

CHEM P106

Hess's Law

Final Report

Student Name Irene Mendoza
Student ID 154855
Lesson Hess's Law
Institution Porterville College
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Course CHEM P106
Instructor Charles Grove

Test Your Knowledge

1. Match each term with the best description.

States the total change in enthalpy is independent of the pathway	1	Hess's Law
The unit of measure for change in the enthalpy according to the International System of Units	2	Joule
Reaction that absorbs heat from the surrounding environment	3	Endothermic
The study of heat that accompanies chemical reactions	4	Thermochemistry
Reaction that releases heat to the surrounding environment	5	Exothermic
The internal energy of a system that includes heat plus the product of pressure and volume	6	Enthalpy

2. Categorize each statement as representing an exothermic or endothermic reaction.

Exothermic		Endothermic	
1	Temperature increases	2	Heat is absorbed from surroundings
	Heat is released to surroundings		Temperature decreases
	The change in enthalpy is a negative number		The change in enthalpy is a positive number

3. Match term with the correct equation.

$= \text{Moles of solute (mol)} / \text{volume of solution (L)}$	1	Molarity
$= \text{Final temperature} - \text{Initial temperature}$	2	Change in temperature
$= (\text{mass of solution}) \times (\text{specific heat}) \times \Delta T$	3	Change in enthalpy
$\frac{\text{Experimental value} - \text{Theoretical value}}{(\text{Theoretical value})} \times 100\%$	4	Percent Error
$= H_{\text{products}} - H_{\text{reactants}}$	5	Heat gain or loss

Exploration

1. When an _____ reaction occurs in an aqueous solution, heat will be released to the water.

- endothermic
- exothermic

2. Enthalpy is the external energy of the system, E , which includes heat plus the product of pressure and volume.

- True
 False

3. The change in enthalpy of a reaction is equal to the enthalpy of the reactants minus the enthalpy of the products.

- True
 False

4. When a reaction is exothermic, the enthalpy of the products is _____ the reactants.

- greater than
 less than
 equal to

5. Hess's law states that the total change in enthalpy is independent of the pathway.

- True
 False

Exercise 1

1. What were the maximum temperatures for each of the reactions? Use the scatter plots in Graph 1, Graph 2, and Graph 3 to support your answers.

reaction 1 = $(35 - 23) = 12.0$
reaction 2 = $(23 - 18) = 5.0$
reaction 3 = $(26.6 - 23) = 3.6$

2. Calculate the heat loss or heat gain of the 3 solution mixtures (q_{rxn}). Then calculate the ΔH for each reaction. Write the calculations on a sheet of paper showing all of your work. Take a photo of your work for each reaction and upload the images into Photo 1, Photo 2, and Photo 3.

3. Use Hess's law and your determination of ΔH for the first 2 reactions to determine ΔH for the third reaction:



-49.223+-30.764=-79.987kj/mole

4. Compare the results of question 3 with the experimental results of the reaction:



The value is higher than the practical valu

5. Use the thermodynamic quantities given below to calculate the theoretical ΔH for this reaction:



- ΔH°_f for NH_3 (aq) = - 80.29 kJ/mol
- ΔH°_f for HCl (aq) = - 167.2 kJ/mol
- ΔH°_f for NH_4^+ (aq) = - 132.5 kJ/mol
- ΔH°_f for Cl^- (aq) = - 167.2 kJ/mol

+247.49+-299.7=-52.21kj/mol

6. What is the percent error of experimental results when using the theoretical value calculated in Question 5?

23.567%

7. Were the reactions performed in this laboratory exercise exothermic or endothermic? How could you determine this?

The reaction were exothermic since there was an increase in temperature .and Heat change is negative

8. Define Hess's law. Did your experimental results support Hess's law? Use your data to explain your answer.

states that the energy change in an overall chemical reaction is equal to the sum of the energy changes in the individual reactions comprising it.

9. What are some possible sources of error in this experiment?

some heat was absorbed by the apparatus
impurities of the reactant
incomplete reaction by reactants

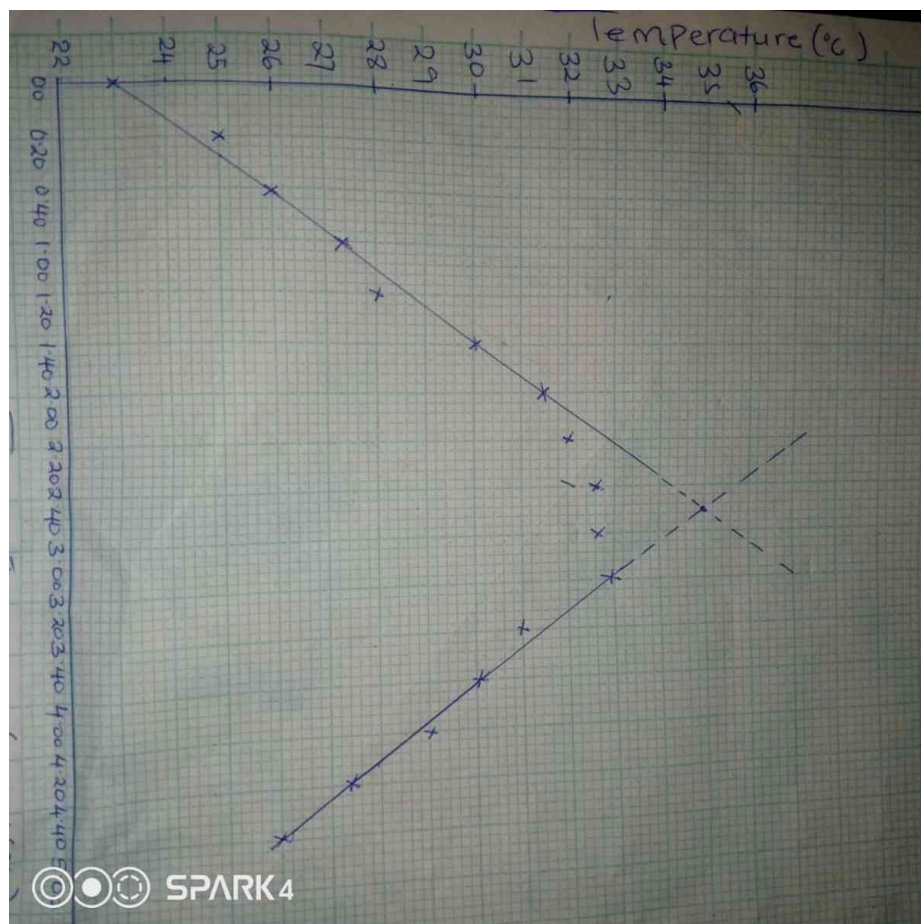
Data Table 1: Temperature (°C) of the Solution (NaOH + HCl)

Initial Temperature of NaOH (°C)	23.0
Initial Temperature of HCl (°C)	23.0
Average Initial Temperature of Two Separate Solutions (°C)	23.0
Highest Temperature of Mixture (May Be Extrapolated from Graph) (°C)	35.0
Change in Temperature of Mixture (°C), ΔT	12

Data Table 2: Temperature of Solution Every 20 Seconds

Time after mixing (min:sec)	Temperature (°C)
Initial	23.0
0:20	25.0
0:40	26.0
1:00	27.5
1:20	28.0
1:40	30.0
2:00	31.5
2:20	32.0
2:40	32.5
3:00	32.5
3:20	33.0
3:40	31.0
4:00	30.0
4:20	29.0
4:40	27.5
5:00	26.0

Graph 1: Reaction 1 (NaOH + HCl)



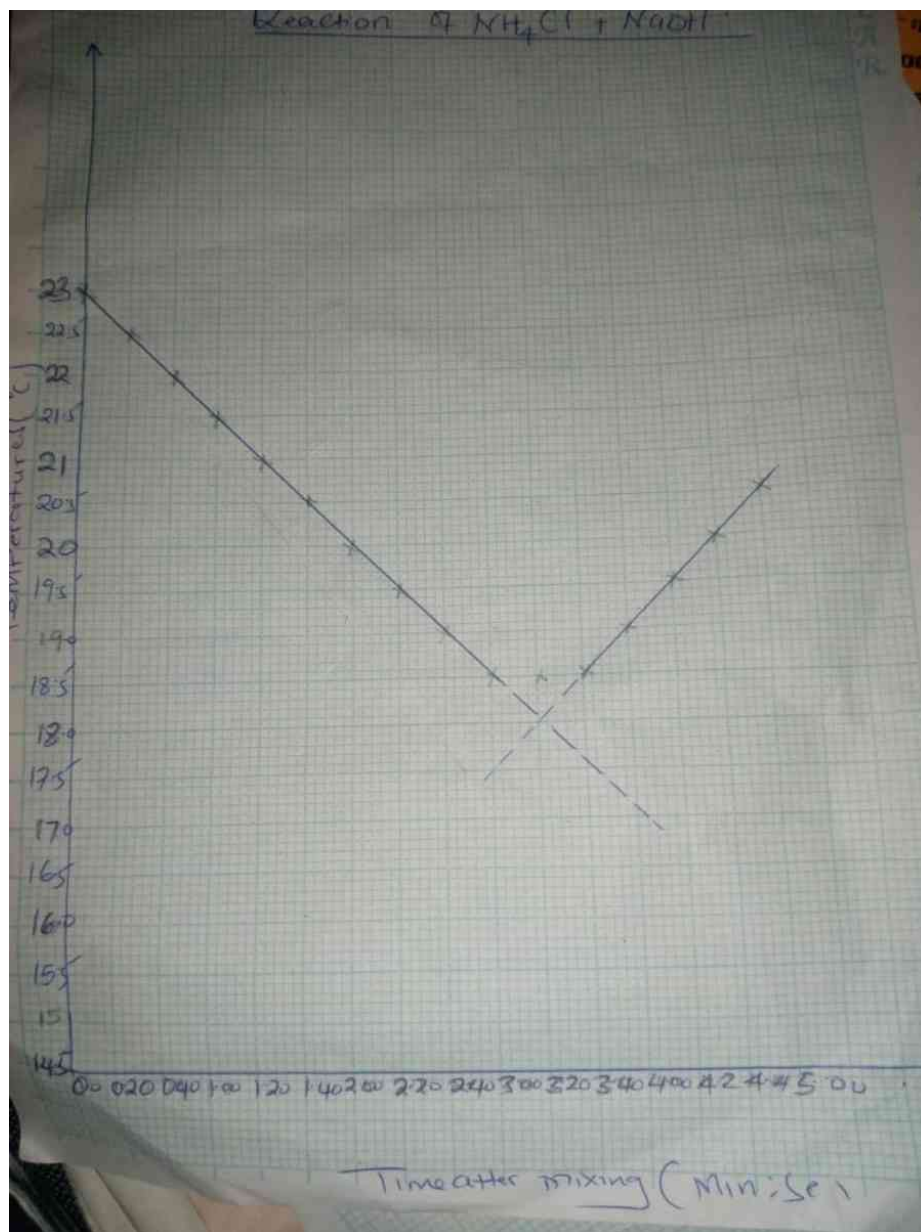
Data Table 3: Temperature (°C) of the Solution (NaOH + NH₄Cl)

Initial Temperature of NaOH (°C)	23.0
Initial Temperature NH ₄ Cl (°C)	22.0
Average Initial Temperature (°C)	22.5
Highest Temperature of Mixture (May Be Extrapolated from Graph) (°C)	18.0
Change in Temperature of Mixture (°C), ΔT	4.5

Data Table 4: Temperature of Solution Every 20 Seconds

Time after mixing (min:sec)	Temperature (°C)
Initial	23.0
0:20	22.5
0:40	22.0
1:00	21.5
1:20	21.0
1:40	20.5
2:00	20.0
2:20	19.0
2:40	18.5
3:00	18.5
3:20	18.5
3:40	18.5
4:00	19.0
4:20	19.5
4:40	20.0
5:00	20.5

Graph 2: Reaction 2 (NaOH + NH₄Cl)



Data Table 5: Temperature (°C) of the Solution ($\text{NH}_3 + \text{HCl}$)

Initial Temperature of NH ₃ (°C)	23.0
Initial Temperature HCl (°C)	23.0
Average Initial Temperature (°C)	23.0
Highest Temperature of Mixture (May Be Extrapolated from Graph) (°C)	26.6
Change in Temperature of Mixture (°C), ΔT	3.6

Data Table 6: Temperature of Solution Every 20 Seconds

Time after mixing (min:sec)	Temperature (°C)
Initial	23.0
0:20	23.5
0:40	24.0
1:00	24.5
1:20	25.0
1:40	25.0
2:00	25.5
2:20	26.0
2:40	26.0
3:00	26.0
3:20	25.5
3:40	25.0
4:00	24.5
4:20	24.0
4:40	24.0
5:00	23.5

Graph 3: Reaction 3 (NH₃ + HCl)

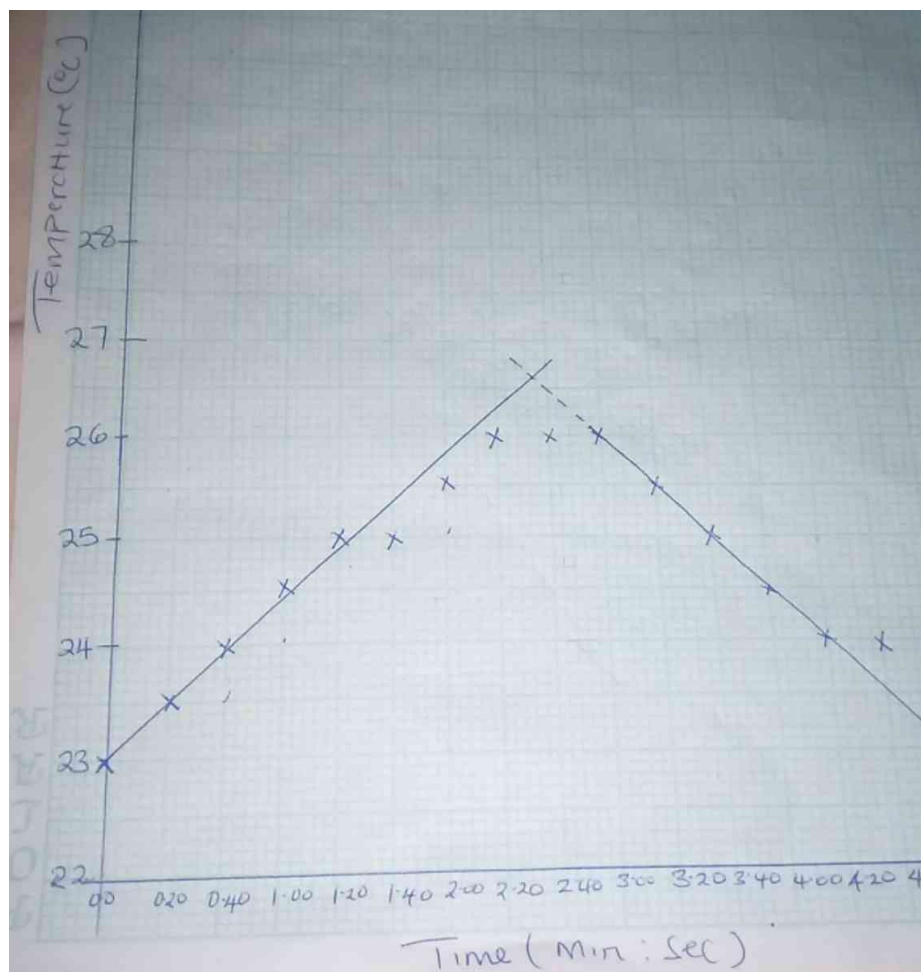


Photo 1: Reaction 1: NaOH + HCl Calculations

Heat lost Q_1

$$q = m \times c \times \Delta T$$

$$q = \frac{40}{1.02} \times 4.184 \times 12$$

$$= 1968.94125$$

Moles of sol = $\frac{2 \times 20}{1000} = 0.04$

$\frac{1968.94125}{0.04}$	$= 49.223 \text{ kJ/mole}$
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Q_2

Photo 2: Reaction 2: NaOH + NH₄Cl Calculations

Handwritten calculations on lined paper:

$$\frac{3.0}{1.02} \times 4.184 \times 5 = \underline{615.2945}$$

Q2

$$\frac{615.2945}{1000} = 0.6152945$$

Moles of NH₄Cl = $\frac{10 \times 2}{1000} = 0.02$

$$\frac{615.2945}{1000} = 0.6152945$$
$$\frac{0.6152945}{0.02} = 30.76475$$

mol

Photo 3: Reaction 3: NH₃ + HCl Calculations

Q3

$$\frac{30 \times 4.184 \times 3.6}{1.02} = 443.01123$$

mols of NH_4OH

$$= \frac{2 \times 10}{1000} = 0.02 \text{ mols}$$
$$\frac{443.0112}{0.02}$$
$$= -22.151 \text{ kJ/mol}$$

Competency Review

1. In an endothermic reaction ____.

- heat is released and temperature increases
- heat is released and temperature decreases
- heat is absorbed and temperature decreases
- heat is absorbed and temperature increases

2. A chemical reaction that releases heat to the surrounding environment is considered ____.

- endothermic
- exothermic

3. The amount of heat given off or absorbed by a chemical reaction is called _____.

- an exothermic reaction
 - the change in enthalpy
 - a Joule
 - the product of pressure and volume
-

4. Enthalpy is denoted by the _____ symbol.

- H
 - J
 - ΔE
 - F
-

5. The change in enthalpy of a reaction is equal to the enthalpy of the _____ minus the enthalpy of the _____.

- products; reactants
 - reactants; products
 - None of the above
-

6. When an _____ reaction occurs the products have a greater enthalpy than the reactants, whereas during an _____ reaction the enthalpy of the products is less than the enthalpy of the reactants.

- exothermic; endothermic
 - endothermic; exothermic
-

7. Hess's Law indicates that if a reaction takes place in one or multiple steps, the change in enthalpy for the overall process must be the sum of the change in enthalpy of the constituent reactions.

- True
 - False
-

8. Calculate the percent error of a chemical reaction with a theoretical value of -45.68 kJ/mol and an experimental value of -54.78 kJ/mol .

- 20.10%
- 16.61%
- 19.92%
- 21.37%

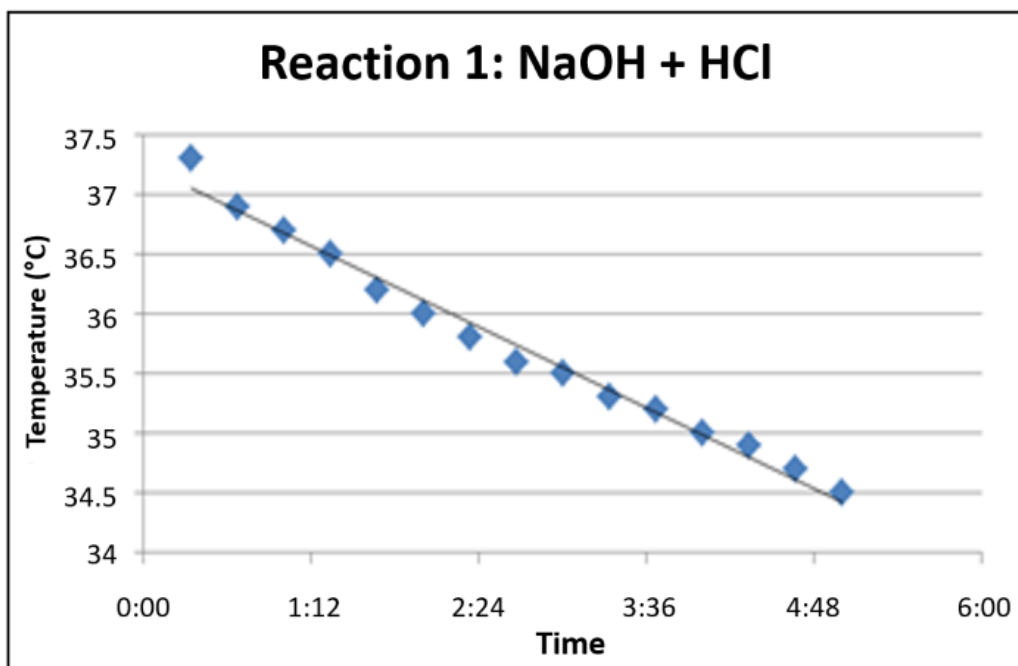
9. Calculate the heat lost from a reaction if the mass of the solution is 18.7 g at a specific heat of $5.008 \text{ J/g}^\circ\text{C}$ and a change in temperature of 7.2°C .

- 674.27 J
- -674.27 J
- -67.42 J
- 67.42 J

10. If an experiment has a q_{rxn} of 518.07 J , calculate the change in enthalpy of the reaction if there were 0.04 mol of product in the solution.

- 12.95 kJ/mol
- -12951.75 kJ/mol
- -12.95 kJ/mol
- 7.72 kJ/mol

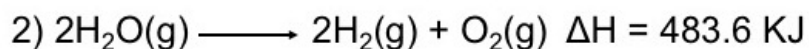
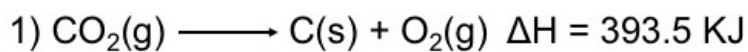
11. In an experiment, NaOH and HCl are mixed. Based on the graph, what is the change in temperature of the mixture if the initial temperature of the NaOH was 23.0°C and the initial temperature of the HCl was 25.2°C?



- 1.3°C
- 12.7°C
- 13.2°C
- 10.4°C

Extension Questions

1. Worldwide, scientists are working on different options for clean energy to replace the burning of fossil fuels. One option that could potentially be successful is the use of hydrogen gas. This gas can be generated through a reaction between carbon and water.



Based on what you have learned in this lab, use the chemical equation and Hess's law to determine the heat of formation and if this reaction is exothermic or endothermic.

exothermic