The kinetics of a reaction | experiment

This experiment is designed to study the kinetics of a chemical reaction. The reaction is called a “ clock” reaction because of the means of observing the reaction rate. The reaction involves the oxidation of iodide by bromate in the presence of an acid:

Step 1: 6 I- (aq) + BrO3- (aq) + 6 H+ (aq) â†’ 3 I2 (aq) + Br- (aq) + 3 H2O (l) SLOW

Step 2: I2 (aq) + 2 S2O32- (aq) â†’ 2 I- (aq) + S4O62- (aq) FAST

Step 3: I2 (aq) + Starch â†’ I2-starch complex FAST

The reaction is somewhat slow at room temperature, and the rate depends on the concentration of the reactants and on the temperature. If we express the rate of reaction as the rate of decrease in concentration of bromate ion, the rate law has the form:

Rate = -âˆ† [BrO3-] / âˆ† t = k [I-]m [BrO3-]n [H+]p

The term k is the rate constant for the equation, and changes as temperature changes. The exponents m, n, and p are the orders of the reaction with respect to the indicated substance, and show how the concentration of each substance affects the rate of reaction.

To find the rate of the reaction we need some way of measuring the rate at which one of the reactants is consumed, or the rate at which one of the products is formed; the method that we will use is based on the rate at which iodine forms. If thiosulfate ions are added to the solution they react with iodine as it forms in this way: Step 1 in the above mechanism is somewhat slow. Step 2 proceeds extremely rapidly, so that as quickly as iodine is produced in Step 1, it is consumed in Step 2, which then continues until all of the thiosulfate is used up. After that, iodine begins to increase in concentration in solution. If some starch is present, iodine will react with the starch to form a deep blue-colored complex that is readily apparent.

MATERIALS & EQUIPMENT:

Potassium iodide, KI, 0. 010 M

Potassium bromate, $KBrO_3$, 0. 040 M

Hydrochloric acid, HCl, 0. 10 M

Sodium thiosulfate, $Na_2S_2O_3$, 0. 0010 M

Starch solution, 2% (by mass)

Copper (II) nitrate, $Cu(NO_3)_2$, 0. 1 M

Distilled water

Pipets (labeled, in labeled sample jars)

Thermometer

(2) ~10-mL beakers

(2) 12-well white microplates

Toothpicks

Stopwatch

Water-soluble marker

Class:

(2) labeled beakers for each chemical

(2) troughs for cold water baths

Warm water bath

Sensitive balance

PROCEDURE:

Part A: Reaction Orders and Rate Law

Hold the droppers vertically and be sure no air bubbles are introduced. Since such small quantities of reagents are used, it is very easy to repeat measurements.

The following table shows the reagent quantities to be used in carrying out the reactions needed. Because we don’t want the reaction to start until we are ready, be sure the KBrO3 solution is the last solution added. It is important to use care in measuring out the solutions, since the total solution volume is quite small; even one extra drop can cause a substantial change.

Measure out the drops of solutions required for Exp 1 in one of the wells of a 12-well strip. Be sure to add KBrO3 last. Stir the mixture thoroughly with a toothpick for about 5-10 seconds. This is very important because it is impossible to achieve good mixing in the small well without stirring. Begin timing the reaction as soon as the KBrO3 is added. Record the time required for the first tint of blue color to appear. Repeat the experiment two times to observe the consistency. Record the room temperature as the temperature of these reactions for later use in Part B.

Carry out two trials of the remaining experiments with solution volumes described in Exp 2 through 8. If you wish, use a water-soluble marker to label the wellplate. Between uses, empty the well plate, rinse with water and shake to dry the wells. Use detergent and a paper towel, if necessary, to be sure the wells are clean and dry for each experiment.

Part B: Activation Energy

This part of the experiment will be carried out at several different temperatures, repeating Exp 6. The temperatures will be about 50°C, 20°C, 10°C, and 0°C. Use your value for Exp 6 at room temperature (Part A) for one of these measurements.

Set up a warm water bath at about 50°C. Repeat the procedure using the concentrations in Exp 6. Mix all of the solutions except $KBrO_3$ and place the wellplate in the warm water bath; and allow enough time (1-2 minutes) for the temperature of the mixture to reach that of the bath. Add the 2 drops of $KBrO_3$ to the well, stir, and time the reaction until the blue color first appears. Leave the wellplate in the water bath while you are timing the reaction. Do not repeat with Exp 1-5 and 7-8.

Repeat with the quantities from Exp 6 for each of the other temperatures listed above in the prepared ice/water baths. Record the time of reaction and the temperature for each.

Part C: Effect of a Catalyst

Repeat the procedure of Exp 1, but this time add 2 drops of 0. 1 M copper (II) nitrate solution, Cu(NO3)2, and only 2 drops of water to the mixture. Add the KBrO3 last, as before. The total volume will still be 12 drops. Record the reaction time.

Cleanup: The solutions can be washed down the drain with water. Rinse the wellplates carefully.

CALCULATIONS HINTS:

Converting “ Reaction Time” to “ Reaction Rate”

The rate will be expressed as -Î”[BrO3-] / Î” t. In each reaction there is 1 drop of 0. 0010 M Na2S2O3 solution. To calculate the number of moles of Na2S2O3 present in 1 drop:

Volume of 1 drop (in L) x 0. 0010 mol Na2S2O3 / L = moles S2O32- ions

The blue color begins to appear when all the thiosulfate ions are consumed. Examination of mechanism Steps 1 and 2 allows us to calculate the moles of BrO3- which react when all of the S2O32- ion is used up:

mol S2O32- x 1 mol I2 x 1 mol BrO3- = mol BrO3- reacted

2 mol S2O32- 3 mol I2

The value of -Î”[BrO3-] = mol BrO3- reacted

volume of 12 drops

The rate of each reaction can be found by dividing – Î"[BrO3-] by the number of seconds required for the reaction to take place.

Calculating Initial Concentrations

Calculate the initial concentration of each reactant for each experiment. This will not be the same as the concentration of the starting solution because combining the reactants dilutes all of the solutions. On dilution, the number of moles of reactant stays the same, therefore:

no. moles = Vconcentrated x Mconcentrated = Vdilute x Mdilute

where Vconcentrated and Mconcentrated are the volume and molarity of the starting, concentrated solutions, and Vdilute and Mdilute are the volume and molarity of the diluted reaction mixtures. Since volumes will be proportional to the number of drops of solution used we can substitute drops for volume:

[I-] = 2 drops x 0. 010 M KI

12 drops solution

Use this to find the initial concentration of each reactant.

Study of the Kinetics of a Reaction Name(s):

AP Chemistry Date: Pd:

DATA/RESULTS:

CALCULATIONS: Show your work using Trial 1 (when appropriate) data to determine each of the following:

Reaction rate:

Initial concentrations:

Order of each reactant:

Rate constant:

Activation energy:

GRAPH: Create a graph of ln k vs. 1/T. Be sure to include a title, axes labels with units, data points, and a best-fit line with equation. Attach it to this report.

ANALYSIS:

What is the experimental rate law for this reaction?

Based on the true rate law provided, calculate your percent error for one of the reaction orders.

Based on the mechanism provided in the Background section, what would the predicted rate law be? Briefly explain how you know.

What is the activation energy of this reaction? Describe how this is determined in the lab.

How does a catalyst increase the rate of a reaction? In your answer, answer in terms of:

Energy

“ Particles.”