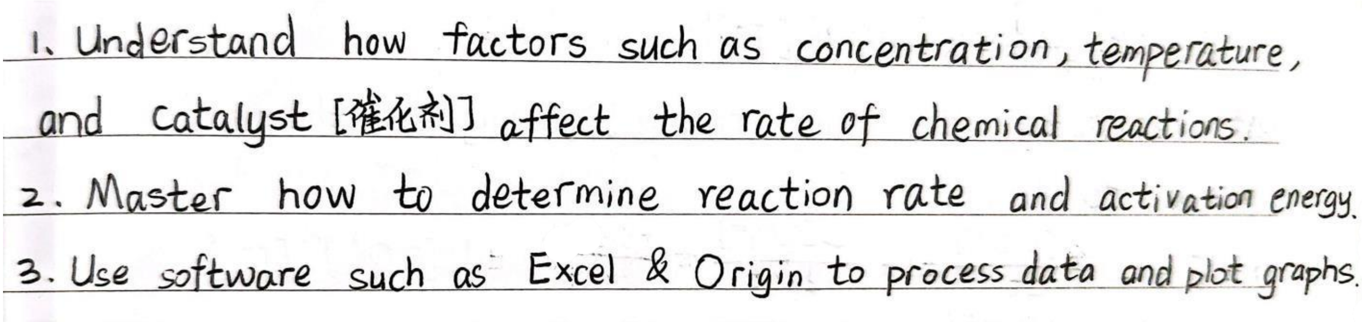
2024-2025学年春夏学期《无机及分析化学实验》实验报告

实验名称：反应速率、反应速率常数和活化能及其影响因素的测定

姓名/同组同学：/ 实验时间：2025 年 3 月 4 日

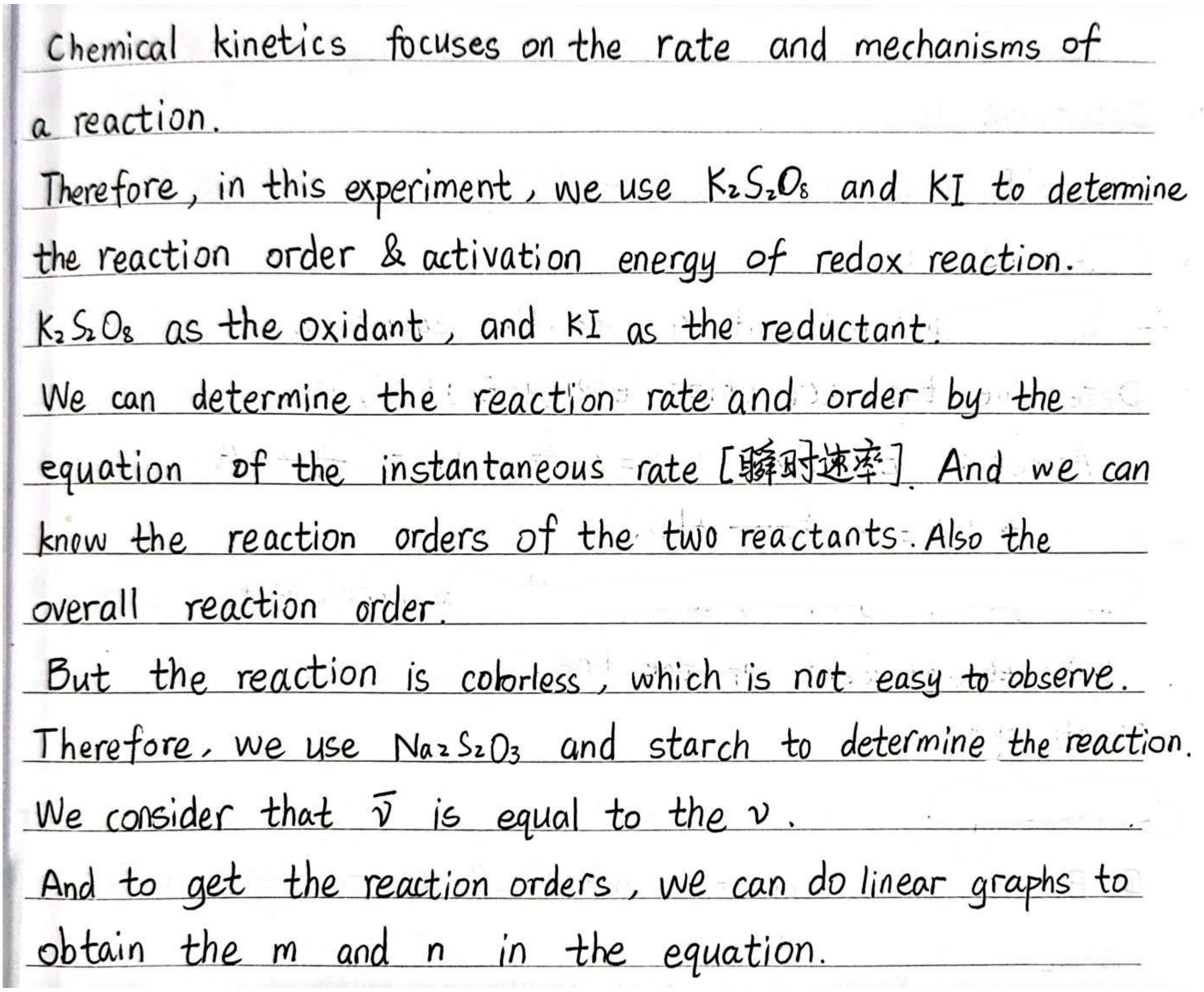
指导老师/助教： 第 1 页

Ⅰ. Objectives



1. Understand how factors such as concentration, temperature, and catalyst [催化剂] affect the rate of chemical reactions.
2. Master how to determine reaction rate and activation energy.
3. Use software such as Excel & Origin to process data and plot graphs.

Ⅱ. Principles



Chemical kinetics focuses on the rate and mechanisms of a reaction.

Therefore, in this experiment, we use $K_2S_2O_8$ and KI to determine the reaction order & activation energy of redox reaction.

$K_2S_2O_8$ as the oxidant, and KI as the reductant.

We can determine the reaction rate and order by the equation of the instantaneous rate [瞬时速率]. And we can know the reaction orders of the two reactants. Also the overall reaction order.

But the reaction is colorless, which is not easy to observe.

Therefore, we use $Na_2S_2O_3$ and starch to determine the reaction.

We consider that $\bar{v}$ is equal to the v.

And to get the reaction orders, we can do linear graphs to obtain the m and n in the equation.

Here are the reaction equations:

① $S_2O_8^{2-} + 2I^- = 2SO_4^{2-} + I_2$ Slow

② $2S_2O_3^{2-} + I_2 = S_4O_6^{2-} + 2I^-$ Fast.

reaction rate: $v = k[S_2O_8^{2-}]^m[I^-]^n$.

$$\bar{v} = \frac{-\Delta[S_2O_8^{2-}]}{\Delta t} = k[S_2O_8^{2-}]^m[I^-]^n.$$

Δt refer to the time from beginning to the solution turns to blue.

$$v = \bar{v} = -\frac{\Delta[S_2O_8^{2-}]}{\Delta t} = -\frac{\Delta[S_2O_3^{2-}]}{2\times\Delta t} = \frac{[S_2O_3^{2-}]_0}{2\times\Delta t} = k[S_2O_8^{2-}]^m[I^-]^n.$$

$$\lg v = \lg\frac{\Delta[S_2O_3^{2-}]_0}{2\times\Delta t} = \lg k + m\lg[S_2O_8^{2-}] + n\lg[I^-]$$

- Determine m:

  keep $[I^-]$ constant, do $\lg v - \lg[S_2O_8^{2-}]$ graph, m=slope.

- Determine n:

  keep $[S_2O_8^{2-}]$ constant, do $\lg v - \lg[I^-]$ graph, n=slope.

- Determine k:

  substitute m and n into the equation.

- Determine the activation energy(E_a)(kJ/mol).

  Arrhenius' Equation: $k = Ae^{\frac{E_a}{RT}}$ $\ln k = -\frac{E_a}{RT} + \ln A$

  $$\Rightarrow \lg k = -\frac{E_a}{2{,}303RT} + \lg A$$

do $\lg k - \frac{1}{T}$ graph, calculate the E_a according to the slope.

$\lg A$: the intercept of the line.

Ⅲ. Pre-class Questions

(1). Briefly summarize the basic concepts of reaction rate, reaction rate constant, reaction order and activation energy.

① 反应速率：单位时间内反应物的浓度减小或生成物浓度增加的量

② 反应速率常数：速率方程中的一个参数.

③ 反应级数：速率方程中各反应物浓度指数的总和

④ 活化能：分子从常态转变为易发生化学反应的活跃状态所需的能量.

(2). Briefly describe how to determine the reaction order and activation energy in this experiment.

Through Part 二. Principle, we can know equation:

$$\lg v = \lg k + m\lg[S_2O_8^{2-}] + n\lg[I^-]$$

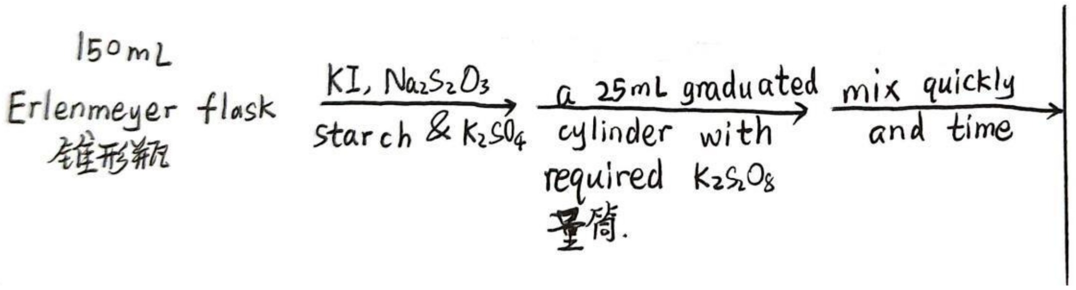
So, do $\lg v - \lg[S_2O_8^{2-}]$ graph & $\lg v - \lg[I^-]$ graph. We can know the m & n by calculate the slope of the line.

The overall reaction order is $m+n$.

Also, $\ln k = -\frac{E_a}{RT} + \ln A$ do $\lg k - \frac{1}{T}$ graph, know E_a through the slope.

Ⅳ. Procedures

① Effect of Concentration of $K_2S_2O_8$ on the Reaction Rate:



till the system becomes blue.	maintain a consistent shaking rate each time.
② Effect of Concentration of KI on the Reaction Rate: 150mL Erlenmeyer flask $\xrightarrow[KNO_3\ \&\ \text{required } KI]{Na_2S_2O_3,\ \text{starch},}$ $\xrightarrow[K_2S_2O_8]{25mL}$ $\xrightarrow[\text{and time.}]{\text{mix quickly}}$ till the system becomes blue.	
③ Effect of temperature on the reaction rate. water bath with different T $\xrightarrow[\text{with } KI,\ KNO_3,\ Na_2S_2O_3,\ \text{starch}]{\text{a 150mL Erlenmeyer flask}}$ $\xrightarrow[K_2SO_4\ \&\ K_2S_2O_8]{\text{a 150mL Erlenmeyer flask with required}}$ $\xrightarrow{\text{mix quickly \& time}}$ till the system becomes blue	measure the temperature change before & after 1 min.
④. Effect of Catalyst on the Reaction Rate 150mL Erlenmeyer flask $\xrightarrow[\text{starch \& 2 drops of } Cu(NO_3)_2]{KNO_3,\ KI,\ Na_2S_2O_3,\ K_2SO_4}$ $\xrightarrow{25mL\ K_2S_2O_8}$ $\xrightarrow[\text{\& time}]{\text{mix quickly}}$ till the system becomes blue.	
⑤. Effect of Ionic Strength on the Reaction Rate 150mL Erlenmeyer flask $\xrightarrow[\text{starch \& water}]{KI,\ Na_2S_2O_3}$ $\xrightarrow{25mL\ K_2S_2O_8}$ $\xrightarrow[\text{\& time}]{\text{mix quickly}}$ till system becomes blue	

Ⅴ. **Data Record Tables**

Table 1 Effect of concentration of $K_2S_2O_8$ on reaction rate (temperature: 20 ℃)

No.	$K_2S_2O_8$ / mL	KI / mL	$Na_2S_2O_3$ / mL	starch / mL	KNO_3 / mL	K_2SO_4 / mL	total volume / mL	reaction time / s
1	25	25	5.0	2.0	0.0	0.0	57	70.02
2	20	25	5.0	2.0	0.0	5.0	57	82.08
3	15	25	5.0	2.0	0.0	10	57	93.57
4	10	25	5.0	2.0	0.0	15	57	163.06
5	5.0	25	5.0	2.0	0.0	20	57	375.31

Table 2 Effect of concentration of KI on reaction rate (temperature: 20 ℃)

No.	$K_2S_2O_8$ / mL	KI / mL	$Na_2S_2O_3$ / mL	starch / mL	KNO_3 / mL	K_2SO_4 / mL	total volume / mL	reaction time / s
6	25	25	5.0	2.0	0.0	0.0	57	56.90
7	25	20	5.0	2.0	5.0	0.0	57	76.82
8	25	15	5.0	2.0	10	0.0	57	97.48
9	25	10	5.0	2.0	15	0.0	57	149.99
10	25	5.0	5.0	2.0	20	0.0	57	333.39

Table 3 Effect of temperature on reaction rate

No.	11	12	13	14
reaction temperature / °C	25	30	35	40
reaction time / s	74.65	53.40	40.16	25.81

4. The effect of catalyst on the reaction rate

t=45.25 s

5. The effect of ionic strength on the reaction rate

Table 1. No. 3: t_1=116.53s

Table 2. No. 8: t_2=114.83s

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Ⅵ. Data Treatment and Analysis

Data Treatment:

According to the data we've recorded, we can linearly fit the graphs and know their equations respectively.

1. Effect of concentration of $K_2S_2O_8$: do $\lg k$-$\lg[K_2S_2O_8]$ graph **Fig.1** We can get its equation: $y = -3.11429 + 1.06293x$. The slope is 1.06293. Therefore, the reaction order of $K_2S_2O_8$ is approximately m=1.
2. Effect of concentration of KI: do $\lg k$-$\lg[KI]$ graph **Fig.2** We can get its equation: $y = -3.7385 + 1.08025x$. The slope is 1.08025. Therefore, the reaction order of KI is approximately n=1. Therefore, the total reaction order is 2.
3. Effect of temperature on reaction rate: do $\lg k$-$1/T$ graph **Fig.3** We can get its equation: $y = 2.92452 - 1.10358 \times 10^{-3}x$. Therefore, the A in ***Arrhenius' Equation*** is $A=e^{2.92452}\approx 18.62$. And the activation energy in this equation is $Ea=1.10358\times 10^{-3}R=9.18\times 10^{-3}J$.
4. Effect of catalyst on reaction rate: When 2 drops of $Cu(NO_3)_2$ are added, the time is 45.25s. This is faster than former reaction. So it indicates that the catalyst can highly promote the reaction rate.
5. Effect of ionic strength on reaction rate: The 2 groups of time are 116.53s and 114.83s. They are nearly the same but far lower than the time 93.57s and 97.48s. So it indicates that the ionic strength can highly promote the reaction rate.

Error Analysis:

1. When doing the vibration, different group members have different speed. This can influence the reaction time.
2. The reaction endpoint is to observe the color's change of the solution. This can cause error to record this total time.
3. There are always errors in the weighing and mixing process.
4. There may be temperature changes during the reaction, which can influence the reaction rate.
5. Although the speed of the indicative reaction is very fast, it still cause time error.

6. There is some solution remaining in the containers during the pouring process.

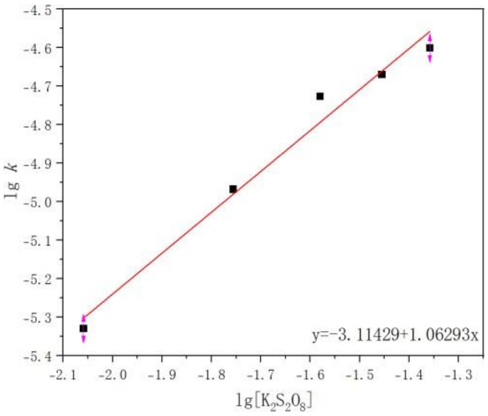

Fig.1

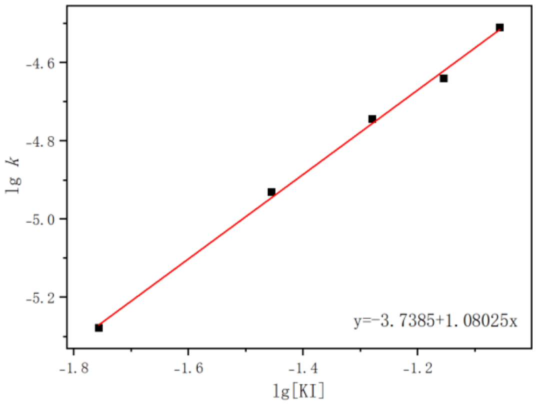

Fig.2

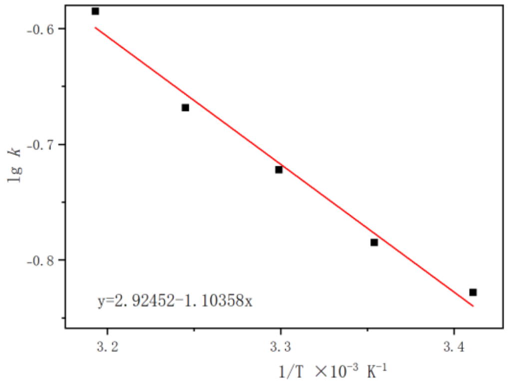

Fig.3

Inspirations:

1. When it’s difficult to determine the relationship between two variables in the equations, we can do some mathematical substitution which simplify the whole equation.
2. I have learnt to use the software ***Origin*** to process my data and fit the graph.
3. When exploring the reaction which is not easy to observe or measure, we can use another reaction which is easy to measure to respond the reaction we want.

Ⅶ.Post-lab Questions

(1) Taking this experiment as an example, can the reaction order be directly obtained from chemical reaction equation ?

The reaction order can’t be obtained directly from the reaction equation. For example, the reaction order of the I^- is n=1, not equal to 2. Therefore, the stoichiometric coefficients are not always the same as its reaction order. We should get the reaction order through experiment and analysis. But for elementary reaction, they are the same.

(2) Why can the reaction rate be calculated by the time the reaction solution appears blue ?

Firstly, the main reaction rate is slow but the indicative reaction rate is fast. So, we can almost ignore the indicative reaction’s time. Secondly, the indicative reaction finished before the main reaction. This helps to calculate the change of $[K_2S_2O_8]$, and the average reaction rate.

Ⅶ.Appendix

Here are the analysis record tables of the data which are used to fit graphics.

Table 4 Effect of concentration of $K_2S_2O_8$ on reaction rate (temperature: 20 °C)

No.	1	2	3	4	5
$[K_2S_2O_8]_0$ /mol·L^{-1}	0.04386	0.03509	0.02632	0.01754	0.00872
reaction time △t /s	70.02	82.08	93.57	163.06	375.31
reaction rate /mol·L^{-1}·s^{-1}	2.506×10^{-5}	2.137×10^{-5}	1.875×10^{-5}	1.076×10^{-5}	4.674×10^{-6}
$\lg[K_2S_2O_8]_0$	-1.358	-1.455	-1.580	-1.756	-2.059
lg$v$	-4.601	-4.670	-4.727	-4.968	-5.330

Table 5 Effect of concentration of KI on reaction rate (temperature: 20 °C)

No.	6	7	8	9	10
$[KI]_0$ / mol·L^{-1}	0.08772	0.07018	0.05263	0.03509	0.01754
reaction time△t/ s	56.90	76.82	97.48	149.99	333.39
reaction rate/ mol·L^{-1}·s^{-1}	3.083×10^{-5}	2.284×10^{-5}	1.800×10^{-5}	1.170×10^{-5}	5.262×10^{-6}
$\lg[KI]_0$	-1.057	-1.154	-1.279	-1.455	-1.756
lg$v$	-4.511	-4.641	-4.745	-4.932	-5.279

Table 6 Effect of temperature on reaction rate

No.	3	11	12	13	14
reaction temperature/ °C	20	25	30	35	40
reaction time/ s	93.57	74.65	53.40	40.16	25.81
reaction rate/mol·L^{-1}·s^{-1}	1.875×10^{-5}	2.350×10^{-5}	3.285×10^{-5}	4.368×10^{-5}	6.797×10^{-5}
1/T / K^{-1}	3.411×10^{-3}	3.354×10^{-3}	3.299×10^{-3}	3.245×10^{-3}	3.193×10^{-3}
k	0.1486	0.1640	0.1896	0.2146	0.2600
lg$k$	-0.8280	-0.7851	-0.7222	-0.6684	-0.5850

评分项目	学术规范	书写工整	写作表达	数据结果和分析讨论	课前和课后思考题	总分
分值	30 分	10 分	10 分	30 分	20 分	100 分
得分/分						
评语						