

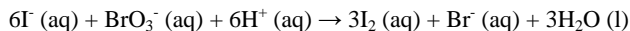
Name: _____
Period: ____

Lab: Kinetics

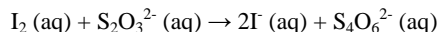
Introduction:

In this experiment, the rate law for a reaction will be determined using the method of initial rates. Also, the activation energy and frequency factor for the reaction will be determined by investigating the rate at various temperatures. In addition, the effect on reaction rate of a catalyst will be examined.

The reaction for this experiment is as follows:



In order to monitor when the reaction is completed, a small amount of thiosulphate ion will be added. Thiosulphate reacts with the iodine being produced according to the following equation:



While the first reaction is relatively slow, this reaction takes place very rapidly, and in the presence of starch will result in a deep blue colour. The time required for the first reaction to be completed can therefore be determined as the time it takes for the blue colour to appear.

The rate in this reaction will be calculated by determining the change in concentration of the bromate ion over time according to the following equation:

$$\text{Rate} = \frac{\Delta[\text{BrO}_3^-]}{\Delta t}$$

By examining how the varying the relative concentration of each reactant effects the rate, the order of each reactant and a rate law can be determined.

The rate of a reaction depends on temperature. This relationship can be described according to the Arrhenius equation:

$$\ln k = \ln A - \frac{E_a}{RT}$$

Where: k = rate constant
A = the frequency factor
E_a = activation energy (J/mol)
R = gas constant (8.314 J/mol K)
T = temperature (K)

The time required for the reaction to take place at temperatures ranging from 0 °C to 40 °C will be determined. A plot of ln(k) vs 1/T will be created in order to calculate the activation energy and frequency factor for the reaction.

The reaction in this experiment can be catalyzed by the compound copper (II) nitrate. The time required for the reaction to occur in the presence of a catalyst will be determined and compared to the time required for the uncatalyzed reaction.

Procedure:

I. Determining the Volume of One Drop of Water

- (1) Determine the mass of an empty beaker and record.
- (2) Add 20 drops of water to the beaker. Determine the mass and record.
- (3) Calculate the mass of 20 drops of water. This information will be used to determine the volume of one drop of water.

II. Determining the Rate Law

- (1) Obtain a clean, dry well plate and approximately 5 mL of 0.040 M potassium bromate solution in a large test tube. The following reactants will be available in the lab: 0.010 M potassium iodide, 0.10 M hydrochloric acid, 2% starch, 0.0010 M sodium thiosulphate, and water.
- (2) For each experiment, the reactants will be combined as described in the table below. **Be sure to add the potassium bromate last.** The time required for the reaction to be completed (ie. the time it takes for a blue colour to appear) will be recorded in the observations. **Begin timing as soon as the potassium bromate is added.** In order to make the colour change easier to observe, place a white piece of paper underneath the well plate. Perform three trials for each experiment and calculate the average time.

Experiment Number	0.010 M KI	H ₂ O	0.10 M HCl	2% Starch	0.0010 M Na ₂ S ₂ O ₃	0.040 M KBrO ₃
1	2 drops	4 drops	2 drops	1 drop	1 drop	2 drops
2	4 drops	2 drops	2 drops	1 drop	1 drop	2 drops
3	2 drops	2 drops	4 drops	1 drop	1 drop	2 drops
4	2 drops	2 drops	2 drops	1 drop	1 drop	4 drops

III. Reaction Rate and Temperature

- (1) Prepare a water bath with a temperature of approximately 20 °C (this should be the approximate temperature of tap water). Record the actual temperature. Place a small test tube in the water bath. In the test tube, combine reactants as described in experiment 1 above. Allow the test tube one minute to reach the temperature of the water bath before adding the potassium bromate. Determine the amount of time required for the reaction to be completed and record.
- (2) Repeat the experiment for the following temperatures 0 °C, 10 °C, 30 °C, and 40 °C. Obtain colder temperatures by adding ice to the water bath and obtain warmer temperatures by using the hot plate. Record the actual temperature of each water bath.

IV. The Effect of a Catalyst

- (1) Obtain a dropper bottle containing the catalyst 0.10 M copper (II) nitrate.
- (2) In a small test tube, combine the following quantities of reactants: 2 drops of 0.010 M KI, 3 drops of H₂O, 2 drops of 0.10 M HCl, 1 drop of 0.10 M Cu(NO₃)₂, 1 drop of 2% starch, 1 drop of 0.0010 M Na₂S₂O₃, and 2 drops of 0.040 M KBrO₃. Determine the amount of time required for the reaction to be completed and record.

Data:

I. Determining the Volume of One Drop of Water

Mass of empty beaker = _____ g

Mass of empty beaker with 20 drops of water = _____ g

Mass of 20 drops of water = _____ g

II. Determining the Rate Law

Experiment Number	Time for Trial 1 (s)	Time for Trial 2 (s)	Time for Trial 3 (s)	Average Time (s)
1				
2				
3				
4				

III. Reaction Rate and Temperature

Temperature (°C)	Actual Temperature (°C)	Time (s)
0		
10		
20		
30		
40		

IV. The Effect of a Catalyst

Time required for the catalyzed reaction = _____ s

Questions:

(1) Using the measured mass of 20 drops of water and the density of water, determine the volume of 20 drops of water. Determine the volume of 1 drop of water in liters.

(2) (a) Using the concentration of each solution, the initial volume of each solution, and the final total volume, determine [I⁻], [BrO₃⁻], and [H⁺] for each experiment.

(b) Determine the rate for each reaction. The rate is defined as the change in concentration of bromate divided by the change in time. An examination of the reaction taking place in this experiment shows that 1 mol BrO₃⁻ produces 3 mol of I₂. Additionally, 1 mol of I₂ produces 2 mol S₂O₃²⁻. As a result, 1 mol of BrO₃⁻ yields 6 mol of S₂O₃²⁻. Since all of the thiosulphate ion added to monitor the reaction is consumed, the moles of thiosulphate ion present can be used to calculate the moles of bromate used. Since the moles of bromate used can be determined and the total volume for each experiment is known, the concentration change of bromate can be determined. (Note: the concentration change will be the same for each experiment as a constant amount of thiosulphate is added.) The rate for each experiment can therefore be determined by dividing the concentration change of bromate by the average time required for each reaction to occur.

Experiment Number	[I ⁻] (M)	[BrO ₃ ⁻] (M)	[H ⁺] (M)	$\frac{\Delta[\text{BrO}_3^-]}{\Delta t}$ (mol/Ls)
1				
2				
3				
4				

(3) Use the concentrations of each reactant and the rates to determine the order for each reactant. (Round to the closest whole number). What is the overall order of the reaction?

(4) Use the data for each experiment to calculate a rate constant. Calculate the average rate constant and specify units.

Experiment Number	Rate Constant, k
1	
2	
3	
4	
Average:	

Write a rate law for this reaction.

(5) Why does the reaction rate change as concentration changes? Explain using collision theory.

(6) (a) Calculate the actual temperature in Kelvin for each experiment and determine $1/K$.

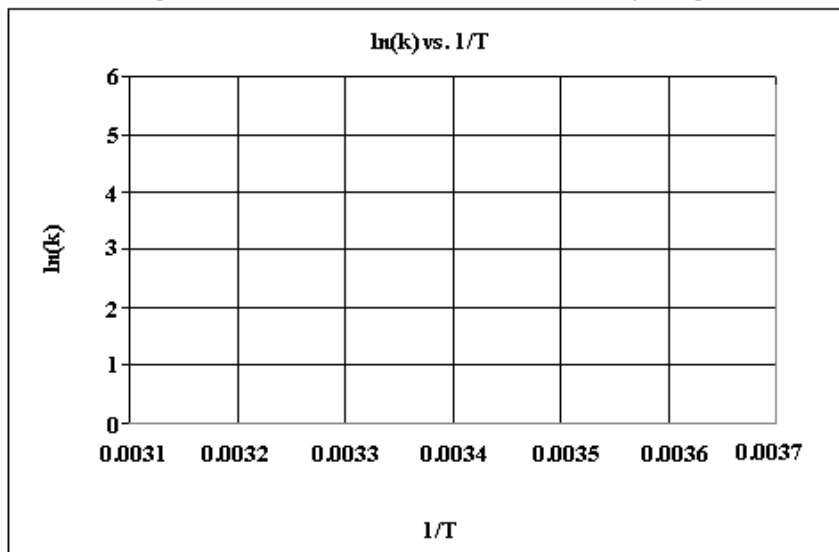
(b) Calculate the rate for each temperature by dividing the change of in concentration of bromate by the time required for each reaction to occur (note: the concentration change for bromate is the same as for question 2).

(c) Determine the rate constant, k, for each reaction by using the rate law and $[I^-]$, $[BrO_3^-]$, and $[H^+]$ for this experiment.

(d) Calculate $\ln(k)$ for each experiment.

Actual Temperature (°C)	Temperature (K)	$\frac{1}{K}$	Time (s)	$\frac{\Delta[BrO_3^-]}{\Delta t}$ (mol/Ls)	Rate Constant, k	$\ln(k)$

(7) (a) Create a plot of $\ln(k)$ vs. $1/T$. Draw a line of best fit through the points.



(b) Calculate the slope of the graph and use it to determine to activation energy in kJ/mol.

(c) Calculate the y-intercept of the graph and use it to calculate the frequency factor.

(8) Why does the reaction rate change as temperature changes? Explain using collision theory.

(9) How does the reaction rate change when a catalyst is added? Why is the change observed?

Conclusion:

Give the rate law and Arrhenius equation for the reaction.

Error Analysis:

Calculate the percent error for the rate constant and the activation energy.