# Online Activity 1

## *Reaction Order*

## Introduction

In Chapter 14, you learn that the isolation method allows you to calculate the reaction order with respect to each of the reactants, (variables m and n) in the rate law where Rate = $k[A]^m[B]^n$. Once the rate constant is determined, the rate law allowed you to predict how reaction rate (concentration/time) would change when the initial concentrations of the reactants were changed. However, the rate law cannot give information about concentration and time separately, only as the ratio of concentration/time. Questions such as “how much of my reactant is left after 5 minutes?” or “when will the reaction be finished?” cannot be answered using the rate law alone. To find an answer to these questions, a better understanding of the reaction order is needed and a new equation, called the **integrated rate equation** is required.

### Reaction order

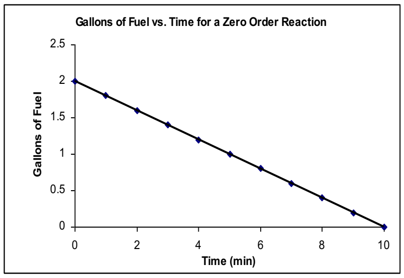
The most common reaction orders are referred to as zero order reactions, first order reactions and second order reactions. Each type will be described below. Each of these orders will have a different mathematical function that can be used to develop an integrated rate equation for a designated reaction. The integrated rate equation will be linear and will fit the equation y=mx + b. This equation will allow you to predict concentration of a reactant at a given time or the total time that a reaction will need to reach a certain concentration.

### *Zero order reactions*

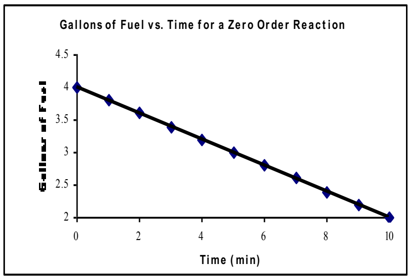
Zero order reactions describe reactions where a reactant decreases at a steady rate regardless of the concentration. One example of a zero order reaction would be a reactant that breaks apart at a steady rate until there is no more reactant left at all in the reaction. It doesn’t break up any faster due to higher concentrations. In addition to decomposition reactions, some combustion reactions are also zero order reactions. It doesn’t matter how much fuel you have, once you have reached a certain temperature, the fuel burns at a steady rate. An increase in the amount of fuel will show as a larger value initially on the y-axis, but does not change the slope of the line which corresponds to the rate of the reaction. The rate of the burning would be constant regardless of how much fuel was present at any particular time.

The first graph below is the result of the amount of fuel used versus time. The second graph demonstrates that when the initial amount of fuel is increased the rate of the reaction (slope) does not change. It is a constant that equals -0.02gallons/min for either graph.

$y = -0.2x + 2$



$y = -0.2x + 4$

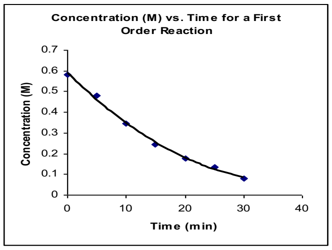


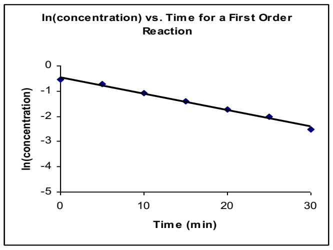
The rate of a zero order reaction is based directly on the linear equation y = mx + b which can be found by finding the slope of the line from the graph. “b” is the intercept on the y axis corresponding to your initial amount of reactant. The variables from the graphs are as follows:

y is the amount of your reactant at a particular time during the reaction
x is a specific time during the reaction
m is the slope of the line which is the rate of reaction (for combustion example = $\Delta$fuel/$\Delta$ time)
b is the y intercept that correlates to the initial amount of a reactant

### *First order reactions*

First order reactions are reactions where the reaction rate is fast at the beginning of the reaction and slows down as the reaction progresses. Unlike a zero order reaction that gives you a straight line when plotting reactant concentration vs. time, you will get a curve for a first order reaction. The rate is continually decreasing over time, thus the mathematical equation for this curved line is more complicated than plotting the concentration/time data directly. However, if the natural logarithm (ln) of the reactant concentration is plotted vs. time, you will now have a straight line which allows you to easily relate reaction time to reactant concentration. Radioactive decay is one example of a first order reaction.

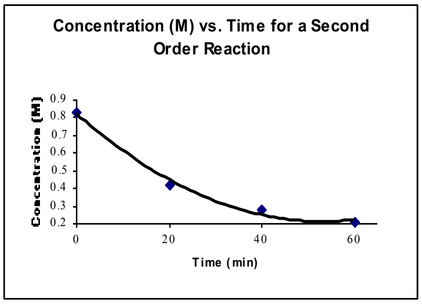


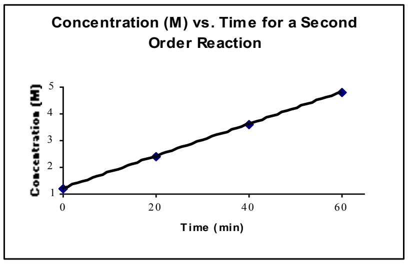


$\ln y = -0.0648x - 0.452$

### *Second order reactions*

Like first order reactions, second order reactions start out quickly and then slow down as the reaction progresses. The relationship between time and concentration for a second order reaction becomes linear when the reciprocal of the concentration (1/conc.) is plotted vs. time. Also note that the linear plot in second order reactions results in a line with a positive slope which will be reflected in the integrated rate equations described in the next section.





$1/y = 0.06x + 1.1998$

### *Limitations in determining the reaction order*

When graphing to find the order of a reactant, we can only monitor a single reactant at a time so that you can be sure that the change is entirely due to a single variable. Therefore, all other reactants must be held constant. This is usually done by forcing the monitored reactant to be the limiting reagent and using all other reactants in excess. As a result, instead of a reaction A + B → products, the chemical equation effectively becomes A → products while monitoring reactant A. Since the amount of B used is very large relative to A, no change is seen in the concentration of B, so it is considered to have a constant concentration. To find the integrated rate law with respect to B, you would need to perform a separate set of experiments where B →products and A is in excess.

### *Determining reaction order*

The ability to generate graphs from experimental data and to use those graphs to analyze the results of an experiment is an essential skill in the sciences. For this activity, you will be using the provided data to make the following 3 plots. First, plot concentration vs. time directly (zero order) then plot ln[A] vs. time (first order) and finally, plot 1/[A] vs time (second order). You will then generate the equation for the line and the correlation constant ($R^2$) from the plotting program. The correlation coefficient ($R^2$) gives an indication of how closely the line fits the data. The graph with the line with the highest correlation coefficient, $R^2$, is the one that best describes the reaction order with respect to the reactant that was plotted. In general, a correlation coefficient of 0.99 or greater is necessary to be confident that the equation for the line is correct.

### Integrated Rate Equations

Once you have determined the order of your reaction, you can use the equation for the line printed on the graph to determine further information about your reaction. These equations are called **integrated rate equations** are based on the chemical reaction: A→ Products. By convention, the following variables are substituted for the variables found in the equation of a line, y = mx +b when generating the integrated rate laws.

The resulting linear equations are as follows:

| Order of reaction | Rate law | Integrated rate equation |
|---|---|---|
| Zero order: | Rate = k | $[A] = -kt + [A_0]$ |
| First order: | Rate = k[A] | $\ln[A] = -kt + \ln[A_0]$ |
| Second order: | Rate = $k[A]^2$ | $1/[A] = kt + 1/[A_0]$ |

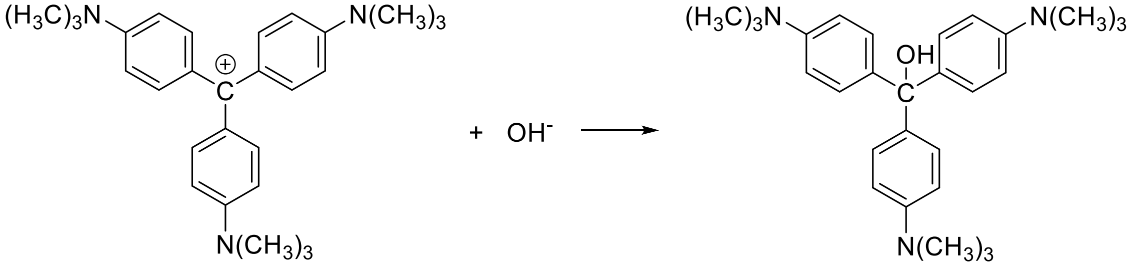
Unlike the rate law for a reaction, the integrated rate equation is based on a single reactant going to products. However, if you have more than one reactant: A+B+C…→ Products, the kinetics gets more complicated. Each reactant is governed by a separate integrated rate equation. To determine each equation, the concentrations of all other reactants must be held constant and separate experiments conducted. This is done by using an excess of all reactants except the one being studied, so that the amount of additional reactants used up in the reaction is minimal.

### Reaction of Crystal Violet with Sodium Hydroxide

### *The Reaction*

To generate the provided data, a purple solution of crystal violet was allowed to react with sodium hydroxide. The sodium hydroxide acts as a bleaching agent by gradually lightening the purple color of the solution. The chemical equation associated with this reaction is given below. You will generate an integrated rate equation for the crystal violet from the data. A large excess of sodium hydroxide relative to the crystal violet was used to minimize changes in the rate due to a change in sodium hydroxide concentration.

Crystal Violet Structures



Crystal Violet (purple)

Product (colorless)

### *Spectrophotometric Analysis*

While the bleaching effect of the hydroxide on the crystal violet is visible to the naked eye, it is impossible to get a precise measurement of just how much crystal violet has been converted to product at any particular time during the experiment. A method is needed that will allow for the monitoring of the color change in such a way that the gradual bleaching of color can be recorded as numerical values. One way to do this is by using an instrument called a **spectrophotometer.** A spectrophotometer measures the absorbance of light by an **analyte** (substance of interest) and gives a numerical reading that correlates to the chemical concentration. A colorimeter works by shining a known amount of light through a sample and measuring how much light comes out through the other side. The "**absorbance**" is a measurement of the amount of light that does not come out, but rather is absorbed by the sample. This is analogous to shining a light through a glass of water versus a glass of grape juice. The grape juice, being darker, will absorb more light, thus the amount of light coming out the other side of the glass is less than that seen through a glass of water.

A spectrophotometer assigns a numerical value that corresponds to the amount of light that is absorbed by the analyte. The absorbance value is linearly correlated to the concentration of the analyte in the solution according to **Beer's Law, $A=\varepsilon bc$** where A is the absorbance, b is the path length of the light and c is concentration of the analyte. The constant, $\varepsilon$, is the **molar absorptivity** which is a function of how much light the solution absorbs per mole of analyte. The molar absorptivity is dependent on the analysis conditions and is found experimentally.

A colorless solution will allow light to go through uninhibited and therefore the value of the absorbance will be very small. As the concentration of a colored analyte increases, the solution gets darker and absorbs more light. The absorbance values increase at a linear rate as the concentration of the analyte in the solution increases. In the crystal violet experiment, you will use the spectrophotometer to monitor the decrease in absorbance over time which correlates to the decrease in the concentration of the purple crystal violet in your solution as it is bleached to a colorless product.

### *Graphically determining the order of the crystal violet (you will be making a total of SIX graphs)*

To obtain the provided data, the absorbance was recorded every minute for a total of 30 minutes. The raw data produced consists of a series of times and absorbance readings. After converting the absorbance to concentration, you will then determine the order of the reaction with respect to the crystal violet by making 3 plots. You will make 3 graphs for each concentration of sodium hydroxide. (2 NaOH concentrations x 3 graphs = 6 graphs total)

Plot 1: The first plot will be a graph of concentration versus time. This represents a zero order reaction.

Plot 2: The second graph is the natural logarithm of the concentration (first order) versus time.

Plot 3. The third graph is a plot of the inverse of the concentration (1/concentration or second order) versus time.

For each concentration of sodium hydroxide, the plot with the best fit line will give you the reaction order with respect to crystal violet. You will use a value called the **correlation coefficient ($R^2$)** to determine which plot is the best. The higher the correlation coefficient, the closer the points are to the line. An $R^2$ value of 1 means perfect correlation, so you will choose the plot with the highest $R^2$ value as the one that represents the reaction order with respect to crystal violet. Instructions for adding the correlation coefficient to your plots will be given in the calculations section.

You must choose the same ORDER for both concentrations of sodium hydroxide even if the correlation coefficients don't fully support your conclusions. Make your best judgment or contact your TA if you have questions.

### *Determining the Rate Law (See Experiment 1 handout for detailed instructions)*

You will monitor the bleaching of the crystal violet with 2 different concentrations of sodium hydroxide. This will allow you to use the isolation method similar to that used in experiment 1 to determine the order of reaction for the sodium hydroxide. (You already have the order of the crystal violet from the graphical analysis). You can then calculate the rate constant, k, of the reaction and finally write the rate law associated with the reaction where

$$\text{Rate} = k[\text{CV}]^m[\text{OH}^-]^n$$

Include both of the rate orders, the rate and the concentrations from the first experiment to solve for the rate constant. Then you will write the rate law associated with the reaction.

### *Determining the Integrated Rate Equation*

One restriction to the integrated rate equation for the crystal violet/sodium hydroxide reaction is that the integrated rate equation applies only when a designated concentration of sodium hydroxide is constant. Thus, the rate constant, k, in the integrated rate equation will incorporate the effect of a constant concentration of an additional reactant. It will vary if the concentration of a second reactant varies. Thus, the k value from the integrated rate equation cannot be substituted into the rate law.

In your lab, you will be doing the experiment using 2 different concentrations of sodium hydroxide to determine how the change in concentration affects the rate constant of the crystal violet/sodium hydroxide reaction. After determining the order of reaction for the crystal violet from one of the graphs, you will use the equation for a line defined by your data to find the intercept and the slope in the equation for your integrated rate equation. You will find the integrated rate equations for both concentrations of sodium hydroxide and observe how the rate constant varies as a result of the change in hydroxide concentration. Your discussion questions will require you to use the rate equations as well as the rate law you calculated to predict the results of hypothetical experiments.

## Data to use for Online Activity 1

absorbance of diluted CV: 0.381AU

[OH-] = 0.01

| Time (min) | A |
|---|---|
| 0.0 | 0.381 |
| 1.0 | 0.352 |
| 2.0 | 0.333 |
| 3.0 | 0.322 |
| 4.0 | 0.314 |
| 5.0 | 0.290 |
| 6.0 | 0.280 |
| 7.0 | 0.270 |
| 8.0 | 0.250 |
| 9.0 | 0.240 |
| 10.0 | 0.231 |
| 11.0 | 0.230 |
| 12.0 | 0.213 |
| 13.0 | 0.204 |
| 14.0 | 0.198 |
| 15.0 | 0.193 |
| 16.0 | 0.184 |
| 17.0 | 0.176 |
| 18.0 | 0.167 |
| 19.0 | 0.160 |
| 20.0 | 0.156 |
| 21.0 | 0.153 |
| 22.0 | 0.149 |
| 23.0 | 0.144 |
| 24.0 | 0.139 |
| 25.0 | 0.135 |
| 26.0 | 0.133 |
| 27.0 | 0.128 |
| 28.0 | 0.123 |
| 29.0 | 0.118 |
| 30.0 | 0.115 |

[OH-]= 0.02

| Time (min) | A |
|---|---|
| 0.0 | 0.381 |
| 1.0 | 0.374 |
| 2.0 | 0.345 |
| 3.0 | 0.287 |
| 4.0 | 0.261 |
| 5.0 | 0.231 |
| 6.0 | 0.207 |
| 7.0 | 0.188 |
| 8.0 | 0.171 |
| 9.0 | 0.143 |
| 10.0 | 0.133 |
| 11.0 | 0.121 |
| 12.0 | 0.109 |
| 13.0 | 0.099 |
| 14.0 | 0.090 |
| 15.0 | 0.081 |
| 16.0 | 0.073 |
| 17.0 | 0.065 |
| 18.0 | 0.058 |
| 19.0 | 0.054 |
| 20.0 | 0.048 |
| 21.0 | 0.047 |
| 22.0 | 0.043 |
| 23.0 | 0.040 |
| 24.0 | 0.039 |
| 25.0 | 0.035 |
| 26.0 | 0.033 |
| 27.0 | 0.032 |
| 28.0 | 0.028 |
| 29.0 | 0.024 |
| 30.0 | 0.022 |

## Online Activity 1: Results Tables and Graphs
## (Submit via Brightspace as part of your report for Online Activity 1)

Name: ____________________________________________ Date: ________ Section: ________

**Attach all 6 Graphs with the results table.**
Each graph must be fully labeled and include the correlation coefficient and equation for the line

| Background Calculations | 0.010M / 0.020M |
|---|---|
| Diluted concentration of sodium hydroxide<br>Record both 0.010M and 0.020M in the box | |
| Diluted concentration of crystal violet | |
| Absorbance of diluted crystal violet | |
| Molar absorptivity | |

| Determining Integrated Rate Equations | 0.010M NaOH | 0.020M NaOH |
|---|---|---|
| Order of reaction with respect to crystal violet | | |
| Equation for trendline shown on graph | | |
| Integrated rate equation for this reaction | | |

| Rate Law Calculations | 0.010M NaOH | 0.020M NaOH |
|---|---|---|
| RATE from rate constant of graph | | |
| Order of reaction with respect to crystal violet | | |
| Order of reaction with respect to NaOH | | |
| Rate constant, k | | |

| Determining the Rate Law | |
|---|---|
| Average rate constant | |
| Overall rate law | |

## Online Activity 1: Results Table Rubric (20pts)

**Points**

| | | |
|---|---|---|
| Tables are neat and legible | 5pts | __________pts |
| Significant figures (>80% correct) | 3pts | __________pts |
| Units (>80% correct) | 2pts | __________pts |
| All results are present and make sense | 10pts | __________pts |

**Deductions (sliding based on TA discretion)**

| | | |
|---|---|---|
| Results to not match data | -20pts | __________pts |
| **Plagiarism!!! Results are identical to another student** | **-100pts** | **__________pts** |

Other: ________________________________________ __________pts

Comments: ____________________________________________________________________

**Grade for Results Table __________pts**

## Online Activity 1: Graph Rubric (30pts, 5 pts per graph)

**Points**

| | | |
|---|---|---|
| Title | 6pts | __________pts |
| $R^2$ value | 6pts | __________pts |
| Equation of line | 6pts | __________pts |
| X axis label | 6pts | __________pts |
| Y axis label | 6pts | __________pts |

**Deductions (sliding based on TA discretion)**

| | | |
|---|---|---|
| Results to not match data | -20pts | __________pts |
| **Plagiarism!!! Results are identical to another student** | **-100pts** | **__________pts** |

Other: ________________________________________ __________pts

Comments: ____________________________________________________________________

**Grade for Graphs __________pts**

## Calculations Section: Submit as part of Online Activity 1 assignment

## Graphs must be included as part of your results section.

***Diluted concentration of reactants***
Equal amounts of both sodium hydroxide and crystal violet were used; therefore you must divide the original concentrations of each reactant by 2 to account for dilution when mixing the two solutions together.

Diluted concentration of 1.0x$10^{-5}$M crystal violet ______________

Diluted concentration of 0.010M NaOH ______________

Diluted concentration of 0.020M NaOH ______________

***Molar absorptivity of crystal violet, ε (Abs/M)***
The absorbance is linearly related to the concentration of crystal violet based on Beer's Law:

$$A=\varepsilon bc$$

A is the absorbance of the diluted crystal violet, b is the pathlength of the light (1.00cm) and c is diluted concentration of the crystal violet. ε is the molar absorptivity and is a conversion factor to convert the absorbance values from our data into concentration in molarity. To find the molar absorptivity, divide the absorbance of the diluted crystal violet by the concentration of the diluted crystal violet. The pathlength, b, cancels out since it has a value of 1cm. This value will be the same for both concentrations of NaOH, as the absorbance of NaOH is essentially zero. **Note; this conversion factor will be a very large number as the concentration of the diluted crystal violet is very low.**

ε(Abs/M) = (abs of diluted CV solution) / [diluted CV]

ε _______________

**Spreadsheet Calculations: Using Excel for Data Analysis**

Microsoft Excel is a program that allows you to perform mathematical manipulations and graphs easily and professionally. It is widely used in academia as well in most industries, thus it is a valuable skill to learn. You will be expected to use Excel to generate data tables and graphs and include them as part of your lab reports. Some general guidelines are listed in the following pages that are specific to using Excel to generate graphs for this lab. They have been written for Excel 2016, but will be similar for other versions of the program. Contact your TA or a TA in the help office if you have questions on using Excel.

For this activity, you will need to enter the data into a spreadsheet and then create 6 different plots for your report. If you do not have a personal copy of Excel, the computers in the library computer lab do have Excel and are available for your use. You are welcome to use any spreadsheet software, but be aware that the TAs may not be familiar with your program and you may have to get help with using it outside the department.

## ***Entering and Calculating Data in Excel***

### *Entering time and absorbance data*

1. Open the Excel program and click on cell A1.
2. Label cell 1A “Time (min)”. Use “enter” to move to the next cell. (A2)
3. Enter 0 in cell A2. Hit enter to move to cell A3.
4. Enter all the times that you recorded for your time data starting in cell A3.
5. Click on cell B1 and label the cell “Absorbance”. Hit “enter” to move to next cell (B2).
6. Enter the absorbance recorded for the diluted concentration of crystal violet. Hit enter to move to cell B3.
7. Enter the all the absorbance values that you recorded for your absorbance data starting in cell B3.

### *Converting absorbance to concentration*

1. Click on cell C1 and label cell “Concentration (M)
2. Hit “Enter” to move to the next cell (C2).
3. Use the value of the molar absorptivity ($\varepsilon$) that you hand calculated to convert all the absorbance values to concentration in the following manner.
4. Enter “= B2/$\varepsilon$” into cell C2 where $\varepsilon$ is the value of the molar absorptivity.
5. To copy this formula into the remaining cells, click on cell C2 and move cursor to lower right hand corner until a + sign appears.
6. Click and hold the + sign and drag down the column until the last cell containing the data from the last time value is reached.
7. Release the cursor and the remaining cells contain the copied formula that converts absorbance to concentration. **Note: your values should be in the $10^{-5}$ -$10^{-6}$ range.**

### *Generating logarithmic and inverse functions*

1. Click on cell D1 and label cell D1 “ln[CV]”.
2. Hit Enter to move to the next cell (D2).
3. Enter “=LN(C2)” to generate the natural logarithm of the concentration from cell C2.
4. Copy this formula into the remaining cells as you did with the time data.
5. Click on cell E1. Enter “1/[CV]” as a label.
6. Hit Enter to move to the next cell (E2).
7. Type “=1/(C2)” to generate the inverse of the concentration from cell C2.
8. Copy this formula into the remaining cells as you did with the time data.

If in the future you want to use other formulas, look for the $\Sigma$ sign on the toolbar at the top of the page. Click on the down arrow to bring up commonly used functions. Click on the one you want to use. If the function you need is not listed, click on the “More Functions” tab at the bottom of the box to bring up a list of additional functions.

## ***Graphing Data in Excel***

### *Generating a scatter plot*

1. Highlight the data for your first graph by holding down the ctrl key and clicking on the top of column A. While still holding the ctrl key click on column C. When you release the ctrl key, you should have both columns highlighted. Click on the insert tab to bring up chart options.

2. Click on the icon for a Scatter plot. It is a graph with dots showing in the graph area. This will bring up a box with instructions to generate different types of graphs. Choose the first option, "Scatter".

3. Clicking on this icon will generate a plot using the data in column A as your x-axis and the data in column C as your y-axis. The plot generated will be representative of a zero order reaction.

4. Make additional scatter plots using time (column A) and lnCV (column D) for the first order plot and time (column A) and 1/CV (column E) for the second order plot. Do this for both 0.010M NaOH and 0.020M NaOH. You should have a total of 6 plots when you are finished

### *Data Analysis of an Excel Graph*

To determine the linearity of a graph, you need to find the correlation coefficient, $R^2$, and the equation for the line. Use the following instructions to add a trendline and these statistics to your graph.

1. Click on a data point in the line, right click to open up a selection box and select "Add Trendline".

2. A selection of options for adding trendlines will arise. Make sure the box labeled "linear" is selected and then check the boxers for "Display $R^2$ Value on Chart and "Display Equation on Chart".

3. Close text box.

4. Your graph will now have these statistics on the graph.

### *Formatting Graphs in Excel*

Next, you will need to format your graph to make it easier to read. Find the "Chart Tools" above the toolbar and use the "add chart elements tab" to access the formatting options for the graph. You need to have a title on each of your graphs as well as labels on the axes.

### Importing graph into other programs

Click on the graph so that small black boxes show up on the outer borders of the graph. Right click to bring up a dropdown menu of options. Click "copy" to copy the graph and then "paste as picture" into a new document. This will then allow you to use the graph as an image in your report. If you prefer to print each graph separately, when the black boxes are showing on the graph, it is all set to print out as a full-size page.

## ***Extracting Data from Excel Graphs***

### *Determining the order of the reaction with respect to crystal violet*

The graph from each set that gives the highest correlation coefficient, $R^2$ is the one that is the best representation of the order of the reaction. This is the graph that corresponds to the order of the reaction with respect to crystal violet. The order of reaction with respect to the crystal violet should be the same for both concentrations of sodium hydroxide. If they differ significantly, contact your TA for help.

**Fill in the results of your graphical analysis here:**

Order of reaction with respect to crystal violet ________________

Correlation coefficient for 0.010M NaOH $R^2$= ________________

Correlation coefficient for 0.020M NaOH $R^2$= ________________

### *Integrated rate equation for crystal violet*

The equation for a line is in the form of y=mx+b. Since the integrated rate equation is a linear relationship between time and some form of concentration, you can use the equation for the line that gives you the best $R^2$ value as the integrated rate equation for that concentration. It must be slightly rewritten to be useful for your reaction. Use the following method to write the integrated rate equation that best fits your reaction.

1. Select the integrated rate equation given below that matches the order of reaction with respect to crystal violet that you chose based on your graphs.

| Order of reaction | Integrated rate equation for the crystal violet/sodium hydroxide reaction |
|---|---|
| Zero order: | $[CV] = -kt + [CV_0]$ |
| First order: | $\ln[CV] = -kt + \ln[CV_0]$ |
| Second order: | $1/[CV] = kt + 1/[CV_0]$ |

2. Substitute the values in the line that correspond to the slope, k, and the intercept. For example, if you have a second order reaction with the following equation, **y=0.089x+12000** you would use the equation for the second order reaction and substitute for k= $0.89M^{-1}min^{-1}$ and the y intercept, $(1/[CV_0])$ =12000.
3. Your integrated rate equation would then be **1/[CV] = 0.089t + 12000.** This tailors the general integrated rate equation to match your data.

The slope of the line is the rate constant, **k**, for your reaction will vary based on the concentration of sodium hydroxide used. The remainder of the integrated rate equation will be the same for both concentrations of sodium hydroxide. Write the integrated rate equation for each experiment below. You may have slightly different intercepts due to error in your data.

Integrated rate equation for 0.010M NaOH: ____________________________________________

Integrated rate equation for 0.020M NaOH: ____________________________________________

### *Rate of reactions*

The slope of the integrated rate equation is the rate constant, k, for the crystal violet and is proportional to the rate of the reaction. You will have a different rate constant for each concentration of sodium hydroxide used since the increase in the sodium hydroxide increases the rate of the reaction. This increase in the value of the rate constant, k, is directly proportional to the rate of the reaction and can be used as a substitution for "**RATE**" in the rate law to find the order of reaction with respect to the sodium hydroxide.

Rate constant, k, from the integrated rate equation for the 0.010M NaOH _________

Rate constant, k, from the integrated rate equation for the 0.020M NaOH _________

### *Determining the order of the reaction with respect to sodium hydroxide*

Use the isolation method (see the Expt. 1 handout for details) and the rate law: RATE = $k[CV]^m[OH^-]^n$ to find the order of the reaction with respect to sodium hydroxide. Remember, you already have the order of reaction with respect to the crystal violet from the integrated rate equations generated earlier. The RATES used in the rate laws are the two calculated rates of reaction, k values, in the previous step. The order of reaction with respect to crystal violet was chosen earlier from the graphs with the highest correlation coefficient.

Order of reaction for NaOH ______________

### *Determining the rate constant, k, for the rate law*

You now have all of the variables except k in the rate law above. Rearrange the rate law to solve for k using both concentrations of sodium hydroxide. The rate constants should be relatively close to one another. Average the two numbers to get a final value. **Note: the value you get for this rate constant, k, IS NOT the same as the value from the integrated rate equation which is also labeled k.** The value for k in the integrated rate equation assumes a given value for the sodium hydroxide concentration. The rate constant, k, in the rate law is independent of the sodium hydroxide equations.

Rate constant for rate law _______________

### *Determining the overall rate law*

The general rate law is Rate = $k[CV]^m[OH]^n$. Fill in the orders of each reactant average rate constant found above into this equation. You now have an equation that allows you to monitor the rate of reaction for any combination of crystal violet and sodium hydroxide concentrations.

Rate law __________________________________________