

THE EFFECT OF TEMPERATURE AND CONCENTRATION ON REACTION RATE

INTRODUCTION

FACTORS INFLUENCING REACTION RATE:

The study of chemical reactions is not complete without a consideration of the rates at which these reactions proceed. We know that some reactions such as those between ions in solution frequently proceed very rapidly, while others proceed so slowly that the rate is not even detectable. The practical importance of these rate considerations is difficult to exaggerate. For example, a metal which is exposed to weather will undergo reactions with oxygen and water which result in corrosion. The speed with which a certain reaction will proceed will often determine the industrial usefulness of the material.

Among the most important factors influencing the rate of a reaction are: temperature, concentration and catalysis. In addition, for solids the condition of the surface is of great importance.

There are two main theories involved in explaining reaction rates. These are the Activated Complex (Transition State) Theory and the Collision Theory. However, in the lecture part of the course, you will also look at the Activated Complex (Transition State) Theory.

COLLISION THEORY

Consider the simple reaction: $A + B \longrightarrow \text{Products}$

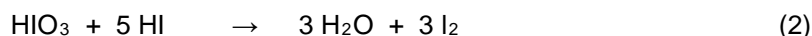
A and B are atoms, ions, or molecules (we shall call them molecules in the discussion which follows) and may be in the gas phase or in solution. In order for A and B to react with each other, they must come together. Since molecules are in rapid and continual motion, molecules of A and B will collide with one another at frequent intervals. However, not every collision of A and B will result in the formation of products. Before a reaction can occur, the reactants collide with a certain amount of energy termed the activation energy. This energy comes from the kinetic energy that A and B possess, so that only those collisions which occur with sufficient force will be effective in causing reaction. If the concentration of either A or B is doubled, the number of collisions between A and B per time is doubled. If the temperature is raised, the kinetic energies of both A and B are increased so that there are more collisions per second, and a greater fraction of these will lead to chemical reaction. The rate, therefore, generally increases with increasing temperature.

CATALYSIS

A catalyst can be thought of as an agent, which alters the speed of a chemical reaction. This results from a decrease in the amount of activation energy necessary for the reaction. When less activation energy is needed, a larger fraction of the collisions will possess the required energy, and the rate will increase. The manner in which the catalyst lowers the activation energy depends upon the type of catalyst. A catalyst which decreases the speed of a reaction is called an inhibitor.

CLOCK REACTION

In this experiment, the effect of temperature and concentration on the rate of a chemical reaction will be studied. The reaction chosen, frequently termed the "clock reaction", is actually a series of consecutive reactions represented by the following equations:



The iodine that is produced in reaction (2) is immediately used up in reaction (3), so that no appreciable concentration of iodine can build up until all of the Na_2SO_3 has been used up. When this occurs, the iodine concentration becomes great enough to change the color of a starch indicator to blue. The appearance of the blue color is thus an indication that all of the Na_2SO_3 has been used up.

Experiment

EQUIPMENT

You will be working on this experiment in pairs. Each pair will fill out a slip (names of both students on slip) to check out the following four items from the stockroom:

3	5 mL volumetric pipets	1	pipet helper
1	10 mL volumetric pipet	1	timer

- During Summer and Fall semesters, students should keep all four items, storing them in their drawers, until they have finished the experiment.
- During Spring semester, students must return all four items to the stockroom at the end of the lab period, unless advised otherwise.

Before returning items to the stockroom, all glassware is to be rinsed out thoroughly, the final rinse with deionized water.

A. THE EFFECT OF TEMPERATURE ON REACTION RATE

Lab Notebook: Set up a table in your lab notebook for the data for this part of the experiment.

TABLE A: Temperature vs. Rate Data (Make this graph at least $\frac{1}{2}$ a page)

Approximate Temperature	Run #	Measured Temperature ($^{\circ}\text{C}$)	Average Temperature ($^{\circ}\text{C}$)	Run Time (seconds)	Average Run Time (seconds)
~50 $^{\circ}\text{C}$					
~ RT* = _____					
~10 $^{\circ}\text{C}$					

*Room Temperature

DO NOT RECORD YOUR DATA ON THIS PAGE. COPY TABLE INTO NOTEBOOK!

Note: You need only do two good runs at each temperature, $\sim 10^{\circ}\text{C}$, $\sim 30^{\circ}\text{C}$, and $\sim 50^{\circ}\text{C}$. Do more than two runs at the same temperature only if the times for the two runs differ greatly. That is -- repeat the measurements at a particular temperature until two consistent values for time are obtained.

CAUTION

IODIC ACID: CAUSES IRRITATION. HARMFUL IF SWALLOWED.

SODIUM SULFITE: HARMFUL IF SWALLOWED. MAY CAUSE ALLERGIC REACTION AND BREATHING DIFFICULTIES. MAY CAUSE IRRITATION TO SKIN, EYES, AND RESPIRATORY TRACT.

1. Set up a water bath in your 250 mL beaker. Heat the water bath to approximately 50°C .
2. Pipet 10 mL of 0.016 M HIO_3 solution into each of two 5" test tubes. Add 5 drops of fresh starch solution to each test tube. Label each test tube with " HIO_3 ". (You may prepare 6 test tubes of HIO_3 at the same time.)
3. Pipet 10 mL of 0.014 M Na_2SO_3 into each of two 5" test tubes. (You may prepare 6 test tubes of Na_2SO_3 at the same time.)
4. Place the test tubes in the water bath that has been heated to the desired temperature. Read and record the temperature of the water bath. Leave the samples in the water bath for at least 4 minutes.
5. Take one of the Na_2SO_3 samples. Pour it into a clean, dry evaporating dish. Immediately add, with stirring, the HIO_3 solution. Begin timing when you add the HIO_3 solution to the evaporation dish. Stop timing, when the blue color appears and record the time of the reaction. (The color change should be very abrupt. If the change does not occur all at once throughout the solution, you did not mix the two reagents well enough.)
6. Repeat Step 5 with another set of Na_2SO_3 and HIO_3 samples, and time the reaction as before. If the time for this second run is significantly different than the time of the first run, repeat the procedure for a third run. Continue until two consistent values for time are obtained.
7. Reduce the temperature of the water bath to approximately $\text{RT} = \underline{\hspace{2cm}}$ and repeat steps 2 through 6 at that temperature.
8. Reduce the temperature of the water bath to approximately 10°C and repeat steps 2 through 6 at that temperature.
9. Make a plot of Time vs. Temperature (use the average time at each temperature); draw a smooth line through the points. **Tape your graph to the blank page following Table A.**

Answer the following question:

1. Does the reaction rate increase or decrease with decrease in temperature? Explain, giving two reasons in terms of Collision Theory

B. The Effect of Concentration on Reaction Rate

Lab Notebook: Set up a table in your lab notebook for the data for this portion of the experiment. (Make this graph at least $\frac{1}{2}$ a page)

Table B: Concentration vs. Rate Data

Dilution	Run #	Volume (mL) 0.016 M HIO ₃	Volume (mL) water	Total Volume (mL) HIO ₃ solution	Molar Concentration HIO ₃ Solution (after dilution)	Time (seconds)	Average Time (seconds)
none	1	10.00	0.00	10.00	0.016	-	*
First		10.00	5.00				
Second		10.00	10.00				
Third		10.00	15.00				

* This one value is from Table A.

DO NOT RECORD YOUR DATA ON THIS PAGE. COPY TABLE INTO NOTEBOOK!

Note: In this part of the experiment, under some conditions, it may take as long as three minutes for the color change to occur.

Heat your water bath to ~ RT (Room Temperature) -- that is -- to the same temperature you used for your ~RT runs in Part A. Try to keep the temperature of the water bath constant throughout this part of the experiment.

1. Undiluted 0.016 M HIO₃
 - * Complete the "Average Time" column for run #1, by simply copying from Table A the "Average Time" for the reactions at RT (Room Temperature).

2. First Dilution:
 - a. Pipet 10 mL of 0.016 M HIO₃ into each of two clean, dry 8" test tubes. Add 5 mL (pipet) of deionized water and 5 drops of starch solution to each test tube and mix well.
 - b. Pipet 10 mL of 0.014 M Na₂SO₃ into each of two 7" test tubes.
 - c. Place all four test tubes into the water bath and leave them there for at least four minutes.
 - d. Take one of the Na₂SO₃ samples and pour it into a clean, dry evaporation dish. Immediately add the HIO₃ solution. Begin timing. Stop timing when the blue color appears and record the time of the reaction.

- e. Repeat Step 5 with another set of Na_2SO_3 and HIO_3 samples, and time the reaction as before. If the time for this second run is significantly different than the time of the first run, repeat the procedure for a third run.
3. Second Dilution:

Proceed exactly as you did in part 2, except the two HIO_3 solutions should be prepared as follows:

Pipet 10 mL of 0.016 M HIO_3 into each of two clean, dry 8" test tubes. Add 10 mL (measure using the 10 mL pipet) of deionized water and 5 drops of starch solution to each test tube and mix well.

4. Third Dilution:

Proceed exactly as you did in part 2, except the two HIO_3 solutions should be prepared as follows:

Pipet 10 mL of 0.016 M HIO_3 into each of two clean, dry 8" test tubes. Add 15 mL (measure using the 10 mL and the 5 mL pipets) of deionized water and 5 drops of starch solution to each test tube and mix well.

5. Make a plot of molar concentration of HIO_3 vs. time; draw a smooth line through the points. **Tape your graph to the blank page following Table B.**

Answer the following questions in your notebook in the form of conclusions:

1. Does the reaction rate increase or decrease with dilution of one of the reactants? Give an explanation in terms of collision theory.
2. Is the reaction first order or second order? You will need to make two plots of your data to answer this question; a plot $\log [\text{HIO}_3]$ vs. time, and a plot of $[\text{HIO}_3]^{-1}$ vs. time. **Tape your graphs (A total of two graphs) to the blank pages following your answer to this question.**

Notebook:

Purpose

Equations

Procedure A

Data Table

Question Part A

Graph A

Procedure B

Data Tables

Graph

Calculations

Questions Part B

Graphs to question #2

Summary