Experiment 1
Determination of Rate Laws

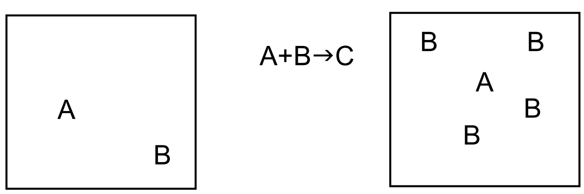
Introduction

The speed of a reaction is an important component to consider when setting up an experiment. Will the reaction be so fast that it is over in a few seconds, or so slow that it does not reach completion for many days or even years? If the speed of a reaction (reaction rate) can be measured, then the length of time needed for a reaction to take place can then be predicted and possibly modified.

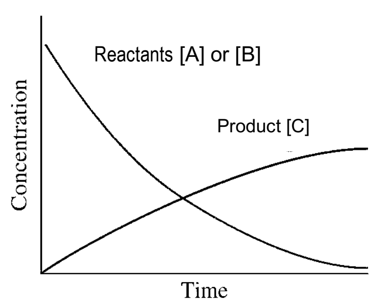
Reaction Rate
The reaction rate is influenced by many factors. Two of these variables, reactant concentration and reaction temperature are often varied to modify the reaction rate. In this experiment, we will study how changes in both of these variables affect the rate of a reaction.

Effect of Concentration on Reaction Rate
An increase in the concentration of a reactant often increases the speed of a reaction. For example, if two molecules, A and B must collide to react, anything that increases the frequency of those collisions increases the rate of the reaction. Thus, an increase in the concentration of a reactant usually results in an increase in the rate of the reaction since molecular collisions can occur more frequently.

In the example below, the goal is to react 1 mole of reactant A with 1 mole of reactant B, to form product C. You can put in 1 mole of each reactant and eventually will get 1 mole of product C. However, if you want the reaction to go faster, you can add more B. You will still only get 1 mole of C since reactant A is the limiting reagent, but more options for collision with B will likely increase the speed that A gets converted to product. Thus, by increasing the reactant concentration, you are likely to increase the reaction rate as well. This is the reason many reactions in Chemistry 101 use one or more reactants “in excess” and a single reactant is the “limiting reagent”.



Reaction rate is defined in terms of either the loss of a reactant over time (Rate= $-\Delta[A]/\Delta T$ or Rate= $-\Delta[B]/\Delta T$) or the increase in a product over time (Rate= $+\Delta[C]/\Delta T$). Any chemicals involved in the reaction can be monitored to determine how fast the reaction is progressing, as their concentrations throughout the reaction are related to the ratio of products to reactants seen in the chemical equation.



For this experiment, we will monitor the rate of disappearance of one reactant, potassium permanganate, $KMnO_4$, by monitoring the loss of the purple color according to the following reaction.

$$\underline{\mathbf{2}}MnO_4^-(aq) + \underline{\mathbf{5}}C_2O_4^{2-}(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

(purple) (colorless)

To determine the rate of the reaction for your experiment, when all of the purple color is gone, we can say that the reaction is finished and that the final concentration of the $KMnO_4$ is now zero. Since the initial time for ΔT is zero, the equation for the rate of disappearance of the potassium permanganate becomes:

$$Rate \;=\; \Delta[KMnO_4]/\Delta T = \frac{(0 - Initial\ [KMnO_4])}{(elapsed\ time - 0)} = \frac{Initial\ [KMnO_4]}{elapsed\ time}$$

For example: If at the end of the reaction the rate of disappearance of the permanganate is found to be 0.2M/min, the rate of disappearance of the oxalate would be 5/2 times greater since you need 5 moles of oxalate for every 2 moles of permanganate. The rate of disappearance of the oxalate ion will then be 5/2 times greater than the rate of disappearance of the permanganate. The mole ratio in the balanced chemical reaction can be used to find the rate of any reactant and product if the elapsed time is the same. This rate is referred to as an **instantaneous rate** and only holds true for a point in the experiment.

$$Rate\ of\ formation\ of\ C_2O_4^{2-} = \frac{0.2M_{KMnO_4}}{min} x \frac{5M_{C_2O_4^{2-}}}{2M_{KMnO_4}} = \frac{0.5M_{C_2O_4^{2-}}}{min}$$

Rate of $KMnO_4$ x Mole ratio = Rate of $C_2O_4^{2-}$

Knowing the rate of reaction for one chemical at a designated time during the reaction allows us to determine the rate of any chemical in the reaction at the same point in the reaction. But we need more information to predict the effect changing the concentration has on the overall rate throughout the reaction. To do this, we need to find the **Rate Law** that governs the reaction.

Rate Laws

While calculating the reaction rate after the reaction is completed provides us with some information, in order to predict changes in the reaction rate, we need to find the **rate law** for the reaction.

A **Rate Law** is an equation that directly relates the concentration of the reactants to the reaction rate when all other conditions, such as temperature, pressure, etc. are held constant.

For a reaction A+B→C The general rate law would be: Rate = $k[A]^m[B]^n$….

Once the variables k, m and n, have been determined experimentally, the rate law allows you to predict the rate of a reaction for any combination of concentrations of A and B as long as all other factors are held constant.

The rate constant, k, is a constant that incorporates the variables associated with the state of the system at the time of the experiment. These variables include the temperature of the reactants, the presence of a **catalyst** (compound present to increase reaction rate) and any other experimental conditions, such as the phase of a reactant or the pressure of any gases in the system. <u>Thus, k will only be constant when all conditions are held constant except for the concentration of the reactants.</u>

The concentrations of the reactants are represented by [A] and [B]. In this experiment, the units used are molarity. Note that the product, C, has no effect on the rate. The rate law being developed is only that of a reactant disappearing, and is independent of the amount of product that has formed.

The exponents, **m** and **n,** determine the degree to which the concentration affects the reaction rate. For example, if m is 1, doubling the [A] doubles the rate, but if m is 2, the rate would increase by a factor of 4. If m is zero increasing the concentration has no effect on the rate of the reaction. These exponential variables are called **reaction orders** and are found experimentally using a procedure called the **Isolation Method.**

The Isolation Method

The **isolation method** is a procedure used to solve for the variables, m, n and k in the rate law. The exponents, m and n are found by running a reaction with a standard set of concentrations, and then varying the concentration of each of the reactants, one at a time to see the effect on the rate. A comparison of the rates at the different concentrations results in the ability to calculate the order of reaction (m or n) for the reactant for which you changed the concentration.

First conduct a control experiment with a set of standard conditions. Next, to determine the orders of reaction for each reactant, you must perform the same experiment again, altering the concentration of one reactant at a time in each experiment. The following example illustrates how to set up an experiment to determine the rate law.

Example of the Isolation Method

1. Set up the Experiment for the reaction, A+B→C: *2 reactants: 3 experiments required.*

Experiment	[A]	[B]	Measured Rate	Analysis
Control	1M	1M	2M/minute	Standard experiment
1^{st} exp.	**2M**	1M	2M/minute	[A] has no effect on rate
2^{nd} exp.	1M	**2M**	8M/min	[B] significantly affects rate

2. Determine the order of reactants, m and n, from the general rate law: Rate = $k[A]^m[B]^n$

From control experiment $2 = k[1]^m[1]^n$
From 1^{st} experiment $2 = k[2]^m[1]^n$
From 2^{nd} experiment $8 = k[1]^m[2]^n$

To solve for m and n, you need to divide one experiment by another to force all but one of the unknown values to cancel out. You then solve for the order of reactant that does not cancel. The rate constant, k will be the same for all experiments, so will always cancel out.

To solve for m:

From 1^{st} experiment / From standard experiment	$\dfrac{2 = \cancel{k}[2]^m\cancel{[1]^n}}{2 = \cancel{k}[1]^m\cancel{[1]^n}}$	Leaves the following equation: $1=[2]^m$ m must equal 0 for this equation to be true.

To solve for n:

From 2^{nd} experiment / From standard experiment	$\dfrac{8 = \cancel{k}\cancel{[1]^m}[2]^n}{2 = \cancel{k}\cancel{[1]^m}[1]^n}$	Leaves the following equation: $4=[2]^n$ n must equal 2 for this equation to be true.

3. Determine k, the rate constant: k = Rate / $[A]^m[B]^n$

You have now solved for all constants except for k, so you can choose any of the experiments, insert the values for the variables, [A] and [B] from the experiment and solve for k. The rate constant, k, should be the same value regardless of which experiment you choose. The units on k will correspond to the units used for concentration and time.

Once you have solved for all of the variables, insert them into the rate law equation to give you a specific equation that relates the rate to the concentrations of all of the reactants.

For the example given the rate law from experiment 2: Rate = $k[A]^0[B]^2$ = 8M/min = $k[1M]^0[2M]^2$

If you rearrange for k: $$k = \frac{\frac{8M}{min}}{[1M]^0[2M]^2} = \frac{2}{M\ min}$$

You will get the same value for k regardless of which experiment you choose. Your units for concentration must be in molarity and the units for time in minutes. If you change units, you must change the value and units of k to match. You must also redo the experiments if you change any experimental parameters, especially the temperature.

Experiment	[A]	[B]	Rate	m	n	k .
Standard	1M	1M	2M/min	0	2	2/(M min)
1^{st} exp.	2M	1M	2M/min	0	2	2/(M min)
2^{nd} exp.	1M	2M	8M/min	0	2	2/(M min)

4. Write the Final Rate Law, Rate = $2[A]^0[B]^2$

The general rate law would be: Rate = $k[A]^m[B]^n$. To modify this to get the rate law that is specific to your experiment, fill in all variables except A and B. Now you have an equation that can be modified for any concentration of A or B to predict the rate. Conversely, if you want a particular reaction rate, you can manipulate A and B to give you that rate you desire. For this reaction, the rate law would be written:

$$\text{Rate} = 2\,[B]^2$$

Note that because m, the order of reaction for A, is zero. **There is no change in the concentration of reactant A that would ever affect the reaction rate. The reaction rate is only dependent on the concentration of reactant B.**

Effect of Temperature on Reaction Rate

The value calculated for the rate constant, k, is dependent on the temperature at which the reaction is performed. If the temperature varies, the rate of the reaction and thus the rate constant will also change. Since m and n are independent of temperature, they will not change due to temperature. The only effect temperature will have on a rate law is in the value of the rate constant.

In your lab

First, you will vary the concentrations of potassium permanganate and oxalic acid to hydroxide to determine the change in rate due to concentration differences. Then you will use the isolation method to write the raw for the reaction at room temperature.

In the second part of this experiment, you will run the same permanganate/oxalic acid reaction that was done to determine the rate law. You will then recalculate the rate constant for the experiment run at different temperatures. You will then write a new rate law for the reaction at each temperature. Remember, all of these rate laws will be identical except for the value of k.

Chemical Hazards

0.500M Oxalic Acid solution

NFPA RATING: HEALTH: 0 FLAMMABILITY: 0 REACTIVITY: 0

DERMAL EXPOSURE: Immediately wash skin with soap and water.
EYE EXPOSURE: Flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Contact your TA immediately.

0.20M Potassium Permanganate solution

NFPA RATING: HEALTH: 1 FLAMMABILITY: 0 REACTIVITY: 3

DERMAL EXPOSURE: Flush with water. Remove contaminated clothing and shoes to avoid further contact with skin. This chemical will permanently stain clothing and will also stain your skin.
EYE EXPOSURE: Flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Contact your TA immediately.
REACTIVITY: Oxidizing. Dangerous for the environment. Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment. Do not use near sinks.

Chemical Disposal

Used Oxalic Acid and Potassium Permanganate solutions

Dispose of in the waste container. Avoid using near sinks due to the chemical toxicity of the potassium permanganate.

Laboratory Equipment Procedures

Using a hot plate

The hot plates used in lab have a ceramic top that will heat up very quickly. Unlike a stove burner, these hot plates will not get red as they heat up, so a heated hot plate looks exactly like a cold hot plate. Please use the following precautions when using a hot plate in lab.

1. Make sure the power cord is not touching the hot plate at any time during use.
2. Keep the hot plate on the lowest setting possible for your experiment.
3. Do not leave your hotplate unattended.
4. Clear glassware should only be used on a hot plate if it contains a liquid or you are carefully monitoring a drying solid.
5. When drying a solid, the hot plate should be on a low setting.
6. Clean up any chemicals that may spill on the hot plate.
7. Many of the hot plates also have a stir setting. Make sure you are using the correct dial before notifying your TA that your hot plate does not work.
8. Turn off and unplug the hot plate before leaving the lab.

Experiment 1: Prelab Worksheet

(Submit via Brightspace BEFORE the start of your lab session.)

Name: ______________________________ Date: ________ Section: ________ Grade: ________

All information needed to complete this worksheet can be found in the pre-lab information and calculations sections of the lab manual. Read this introductory material first!

- Record all values with the correct number of significant figures and units.
- Place all answers on the line when provided.
- Show calculations for any numerical answers; **work must be shown to receive credit.**
- See any 114 TA via zoom before your prelab is due if you have any questions.
- Each question is worth 2 points.

1. Which chemical in the experiment will stain skin and clothing?

 ____

2. Why is ice used in this experiment?

 ____

3. What is the purpose of a rate law?

 ____

4. Calculate the [MnO_4^-] concentration of the diluted sample when the sample is prepared in the following manner. Add 2 drops oxalic acid, 4 drops permanganate and 8 drops water. The original permanganate is 0.25M.

 ____

Consider the following reaction and the data from 3 experiments performed at constant temperature:

$$NH_4^+ (aq) + NO_2^- (aq) \longrightarrow 2H_2O(l) + N_2(g)$$

Exp.#	$[NH_4^+]$ M	$[NO_2^-]$ M	Rate of formation of N_2 M s^{-1}
1	2.0	2.0	1.25
2	6.0	2.0	1.25
3	2.0	6.0	11.25

5. How is the reaction rate expected to change if the concentration of NH_4^+ is increased?

   Increase Decrease No Change

6. Based on the given rate of formation of $N_2(g)$ in experiment 1, what would be the rate of formation of $H_2O(l)$?

   Rate of formation of $H_2O(l)$ _________

7. What is the value of the reaction order with respect to $[NO_2^-]$?

   Reaction Order of $[NO_2^-]$ ___________

8. If $[NH_4^+]$ is zero order, calculate is the value of the rate constant for this reaction.

   Rate Constant _______________

9. Write the rate law for this reaction.

   ____

10. At an increased temperature, the rate constant increases to 12.00. Calculate the rate of reaction at this new temperature using the concentrations in experiment 1 and the rate law you calculated in the previous question. Include units in your answer.

    Rate of formation of N_2 _______________

Experiment 1: Experimental Procedures and Data Sheet
(Submit as part of your informal report.)

Name: ____ Date: ________ Section: ________

TA Signature: _______________________________________

All data must be written in pen at the time it is collected. **Pencil is not allowed!!**
Record all measurements with the correct number of significant figures and units.
TA signature and TA initials on any changes made to the data must be present or your data is invalid.

Preparation

1. Check that you have the following solutions present at your station in dropper bottles.
    a. 0.500M Oxalic acid
    b. Potassium permanganate
    c. Distilled water
2. Record the exact concentration of the potassium permanganate solution below. (It will be given to you by your TA.

Concentration of stock solution of potassium permanganate ________________

Concentration of oxalic acid ______0.500M_____

3. Set up a 250 mL beaker nearby to collect the waste solution after each trial.
4. If not already on, turn on the LabQuest unit by pushing the power button on the top of the unit. The room temperature will show up immediately.
5. Set the timer on the unit to 3000 seconds.
6. To use the LabQuest unit for timing, push the green arrow on the lower left of the screen. This will bring up a new screen with the temperature in the upper right and the timer on the lower right of the screen.
7. When you are finished with the timing trial, push the red square on the lower left of the screen. This will reset the clock.
8. When ready for the next trial, push the green square again and discard your old data by pushing discard. The next run will automatically start timing.
9. Make sure you are comfortable with this procedure before moving on to the next section.

Part 1: Determining the Effect of Reaction Concentration on Reaction Rate

You will use the following instructions for each trial listed in Table 1.

All volumes are measured in drops, so be careful to make the drop size consistent by dispensing the drops in the same manner each time.

Table 1			
Reactants (in drops)			
	Standard	Exp 1	Exp 2
Oxalic acid	6	12	6
Potassium permanganate	1	1	2
Distilled water	7	1	6
Total volume	14	14	14

Instructions:

1. Record the room temperature. __________°C

2. Dispense the solutions under the Standard heading in Table 1 in the following order.
    a. Dispense oxalic acid solution into a clean dry 4” test tube.
    b. Add water. Swirl to mix.
    c. Add potassium permanganate solution to test tube and swirl to mix.

3. Push the green arrow on the lower left of the screen on the LabQuest 2 unit to start timing.
4. Place the test tube in a test tube rack. The color will change from purple to yellow-brown.
    a. **Note: Swirling the test tube to make a thin layer of solution on the glass will allow you to see when the purple color has disappeared and only yellow solution remains. Putting a piece of white paper under the test tube may also help.**

5. Stop timing when the last trace of purple disappears. For the standard, this should be no more than 8 minutes. Notify your TA if it is taking too long.
6. Record the elapsed time in seconds below.
7. Set up the LabQuest 2 unit for the next run.
8. Pour the used solution into the waste beaker.
9. Rinse the test tube with distilled water from your wash bottle and dry with a paper towel. Pour the rinse water in the waste beaker.
10. Repeat these steps a second time. Your values should be within 30s of each other. If not, perform additional trials so that you get 2 values that are within 30s of each other.
11. Repeat the procedure for the other two experiments in Table 1.
    a. Note: The elapsed times for Experiment 1 and Experiment 2 trials should require approximately half of the time used in the standard trial. If not, you may want to repeat any experiment that seems incorrect. See your TA for help.

Elapsed time (Standard) ________s ________s ________s ________s

Elapsed time (Experiment 1) ________s ________s ________s ________s

Elapsed time (Experiment 2) ________s ________s ________s ________s

Part 2: Determining the Effect of Temperature on Reaction Rate

Preparing a warm water bath:

1. Fill a 250 mL beaker half full of tap water.
2. Heat the beaker on a hot plate until the water temperature is a constant ~20°C above room temperature. Stir the water with your spatula to distribute the heat. Keep the water temperature constant to +/- 2°C by adding ice or increasing the heat while you perform the remaining steps. Your temperature must be constant to record an accurate rate.

Performing Rate Determinations:

Use the following instructions for one experiment at approximately 20°C above room temperature. You will then compare the data to the data collected at room temperature.

1. Dispense 6 drops of oxalic acid stock solution into a clean dry 4" test tube.
2. Add 7 drops of water into the same test tube. Swirl to mix.
3. Place this test tube into the warm water bath for approximately 2 minutes.
4. Record the temperature of the water bath below.
5. Add 1 drop of potassium permanganate to the diluted oxalic acid in the test tube, swirl, return to water bath and immediately start timing.
6. Do not remove the solution from the water bath except to swirl occasionally.
7. Stop timing when the last trace of purple disappears.
8. Record the elapsed time in your data sheet.
9. Set up the workstation for the next run.
10. Pour used solution into the waste beaker.
11. Rinse the test tube with distilled water and dry with a paper towel.
12. Repeat these steps until you perform 2 trials with times within 30s of each other.

Elapsed time at ________°C _______s _______s _______s _______s

Cleanup

1. Empty the contents of the waste beaker into the approved waste container. Remember to close the waste container when you are finished.
2. Rinse out all test tubes and the waste beaker with soap and water until clean. Be especially careful to clean anything that contained permanganate as the residue can cause permanent stains.
3. Wipe down your lab bench area with a sponge to remove any traces of spilled chemicals.
4. Turn off and unplug your hot plate.
5. Make sure you have your TA sign your data before leaving the lab.

Experiment 1: Data Rubric (20pts)

Points

Data are neat and legible	5pts	__________pts
Significant figures (>80% correct)	3pts	__________pts
Units (>80% correct)	2pts	__________pts
All data are present and make sense	10pts	__________pts

Deductions (sliding scale based on TA discretion)

Lab area left unclean	−20pts	__________pts
Improper waste disposal	−20pts	__________pts
Disruptive behavior	−20pts	__________pts
Lab coat or safety glasses removed while in lab	−20pts	__________pts
Data sheet is missing TA signature	−20pts	__________pts
Other: ____		__________pts

Comments: ____

Grade for Data Sheet __________**pts**

Experiment 1: Results Table
(Submit as part of your informal report.)

Name: ______________________________________ Date: ________ Section: ________

All data must be written in pen at the time it is collected. **Pencil is not allowed!!**
Record all results with the correct number of significant figures and units
No stray marks or notes should be present on this page. Only the tabulated results are allowed

Part 1: Determining the Effect of Reaction Concentration on Reaction Rate

Concentrations of [$H_2C_2O_4$] and [MnO_4^-] in solutions	[$H_2C_2O_4$]	[MnO_4^-]
Concentrations in the Standard		
Concentrations for Experiment 1:		
Concentrations for Experiment 2:		

Average elapsed time (ΔT)	
Average elapsed time for the Standard	
Average elapsed time for Experiment 1:	
Average elapsed time for Experiment 2:	

Rate of disappearance of potassium permanganate	
Rate of disappearance of permanganate in the Standard	
Rate of disappearance of permanganate in Experiment 1	
Rate of disappearance of permanganate in Experiment 2	

Determination of orders of reaction for oxalic acid and potassium permanganate	
Order of reaction for oxalic acid	
Order of reaction for permanganate	

Determination of Rate Constant (k)	
Rate constant from Standard data	
Rate constant from Experiment 1 data	
Rate constant from Experiment 2 data	

Rate law ______________________________________

Part 2: Determining the Effect of Temperature on Reaction Rate $[H_2C_2O_4]$

Averaged elapsed time at ~ 20°C above standard temperature	
Rate of disappearance of permanganate at ~ 20°C above standard temperature	
Rate constant at ~ 20°C above standard temperature	

Rate law at ~ 20°C above standard temperature ______________________

Experiment 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

Experiment 1: Calculations

Perform the following calculations & submit as part of your informal report.

Part 1: Determining the Effect of Reaction Concentration on Reaction Rate

Concentrations of oxalic acid* [$H_2C_2O_4$] *and potassium permanganate* [MnO_4^-] in the *experimental solutions

Use the following equation and the number of drops in Table 1 to calculate the molarity of the diluted solutions for each part of the experiment. Perform the calculation for both the permanganate and oxalic acid concentrations for each of the solutions in Table 1.

$$M_sV_s=M_dV_d \quad \text{rearranged to} \quad M_d= M_sV_s/V_d$$

M_s = molarity of stock solution
M_d = molarity of chemical in solution
V_s = volume of stock solution (drops in Table 1)
V_d = volume of diluted solution (14 drops)

Note: When you rearrange the algebra to solve for M_d, the volume unit of drops cancels out.

Standard: [$H_2C_2O_4$]: __________ [MnO_4^-]: __________

Experiment 1: [$H_2C_2O_4$]: __________ [MnO_4^-]: __________

Experiment 2: [$H_2C_2O_4$]: __________ [MnO_4^-]: __________

***Average elapsed time* (ΔT)**

Add the values of the times in seconds and divide by the total number of trials performed at the same concentrations and temperature. Use only the trials that are within 30s of each other.

Average elapsed time for the Standard: _________

Average elapsed time for Experiment 1: _________

Average elapsed time for Experiment 2: _________

Rate of disappearance of potassium permanganate (Rate)

Divide the molarity of the diluted potassium permanganate by the average elapsed time in seconds. Find this for each experiment.

Rate of disappearance of potassium permanganate in the Standard: _________

Rate of disappearance of potassium permanganate in Experiment 1: _________

Rate of disappearance of potassium permanganate in Experiment 2: _________

Determination of order of reaction for oxalic acid (m)

Use the isolation method and the results of the standard experiment and experiment 1 to solve for the order of reaction, m, for the oxalic acid. Round to the value of 0, 1 or 2.

Order of reaction for oxalic acid: _________

Determination of order of reaction for potassium permanganate (n)

Use the isolation method and the results of the standard experiment and experiment 2 to solve for the order of reaction, n, for the potassium permanganate. Round to the value of 0, 1 or 2.

Order of reaction for potassium permanganate _________

Determination of Rate Constant (k)

Use the data and calculated results from the standard experiment to solve for k using the general rate equation.

$$\text{Rate} = k\,[H_2C_2O_4]^m\,[MnO_4^-]^n$$

m and n: Orders of reaction for oxalic acid and potassium permanganate
$[H_2C_2O_4]$: Concentration of diluted $H_2C_2O_4$ from the standard experiment
$[MnO_4^-]$: Concentration of diluted $KMNO_4$ from the standard experiment
Rate: Rate of disappearance of $KMNO_4$ from the standard experiment

Repeat the calculation for experiments 1 and 2. The orders of reaction, m and n will be the same for both experiments.

Rate constant from Standard data _________

Rate constant from Experiment 1 data _________

Rate constant from Experiment 2 data _________

Writing the Rate Law for a reaction

Average the values for the rate constants from all 3 experiments. Use this as your rate constant, k, in the rate law. Then substitute in the calculated values for the orders of reaction, m and n. Leave the word "Rate" and reactant concentrations as variables. This gives you a usable equation for solving for rate for any concentration of oxalic acid and potassium permanganate.

$$\text{Rate} = k\,[H_2C_2O_4]^m\,[MnO_4^-]^n$$

Rate Law at standard temperature ____

Part 2: Determining the Effect of Temperature on Reaction Rate

Average elapsed time (ΔT)

Add the values of the times in seconds and divide by the total number of trials performed at the same concentrations and temperature. Use only the trials that are within 30s of each other.

Average elapsed time: ______________

Rate of disappearance of potassium permanganate (Rate)

Divide the molarity of the diluted potassium permanganate by the average elapsed time in seconds.

Rate of disappearance of potassium permanganate: ________

Determination of Rate Constant (k)

Use the data and calculated results from the experiment at increased temperatures to solve for k using the general rate equation. The orders of the reaction will not change due to the increase temperatures. They should be the same as you calculated at room temperature, so round accordingly.

$$\text{Rate} = k\,[H_2C_2O_4]^m\,[MnO_4^-]^n$$

m and n: Orders of reaction for oxalic acid and potassium permanganate from Part 1
$[H_2C_2O_4]$: Concentration of diluted $H_2C_2O_4$ from the standard experiment
$[MnO_4^-]$: Concentration of diluted $KMnO_4$ from the standard experiment
Rate: Rate of disappearance of $KMnO_4$ at the elevated temperature

Rate constant ____________________

Writing the Rate Law for a reaction

Substitute in the calculated values for the rate constant and the orders of reaction, m and n. Leave the word "Rate" and reactant concentrations as variables.

Rate law at increased temperature ____

Experiment 1: Questions

Answer the following questions & submit as part of your informal report.

1. Briefly describe, on a molecular level, why increasing concentration tends to increase the rate of a chemical reaction.

2. Briefly explain, on a molecular level, why increasing temperature tends to increase the rate of a chemical reaction.

3. Suppose you were not careful while running your experiment, and the size of your drops varied widely. Briefly describe the impact you would expect inconsistent drop size to have on your results.

4. Explain why it is better to take calculate the rate constant, k, three times (from the standard data and from experiments 1 & 2) and take the average rather than just select one of the tests to use for the calculation of k.

5. How would your overall results be impacted if you used the original concentrations in your calculations rather than calculating the diluted concentrations?