Investigation 8: Reaction Kinetics: Effect of Temperature

Focus Questions: *How does temperature effect the rate of a reaction? How can we determine the rate law for a reaction as a function of temperature? How can we apply this to a real life situation?*

Pre-lab required reading

Chemistry; an Atoms-Focused Approach: Sections 13.4

Primers:

Keeping a Laboratory Notebook
Using a micropipette
Volumetric glassware – general
Volumetric glassware – volumetric flask
Pseudo-first order reactions: the method of isolation
Spectrophotometry
SpectroVis usage

Safety and Waste Disposal

- Eye protection should be worn at all times. Bleach is a corrosive oxidizing agent that will react with eyes and skin and can remove color from clothing.
- Gloves should be worn when handling the bleach.
- Dispose of all solutions down the drain with plenty of water.

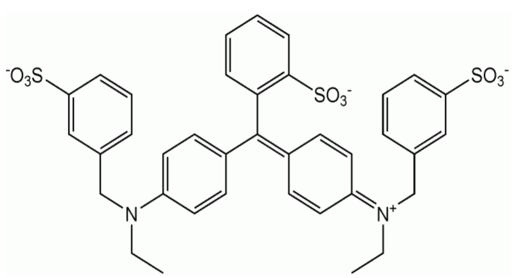
Background

The Reaction

In this experiment we will be studying the reaction between blue food dye #1, erioglaucine, and bleach, $NaOCl_{(aq)}$ in solution. The overall reaction equation is:

$$NaOCl_{(aq)} + \text{FD\&C Blue \#1}_{(aq)} \rightarrow \text{colorless products}_{(aq)} \qquad (1)$$

The structure of aqueous FD&C Blue #1 is shown below:



Observing the reaction

The FD&C Blue#$1_{(aq)}$ ion is colored. Thus a solution of the reactants will be colored. However, the products are not colored and a solution of the products will be colorless. The progress of the oxidation-reduction reaction represented by equation 1 above can be observed by watching the color of the solution disappear. Quantitative information will be obtained by using the absorbance of the solution at the wavelength of maximum absorption for the FD&C Blue#1 ion (630 nm). We will use the SpectraVis spectrometers to record the absorbance as a function of time.

The general rate law for this reaction (1) is

$$\text{Rate} = k[NaOCl]^x[\text{Blue\#1}]^y \qquad (2)$$

The purpose of the experiment is to fully define the rate law shown in equation (2) by determining experimental values for the variables x, y and k. The *method of isolation* will be used with an excess of NaOCl.

Procedure

Part one:

Part A: Preparation of materials:

Obtain 10-20 mL of Blue#1 Stock solution. Volumetrically prepare 50mL of diluted Blue#1 (concentration of ~1.7×10^{-5} *M* is desired). Be sure to record the exact value of the concentration of solution prepared. Place some of this diluted solution, ~20mL distilled water, and ~10mL bleach solution in separate clean, dry, labeled beakers. Record the brand name and label information about the bleach used in your investigation. Use the label information (i.e. 6% NaOCl) to calculate the concentration of NaOCl in your bleach solution. Obtain a clean dry cuvette and three clean micropipettes (with tips) – these will be used to measure all the solutions and also the distilled water. Be careful to keep the micropipette clean and dry by not setting it sidewise on the counter, use the clips provided. Be sure to use the same tip with the appropriate solution at all times so that your solutions do not become contaminated (if not sure – use a new tip!).

Part B: Effect of temperature

Using a hot plate, make a hot water bath in a half-filled 150-mL beaker. Heat the bath until it is approximately the appropriate temperature. Try to maintain this temperature to within 1-2 °C by taking the beaker on or off the hot plate as necessary. Be careful when handling the hot beaker!

Choose one of the trials that you designed last semester which is relatively slow at room temperature. Transfer water, bleach, and Blue#1 into separate test tubes and store in the warm water bath. Measure the appropriate volumes of bleach and water into a clean dry cuvette. Be sure to blank the spectrometer with the warmed cuvette before adding the Blue#1. The Blue#1 should always be added last. After adding the Blue#1 mix the solution by drawing it up into the micropipette tip and releasing it into the cuvette. Record the temperature in the cuvette, it will cool slightly upon removal from the warm water bath. Record the absorbance as a function of time, as before. Repeat at 4-5 temperatures above room temperature.

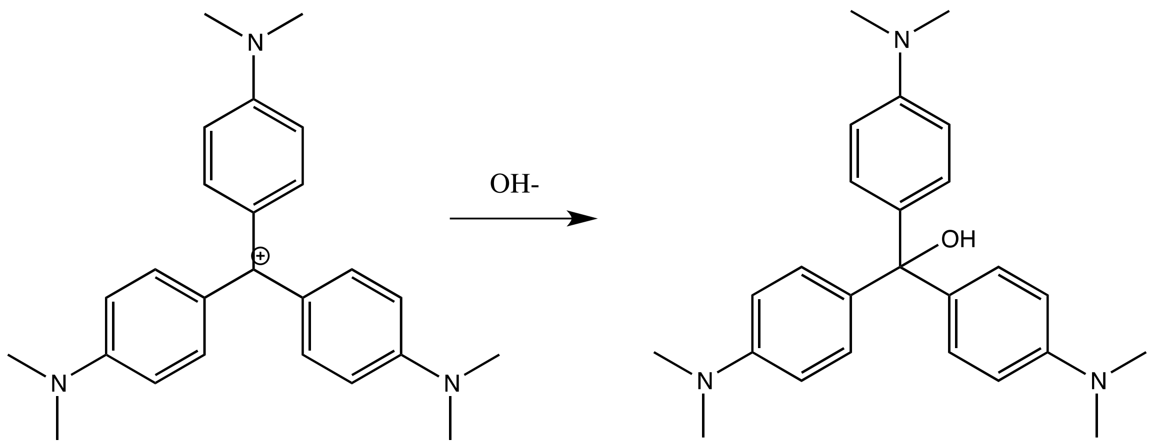
Part two:

The Case of the Disappearing Ink Novelty Pen

You and your consulting team have been contacted by a novelty toy company to help them develop a pen that will write messages in disappearing ink. They have in mind a basic concept but need help with the specifics and recently learned that your team has some expertise in chemical kinetics. An outline of the design concept is provided below along with the questions the toy company would like your team to answer.

Design concept:

A fairly common blue ink used in ball point pens is Crystal Violet (notice the similar structure to erioglaucine). As it turns out, when Crystal Violet is mixed with a basic solution (NaOH rather than bleach in this case) the blue color will be bleached out or faded. The chemical reaction involved is shown below along with the structure of crystal violet as reaction (1).



Reaction 3: The reaction of crystal violet with aqueous sodium hydroxide

The toy company engineers have already tested a two-chamber pen design that will deliver and mix equal volumes of two solutions to the nib (or writing point) of the pen.

This is where your team comes in. They would like to have a pen with the correct concentrations of crystal violet solution in one chamber and NaOH(aq) in the other chamber so that a message can be written with the pen that will persist for 5 minutes before fading and becoming invisible. From experience, the toy company knows that concentrations of crystal violet need to be at least 1mM with an absorbance of about 87 to provide dark enough writing and concentrations less than 0.34 μM or an absorbance of 0.03 will not be visible.

What you will need to do:

1. Determine the rate law for the CV^+ and OH^- reaction. In other words, determine the values of the variables x, y and k in the generic rate law for the reaction shown below:

$$r = k[CV^+]^x [OH^-]^y$$

<u>Hint</u>: To do this, think about how you determined the rate law for the blue food dye and bleach reaction using the method of isolation last semester. Since this reaction is very similar you should be able to design a very similar experiment to determine the rate law for the CV^+ and OH^- reaction. Note that you will need to find the wavelength of maximum absorbance of the CV^+ in order to know what wavelength to use to monitor the reaction.

<u>More information</u>: If your stock solution of CV^+ is about $3x10^{-6}$ M and you use 850 μL in a total of 2 mL of solution you will have a starting concentration of $1.3x10^{-6}$ M. This solution will have an absorbance of about 0.11 (ε = 87,000 $M^{-1}cm^{-1}$) which is well within the Beer's law region. Recall that your NaOH solution will need to be in at least 10 times excess for all trials. Thus if you start with a 0.5 M stock NaOH solution you will have an excess of OH^- in all reacting solutions.

2. Use the rate law you have determined to calculate the value of k_{obs} that is necessary to have the concentration go from 1 mM to 0.23 μM in 5 min (300 s). Given this value of k_{obs} determine the concentration of OH^- that the toy company should use to make their pens.

3. In your final report, discuss the effect of temperature on your results. Explain to the toy company how different temperatures in which the pen operates will affect the time before the ink disappears.

References

Atkins, P.; Jones, L. "Chemical Principles: The Quest for Insight", 5th ed.; Freeman: New York. **2010**.

Henary, M.M.; Russell, A.A. *J. Chem. Ed.* **2007**, *84*, 3.