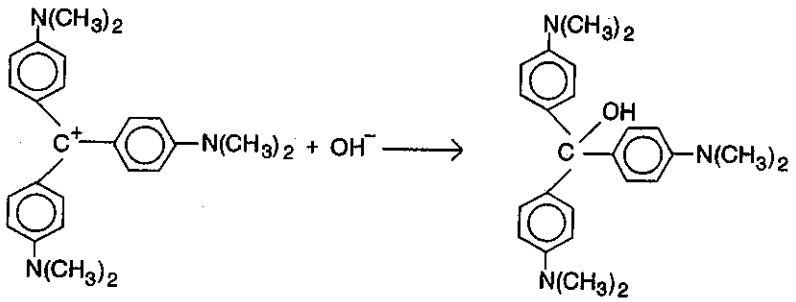
Experiment
30

Rate Law Determination of the Crystal Violet Reaction

In this experiment, you will observe the reaction between crystal violet and sodium hydroxide. One objective is to study the relationship between concentration of crystal violet and the time elapsed during the reaction. The equation for the reaction is shown here:



A simplified (and less intimidating!) version of the equation is:

$$CV^+ + OH^- \longrightarrow CVOH$$

(crystal violet) (hydroxide)

The rate law for this reaction is in the form: rate = $k[CV^+]^m[OH^-]^n$, where k is the rate constant for the reaction, m is the order with respect to crystal violet (CV^+), and n is the order with respect to the hydroxide ion. Since the hydroxide ion concentration is more than 1000 times as large as the concentration of crystal violet, $[OH^-]$ will not change appreciably during this experiment. Thus, you will find the order with respect to crystal violet (m), but not the order with respect to hydroxide (n).

As the reaction proceeds, a violet-colored reactant will be slowly changing to a colorless product. Using the green (565 nm) light source of a computer-interfaced Colorimeter, you will monitor the absorbance of the crystal violet solution with time. We will assume that absorbance is proportional to the concentration of crystal violet (Beer's law). Absorbance will be used in place of concentration in plotting the following three graphs:

- Absorbance *vs.* time: A linear plot indicates a *zero order* reaction (k = –slope).
- ln Absorbance *vs.* time: A linear plot indicates a *first order* reaction (k = –slope).
- 1/Absorbance *vs.* time: A linear plot indicates a *second order* reaction (k = slope).

Once the order with respect to crystal violet has been determined, you will also be finding the rate constant, k, and the half-life for this reaction.

Materials: Spectrophotometer or Colorimeter
Cuvettes
0.020 M NaOH solution
2.0×10^{-5} M crystal violet solution
Graduated cylinders
Small beaker
Stir rod

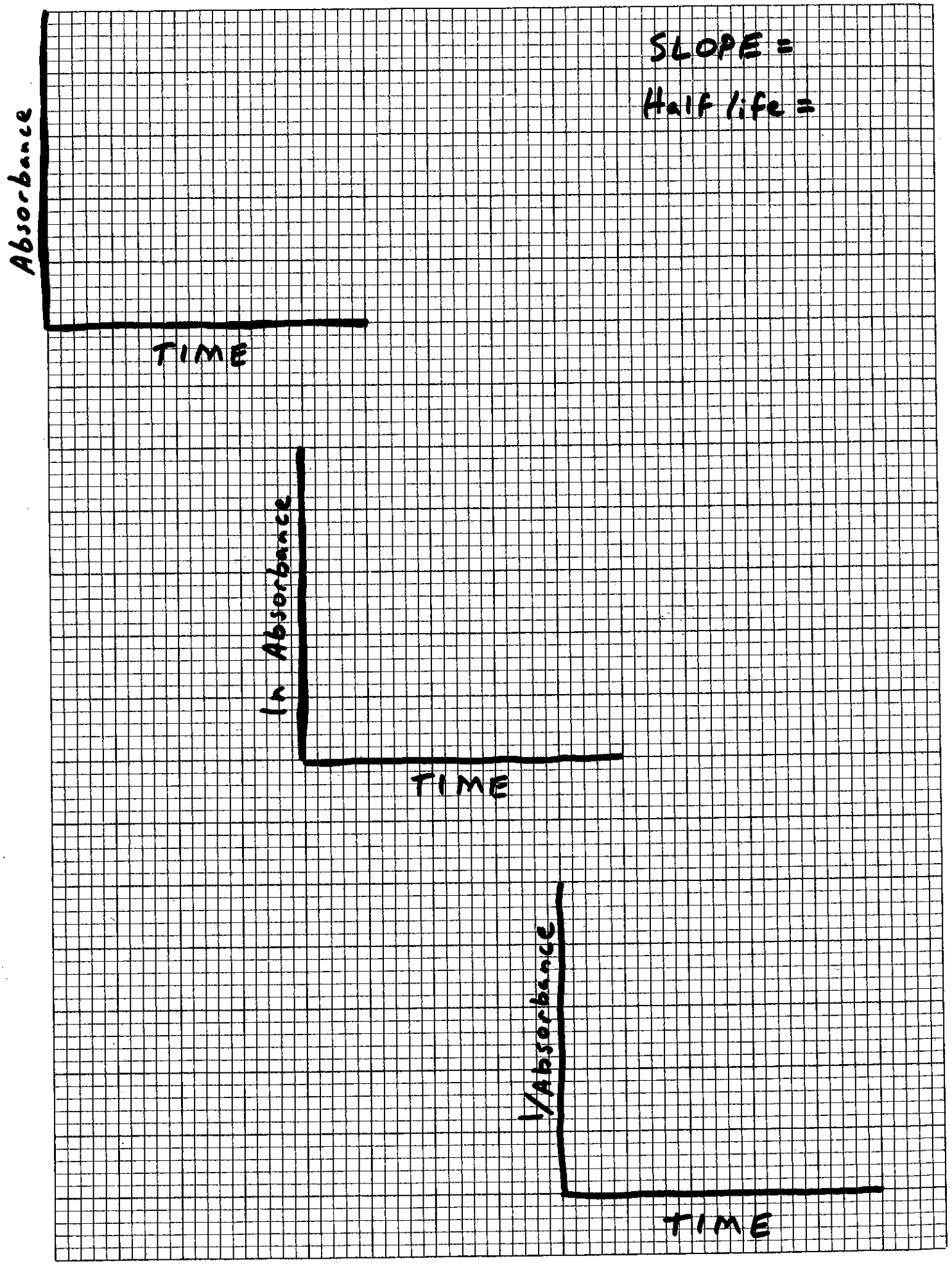
Procedure:
1. Go to Lab #30 in "Chemistry with Computers" file
2. Initiate the reaction by combining 10 ml of the NaOH solution and 10 ml of the crystal violet solution in a small beaker. Stir. Allow the mixture to set about three minutes before taking any measurements.
3. Select a wavelength of 565 nm (green) on the colorimeter.
4. Place a cuvette, ¾ full of distilled water, into the colorimeter and adjust to 100% Transmittance, or 0 Absorbance.
5. Remove the cuvette with distilled water and replace with a cuvette that is ¾ full of the reaction mixture.
6. Click on "Start". When the absorbance stabilizes click "Keep". This will plot the first point on the graph. Click "Keep" every minute for the 20 minute period.
7. Click the linear fit button and observe. If this graph is linear, the reaction is *zero order*. Sketch the graph.
8. Click "New Calculated Column" from the Data menu. Enter "ln Absorbance" as the Name, "ln Abs" as the Short Name, and leave the unit blank. Choose "ln" from the Function list and select "Absorbance" from the Variables list. Click "Done".
9. Click on the y-axis label on the graph. Choose "ln Absorbance". Click the linear fit button and observe. If this graph is linear, the reaction is *first order*. Sketch the graph.
10. Click "New Calculated Column" from the Data menu. Enter "1/Absorbance as the Name, and "1/Abs" as the Short Name, and leave the unit blank. Type in "1/" into the Equation edit box, then select "Absorbance" from the Variables list. Click "Done".
11. Click on the y-axis label on the graph. Choose "1/Absorbance". Click the linear fit button and observe. If this graph is linear, the reaction is *second order*. Sketch the graph.
12. Get the slope value of the linear graph. (slope=m, when y=mx + b)
13. Estimate the half-life of the reaction.

Questions:
1. Data can be analyzed graphically to determine if the reaction is zero, first, or second order with respect to crystal violet. According to your data, what is the order?

2. Calculate the rate constant, k. (k = -slope for zero and first order, and k = +slope for second order)

3. Write the correct rate law expression for the reaction, in terms of crystal violet.

4. Half-life of the reaction =



10 DIVISIONS PER INCH