

Name \_\_\_\_\_

Section \_\_\_\_\_

Partner(s) \_\_\_\_\_

Date \_\_\_\_\_

## DETERMINATION OF THE RATE LAW FOR CRYSTAL VIOLET/SODIUM HYDROXIDE REACTION

### PRE-LAB QUERIES

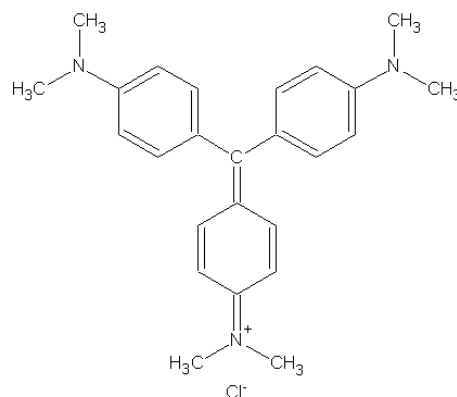
1. Crystal violet has an intense violet or purple color when dissolved in aqueous solution. If the crystal violet was slowly converted to a colorless compound, how would the color intensity of the mixture change?
2. Based on laboratory techniques you have used in the past, how could we measure the color change above and relate it to the concentration of crystal violet?

### OBJECT

This activity involves the measurement of the initial rate of reaction for crystal violet and sodium hydroxide by spectrophotometric determination of crystal violet concentration over time. From the data collected the rate law or rate expression and rate constant will be determined.

### INTRODUCTION

Crystal violet (or methyl violet) is used as an acid-base indicator, biological stain (gram positive test in microbiology), textile dye, and as a topical antibacterial agent. The intense violet color is due to the resonance of electrons in the alternating single and double bonds. Hydroxide ion in high concentration will attack the crystal violet cation at the central carbon atom where the three rings are bonded. When the  $\text{OH}^-$  bonds to the carbon, a colorless product is formed.



Since the crystal violet cation has an intense color, we can monitor its concentration by measuring the absorbance using spectrophotometry.

The crystal violet-sodium hydroxide reaction has the following general rate law:

$$\text{Rate} = k(\text{CV}^+)^x(\text{OH}^-)^y$$

By conducting three experiments where different concentrations of  $\text{CV}^+$  and  $\text{OH}^-$  are mixed, we can measure the initial rate of reaction and derive the rate law and rate constant,  $k$ .

The absorbance of  $\text{CV}^+$  as a function of time will be measured using the Spec-20D and computer. Beer's law allows us to relate the concentration to absorbance, hence a plot of  $A$  vs. time is essentially concentration vs. time, or the slope is the initial rate of reaction:

$$\text{Rate}_o = \text{slope} = -\Delta A / \Delta \text{time} = -\Delta \text{conc.} / \Delta \text{time}$$

### PROCEDURE

1. Determine the  $\lambda_{\text{max}}$  for  $\text{CV}^+$  by scanning the  $6 \times 10^{-6}$  M solution of crystal violet from 400-650 nm at 20 nm intervals using the Spec-20D and SpectroPro on the computer. Use distilled water as the blank. Print the absorption spectrum when completed.
2. Set  $\lambda_{\text{max}}$  and standardize the Spec-20D. Have the computer set up to measure absorbance vs. time for 5 minutes with absorbance readings every 10 seconds. Three experiments will be run with reactant concentrations given in the table below:

Expt.	( $\text{CV}^+$ )	( $\text{OH}^-$ )
1	$1.6 \times 10^{-5}$ M	0.020 M
2	$1.6 \times 10^{-5}$ M	0.010 M
3	$3.2 \times 10^{-5}$ M	0.020 M

3. Pipet 2 mL of each solution into a spectrophotometer tube. Mix well. Wait one minute and then place the tube in Spec-20D and start the computer run. Record the laboratory temperature. The one minute delay is to allow the reaction to get started. When the run is completed, check the output. If there are two or more readings that are identical at the beginning of the run, repeat the run (since this indicates that the reaction had not started when the run began)
4. At completion of each run or experiment, the computer will fit a linear regression line to the data plotted. The slope of the line is the initial rate of reaction. Record the slope ( $m$ ) and the coefficient of determination ( $r^2$ ) in the data table.

5. Set up Experiment 3 again as above; however, change the time of the run from 5 to 20 minutes. Fit the resulting data with a linear regression and record the  $r^2$  value in the data table.
6. Transfer the data from the 20 minute experiment to an Excel file. Save the file in the CHM 103 folder in "CV\_Order" using the name "group\_id\_section #". "group\_id" is some name that identifies your group.

Generate plots of A vs time, log A vs time, and 1/A vs time. Fit each plot with a linear regression and record the  $r^2$  values in the table provided. The plot with the highest  $r^2$  value (best fit) indicates the reaction order.

7. When you are finished, place all spectrophotometer tubes in the solution of 1M HCl provided to remove any crystal violet stains.

## DATA

### Absorption Spectrum

Wavelength	Absorbance	Wavelength	Absorbance
400 nm		540	
420		560	
440		580	
460		600	
480		620	
500		640	
520		650	

Laboratory temperature \_\_\_\_\_

### Rate Experiments

Expt.	Initial Rate	Correlation Coefficient
1		
2		
3		

## RESULTS

1. Generate the absorption spectrum for the crystal violet cation. Locate  $\epsilon_{\text{max}}$  on the graph.
2. Calculate the concentration of each reactant after mixing and record the rate constant from each run. Compute the average  $k$ .

Expt.	$(\text{CV}^+)_0$	$(\text{OH})_0$	Rate Constant, $k$
1			
2			
3			
AVERAGE			

3. Derive the rate law (or rate expression) and evaluate the rate constant,  $k$ , using the initial concentrations for each experiment. Calculate the average rate constant. Attach a separate sheet with calculations.
4. Results from the 20 minute run data.

Order	Zero	First	Second
Graph	A vs t	log A vs t	1/A vs t
$r^2$			

Based on the results above, the order of the reaction is: \_\_\_\_\_

5. Overall order from the 20 minute run  $n_{\text{overall}} =$  \_\_\_\_\_

What does the 20 minute run tell you about the overall order of the reaction? Does this agree with your result for the 5 minute runs?

## CONCLUSION

State the rate law found and your average rate constant at the temperature measured. Discuss any possible errors in your experimental process.

## POST-LAB QUESTIONS

1. After initially mixing the reactants, it takes time to completely mix the reactants and place the tube in the spectrophotometer (including the one minute delay). Would a two or three minute delay cause an error? How would it influence the graph of A vs. time?
2. If the temperature increased while the reaction was occurring in the spectrophotometer, how would the graphical results (A vs. time) be influenced? Explain.
3. What is the pH range and color change for crystal violet (methyl violet) as an acid-base indicator? Would this have been a consideration for this laboratory activity? Why or why not?
4. Why do we use initial rates to study a reaction?