AP CHEMISTRY

Kinetics of Crystal Violet Fading

(135 Points)

Name, Date and Lab Partner (5 Points)

Procedure (10 Points)

Complete, step-by-step account

of actions performed

Data (35 Points)

Observation Table (15 Points)

Materials (5 Points)

Reagents Volumes (3 Points)

Reagent Concentrations (2 Points)

Standard Curve Absorbance Values (5 Points)

Experimental Absorbance Values (5 Points)

Calculations (50 Points)

Pre-Lab Questions (20 Points)

Calibration Curve (5 Points)

Experimental Concentration Values (5 Points)

Integrated Rate Law Graphs: [A], ln[A], 1/[A] (20 Points)

Conclusion (20 Points)

Overall Neatness and Organization (5 Points)

Safety (10 Points)

This part is determined by proper lab safety which includes having your goggles and lab coat on properly at all times. Each reminder by the instructor will result in a deduction of 5 or 10 points. This component of the grade can be negative.

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**INTRODUCTION TO ANALYTICAL CHEMISTRY – LAB**

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**EXPERIMENT VIII**

**KINETICS OF CRYSTAL VIOLET FADING**

**INTRODUCTION**

Crystal Violet is a common, beautiful purple dye. In strongly basic solutions, the bright color of the dye slowly fades and the solution becomes colorless. The kinetics of this “fading”, or the progression of the reaction, can be analyzed by measuring the color intensity (absorbance) of the solution versus time to determine the rate law.

**BACKGROUND**

Crystal violet belongs to a class of intensely colored organic compounds called triphenylmethane dyes. The structure of crystal violet depends upon the pH of the solution it is dissolved in. The major structural form is the monovalent cation, abbreviated CV+. (Figure 1a) Crystal violet is predominantly found in this form from pH values ranging from 1-13. Notice that the positive charge of the cation is centralized on the carbon adjoining the three phenyl groups. This formal charge would be delocalized due to resonance between the central carbon and the three nitrogen atoms of the phenyl groups. (Figure 1b) Delocalization of the charge across the system of double bonds in the benzene rings stabilizes the carbocation and is responsible for the vibrant purple color of the dye.



1. Use electron pushing to demonstrate resonance between these structures. (Hint: the lone pair on nitrogen is missing) How many total resonance structures would there be?

In strongly basic solutions (high concentration of OH- ions), the purple CV+ cation combines with hydroxide ions to form a neutral product, CVOH, which is colorless. (Figure 2)



The rate of this reaction (Equation 1) is slower than typical acid-base proton transfer reactions and depends on the initial concentration of both crystal violet and hydroxide ions.

CV+ (aq) + OH- (aq) → CVOH (aq) *Equation 1*

*Purple Colorless*

Exactly how much the rate changes as the reactant concentration is varied depends upon the rate law for the reaction.

1. Determine the general rate law for the reaction of CV+ with OH-. Use *n* for the order of CV+ and *m* for the order of OH-.

*Equation 2*

The exponents *n* and *m* are defined as the order of reaction for each reactant and k is the rate constant for the reaction at a particular temperature. The values of the exponents *n* and *m* must be determined experimentally. If the reaction is carried out under certain conditions, then the rate law will reduce to the form:

Rate = k’[CV+]n *Equation 3*

where k’ = k[OH-]m *Equation 4*

The constant k’ is called a ***pseudo rate constant***, as it incorporates both the true rate constant (k) and the [OH-]m term. Equation 3 is therefore referred to as a ***pseudo rate law*** because it is a simplification of the actual rate law, Equation 2.

1. What conditions would your experimental reaction have to be performed under in order for the pseudo rate law to be applicable?

Under the conditions you proposed in question #3 above, the term [OH-]m should not change much over the course of the reaction compared to the [CV+]n term. Therefore, it should have a negligible effect on the rate of the reaction and can therefore be assumed constant in the rate law. That is why we can treat it as part of the constant value k’.

**THEORY**

The experimental goal of this lab is to monitor and analyze how the concentration of your crystal violet solution changes over time.

1. What observation provides evidence of the CV+ ion reacting?
2. How you use this observation to determine the concentration of a solution?

Recall that the absorbance for a specific solution varies directly with the concentration of the solution, according to Beer’s Law.

A = abc *Equation 5*

Where A is absorbance, a is the molar absorptivity coefficient, b is the path length in cm, and c is the concentration of the solution. Beer’s law provides the basis of using spectroscopy in quantitative analysis of concentration. Obviously, for reactions which experience a change in color intensity, spectroscopy can be a useful tool to help determine the kinetics of the reaction since a change in concentration can be tracked over time.

1. Looking at Beer’s equation, if you plot concentration versus absorbance, what does the slope of that linear plot reflect?
2. How can a linear relationship of concentration and absorbance be obtained/determined in lab?

**EXPERIMENT OVERVIEW**

The purpose of this lab will be to use spectroscopy and graphical analysis to determine the rate law for the color-fading reaction of crystal violet with sodium hydroxide. Continue your pre-lab now to determine the proper steps that must be taken to determine the order of this reaction.

PRE-LAB (Continued)

1. Summarize your understanding of the experiment parameters by discussing
   1. The conditions necessary to apply a pseudo rate law for CV+
   2. How concentration can be determined experimentally
   3. What steps must be taken to determine the linear relationship between CV+ concentration and absorbance
   4. How this linear relationship can be applied to determine the kinetics of a reaction between CV+ and OH-.
2. The visible absorption spectrum for CV+ is shown in Figure 3 using a 12.5μM CV+ solution (12.5 x 10-6M). What would be the optimal wavelength to use in your experiment? Recall that absorbance is most accurate and sensitive between 0.2 and 1.0.



1. A calibration curve is required to determine the linear relationship between CV+ absorbance and concentration. If you are supplied with a 25μM stock solution, complete the following table to show how you would prepare 2.5, 5, 7.5, 10, and 12.5 μM solutions of CV+. Assume a final volume of 10.0mL in all cases.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | CV Stock Solution | A | B | C | D | E |
| Concentration (μM) | 25 μM | 2.5 μM | 5.0 μM | 7.5 μM | 10.0 μM | 12.5 μM |
| Water (mL) | 0 |  |  |  |  | 5.0 |
| Stock Solution (mL) | 10.0 |  |  |  |  | 5.0 |

1. Assume you have made the standard solutions A-E and have measured the absorbance of each. How can you determine whether or not an acceptable standard curve has been constructed?
2. With regard to the reaction, determine the concentration of CV+ you should start with. How will you know when to stop collecting absorption data?

**Safety and Disposal**

Dilute sodium hydroxide is irritating to skin and eyes. Crystal violet is a strong dye and will stain anything it is exposed to, including clothes and skin. Wrap a paper towel around the neck of the container as you pour the stock solution to avoid dripping/spills. Clean up spills immediately.

**Investigation**

***Constructing a Calibration Curve for Crystal Violet***

1. Turn on the spectrophotometer and allow it to warm-up for 15-20 minutes. Adjust to the wavelength determined in the pre-lab.
2. Construct your standard solutions and build your standard curve. Print 2 copies for each lab partner and make sure it includes labels and mathematical evidence of a linear relationship between absorbance and concentration.
   1. Use a serological pipette.
   2. Do not contaminate the stock CV+ solution. Pipette all water volumes first, then go back and add the desired stock CV+ volume. Mix the solutions prior to analysis.
   3. Recall proper procedure when using cuvettes.

***Analysis of Crystal Violet Kinetics***

1. React the predetermined amount of each reactant in a cuvette.
   1. Make sure you are creating the desired conditions of [CV+] vs [OH-] discussed in the pre-lab.
   2. Be ready to collect absorbance data immediately upon mixing the reagents in the cuvette.
2. Analyze the absorbance data to determine the kinetics of the reaction with respect to CV+
   1. Determine how to use graphical depictions of your concentration data to determine the order of reaction for CV+.
   2. I suggest using a spreadsheet to facilitate your data calculations/graphing

**Conclusion**

* Discuss the concepts of spectroscopy, absorbance, concentration, and kinetics.
* Display your understanding of pseudo rate laws and why it was applicable to your experiment.
* Reference your results (data and graphs) to support your conclusion of the order for [CV+]
* Identify sources of error and future improvements
* Propose an experiment to determine the overall order of the reaction (ie: the order of [OH-])