Prelab #10 — Bromophenol Blue

Names (groups of 2) ____________________________________

Lab section: M T W Th F

- ***Work in groups of 2. Get permission ahead of time to work in a group of 3.***
- ***Please show all work.***

Reading Assignment:

- Lab manual—Lab 10, including Background and Experimental sections.
- Kinetics—Zumdahl, Chapter 15, especially p. 723: Integrated Rate Laws for Reactions with More Than One Reactant.

1) Consider the reaction **A + B → AB**.

   a) Write the rate law for this reaction. Use "*k*" for the rate constant. Use "*m*" and "*n*" to represent the order of reaction with respect to A and B, respectively:

   ____

   b) In terms of *m* and *n*, what is the overall order of the reaction: ____________

   c) When there are multiple reactants in a reaction, it can be difficult to experimentally determine the reaction order of each reactant because both concentrations are changing as a function of time. In a pseudo-first-order reaction, one reactant is in extreme excess and its concentration essentially remains constant during the reaction. This allows the rate law to be simplified. Instead of using the rate constant, *k*, we use a pseudo rate constant, *k'*, which combines both k and the concentration of the reactant which remains constant. Thus, the rate law is written in terms of only one reactant concentration. If B is in extreme excess, write the simplified rate law, using the pseudo rate constant, *k'*:

   ____

   d) Write an expression for *k'* in terms of *k*, [B], and *n*:

   ____

   e) The following exercise simulates what you will do with the data you collect in this lab. In this exercise, the reaction above (**A + B → AB**) is performed twice. In the first trial, [B] = 1.0M. In the second trial, [B] = 2.0M. In both trials [B] is not changing measurably during the reaction. However, [A] is measured as a function of time and its values are listed in the data table below. This same data table (in an Excel spreadsheet) can also be found in the lab manual.

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	Trial 1	Trial 2
	[B] = 1.0M	[B] = 2.0M
Time (s)	[A]	[A]
0	0.0200	0.0200
1	0.0198	0.0196
2	0.0196	0.0192
3	0.0194	0.0189
4	0.0192	0.0185
5	0.0190	0.0182
6	0.0189	0.0179
7	0.0187	0.0175
8	0.0185	0.0172
9	0.0183	0.0169
10	0.0182	0.0167

i) Using Excel and the directions below, determine the order of the reaction with respect to [A].
- Add two new columns to the right of the data for Trial 1. Label the first column "ln [A]" and label the second column "1/[A]".
- Use Excel to calculate the ln [A] and 1/[A] in the appropriate columns.
- Now make three plots.
    1. Time vs. [A]
    2. Time vs. ln [A]
    3. Time vs. 1/[A]
- Insert a linear trendline for each of the three plots. Include the equation and the R^2 on each plot.
- Choose the relationship (time vs. [A], time vs. ln [A] or time vs. 1/[A]) that has the most linear relationship (R^2 closest to 1). From the plots, determine the order of the reaction with respect to [A]: zero order (time vs. [A] most linear), first order (time vs. ln [A] most linear) or second order (time vs. 1/[A] most linear). Order of reaction with respect to [A]: _______
- Print out the most linear Excel plot and attach it to this pre-lab.

ii) Now that you have determined the order of the reaction with respect to [A], you know which plot will be linear for Trial 2. Make this plot, including the equation and R^2, and attach it to this pre-lab.

iii) Just like the rate constant is the |slope| of the most linear plot for a one-reactant reaction, *k′* is the |slope| of the most linear plot for a pseudo-first-order reaction. Report your *k′* values for each trial, including appropriate units of time:

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Trial 1, *k'* = _______________

Trial 2, *k'* = _______________

iv) Using your calculated values of *k'* and your expression for *k'* in terms of *k*, [B], and *n*; solve for *n*, the order of the reaction with respect to [B]. Show your work here:

n = ________________

v) Solve for *k*. Include appropriate units of time. *k* = _________________

vi) Finally, write out the rate law including numerical values for *k*, *m*, and *n*:

____

2) In this lab, you will be reacting Bromophenol Blue (Bp^{2-}) with NaOH. NaOH will be in extreme excess so that the reaction will be pseudo-first-order. You will be measuring the concentration of Bp^{2-} as a function of time and using plots to determine the order with respect to Bp^{2-}. Bp^{2-} is blue in color, but when it combines with NaOH, the products are colorless. The solution appears to fade with time. You will be measuring [Bp^{2-}] spectroscopically: absorbance as a function of time. Because Bp^{2-} begins to react immediately, as soon as you make your solution you no longer know the concentration of Bp^{2-} in solution. Therefore, it is not necessary to use volumetric glassware to measure Bp^{2-}. However, the ratio of NaOH concentrations for your two trials is very important to your calcualtions, so you must use volumetric glassware to measure NaOH. ***Use the solutions given in the Materials and Equipment list (shown below) to create the solutions you will need for your experiment. Show all calculations.***

Materials and Equipment

- 4 M NaCl
- 4 M NaOH
- 0.5 g/L bromophenol blue ($Na_2Bp = Na_2C_{19}O_5Br_4SH_8$)
- 50.00 mL and 100.00 mL volumetric flasks
- 25.00, and 50.00 mL volumetric pipettes
- Graduated cylinders
- Computers with Logger Pro software and colorimeters.

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a) Describe how you would prepare 50.00 mL of a solution that is 0.03 g/L Bromophenol Blue in 2 M NaOH. Show all calculations.

Volume of Bp^{2-}: ____________ Glassware: ____________________________

Volume of NaOH: ____________ Glassware: ____________________________

Glassware to prepare solution in: ____________________________________

b) Describe how you would prepare 100.00 mL of a solution that is 0.03 g/L Bromophenol Blue in 1 M NaOH and 1 M NaCl. [The reason we include NaCl is that "ionic strength" (a measure of the total number of ions in solution) affects the rate of reaction. We use NaCl so that we can change the NaOH concentration without changing the ionic strength.] Show all calculations.

Volume of Bp^{2-}: ____________ Glassware: ____________________________

Volume of NaOH: ____________ Glassware: ____________________________

Volume of NaCl: ____________ Glassware: ____________________________

Glassware to prepare solution in: ____________________________________

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c) Calculate the Bp^{2-} concentration of the above solutions in moles/L. The formula for Na_2Bp is: $Na_2C_{19}O_5Br_4SH_8$ (Try this molar mass calculator, noting that it is case sensitive: http://www.humboldt1.com/~medusa/page/molecalc/). Show work.

Bp^{2-} concentration ________________ M

d) When you make your solutions, you do not want them to react before you have a chance to measure them. So you will want to make your solutions just before measuring, and try to get your solutions to the colorimeter within a minute of making them. In addition, you can you prepare your solutions to minimize the contact between Bp^{2-} and concentrated NaOH?

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3) For the Bromophenol blue experiment, rate = $k[Bp^{2-}]^m[OH^-]^n$.

   a) In the solutions that we designed above, NaOH is in such excess that its concentration is essentially not changing during the reaction. Therefore, we can treat this as a pseudo-first-order reaction. Fill in the blanks below, using $[Bp^{2-}]$, $[OH^-]$, k, m, and n:

      rate = k'______________________

      k' = __________________________

   b) You will be measuring absorbance vs. time for each of the solutions designed above. We know from Beer's Law that absorbance is proportional to concentration, and, for the purposes of this lab, we can assume absorbance equals concentration Therefore, we can plot the concentration vs. time data just like we did in question 1, and determine k'. How will you determine k' from the data plots?

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   c) What concentrations of Bp^{-2} and OH^- will you use in your experiment today? (From question 5)

      Solution 1: $[Bp^{2-}]_{initial}$ = _______________ $[OH^-]$ = _______________

      Solution 2: $[Bp^{2-}]_{initial}$ = _______________ $[OH^-]$ = _______________

   d) Using the information you have provided in parts a-c, describe how you will determine the complete rate law (i.e. how you will identify k, m, and n) for the Bromophenol blue reaction, just as you did in question 1. Include equations. Plug in relevant numbers from part c.