Experiment 4

Determining the Rate Law and Activation Energy for the Methyl Blue Reaction:

An exercise in experimental design

Pre-Lab Assignment

Before coming to lab:

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise. The questions should be answered on a separate (new) page of your lab notebook. Be sure to show all work, round answers, and include units on all answers.
- Follow the guidelines in the "Lab Notebook Policy and Format for Lab Reports" section of the lab manual to complete in your lab notebook the following sections of the report for this lab exercise: Title, Lab Purpose, and Procedure
- **You will need to write your own detailed procedure for this lab.**

Purpose

The goal of this lab is to determine the rate law for the reaction between methyl blue and hydroxide ions. This will be accomplished by monitoring the absorption of a methyl blue solution as it fades at it reacts with hydroxide.

Specifically you will need to:

a) Determine the best wavelength of light to use for the experiment (λ_{max})
b) Construct three graphs that will allow you to determine the order of the reaction with respect to methyl blue using the integrated rate laws.

Background

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

A simplified version of the equation is:

$$MB^+ \text{ (aq)} \quad + \quad OH^- \text{ (aq)} \quad \rightarrow \quad MBOH \text{ (aq)}$$
Color: *Blue*   *Colorless*   *Colorless*

As usual, the rate law for this reaction is in the form: rate = $k[MB^+]^x[OH^-]^y$, where k is the rate constant for the reaction, m is the order with respect to methyl blue (MB^+), and n is the order with respect to the hydroxide ion.

As the reaction proceeds, the blue-colored reactant will be slowly changing to a colorless product. You will measure the absorbance change with a Vernier Spectrometer as the reaction proceeds.

We will assume that absorbance is proportional to the concentration of methyl blue (Beer's Law) and therefore can use absorbance in place of concentration of MB in constructing our graphs. By determining which of your graphs is linear, you will be able to determine order of the reaction with respect to MB (x in the above rate law).

Because hydroxide (OH⁻) is colorless and therefore unable to be detected with a spectrometer, we will not be determining the order of the reaction with respect to OH⁻ (y in the above rate law). To insure that the concentration of OH⁻ is a constant as the reaction proceeds and therefore does not affect your results, we will use a concentration of OH⁻ more than 1000 times as large as the concentration of methyl blue, $[OH^-]$ will not change appreciably during this experiment. Thus, you will find the order with respect to methyl blue (*x*), but not the order with respect to hydroxide (*y*).

Procedure

Safety
GENERAL SAFETY: Methyl Blue is a stain. Avoid spilling it on your skin or cloths. Sodium hydroxide solution is caustic. Avoid spilling it on your skin or clothing. Students must wear safety goggles at all times. The hot-water baths used in Part B of this experiment can become hot enough to burn your skin. Use caution when working with them.

WASTE DISPOSAL: All solutions used in this lab may be disposed of in the sink.

Materials and Equipment you will be provided beyond what is in your drawer:

- computer
- Vernier Spectrometer
- cuvettes
- two 10 mL pipettes

- 0.10 M sodium hydroxide, NaOH, solution
- 2.5×10^{-5} M methyl blue solution

**A detailed procedure is not provided in this experiment- only a general outline.
You will need to write out a step by step-by-step procedure as part of your pre-lab.**

Determining the Rate Law and Activation Energy for the Methyl Blue Reaction

Part A: Determine the best wavelength of light to use for the experiment (λ_{max})

Using the Vernier Spectrometer, you will need to determine the wavelength of light that methyl blue absorbs most strongly (λ_{max}). This will be the best wavelength of light to use for the rest of the experiment.

1.Write out a detailed procedure of how you will accomplish this in you lab notebook. Be sure to include the steps necessary to calibrate the spectrometer.

The procedure should include numbered steps- at least four for this part of the lab including the amounts and concentrations of chemicals to be used.

Part B: Construct three graphs that will allow you to determine the order of the reaction with respect to methyl blue using the integrated rate law.

You will be mixing 0.10 M NaOH with 2.5×10^{-5} M methyl blue in order to construct three graphs that will allow you to determine the order of the reaction with respect to methyl blue. Since absorbance and concentrations are proportional, we will be using absorbance in place of concentration in constructing our graphs.

1. Write out a detailed procedure of how you will accomplish this in your lab notebook***. The procedure should include numbered steps- at least eight for this part of the lab including the amounts and concentrations of chemicals to be used.***

Some details regarding the proper use of the Vernier Software is given below.

- Absorbance data will need be collected for at least three minutes.
- Analyze the data graphically to decide if the reaction is zero, first, or second order with respect to methyl blue. Print your graphs!
- To help construct one of your graphs, you will need to create a calculated column, **ln Absorbance**. To do this,

   a. Choose New Calculated Column from the Data menu.
   b.   Enter "ln Absorbance" as the Name, and leave the unit blank.
   c.   Enter the correct formula for the column into the Equation edit box by choosing "ln" from the Function list, and selecting "Absorbance" from the Variables list. Click ⬚ Done
   d.   Click on the y-axis label. Choose ln Absorbance. A graph of ln absorbance *vs.* time should now be displayed. Change the scale of the graph, if necessary.
   e.   To see if the graph is linear, click the Linear Regression button, ⬚.
   f.   Close the Linear Regression box by clicking the X in the corner of the box.

To help construct one of your graphs, you will need to create a calculated column, **1/Absorbance.**
   a. Choose New Calculated Column from the Data menu.
   b.   Enter "1/Absorbance" as the Name, "1/Abs" as the Short Name and leave the unit blank.
   c.   Enter the correct formula for the column into the Equation edit box by choosing "1/". Then select "Absorbance" from the Variables list. Click ⬚ Done
   d.   Click on the y-axis label. Choose 1/Absorbance and uncheck any other boxes. A graph of 1/Absorbance *vs.* time should now be displayed. Change the scale of the graph, if necessary.
   e.   To see if the graph is linear, click the Linear Regression button, ⬚. Write down the slope value in your data table as the rate constant, *k*.
   f.   Close the Linear Regression box by clicking the X in the corner of the box.

Determining the Rate Law and Activation Energy for the Methyl Blue Reaction

Data Tables and Calculations

Prepare a data table for each part of the lab. Include both measured values and calculated values. Be sure to properly label each value and include the units.

Post-Lab Questions

1. Suggest three specific improvements in your procedure from Part B of the experiment you could make to improve the reliability of your data.

2. In lab, you have learned two ways to determine the rate law for a reaction- the method of intial rates and using integrated rate laws. Explain the differences between these two methods.

Pre-Lab Questions

1. Methyl Blue is (not surprisingly) blue in color. At approximately what wavelength should it most strongly absorb light?   Note: You will be determining the exact wavelength in lab.

2. In this experiment, you will need to construct three graphs to determine if the reaction is zero, first or second order with respect to methyl blue.

    a. For a zero order reaction a graph of _____ versus _____ will be a straight line. The slope of the line is equal to _____.
    b. For a first order reaction a graph of _____ versus _____ will be a straight line. The slope of the line is equal to _____.
    c. For a second order reaction a graph of _____ versus _____ will be a straight line. The slope of the line is equal to _____.

3. The following data were collected for a reaction of type: A $\rightarrow$ Products.
Complete the last two columns and answer the questions below:

Time (s)	[A] (M)	ln[A]	1/[A]
0	1.00×10^{-3}		
5	6.07×10^{-4}		
10	3.68×10^{-4}		
15	2.23×10^{-4}		
20	1.35×10^{-4}		

Determine the order of the reaction with respect to A and the find the value of the rate constant. You must graph the data to determine the order. Use Excel to graph your data and include a brief explanation.