LAB REPORT

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Lab 2: Heat of Reaction

1.1 Experimental Results

1.1.1 Experiment 1

Temperature ($°C$)	1^{st}	2^{nd}	3^{rd}
t_1			
t_2			
t_3			
m_0c_0			

$\overline{m_0c_0} =$ (cal/K)

Detailed calculations using the 1^{st} test:

$$m_0c_{0-1} = mc\frac{(t_3 - t_1) - (t_2 - t_3)}{t_2 - t_3} =$$

1.1.2 Experiment 2

Temperature ($°C$)	1^{st}	2^{nd}	3^{rd}
t_1			
t_2			
t_3			
Q			
$\overline{Q}$			
$\Delta H = \frac{\overline{Q}}{n}$ (cal/mol)			

Detailed calculations using the 1^{st} test:

$$Q_1 = (m_0c_0 + m_{\text{HCl}}c_{\text{HCl}} + m_{\text{NaCl}}c_{\text{NaCl}})(t_3 - \frac{t_1 + t_2}{2})$$
$$=$$

1.1.3 Experiment 3

Temperature ($°C$)	1^{st}	2^{nd}	3^{rd}
t_1			
t_2			
Q (cal)			
ΔH (cal/mol)			
$\Delta\overline{H}$ (cal/mol)			

Detailed calculations using the 1^{st} test:

$$Q_1 = (m_0 c_0 + m_{\mathrm{H_2O}} c_{\mathrm{H_2O}} + m_{\mathrm{CuSO_4}} c_{\mathrm{CuSO_4}})(t_2 - t_1)$$
$$=$$

$$\Delta H_1 = \frac{Q_1}{n} = \qquad =$$

Since this is

1.1.4 Experiment 4

Temperature ($°C$)	1^{st}	2^{nd}	3^{rd}
t_1			
t_2			
Q (cal)			
ΔH (cal/mol)			
$\Delta\overline{H}$ (cal/mol)			

Detailed calculations using the 1^{st} test:

$$Q_1 = (m_0 c_0 + m_{\mathrm{H_2O}} c_{\mathrm{H_2O}} + m_{\mathrm{NH_4Cl}} c_{\mathrm{NH_4Cl}})(t_2 - t_1)$$
$$=$$

$$\Delta H_1 = \frac{Q_1}{n} = \qquad =$$

This is

1.2 Answer the questions

1. Is $\Delta\overline{H}$ of reaction HCl + NaOH $\longrightarrow$ NaCl + H_2O calculated based on the molar of HCl or NaOH when 25ml Hcl 2M solution reacts with 25ml NaOH 1M solution? Explain.

   - We have the following relation:

HCl + NaOH	$\longrightarrow$ NaCl + H_2O
0.05	0.025
0.025	0.025
0.025	0

   - NaOH was fully reacted and HCl still remained 0.025 mol. Thus, ΔH was calculated according to n_{NaOH}. Since the residue HCl did not react, the total reaction did not produce heat.

2. If we replaced HCl 1M with HNO_3 1M, would the result in experiment 2 change? Explain.

   - It would be the same , since ΔH is a specific quantity for each separated reaction. Replacing HCl 1M with HNO_3 1M resulted in neutralization of the solution due to having the same number of moles (or concentration of H^+).

3. Calculate ΔH_3 based on Hess's law. Compare the result with its experimental one. Considering 6 reasons for errors.

   - Heat loss from calorimeter.
   - Thermometer.
   - Volumetric glassware.
   - Balance.
   - Water absorption from $CuSO_4$.
   - Assuming that specific heat of $CuSO_4$ is $1\ (cal/mol \cdot K)$.

   Which could be the most significant factor causing errors? Explain.

   - Hess's law: $\Delta H_3 = \Delta H_1 + \Delta H_2 = \qquad = \qquad (kCal/mol)$

   - The experimental results are smaller than the theoretical ΔH_3 calculated by Hess's law. The most important reason for this comes from $CuSO_4$ absorbing a small amount of water at anhydrous form:

   $$CuSO_{4(\text{anhydrous})} + 5\,H_2O \longrightarrow CuSO_4 \cdot 5\,H_2O$$

   - The equation above produces ΔH_1. Once $CuSO_4$ is in hydrated form, it releases less heat than that in theory.

   - In addition, hydrated $CuSO_4$ causes difference in n_{CuSO_4} since $n_{CuSO_{4(\text{anhydrous})}} \neq n_{CuSO_{4(\text{hydrated})}}$.

Lab 4: Reaction Rate

2.1 Experimental Results

2.1.1 Reaction order with respect to $Na_2S_2O_3$

No.	Initial concentration (M)		Δt_1	Δt_2	Δt_3	$\Delta\bar{t}$
	$Na_2S_2O_3$	H_2SO_4				
1	$0.4{\cdot}10^{-3}$	$3.2{\cdot}10^{-3}$				
2	$0.8{\cdot}10^{-3}$	$3.2{\cdot}10^{-3}$				
3	$1.6{\cdot}10^{-3}$	$3.2{\cdot}10^{-3}$				

From $\Delta\bar{t}$ of experiments 1 and 2, determine m_1 and m_2 (sample calculation).

$$m_1 = \log_2 \frac{\Delta\overline{t_1}}{\Delta\overline{t_2}} =$$

$$m_2 = \log_2 \frac{\Delta\overline{t_2}}{\Delta\overline{t_3}} =$$

Reaction order with respect to $Na_2S_2O_3 = \dfrac{m_1 + m_2}{2} =$

2.1.2 Reaction order with respect to H_2SO_4

No.	Initial concentration (M)		Δt_1	Δt_2	Δt_3	$\Delta\bar{t}$
	$Na_2S_2O_3$	H_2SO_4				
1	$0.8{\cdot}10^{-3}$	$1.6{\cdot}10^{-3}$				
2	$0.8{\cdot}10^{-3}$	$3.2{\cdot}10^{-3}$				
3	$0.8{\cdot}10^{-3}$	$6.4{\cdot}10^{-3}$				

From $\Delta\bar{t}$ of experiments 1 and 2, determine m_1 and m_2 (sample calculation).

$$m_1 = \log_2 \frac{\Delta\overline{t_1}}{\Delta\overline{t_2}} =$$

$$m_2 = \log_2 \frac{\Delta\overline{t_2}}{\Delta\overline{t_3}} =$$

Reaction order with respect to $H_2SO_4 = \dfrac{m_1 + m_2}{2} =$

2.2 Answer the questions

1. In the experiment above, what is the effect of the concentrations of $Na_2S_2O_3$ and H_2SO_4 pm the reaction rate? Rewrite the reaction rate expression, determine, the order of reactions.

   - The concentration of $Na_2S_2O_3$ is directly proportional to reaction rate.

   - The concentration of H_2SO_4 almost does not affect to reaction rate.

   - Expression for reaction rate:

   $$v = k[\mathrm{Na_2S_2O_3}]^m[\mathrm{H_2SO_4}]^n$$

   where:

   k: constant coefficient

   m: reaction order with respect to $Na_2S_2O_3$

   n: reaction order with respect to H_2SO_4

   Overall order of reaction: $m + n =$

2. The mechanism of reactions can be rewritten as follows:

   H_2SO_4 + $Na_2S_2O_3$ $\longrightarrow$ Na_2SO_4 + $H_2S_2O_3$ (1)

   $H_2S_2O_3$ $\longrightarrow$ H_2SO_3 + S$\downarrow$ (2)

   Based on the experimental results, is it plausible to conclude that the reaction (1) or (2) is the rate-determining step, which is the slowest step of the reaction? Recall that in the experiments, the amount of H_2SO_4 is always abundant.

   - Reaction (1) is ion-exchange reaction. Thus, the reaction rate is high.

   - Reaction (2) is reduction/oxidation reaction. Thus, the reaction rate appears to be slower than reaction (1).

   $\rightarrow$ Reaction (2) is the rate-determining step and is the slowest step of the reaction since the overall order of the reaction is the order of reaction (2).

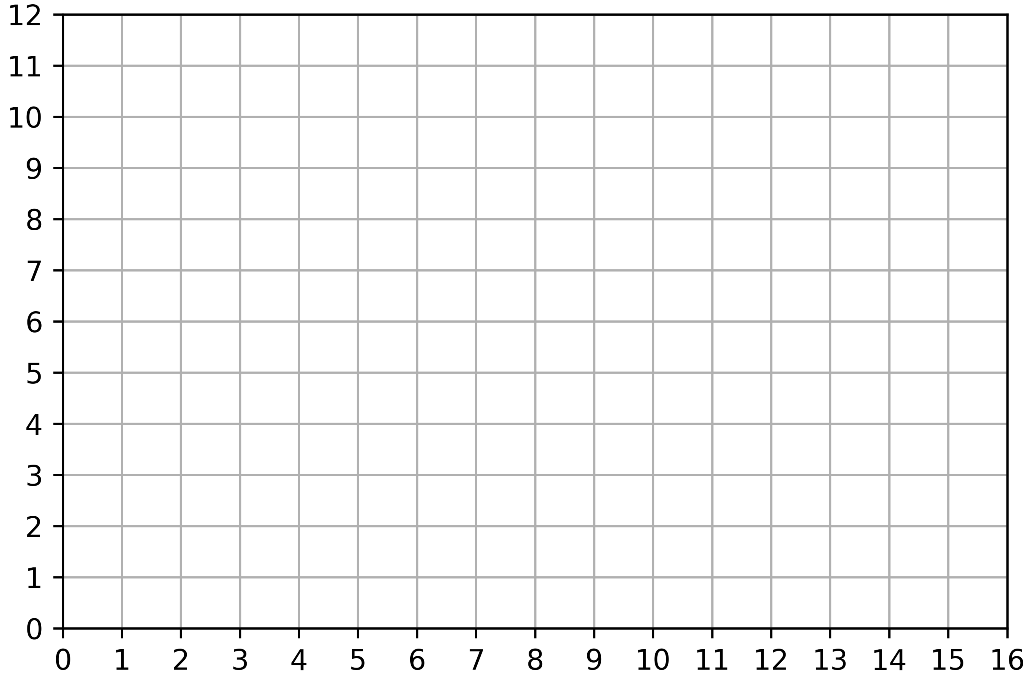
3. Based on the principle of experimental method, decide if the reaction rate is instantaneous or average.
   The reaction rate is considered to be instantaneous since the reaction rate is defined by $\frac{\Delta C}{\Delta t}$ with $\Delta C \approx 0$. This can be explained with consistency of sulfur's concentration throughout the experiment.

4. Reverse the order of H_2SO_4 and $Na_2S_2O_3$. Does the reaction order change? Explain.
   The reaction rate does not change because the reaction order depends on the properties of reactions (temperature, pressure, concentration, area of contact, etc.). It is independent of experimenting orders.

Lab 8: Volumetric Analysis

3.1 Experimental Results

3.1.1 Titration curve of HCl with NaOH



Determine:

- pH at equivalence point:
- Titration jump pH:

3.1.2 Experiment 2

No.	$V_{\text{HCl}}\ (ml)$	$V_{\text{NaOH}}\ (ml)$	$C_{\text{NaOH}}\ (N)$	$V_{\text{HCl}}\ (N)$	Deviation
1					
2					

$$\Delta\overline{C_{\text{HCl}}} =$$

$$\overline{C_{\text{HCl}}} =$$

3.1.3 Experiment 3

No.	$V_{\text{HCl}}\ (ml)$	$V_{\text{NaOH}}\ (ml)$	$C_{\text{NaOH}}\ (N)$	$V_{\text{HCl}}\ (N)$	Deviation
1					
2					

$$\Delta\overline{C_{\text{HCl}}} =$$

$$\overline{C_{\text{HCl}}} =$$

3.1.4 Experiment 4

No.	Indicator	$V_{\text{CH}_3\text{COOH}}\ (ml)$	$V_{\text{NaOH}}\ (ml)$	$C_{\text{NaOH}}\ (N)$	$C_{\text{CH}_3\text{COOH}}\ (N)$
1	Phenolphthalein				
2	Methyl orange				

3.2 Answer the questions

1. When changing the concentration of HCl or NaOH, does the titration curve changes accordingly? Explain.

   The titration curve will not change since the chemical equivalence of reactants stays the same. Only titration jump varies according to the concentration:
   - Decrease in concentration results in a short titration jump.
   - Increase in concentration results in a long titration jump.

2. If we were to find the concentration of HCl, determine from experiments 2 and 3 the experiment yielding higher accuracy.

   Phenolphthalein contributes to accurate result since the titration jump of the indicator is ranging from 8 to 10. However, the jump of metyl orange varies from 3.1 to 4.4, which is further from the equivalence point than that of phenolphthalein. Therefore, experiment 2 using phenolphthalein yields high accuracy.

3. From the result of experiment 4, which indicator is more accurate when determining the concentration of CH_3COOH solution?

   Phenolphthalein gives more accurate result than methyl orange. In acidic environment, phenolphthalein has an advantage of being transparent and only visible in basic solution through its distinctive violet color. In contrast, the change in color of methyl orange is much harder to observe (red in acidic environment to orange-yellow in basic environment).

4. In volumetric titration, if NaOH and HCl were interchanged, would the result be changed accordingly? Explain.

   The result remained consistent since the initial properties of the reaction stays the same (it is a neutralization reaction and will change the color of an indicator at equivalence point).