VC211 Spring 2023 Chemistry Lab Memo

Experiment E4

Introduction to Kinetics

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This is for TAs ONLY. DO NOT write in this table.

Grades				**Grader/s**
Post-lab (100+10 pts)	Observation (40 pts)			
	Data Analysis (20 pts)			
	Discussion (30+10 pts)			
	Data Sheet (10 pts)			
	Total			

University of Michigan – Shanghai Jiao Tong University Joint Institute (UM-SJTU JI)

POST-LAB

*Please finish (hand-written or typed) this memo during and/or after the lab and submit it through canvas (pdf file name convention: Name_Student ID_E4_Post-lab.pdf) before due time, typically the start of the next experiment. This memo consists of OBSERVATION, DATA ANALYSIS, DISCUSSION, and DATA SHEET, and are worth a total of 100 points, counted as **6%** of the total course grade. This is an individual assignment and your own work is expected. The sample DATA SHEET is for recording of raw data **during** your lab work and shall be submitted as it is (the very original copy you filled in during lab). We strongly recommend you to handwrite the original datasheet.*

*Calculations and data analysis shall use the original data you obtained in the lab. Any alteration to raw data is a serious violation of **HONOR CODE** and you will receive '0' point for Post-Lab Memo.*

***Note:** This memo first describes experimental observations, then analyzes data, finally discusses the results. Although a frame is provided with useful tips, you are **encouraged** to conduct critical thinking on your own and try to write a coherent and complete report by yourself (passive piecing together tips is not considered to be a complete memo). Bonus is available for outstanding points as mentioned in detail below.*

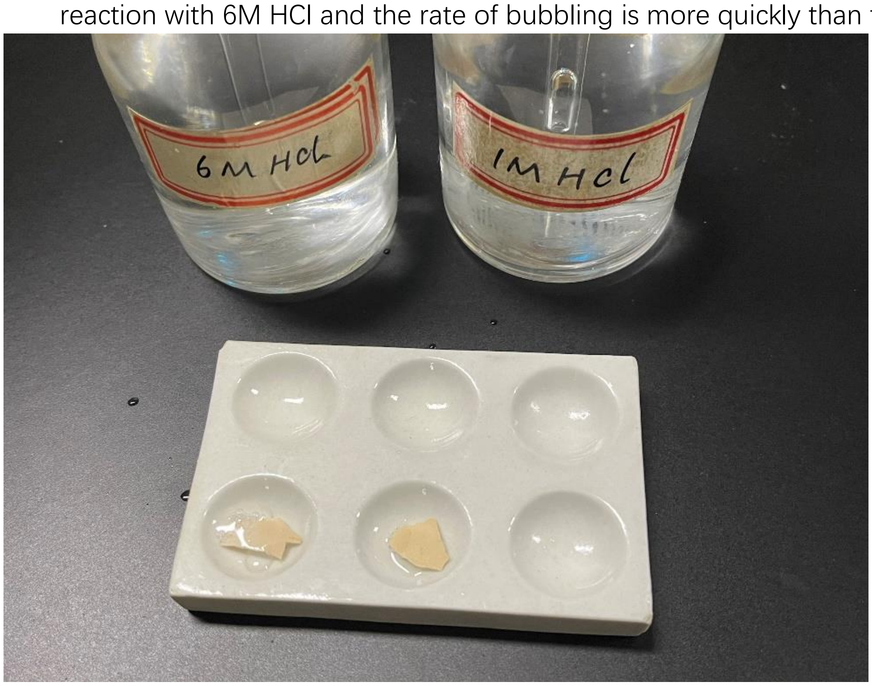
OBSERVATION

E4(I). Introduction to Kinetics: Factors that Affect the Rate of Reaction

Part A. Effect of Changing the Concentration of Reactants

- *Describe your observations of two reactions qualitatively (amount of bubbles, rate of bubbling).*
- *Attach photos of the two reactions.*
- *In what ways was the reaction between the eggshells and the 1 M HCl similar to the reaction between the eggshells and the 6 M HCl? In what ways were the reactions different?*
- *Briefly explain how concentration of reactants affect the reaction rates in these reactions.*

  In this experiment, I notice that the reaction between 6M HCl and the eggshell is fiercer than 1M HCl with the eggshell. With the same amount of HCl and eggshell, there are more bubbles in the reaction with 6M HCl and the rate of bubbling is more quickly than the reaction with 1 M HCl.



(1)left: eggshell with 6M HCl; right: eggshell with 1M HCl, both are at the very beginning

(2)left: eggshell with 6M HCl; right: eggshell with 1M HCl, a few seconds after the beginning

The reaction between the eggshells and the 1 M HCl and the reaction between the eggshells and the 6 M HCl would be similar in that both reactions will produce the same products and their phenomenon both include bubbles, but the reaction rate and extent are different.

In these experiments, with other conditions the same, the higher concentration of reactants leads to the higher reaction rate.

Part B. Effect of Changing the Surface Area

- *Describe your observations of two reactions qualitatively (time of color change, depth of color).*
- *Attach photos of the two reactions.*
- *Describe the appearance of the solution before addition of the iron metal. Describe and compare the appearance of the solution and the iron wire/iron powder after the reaction. Which reaction went faster?*
- *Briefly explain how surface area affects the reaction rates in these reactions.*

In this experiment, I notice that with other conditions the same, in a short time, the $CuSO_4$ solution changes from blue to pale green with iron powder but the color of the solution with iron wire just becomes a bit shallower in a long time. The depth of the $CuSO_4$ solution with iron wire is deeper than the the depth of the $CuSO_4$ solution with iron powder.

(3)left: $CuSO_4$ solution with iron powder; right: $CuSO_4$ solution with iron wire

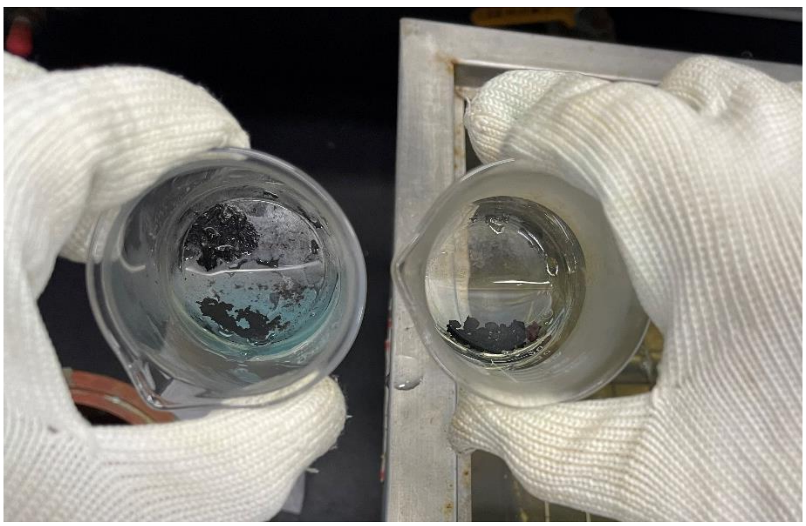
Before addition of the iron metal, the CuSO4 solution is clear and bright blue. After the reaction, for the reaction including iron wire, the blue color of the $CuSO_4$ solution goes lighter and the iron wire is covered with a reddish-brown color solid. For the reaction with iron powder, the color of the solution changes from blue to pale green and the iron powder is covered with reddish-brown color solid and form some particles. The reaction with iron powder went faster.

Because iron powder has a lot more surface area than solid iron wire in these processes, more iron atoms can interact with the CuSO4 solution at once, speeding up the reaction.

Part C. Effect of Changing the Temperature

- *Describe your observations of two reactions qualitatively (time for the color change, colors of solutions and metals).*
- *Attach photos of the two reactions.*
- *Briefly explain how temperature affects the reaction rates in these reactions.*

In this experiment, I notice that with other conditions the same, the color of the $CuSO_4$ solution with iron powder at 80℃ changes from blue to pale green in a short time and the color of the metals changes from silver to reddish-brown. However, the color of the $CuSO_4$ solution with iron powder at 0°C just becomes shallower in a longer time and still remains blue and the color of the metals changes from silver to reddish-brown.

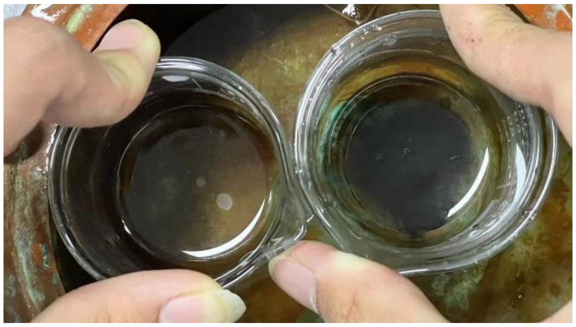

(4)left: $CuSO_4$ solution with iron powder at 0°C; right: $CuSO_4$ solution with iron powder at 80°C

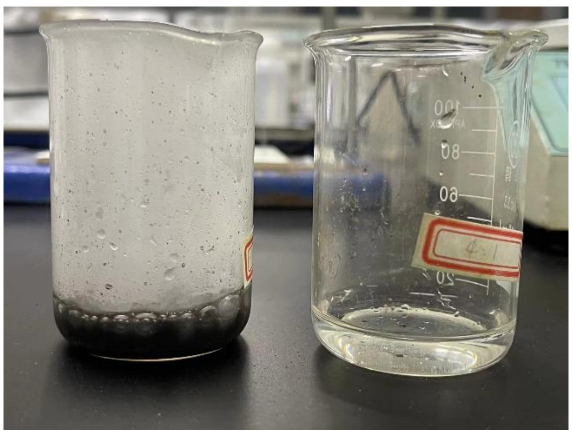
The kinetic energy of the CuSO4 and Fe molecules increases with temperature, and this increase in kinetic energy causes a greater frequency of collisions between the reactant molecules, making it easier to cross the activation energy barrier and facilitate the reaction.

Part E. Effect of adding a catalyst

- *Describe your observations of four reactions qualitatively (amount of bubbles, rate of bubbling).*
- *Attach photos of the four reactions (room temperature or ice-cold, add catalyst or not).*
- *Compare the reaction rates of the four reactions qualitatively and briefly explain the reasons.*
- *Briefly explain how catalyst affects the reaction rates in these reactions.*

In this experiment, I notice that there are a few bubbles in H_2O_2 solution without catalyst at room temperature and the rate of bubbling is slow and steady. As for the H_2O_2 solution with catalyst at room temperature, there are a lot of bubbles in the H_2O_2 solution and the rate of bubbling is extremely quickly and the solution sends much heat. The H_2O_2 solution without catalyst at 0℃ shows no obvious phenomenon, and the H_2O_2 solution with catalyst has a few of bubbles and the rate of bubbling is really slow.


(5)ice-cold: left: H_2O_2 solution without catalyst; right: H_2O_2 solution with catalyst


(6)room temperature: left: H_2O_2 solution with catalyst; right: H_2O_2 solution without catalyst

The reaction rate of the H_2O_2 solution with catalyst at room temperature is the fastest because the temperature is comparatively higher and the catalyst can speed up the reaction. The rate of the H_2O_2 solution without catalyst at ice-cold is the slowest because the low temperature lowers the kinetic energy of H_2O_2 molecules and makes the activation energy more difficult to cross. The rates of the other two situations are similar and are between the former two rates. The effects of low temperature and catalyst counteract and leads to similar rate to the solution without catalyst at room temperature.

Catalysts provide an alternative pathway for the reaction with a lower activation energy so that they can lower the activation energy required for the reaction to occur. This allow more H_2O_2 molecules to have enough energy to overcome the activation energy barrier and convert into products.

DATA ANALYSIS

E4(II). Determining the Rate Law: A Kinetics Study of Iodination of Acetone

- *Fill in the following two tables.*
- *Show **calculation process** from primary experimental results to summarized results.*
- *Determine the rate law using the **first three trials**.*
- ***Predict** the reaction time for the fourth trial using the determined rate law, and compare the data you got in the lab with your prediction. Do the results meet with your expectations? If not, why?*

Table 1: Primary results

Solution	1	2	3	4
Volume of 4M acetone solution (mL)	10.0	10.0	20.0	20.0
Volume of water (mL)	20.0	10.0	10.0	0.0
Volume of 1M HCl solution (mL)	10.0	10.0	10.0	10.0
Volume of 0.00118M iodine solution (mL)	10.0	20.0	10.0	20.0
Reaction time, trial 1 (s)	28.99	55.53	13.29	23.81
Reaction time, trial 2 (s)	29.03	56.21	14.33	24.67
Reaction time, average (s)	29.01	55.87	13.81	24.24

Table 2: summarized results

Solution	Acetone (M)	Iodine (M)	Initial rate (M/s)
1	0.8	2.36×10^{-4}	8.13×10^{-6}
2	0.8	4.72×10^{-4}	8.4×10^{-6}
3	1.6	2.36×10^{-4}	1.7×10^{-5}
4	1.6	4.72×10^{-4}	1.9×10^{-5}

According to the rate law: rate $= k[A]^m[B]^n$, let [A] be acetone and let [B] be iodine.

#1: $C_A = \frac{4\times10}{50} = 0.8\,M$, $C_B = \frac{0.00118\times10}{50} = 2.36\times10^{-4}\,M$

$rate_1 = \frac{\Delta[I_2]_1}{t_1} = \frac{2.36\times10^{-4}}{29.01} = 8.13\times10^{-6}\,M/s$

#2: $C_A' = \frac{4\times10}{50} = 0.8\,M$, $C_B' = \frac{0.00118\times20}{50} = 4.72\times10^{-4}\,M$

$rate_2 = \frac{\Delta[I_2]_2}{t_2} = \frac{4.72\times10^{-4}}{55.87} = 8.4\times10^{-6}\,M/s$

According to the rate law: rate $= k[A]^m[B]^n$, let $[A]$ be acetone and let $[B]$ be iodine.

#3: $C_A'' = \frac{4 \times 20}{50} = 1.6\,M$, $C_B'' = \frac{0.00118 \times 10}{50} = 2.36 \times 10^{-4}\,M$

$$rate_3 = \frac{2.36 \times 10^{-4}}{13.81} = 1.7 \times 10^{-5}\,M/s$$

#4: $C_A''' = \frac{4 \times 20}{50} = 1.6M$, $C_B''' = \frac{0.00118 \times 20}{50} = 4.72 \times 10^{-4} M$

$$rate_4 = \frac{4.72 \times 10^{-4}}{24.24} = 1.9 \times 10^{-5}\,M/s$$

Comparing #1 & #2:

$$\frac{rate_1}{rate_2} = \frac{k[A_1]^m[B_1]^n}{k[A_2]^m[B_2]^n} \Rightarrow \left(\frac{1}{2}\right)^n = \frac{8.13 \times 10^{-6}}{8.4 \times 10^{-6}} \Rightarrow n \approx 0$$

Comparing #2 & #3:

$$\frac{rate_2}{rate_3} = \frac{k[A_2]^m[B_2]^n}{k[A_3]^m[B_3]^n} \Rightarrow \left(\frac{1}{2}\right)^m = \frac{8.4 \times 10^{-6}}{1.7 \times 10^{-5}} \Rightarrow m \approx 1$$

$$k = \frac{rate_1}{[A]^1[B]^0} = \frac{8.13 \times 10^{-6}}{0.8} \approx 1.02 \times 10^{-5}\,s^{-1}$$

Therefore, the rate law is rate $= 1.02 \times 10^{-5}$ [acetone]

Therefore, the rate law is rate $= 1.02 \times 10^{-5}$ [acetone]

According to the rate law, the #4 rate should be

$$rate_4 = 1.02 \times 10^{-5} \times 1.6 = 1.632 \times 10^{-5}\,M/s$$

The calculated result doesn't meet with my expectation because it is smaller than the actual value. Possible reasons may be errors of time measuring or the errors of solution configuration.

DISCUSSION*

This is the most important part of the memo. The basic requirement is that you should summarize the results of the experiment and the knowledge gained from the results. Bonus can be earned by including the following points or showing creative ideas. ***(Strictly 2 pages limit for Discussion part)***

Bonus:

1. *Whether the experiment results met your expectation? Explain it if not.*
2. *Find the possible reasons of potential errors in the experiment.*
3. *Provide the suggestions to optimize the experiment.*
4. *Cite good literatures to illustrate the results of the experiment. Don't forget to add it to reference list.*

We suggest that you list the contents point by point when you write bonus part.

E4-1. Part A: Effect of Changing the Concentration of Reactants

①The result of the experiment is that the reaction between 6M HCl and the eggshell is fiercer than 1M HCl with the eggshell. With the same amount of HCl and eggshell, there are more bubbles in the reaction with 6M HCl and the rate of bubbling is more quickly than the reaction with 1 M HCl.②We know from the experiment that with other conditions the same, the higher concentration of reactants leads to the higher reaction rate.③The result met my expectation because according to the manual and *Chemical Principles*, increased concentration of reactants will lead to increased number of reactants molecules in the same amount of space, making more chances for a collision to occur and speed up the reaction.

E4-1. Part B: Effect of Changing the Surface Area

①The result of the experiment is that with other conditions the same, in a short time, the CuSO4 solution changes from blue to pale green with iron powder but the color of the solution with iron wire just becomes a bit shallower in a long time.②We know from the experiment that with other conditions the same, larger surface area leads to higher reaction rate.③The result met my expectation because according to the manual and *Chemical Principles*, only the atoms on the surface are available to collide with the other reactant. Therefore, larger surface area leads to higher rate of reaction.

E4-1. Part C: Effect of Changing the Temperature

①The result of the experiment is that with other conditions the same, the color of the CuSO4 solution with iron powder at 80°C changes from blue to pale green in a short time and the color of the metals changes from silver to reddish-brown. However, the color of the CuSO4 solution with iron powder at 0°C just becomes shallower in a longer time, still remaining blue and the color of the metals changes from silver to reddish-brown.②We know from the experiment that with other conditions the same, higher temperature leads to higher reaction rate. ③The result met my expectation, because according to the manual and Chemical Principles, The kinetic energy of the CuSO4 and Fe molecules increases with temperature, and this increase in kinetic energy causes a greater frequency of collisions between the reactant molecules, making it easier to cross the activation energy barrier and facilitate the reaction.

E4-1. Part E: Effect of adding a catalyst

①The result of the experiment is that there are a few bubbles in H_2O_2 solution without catalyst at room temperature and the rate of bubbling is slow and steady. As for the H_2O_2 solution with catalyst at room temperature, there are a lot of bubbles in the H_2O_2 solution and the rate of bubbling is extremely quickly and the solution sends much heat. The H_2O_2 solution without catalyst at 0℃ shows no obvious phenomenon, and the H_2O_2 solution with catalyst has a few of bubbles and the rate of bubbling is really slow.②We know from the experiment that with other conditions the same, catalysts can improve the reaction rate but when the temperature is very low the effect of catalysts will be reduced.③ Catalysts provide an alternative pathway for the reaction with a lower activation energy so that they can lower the activation energy required for the reaction to occur. This allow more H_2O_2 molecules to have enough energy to overcome the activation energy barrier and convert into products. However, when the temperature is low, the kinetic energy of H_2O_2 molecules is reduced, making the activation energy barrier more difficult to cross despite the decrease in total energy needed for activation.

E4-2. Determining the Rate Law: A Kinetics Study of Iodination of Acetone

①In this experiment, we determine the rate law of iodination of acetone. We do four trails of the experiment and each trail is repeated for 2 times to decrease errors. According to the data we got, the rate law of this reaction with the same amount of HCl is that: rate=$1.02\times 10^{-5}\times$[acetone]. ②The result basically met our expectation because it was supported by similar research results (Anderson) and the calculated value with this law of #4 trail was close to the actual value.③ However, the calculated value with this law is a bit smaller than the actual value in trail #4. It means there are some errors when exploring the rate law.④The biggest laboratory error was improper measurement of the chemicals, which led to a not accurate record of reaction time and rate. The rate at which I_2 vanished was directly impacted by the wrong amounts of each solution in the Erlenmeyer flask, which led to less precise and concise results.⑤To optimize the experiment, every trail may be repeated for more times to reduce the error when making solutions. In addition, the concentration of acetone can be decreased to slow down the reaction rate, and thus the error of time recording can be reduced.

<u>REFERENCE</u>

- *Please list all the references here. Note that the manual of this experiment is also one of the references.*

William Anderson. Kinetics Lab Explained: Iodinatuion of Acetone.
VC211_SP23_E4_Manual

DATA SHEET

Datasheet for E4-1									
Section	11	Group	5						
Name	Xiao Luyan			ID	522370910178				
Part A		Part B		Part C		Part E			
1M HCl	6M HCl	Fe wire	Fe powder	Iced cold	Hot at 80℃	Without MnO_2	With MnO_2	Without MnO_2	With MnO_2
Same mass of eggshells		All 0.2g		With Fe/Zn powder		At room temperature		Iced condition	
moderate	fast	The wire turned to red but the solution's color does not change	The iron powder became red quickly and the solution became green	No significant change	The red solid generated quickly and the solution color changed quickly	No significant change	The bubbles come out very fiercely	No significant change	No significant change

6M HCl

↓

fast

1M HCl

↓

moderate

Fe wire & Fe powder

The wire turned to red but the solution's color doesn't change

The iron powder became red quickly and the solution became green.

Iced cold & Hot at 80°C

No significant change

The red solid generated quickly and the solution color changed quickly

room tem. — with MnO_2 : The bubbles come out very fiercely
— without MnO_2 : no significant change

iced - cold — with MnO_2 : no significant change
— without MnO_2 : no significant change

Datasheet for E4-2				
Solution #	1	2	3	4
Volume of 4M acetone solution (mL)	10.0	10.0	20.0	20.0
Volume of water (mL)	20.0	10.0	10.0	0.0
Volume of 1M HCl solution (mL)	10.0	10.0	10.0	10.0
Volume of 0.00118M iodine solution (mL)	28.99	55.53	13.29	23.81
Reaction time, trial 1 (s)	29.03	56.21	14.33	24.67
Reaction time, trial 2 (s)	29.01	55.87	13.81	24.24

Table 1: Primary results

Solution mol/L	1	2	3	4
Volume of 4M acetone solution (mL)	10.0	10.0	20	20
Volume of water (mL)	20.0	10	10	0
Volume of 1M HCl solution (mL)	10.0	10	10	10
Volume of 0.00118M iodine solution (mL)	10.0	20	10	20
Reaction time, trial 1 (s)	28.99	55.33	13.29	23.81
Reaction time, trial 2 (s)	29.03	56.21	14.33	24.67
Reaction time, average (s)	29.01	55.87	13.81	24.24