Introduction:

Chemical Kinetics is the branch of chemistry that is concerned with the study of the rate of chemical reactions. The rate of a reaction is a measure of its speed. Consider the hypothetical reaction

$$E + 2B \rightarrow 2C + D \quad (1)$$

The rate of formation of C is then given by the formula

$$\text{Rate}_C = \frac{[C]_f - [C]_i}{t_f - t_i} = \frac{\Delta[C]}{\Delta t} \quad (2)$$

where $[C]_f$ and $[C]_i$ are the concentrations of C at times $t_f$ and $t_i$, respectively. The symbol $\Delta$ stands for “the change in” whatever follows it in place in the formula. The rate of formation of C is the change in the concentration of C over the time interval $\Delta t$. Similarly, the change in concentration of D over time would be:

$$\text{Rate}_D = \frac{\Delta[D]}{\Delta t} \quad (3)$$

The rates of consumption of A and B are

$$\text{Rate}_E = -\frac{\Delta[E]}{\Delta t} \quad (4)$$

$$\text{Rate}_B = -\frac{\Delta[B]}{\Delta t} \quad (5)$$

The negative signs in equations (4) and (5) arise from the fact that although the rates are positive numbers, the concentrations of the reactants decrease with time, and their changes are negative. From the stoichiometry of reaction (1) we see that the consumption of 1 mole of E results in the consumption of 2 moles of B and the formation of 2 moles of C and 1 mole of D. B is consumed twice as fast as A, and C is produced twice as fast as D. Thus, the relationships between the rate expressions in equations (2)-(5) is

$$\frac{\Delta[D]}{\Delta t} = 2 \cdot \frac{\Delta[C]}{\Delta t} = -\frac{\Delta[E]}{\Delta t} = -\frac{\Delta[B]}{2 \cdot \Delta t} \quad (6)$$
The rate of the reaction, \( \text{Rate}_{RXN} \), can be expressed either in terms of the rate of disappearance of reactants or the rate of appearance of products:

\[
\text{Rate}_{RXN} = \frac{\Delta[D]}{\Delta t} = \frac{1}{2} \frac{\Delta[C]}{\Delta t} = \frac{\Delta[B]}{\Delta t} = -\frac{1}{2} \frac{\Delta[A]}{\Delta t}
\]  

(7)

**Purpose:** You will run a set of experiments to examine how changing the concentration of a reactant affects the rate of the reaction between sodium hypochlorite, NaOCl, and a food dye FD&C Blue #1. Sodium hypochlorite is the active ingredient in commercial bleaches, such as Clorox and Purex. The reaction is

\[
\text{NaOCl} + \text{FD&C Blue #1} \rightarrow \text{Colorless products}
\]

The structure of FD&C Blue #1 is below.

All of the reactants and products are colorless except Blue #1. The blue color of a solution of blue #1 is due to the fact that the dye molecules absorb a portion of the visible spectrum. That part of the spectrum that is not absorbed is transmitted and gives the solution its blue color. As shown in Figure 2, the dye molecules absorb orange light.
The measurement of light absorption will be accomplished with a visible spectrometer.

In the spectrometer, orange light from the light source passes through the sample solution and reaches the light detector. The light detector measures the intensity of the light reaching it. In this case, the only light absorbing substance in solution is the dye. The amount of light absorbed by the solution is a measure of the dye concentration. The absorbance of the solution is directly proportional to the concentration of the dye.

We will read off the spectrophotometer %T and then calculate absorbance (see equation 18) because %T is easier to read off of the dial. After making a table of absorbance vs. time, you will be asked to make conclusions as to how concentration effects rate.

\[
A = -\log \left( \frac{\%T}{100} \right)
\]  

(18)
Chemical Kinetics Lab

Procedure

1. **Part 1, Calibration of Spectrophotometer:**
   Will be demonstrated.

2. **Part 2, Using the stock blue dye solution and a Spec 20 spectrophotometer, determine the %T for multiple wavelengths from 420 to 700 nm.** Find the wavelength that has the lowest %T (Highest absorbance). This wavelength will be what you use for the rest of the lab. Make a plot of wavelength on the x axis and absorbance on the y axis. Remember that \( A = \log\left(\frac{\%T}{100}\right) \). Paste this in your notebook.

3. **Part 3, Measurement of percent transmission of the stock blue #1 solution:**
   Mix 10 ml of stock blue solution with 10 ml of water and measure its %T. This will be your time zero value since the bleach you will be adding will dilute your stock solution.

4. **Part 4, Measurement of %T versus time for the reaction:**
   Carefully measure 10 mL of the stock blue #1 solution with a graduated cylinder, and pour it into a 150 mL beaker. Prepare 10.0 mL of bleach solution by mixing 8.0 mL of deionized water and 2.0 mL of commercial bleach in a 10 mL graduated cylinder.
   
   a. Add the bleach solution to the dye solution in the beaker. Quickly stir the mixture, and pour it into a clean, dry cuvette. Hold the cuvette by the top edge to avoid getting fingerprints on the light-transmitting walls. Place the cuvette in the colorimeter, cover it, and collect %T values every 15 seconds. Place the beaker containing the remaining reaction mixture next to the colorimeter, and observe the color change as the reaction progresses. Stop the data collection when the %T values reach a constant value. Repeat this measurement once.
   
   b. Repeat the procedure above *using one-half the concentration of bleach*. Do this by mixing 9.0 mL of water and 1.0 mL of commercial bleach in a 10 mL graduated cylinder. Add it to 10 mL of stock blue #1 solution in a 150 mL beaker, and proceed as in a). Repeat this measurement once.

Conclusion and Questions

Please answer each question below clearly.

1. Convert the %T value of the stock blue #1 solution, measured in Part 2 of the procedure, to absorbance, using equation (18).

2. Commercial bleach is a 5%, by mass, aqueous solution of sodium hypochlorite, NaClO. What is the molar concentration of NaClO?

3. What conclusions can you make about concentration and rate for the reaction you studied?