Introduction to Kinetics: Factors that Affect the Rate of Reaction

Zhao Yiqing

April 12, 2018

Student ID	517370190190
Section	5
Group	29
Group Members	Cai Weihao
	Guo Yunjie
	Yang Yiwei
Telephone	13611793719
Email Address	*cissy*1999@*sjtu.edu.cn*

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

I OBJECTIVES

- Have the ability to list and rationalize the factors that affect the rates of reaction such as that shown in Figure 1.
- Explain various phenomena using the factors that affect reaction kinetics.
- Learn how team works to balance theory with practice.

II INTRODUCTION

The field of chemistry that related to the rate at which reaction occurs is called **chemical kinetics**. Some reactions such as the rusting of iron are relatively slow while others such as the combustion of hydrogen occur very quickly. Scientists have already found out factors that can be used to control the rate of reaction.
There are problems also exists in other areas such as biology and engineering(Table 1). But for each problem there is a solution. It just takes a little knowledge or theory and a few tries at improvement or experiments.

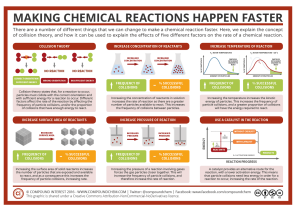

Figure 1: Factors

Consider these examples:

Career	Application
Biologist	Preservation or decomposition of specimens
Chemical Engineer	Speed of production effecting cost
Civil Engineer	Concrete and asphalt curing
Doctor	Medication or poison effecting the body
Museum Curator	Dating, restoration, preservation of artifacts
Restaurant Owner	Food spoilage and safety

Table 1: Careers & Application

III BACKGROUND

In order to learn how each factor affects each of the rate of a chemical reaction, we can use the simple model of atoms as very small spheres and picture what happens to them in different circumstances.

A Effect of Changing the Concentration of Reactants

In order to make chemical reactions occur, molecules must collide with each other. If there are only a few molecules of each reactant in a given volume, the number of collisions between them will be relatively low, causing low rates of reactions. By increasing the concentration of the reactants, we can then increase the number of reactants molecules in the same amount of space (Figure 2). This means there are more opportunities for a collision to occur and thus the rate of reaction rises.

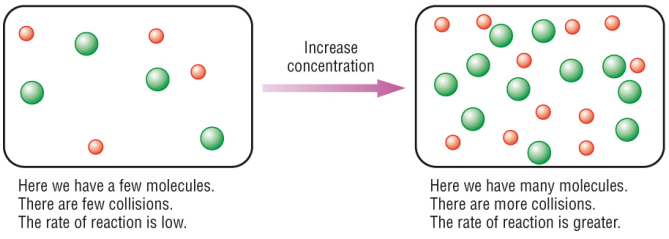

Figure 2: Concentrations and Collides

B Effect of Changing the Surface Area

Only the atoms on the surface are available to collide with the other reactant. When a cube is cut into smaller pieces (Figure 3), the amount of surface area increases, even though the total volume does not

change. When we turn a solid into a powder, we vastly increases the surface area, making a large portion of the atoms available to collide with the other reactant and then the rate rises.

C Effects of Changing the Temperature

Only when a molecule is able to acquire at least that much energy does a reaction take place. Also, chemical reactions differ in the amount of energy needed to make them occur. As the temperature of the system is increased, the kinetic energy available during collisions rises and the proportion of collisions exceeding E_a increases (Figure 4). This allows a higher rate of reaction at a higher temperature.

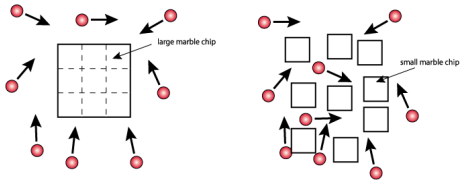

Figure 3: Surface Area

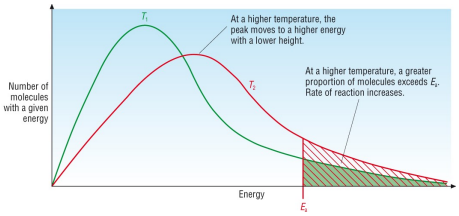

Figure 4: Temperature

D Orientation of the Collisions

Every collision does not necessarily result in a chemical reaction (Figure 5). In order to make bonds form, atomic orbitals must overlap just right. Complex molecules may have shapes that make it unlikely for this overlapping of orbitals to happen in any particular collision.

E Effect of Adding a Catalyst

A catalyst is a material that does not permanently change or get used up in a reaction, but helps the reaction run faster. The catalyst lets a reaction form the same product as it normally would, but by following a different, less energy intensive route by lowering the activation energy (Figure 6).

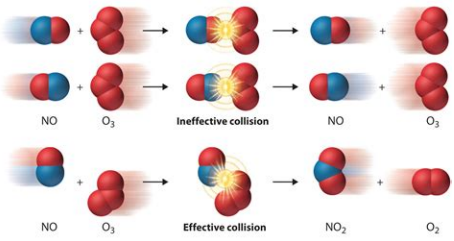

Figure 5: Orientation

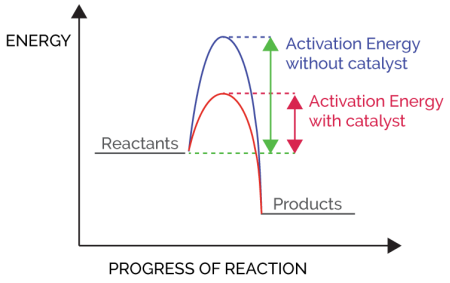

Figure 6: Catalyst

F Overview

As illustrated above, many factors lead to the changes of the rate of reaction.
In this experiment, safety rules and warnings should be obeyed.

- Do not dump any of the reagents down the sink! Discard the waste in an appropriate waste container under the supervision of your instructor!
- Do not allow solutions to come in contact with your skin! Wear gloves and goggles! (Silver ion, Ag^+, will color your skin. Some ions are **toxic**).
- Separate chemical waste to recycle Fe and Zn.

In experiment E4-I, the results are mostly qualitative but not quantitative, so do not make accurate efforts. Comparison to sample amounts is enough. Again, try not to waste and contaminate the chemicals.

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

Name:	**Lab Instructor:**
Date:	**Lab Section:**

VI RESULTS & POST-LABORATORY QUESTIONS(PLQ)

Part A. Effect of Changing the Concentration of Reactants

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?

Part B. Effect of Changing the Surface Area

Case I: Flammability of Coffee Creamer (SKIP CASE I & PROCEED TO CASE II)

Case II: Reaction Between $CuSO_4$ and Iron Metal

Describe the apprearance of the solution before addition of the iron metal.

Describe the appearance of the solution and the iron wire after the reaction.

Describe the appearance of the solution and the iron powder after the reaction.

In which case did the reaction occur first? Explain why.

Part C. Effect of Changing the Temperature

Case I: Dispersal of Dye in Hot and Cold Water (SKIP CASE I)

Case II: Reaction Between $CuSO_4$ and Zinc

Record any color changes & time to occur	**Cold Solution**	**Hot Solution**
Time For First Color Change		
Time For Second Color Change		

What effect does increasing the temperature have on the rate of reaction? Explain why.

Case III: Modeling Activation Energy(SKIP THIS CASE III)

Part D. Modeling the Significance of the Orientation of Collisions(SKIP THIS PART D)

Part E. Effect of Adding a Catalyst

Case I: Decomposing H_2O_2

Observations after addition of MnO_2:

Observations after addition of ice:

In Case I, which material is the catalyst?

Does the temperature affect the usefulness of a catalyst?

Case II: Hydrolysis of Starch(SKIP THIS CASE II)

VII CALCULATION/ANALYSIS/DATA PROCESSING

A Effect of Changing the Concentration of Reactants

A.1 Data Processing

In this part, we add 10 drops of 1M HCl to the right sample of eggshells and 6M HCl on the left. The observation is recorded in the figure below(Figure 7).

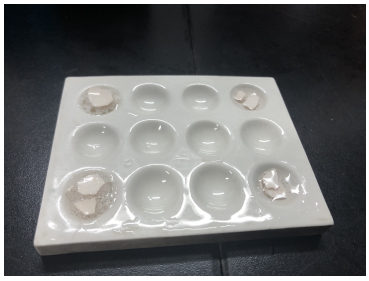

Figure 7: Effect of Changing the Concentration of Reactants

In this part, the calcium carbonate($CaCO_3$) in the eggshells reacts with HCl.

$$CaCO_3(s) + 2\,HCl\,(aq) \longrightarrow CaCl_2(aq) + H_2O\,(l) + CO_2(g)\uparrow$$

The observation we get is shown in the table(Table 2) below.

	1M HCl	6M HCl
Observation	Fewer bubble	More bubbles
Rate	Slow	Fast

Table 2: Observation of Different Concentration of Reactants

A.2 Analysis

From the amount of the bubbles and the rate of the reaction, we can get that the **higher** the concentration of the reactants, the **faster** it reacts.

B Effect of Changing the Surface Area

B.1 Data Processing

In this part, we add 5 mL of 0.2M $CuSO_4$ to each of two 50-mL beakers and heat both in hot water bath to $80°C$. Then we add a piece of 0.2g iron wire to one beaker and 0.2g iron powder the other. The iron(Fe) will replace the copper(Cu) in the $CuSO_4$ solution. We record the phenomenon(Figure 8).

$$Fe\,(s) + CuSO_4(aq)(blue) \longrightarrow FeSO_4(aq)(light\,green) + Cu\,(s)$$

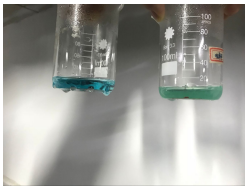

Figure 8: Effect of Changing the Surface Area

The time of color changes we measure and the phenomenon are shown in the table(Table 3) below.

	Iron Wire	Iron Powder
Color (t=80s)	Blue	Light Green
Time of Color Changes	340s	80s
Rate	Slow	Fast

Table 3: Observation of Different Surface Area of Reactants

B.2 Analysis

From the reaction time and the rate of the reaction, we can get that the **larger** the surface area of the reactants, the **faster** it reacts.

C Effect of Changing the Temperature

C.1 Data Processing

In this section, we add in 5 mL of 0.2 M CuSO4 into each of two 50-mL beakers and heat one solution to $80°C$ in the hot water bath, while cooling the other in an ice bath. Then we add a few pieces of zinc powder to each beaker. The zinc(Zn) will replace the copper(Cu) in the $CuSO_4$ solution. We record the color changes(Figure 9).

$$Zn(s) + CuSO_4(aq)(blue) \longrightarrow ZnSO_4(aq)(blank) + Cu(s)$$

The time of color changes we measure and the phenomenon are shown in the table(Table 4) below.

Figure 9: Effect of Changing the Temperature

	Cold Solution	Hot Solution
Color (t=70s)	Blue	Blank
Time of 1^{st} Color Changes	240s	70s
Time of 2^{nd} Color Changes	230s	65s
Rate	Slow	Fast

Table 4: Observation of Different Temperature of Reactants

C.2 Analysis

From the reaction time and the rate of the reaction, we can get that the **higher** the temperature of the reactants, the **faster** it reacts.

D Modeling the Significance of the Orientation of Collisions(SKIP)

E Effect of Adding a Catalyst

E.1 Data Processing

In this part, we add 10 mL of 6% H2O2 to a beaker and heat it to $80°C$. Then we add roughly 0.05g of MnO_2 to the H_2O_2. After 30 45 seconds, we then add 10 mL of ice to the solution. The MnO_2 is the catalyst to make H_2O_2 to decompose faster. We record our observations(Figure 10).

$$2\,H_2O_2(aq) \xrightarrow{MnO2} 2\,H_2O\,(l) + O_2(g)\uparrow$$

(a) Hot Solution (b) Ice Solution

Figure 10: Effect of Adding a Catalyst

The phenomenon are shown in the table(Table 5) below.

	Hot Solution Without MnO_2	Hot Solution With MnO_2	Ice Solution With MnO_2
Observasions	No Bubbles	Many more Bubbles	Fewer Bubbles
Rate	Very Slow	Very Fast	Fast

Table 5: Observation of Adding a Catalyst

E.2 Analysis

From the phenomenon and the rate of the reaction, we can get that if we add a catalyst, it reacts **faster**. Furthermore, the **higher** the temperature, the **faster** it reacts when a catalyst is added.

VIII DISCUSSION

A Effect of Changing the Concentration of Reactants

During this part, we estimated that the reactants with **higher** concentration react **faster** because reactants with **higher** concentration have **larger** number of reactants molecules in the same amount of space, in other words, may have **more** oppotunities for collisions to occur according to the background.

We then observed the differences of the reaction after changing the concentration of reactants. When adding 1M HCl and 6M HCl to the eggshells, both of them reacts quickly and have bubbles. However, when adding 6M HCl to the eggshells, it reacts much **faster** and has **more bubbles** than the 1M HCl. We then get the conclusion that the **higher** concentration of the reactants, the **faster** it reacts, which proved our estimation.

B Effect of Changing the Surface Area

During this part, we estimated that the reactants with **larger** surface area react **faster** because reactants with **larger** surface area have **more** area for collisions. We then observed the differences of the reaction after changing the surface area of reactants. When adding the iron wire and the iron powder to the $CuSO_4$ solution at $80°C$, both of them turn from blue to light green finally. However, the iron powder makes the solution turn light green **faster** than the iron wire.
We then get the conclusion that the **larger** the surface area of the reactants, the **faster** it reacts, which proved our estimation.

C Effect of Changing the Temperature

During this part, we estimated that the reactants with **higher** temperature react **faster** because reactants with **higher** temperature have **more** kinetic energy available then collisions goes up. We then observed the differences of the reaction after changing the temperature of reactants. After heating and freezing the $CuSO_4$ and Zn, both of them turn from blue to blank eventually. However, the one with **higher** temperature turns blank more quickly than the one with **lower** temperature.
We use the stop watch to measure the time.
Error 1:
The two trials have a relative large percent difference of time.
Cause 1:
The zinc we add and the $CuSO_4$ solution we add, are all roughly the same. There might be some slight difference in the amount causing the time difference.
Cause 2:
During the reaction, we stirred the beaker to make it react faster so that we have enough time for the second experiment, so the time may be different because the speed we stirred may not be the same, and thus caused the error.
We then get the conclusion that the **higher** temperature of the reactants, the **faster** it reacts, which proved our estimation.

D Modeling the Significance of the Orientation of Collisions(SKIP)

E Effect of Adding a Catalyst

During this part, we estimated that the reactants with catalysts react **faster** because the catalyst makes the reactants follow a different, **less energy** intensive route. We then observed the differences of the reaction after adding the catalyst. Before adding MnO_2, there is few bubbles in the beaker at $80°C$, however, after adding MnO_2, there is **many more bubbles** in the beaker. Then we put the beaker into the ice, there is **less bubbles**.
One accident is that the beaker was knocked over in the ice container.
We then concluded that the catalyst makes the reaction react faster. Furthermore, the temperature also have impact on the catalyst. In this case, the **higher** the catalyst, the **faster** the reactants react.

F Other Problems

Confusing Problem 1:
In this experiment, we know that the temperature has an impact on the catalyst. During $0°C$ to $80°C$, the catalyst makes the reaction have a higher rate, but what about higher than $80°C$?
Possible Answer 1:
After searching for some information, I get that the activation temperature is at which the catalyst can activate the reactants best. The activation temperature of MnO_2 is just around $80°C$, so higher than

$80°C$, the rate of the reaction may become lower.

IX CONCLUSION & RECOMMENDATIONS

In the experiment *Introduction to Kinetics: Factors that Affect the Rate of Reaction*, I learn:

- How does the concentration of reactants affects the reaction rate?
- How does the surface area of reactants affects the reaction rate?
- How does the temperature of reactants affects the reaction rate?
- How does the catalyst affects the reaction rate?
- How to list and rationalize the factors that affect the rates of reaction such as that shown in Figure 1?
- How to explain various phenomena using the factors that affect reaction kinetics?

However, I also failed to:

- Keep the beaker balanced in the ice container.

In part A, we examined how the concentration of reactants affects the reaction rate, and finally we concluded that the **higher** concentration of the reactants, the **faster** it reacts.
In part B, we examined how the surface area of reactants affects the reaction rate, and finally we concluded that the **larger** the surface area of the reactants, the **faster** it reacts.
In part C, we examined how the temperature of reactants affects the reaction rate, and finally we concluded that the **higher** temperature of the reactants, the **faster** it reacts.
In part E, we examined how the catalyst affects the reaction rate, and finally we concluded that the catalyst makes the reaction react faster. Furthermore, the temperature also have impact on the catalyst. In this case, the **higher** the catalyst, the **faster** the reactants react.

I do recommend to save the reagents as well as keep the balance of the beaker in the water bath and the ice container.
Safety is always the most important when doing the experiment. When some glasswares are broken, get away from it first and then remember to wear the gloves to clean it.

X REFERENCES

-1. Peter Atkins, Loretta Jones, Leroy Laverman, "Chemical Principles The Quest for Insight Seventh Edition", macmillan education,2016.
-2. T. Hamade, "Introduction to Kinetics: Factors that Affect the Rate of Reaction", UM-SJTU JI & SJTU Chemistry Department,2018.