{-}_{(aq)}$ --> $H_2O_{(l)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)}$ ΔH_2

(3) $Na^{+}_{(aq)} + OH^{-}_{(aq)} + H^{+}_{(aq)} + Cl^{-}_{(aq)}$ --> $H_2O_{(l)} + Na^{+}_{(aq)} + Cl^{-}_{(aq)}$ ΔH_3

Procedure:

1. Wear protective equipment.
2. Open Vernier Graphical Analysis. Connect the temperature probe.
3. Use a utility clamp and a slit stopper to suspend the temperature probe from a ring stand.
4. Place a Styrofoam cup into a 250mL beaker. Measure out 100.0mL of distilled water into the cup. Lower the temperature probe into the solution.
5. Weigh out around 2 grams of solid sodium hydroxide and record the mass to the nearest 0.01g.
6. Begin collecting data and obtain the initial temperature, t_1. After obtaining the initial temperature, add the NaOH to the cup. Stir continuously until the temperature has maximize and has begun to drop. Record the maximum temperature, t_2. After 3.3-4 minutes, data collection is completed.
7. Graph temperature vs. time(done automatically). Examine the data points along the curve to verify the values of t_1 and t_2.

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8. Rinse and dry the temperature probe, cup, and stirring rod. Dispose of the solution as directed.

9. Repeat steps 4-8, using 100.0mL of 0.5M hydrochloric acid instead of water. Use the same amount of NaOH.

10. Repeat steps 4-8, instead using 50.0mL of 1.0M HCl, and using 50.0mL of 1.0M NaOH.

Observations:

Combining the water and NaOH creates some bubbles. Combining 1.0M HCl and NaOH turns a litle pink.

Data:

	Reaction 1	**Reaction 2**	**Reaction 3**
Mass NaOH	2.00g	2.00g	
Mass Total	102g	102g	100g
Final Temperature	25.073 ^oC	31.593 ^oC	27.357 ^oC
Initial Temperature	20.675 ^oC	20.622 ^oC	20.504 ^oC
Change in Temperature	4.397 ^oC	10.972 ^oC	6.853 ^oC

Calculations:

$Mass_{R1}$= 100mL*1.00g/mol=100g +2.00g = 102g

$Mass_{R2}$= 100mL*1.00g/mol=100g +2.00g = 102g

$Mass_{R3}$= 50mL*1.00g/mol=50g *2=100g

q_{R1}= 4.18*102*4.397 =1875J /1000=1.875kJ

q_{R2}= 4.18*102*10.972 =4678J /1000=4.678kJ

q_{R3}=4.18*100*6.853 =2865J /1000=2.865kJ

ΔH=-q   q=-ΔH

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ΔH_{R1}= -1.875 kJ

ΔH_{R2}= -4.678 kJ

ΔH_{R3}= -2.865 kJ

mol_{R1}=2.00/(22.99+16.00+1.008)= 0.05 mol

mol_{R2}=2.00/(22.99+16.00+1.008)= 0.05 mol

mol_{R3}=1.0*50.1000= 0.05 mol

$\Delta H/mol_{R1}$=-1.875/0.05= -37.5 kJ/mol

$\Delta H/mol_{R2}$=-4.678/0.05= -93.6 kJ/mol

$\Delta H/mol_{R3}$=-2.865/0.05= -57.3 kJ/mol

$-\Delta H_{R1}$ ΔH_{R2} ΔH_{R3}

-37.5+-57.3= -94.8 kJ/mol

37.5+-93.6= -56.1 kJ/mol

|-94.8+93.6| / |-93.6| *100= 1.28% error

Conclusion:

The purpose of the lab was to practice applying Hess's Law and verifying that the heat of a reaction is equal to the sum of the other reactions. We achieved this by using a coffee cup calorimeter to combine NaOH with water and HCl and using a thermal probe to measure the initial and final temperature, which was used along with the mass or volume of NaOH, to find the heat released, which was used to find ΔH. We then used the mass of NaOH to find the

ΔH/mol. We then added two reactions and compared them against the third to verify the data/calculations.

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We ended up with a 1.28% error, meaning some heat was probably lost, though it was close. This error could stem from inaccurate measuring of the NaOH or HCl, but it is more likely from losing heat to the Styrofoam cup or the atmosphere. If I were to do this lab again, I would use more accurate measuring tools, something that would absorb or lose less heat, like 2 coffee cups, and a more enclosed environment, such as a sealed container to minimize heat lost to the atmosphere.