THE EFFECT OF TEMPERATURE AND CONCENTRATION ON REACTION RATE

INTRODUCTION

FACTORS INFLUENCING REACTION RATE:

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. 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.

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 collide with each other. 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:

$$HIO_3 + 3\,Na_2SO_3 \ \_\ HI + 3\,Na_2SO_4 \qquad (1)$$

$$HIO_3 + 5\,HI \ \_\ 3\,H_2O + 3\,I_2 \qquad (2)$$

$$I_2 + Na_2SO_3 + H_2O \ \_\ 2\,HI + Na_2SO_4 \qquad (3)$$

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 **1 timer** form the stockroom:

A. THE EFFECT OF TEMPERATURE ON REACTION RATE

TABLE A: Temperature vs. Rate Data

Approximate Temperature	Run #	Measured Temperature (°C)	Average Temperature (°C)	Run Time (seconds)	Average Run Time (seconds)
50°C					
Room Temp = _____					*
10°C					

*use this value in the table below

Note: You to do two good runs at each temperature, ~10°C, Room temperature, and ~50°C.

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. To go quicker start with hot water from the tap.

2. In your 10 mL graduated cylinder, measure 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 will need 6 total tubes so you may prepare 6 test tubes of HIO_3 at the same time.)
3. In a clean 10 mL graduated cylinder measure 10 ml of 0.014 M Na_2SO_3 into each of two 5" test tubes. (You will need 6 total tubes so you may prepare 6 test tubes of Na_2SO_3 at the same time.)

4. Place 2 of each of the test tubes you prepared in the water bath that has been heated to the desired temperature. You could start with hot water from the tap and heat it to 50 degrees. 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.)

   Record your observations:

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. Now repeat the experiment with water that is room temperature Record the actual temperature = _____ and repeat steps 4 through 6 at that temperature.

8. Repeat the experiment again with the water bath that is about 10°C and repeat steps 4 through 6 at that temperature. You will need ice from your instructor.

9. Make a graph of Time vs. Temperature (use the average time at each temperature); draw a smooth line through the points.

B. The Effect of Concentration on Reaction Rate

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 at room temperature.

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 room temperature 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 HIO_3
   *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. Measure10 mL of 0.016 M HIO_3 into each of two clean, dry 8" test tubes. Add 5 mL of deionized water and 5 drops of starch solution to each test tube and mix well.

   b. Measure 10 mL of 0.014 M Na_2SO_3 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 Na_2SO_3 samples and pour it into a clean, dry evaporation dish. Immediately add the HIO_3 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:

   Measure 10 mL of 0.016 M HIO_3 into each of two clean, dry 8" test tubes. Add **10** mL 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:

   Measure 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 graduated cylinder) of deionized water and 5 drops of starch solution to each test tube and mix well.

Calculations:

Use the following equation to determine the molar concentration of the reactants.

$M_1 V_1 = M_2 V_2$ You are trying to find M_2 the new molarity. $M_2 = \frac{M_1 V_1}{V_2}$

Here is an example for the first run on table 2:

First Dilution

M_1 = .016 M V_1 = 10.00ml M_2 = ? V_2 = 10.00 ml + 5.00 ml = 15 .00 ml	$M_2 = \frac{M_1 V_1}{V_2} = \frac{.016 \text{ M} \times 10.00 \text{ ml}}{15.00\text{ml}}$ **M_2 =0.0107M**

Second Dilution

M_1 = .016 M V_1 = 10.00ml M_2 = ? V_2 =	$M_2 = \frac{M_1 V_1}{V_2}$ = ______________ **M_2 =**

Third Dilution

M_1 = V_1 = M_2 = ? V_2 =	$M_2 = \frac{M_1 V_1}{V_2}$ = ______________ **M_2 =**

Put the answers to each of these calculations into Table B in the column that says "Molar Concentration HIO_3 Solution (after dilution)".

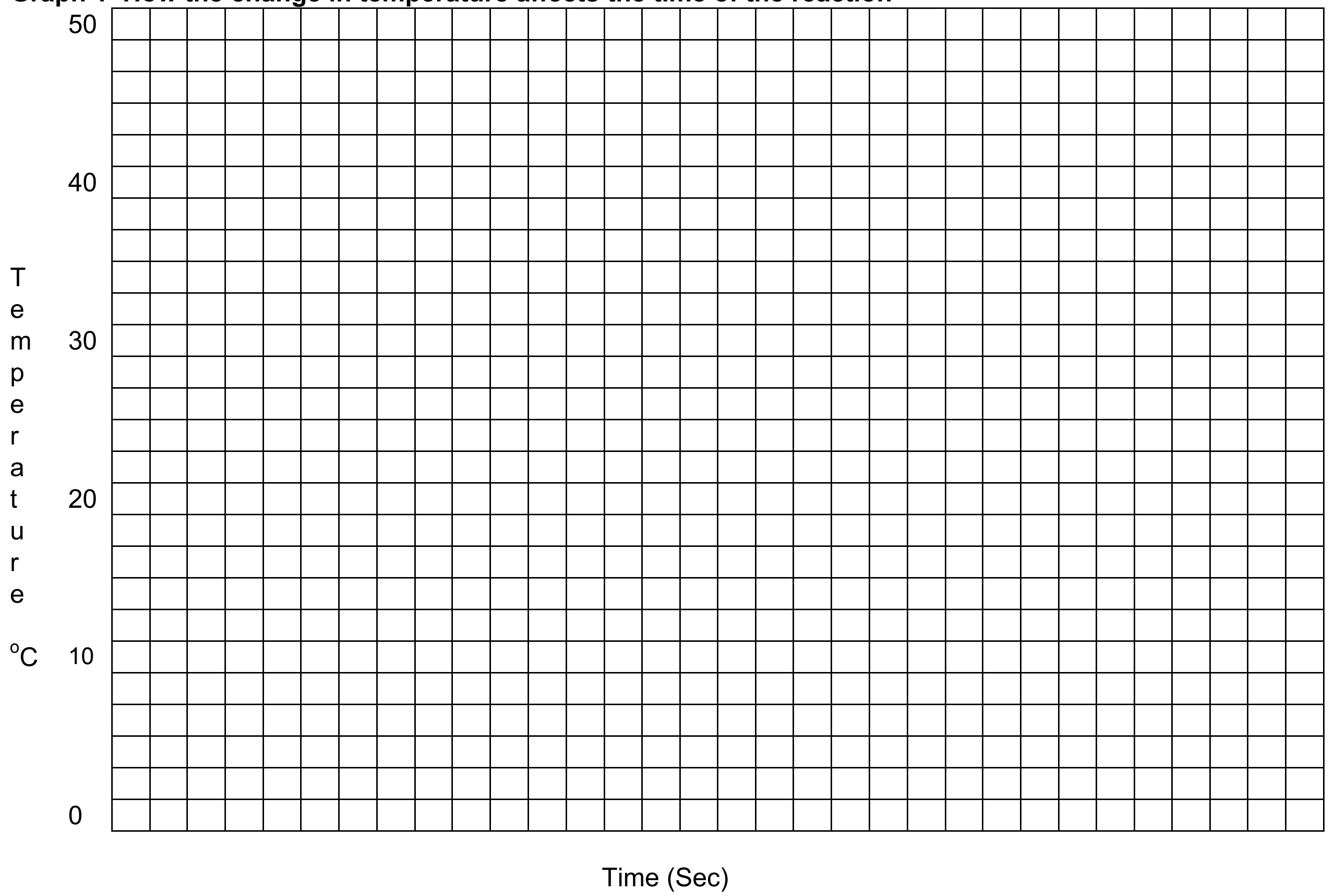
5. Make a graph of molar concentration of HIO_3 vs. time; draw a smooth line through the points.

Name:______________________________

Report Sheet Experiment

You must complete the two graphs before you get your report sheet initialed. You must turn in the graphs as part of the report sheet.

Graph 1 How the change in temperature affects the time of the reaction

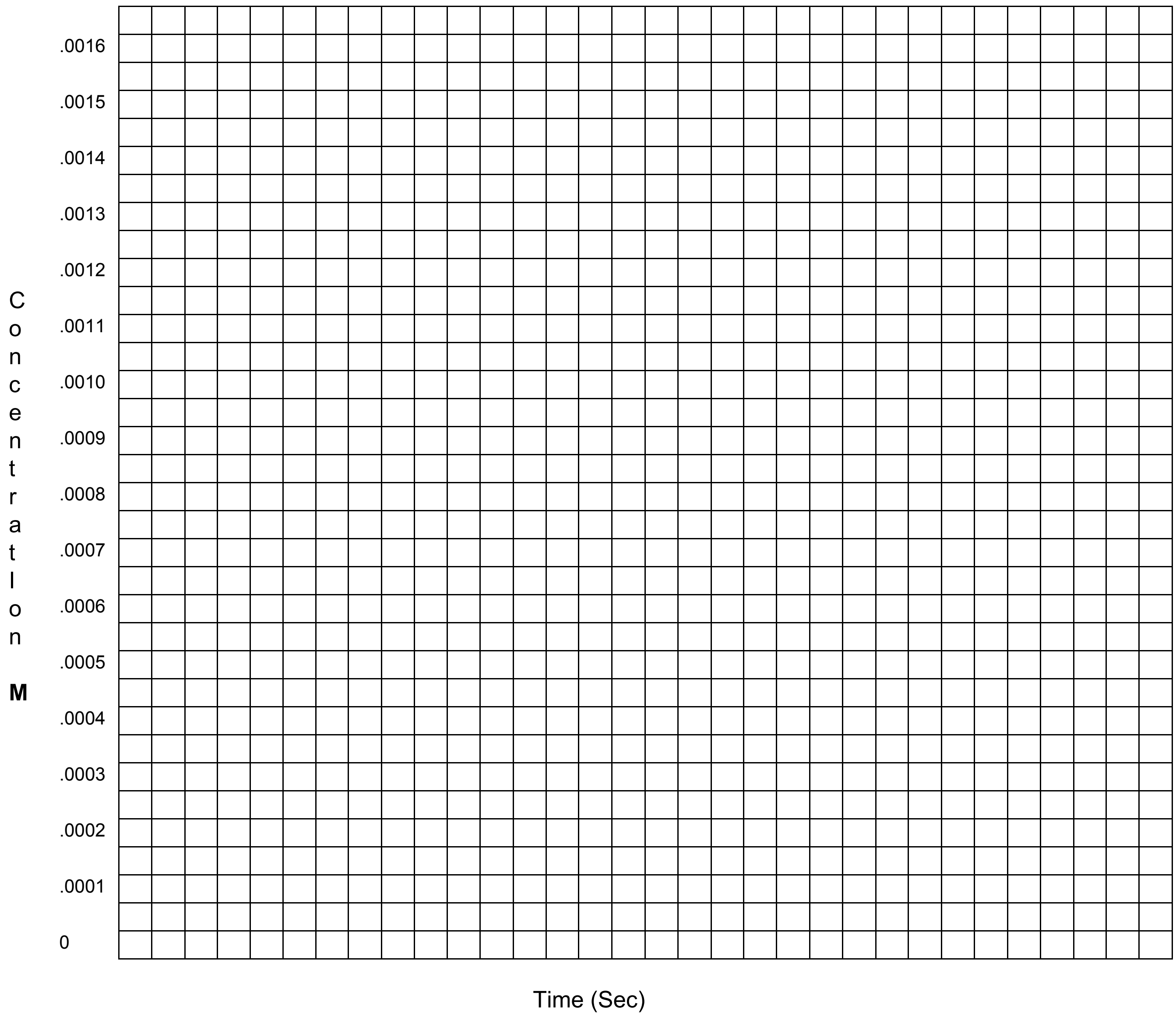


C. THE EFFECT OF TEMPERATURE ON REACTION RATE

TABLE A: Temperature vs. Rate Data

Approximate Temperature	Run #	Measured Temperature (°C)	Average Temperature (°C)	Run Time (seconds)	Average Run Time (seconds)
50°C					
Room Temp = _____					*
10°C					

Graph 2 How the change in concentration affects the time of the reaction



D. The Effect of Concentration on Reaction Rate

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				

Answer the following question:

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

2. Look at graph 1. What is the relationship between the temperature of the reaction and how fast the reaction occurred?

3. Does the reaction rate increase or decrease with dilution of one of the reactants? Give an explanation in terms of collision theory.

4. Look at graph 2. What is the relationship between the concentration of the reaction and how fast the reaction occurred?

5. What did you learn from this experiment?