Matter and Motion Winter 2016

LAB 2: Chemical Kinetics

The Clock Reaction in the System H_2O_2 – KI – $Na_2S_2O_3$

From C. Barlow, P. Pessiki, The Evergreen State College

Purpose: The reaction of the iodide ion with hydrogen peroxide provides a convenient system to study chemical kinetics. We will use this system to determine the order of the reaction with respect to the iodide ion, and to determine the rate constant for the reaction. Temperature dependence of this reaction will also be investigated.

$$2I^- + 2H^+ + H_2O_2 \rightarrow I_2 + 2H_2O$$

Introduction

The part of chemistry that deals with measuring the rate at which chemical reactions occur is known as kinetics. Some processes occur slowly, like iron rusting, and others occur at a rapid pace, like oxygen uptake by blood. Fast and slow must be thought of in the proper context. Electron transfer reactions in photosynthesis can occur in femtoseconds (fast) or milliseconds (slow). A millisecond time frame in other systems might be considered a fast process.

To determine the rate of reactions there must be a way to measure changes in concentration of the reactants or products. Our ability to quantify these changes in concentrations determines how accurately we can measure the rate at which chemical reaction proceeds. Today we will use a color change to indicate the presence of I_2. The use of absorption spectroscopy, NMR, and other types of spectroscopy are also used in the field of experimental chemical kinetics.

Prelab Assignment

Read the lab carefully and then complete the Prelab before coming to lab. It should be completed in your chemistry lab notebook.

1. Some of the words in this lab may be new to you. Make a list of any new vocabulary and their definitions.
2. Identify and describe the quantities you will calculate in this lab (and Postlab). What equations will you use to calculate them?
3. Based on the equations you wrote in question two, what values will need to be *measured* to calculate the desired quantities?
4. Identify any parts of the lab that are unclear to you (what to do for certain step, the purpose of a certain step, etc…) and come prepared to lab with questions about these parts.

Experimental Procedure – Overview

1. The concentration of the product, I_2, is not allowed to build because sodium thiosulfate ($Na_2S_2O_3$) is added. $Na_2S_2O_3$ does not react at a measureable rate with any of the other species in the reaction vessel, but does react rapidly and irreversibly with the elemental iodine, according to the equation:

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

As long as thiosulfate is present, no free iodine will exist in the solution.

2. The addition of thiosulfate serves a second purpose. It reacts with the iodine as rapidly as it is formed, maintaining the concentration of the iodide ion at its original value. As long as thiosulfate is present, no net change in the iodide ion concentration occurs.

3. Sodium thiosulfate serves an additional purpose in this experiment. It allows us to accurately measure the rate at which the reaction takes place. The starch is added as an indicator, which changes color when I_2 is present. I_2 can only be present when all of the thiosulfate has been consumed. We then know how many moles of thiosulfate have been oxidized (all of it), and the time required to oxidize it. We can deduce how many moles of iodine were required to oxidize this much Sodium thiosulfate from the stoichiometry of the second reaction. From the stoichiometry of the first reaction we can calculate the number of moles of I^- and H_2O_2 consumed during a known time.

REMEMBER: rates are expressed as the change in concentration, (not moles) with time: $\Delta[A]/\Delta t$. So, the number of moles must be divided by the final reaction volume as well as by the time in order to get a value for rate.

Experimental Procedure

***DO NOT add hydrogen peroxide until you have accurately measured all your other reagents into a flask, taken its temperature and obtained a stir plate, stir bar, and stopwatch and are ready to time!

1. With your partner, obtain a stir plate, stir bar, thermometer, 125 mL Erlenmeyer flask(s), stopwatch, and small graduated cylinder.

2. Measure the following reagents into your Erlenmeyer flask for a standard run:

Buffer A, 1.0 M acetate/acetic acid buffer	5.0 mL
$Na_2S_2O_3$, O.10 M	5.0 mL
Starch, 3% solution	1.0 mL
KI (potassium iodide), 0.25 M	10.0 mL
Deionized (DI) water	74 mL

3. When ready, add

H_2O_2 (hydrogen peroxide), 3% or 2.0M	5.0 mL
TOTAL VOLUME	100.0 mL

4. When ready, take the temperature of your stirring solution, begin timing when you add your hydrogen peroxide, watch for a color change to a golden or purple color, stop timing.

5. Follow the table below to try 4 more different concentrations of KI. NOTE: always vary the concentration of distilled water so that your total volume is always 100.0 mL. Don't vary the volumes of other reactants.

RUN#	Volume of KI	Vol., DI water	$[Na_2S_2O_3]$	t (sec)	Rate WRT to I_2
1	10.0 mL	74.0 mL			
2	5.0 mL	79.0 mL			
3	20.0 mL				
4					
5					

TABLE 1. note: WRT = "with respect to"

The rate of the reaction is equal to the rate of disappearance of hydrogen peroxide, ½ the rate of the appearance of iodide, and also the rate of appearance of iodine.

PART II

6. Experiment with the temperature dependence of this reaction; use a concentration of KI from Part 1 that makes you feel warm and fuzzy about your data.

Run #	Temp.	t (sec)	[KI]	$[Na_2S_2O_3]$	Rate constant (k)
1	Hot:				
2	Cold:				
3	Room:				

TABLE 2.

CLEAN UP
Do not leave without fully cleaning your workstation and asking Sina about a community cleaning job.

Continue to the Post-lab in class if time allows, or complete it outside of class. It should be done in your lab notebook and turned in at the beginning of class next Monday Jan. 18th at 10:00 AM

Postlab assignment

1. a) Determine the order of the reaction with respect to the iodine ion, assume the order of the reaction with respect to hydrogen peroxide is one (1), and with respect to the hydrogen ion is zero (0). b) Calculate the rate constant for the reaction. Use your results to complete Table 1 and Table 2. Please make a note of where to find these tables in your lab notebook.

2. Use your data from Table 2 to determine the activation energy of this reaction.

3. Draw the Lewis structures of sodium thiosulfate and hydrogen peroxide, show all bonds.

4. Try to find a *reliable* literature value for the activation energy of the iodide/hydrogen peroxide reaction. Cite your source. Use the percent error calculation to compare your experimental value to the literature value.

5. Considering your answer to #4, discuss the reliability of our experimental methods. Suggest ways to improve the accuracy of our measurements (or suggest different, more accurate measurements that would achieve the same goals).