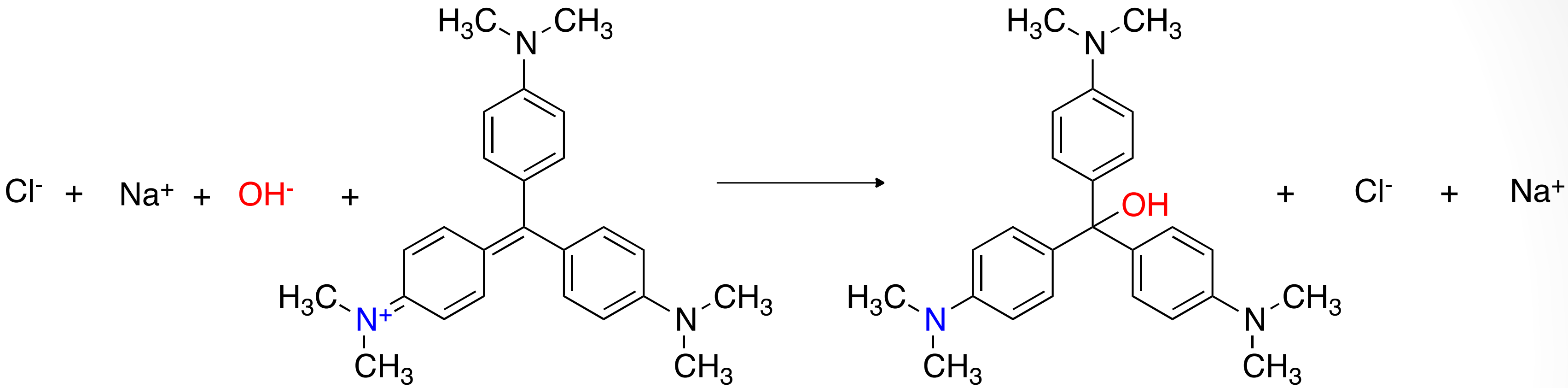
Integrated Rate Law Kinetics

Ellie Zheng

Reaction of Crystal Violet with NaOH



Violet-colored

Colorless

Crystal Violet – contains three six-membered rings with alternating double and single bonds. C. V. has extended resonance.

Molecules that are highly conjugated or in resonance tend to form **colored** solutions because they absorb visible light.

Disruption of the conjugation of C.V. by NaOH produces a **colorless** species.

We can monitor this reaction by UV-Vis spectroscopy.

UV-Vis Spectroscopy

- Instrument that measures the Absorbance (A) of light by a solution

- By measuring the absorbance of a species, we can find its concentration using Beer's Law:

$$A = \varepsilon b c$$

Absorbance

Molar absorptivity ($L\ mol^{-1}\ cm^{-1}$)

Path length (cm)

Concentration ($mol\ L^{-1}$)

- Molar absorptivity and path length are constants for each experiment; therefore, A(Abs) and c are directly proportional to one another.

Rate Law Equations

- The Rate of reaction for A + B ↔ C can be expressed by the following equations:

  Rate = $k[A]^{m}[B]^{n}$ & Rate = $-\Delta[A]/\Delta t$

- where *m*&*n* is called the “order of reaction” with respect to A or B

Zero Order

$$Rate = -\frac{\Delta A}{\Delta t} = k[A]^0[B]^Y$$

$$\int_{[A]_o}^{[A]} \Delta A = \int_0^t -k[B]^Y \Delta t$$

$$[A]-[A]_o = -k[B]^Y(t-0)$$

$$[A] = -k[B]^Y t + [A]_o$$

First Order

$$Rate = -\frac{\Delta A}{\Delta t} = k[A]^1[B]^Y$$

$$\frac{\Delta[A]}{[A]} = -k[B]^Y \Delta t$$

$$\int_{[A]_o}^{[A]} \frac{\Delta[A]}{[A]^1} = \int_0^t -k[B]^Y \Delta t$$

$$\int_{[A]_0}^{[A]} \ln[A] = \int_0^t -k[B]^Y t$$

$$\ln[A] - \ln[A]_o = -k[B]^Y t$$

$$\ln[A] = -k[B]^Y t + \ln[A]_o$$

Second Order

$$Rate = -\frac{\Delta A}{\Delta t} = k[A]^2[B]^Y$$

$$\int_{[A]_o}^{[A]} -\frac{\Delta[A]}{[A]^2} = \int_0^t k[B]^Y \Delta t$$

$$\int_{[A]_0}^{[A]} \frac{1}{[A]} = \int_0^t k[B]^Y t$$

$$\frac{1}{[A]} - \frac{1}{[A]_o} = k[B]^Y t$$

$$\frac{1}{[A]} = k[B]^Y t + \frac{1}{[A]_o}$$

Integrated Rate Laws

Order	*Integrated Rate Law Equations*	*y vs. x*
Zero, m = 0	$[A] = -k[B]^n t + [A]_o$	[A] vs. t
First, m = 1	$\ln [A] = - k[B]^n t + \ln [A]_o$	ln [A] vs. t
Second, m = 2	$\frac{1}{[A]} = k[B]^n t + \frac{1}{[A]_o}$	1/[A] vs. t

- All equations are written in the form y = mx + b

- The order of the reaction with respect to “A” (here A = Crystal Violet) can be found by plotting [A], ln [A], or 1/[A] versus *t* (time);
- The equation that provides a linear slope is evidence of the order of the reaction

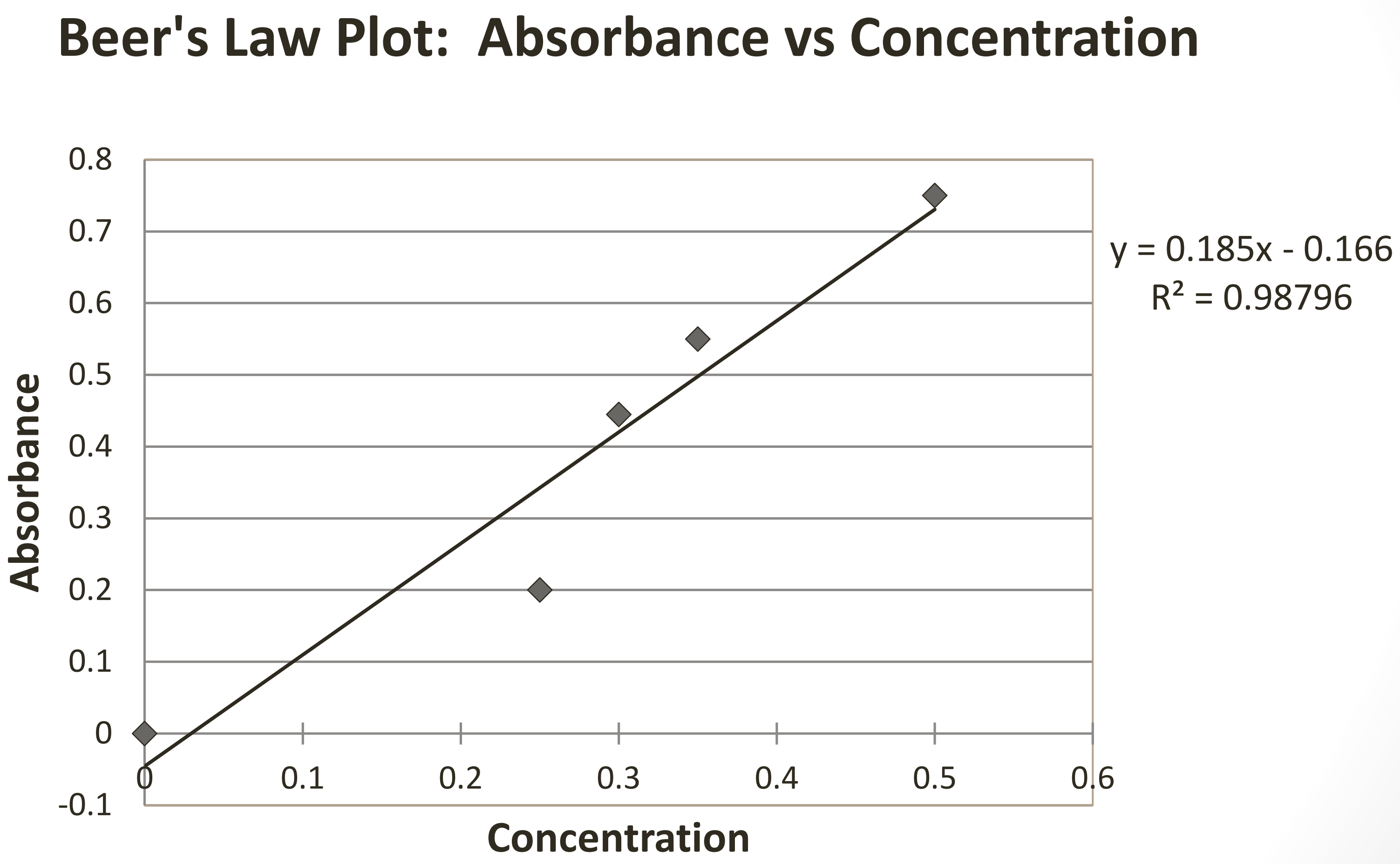
Goals for Experiment: [C.V.]&*t*

1. Make a calibration curve for Crystal Violet:
   - Prepare 3 C.V. solutions of different concentration([C.V.])
   - Measure the absorbance (A) of 4 C.V. solutions
   - Draw calibration curve: **Abs** v. **[C.V.]**

2. Determine the Order of Reaction with respect to C. V.:
   - Follow the reaction using the spectrophotometer by recording the absorbance (**Abs**) of C.V. every 10 seconds for 2 min (***t***).
   - Repeat twice (perform a total of 3 times)

3. Determine the Order of Reaction with respect to NaOH:
   - The same way as in goal #2, except with a different concentration of NaOH.

Calibration Curve

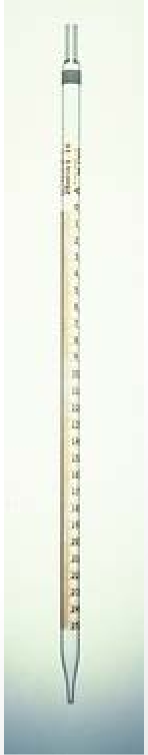


Experimental Details

- Preparing C.V. stock solutions – using one 10.0 mL volumetric flask
  - Use LESS THAN 20 mL of 8 x 10^{-6} M C.V. in total
  - Solvent: 5% EtOH/H_2O
  - Put the prepared solution in a cuvette; rinse the flask thoroughly; then move on to next preparation

- Transferring solutions – using graduated pipets
  - Rinse with solutions for 3 times
  - Don't draw solutions into the bulb

- Syringes:
  - get rid of bubbles at the tip first



Spectrophotometers

- “cuvette” : 13 x 100 mm test tube
- Blank the spectrophotometer between each trial
  - 5% EtOH H_2O for part 1 (calibration curve)
  - 0.050 M NaOH for part 2 (order for CV)
  - 0.025 M NaOH for part 3 (order for NaOH)

Contamination Prevention

- Rinse glassware several times with DI water and EtOH/H_2O
- HCl & NaOH will react with Crystal Violet!

- Use new cuvettes (don't need to rinse)

- label graduated pipets, beakers and cuvettes

- Use your own beakers to get solutions.
  Never put your graduated pipets into public solutions!

Safety & Waste

Waste

- Keep a labeled Waste beaker in your hood.
- Dispose of waste solutions in the liquid waste container.
- Dispose of syringes in the solid waste.

Safety

- Wear safety glasses and gloves at all times!
- NaOH and Crystal Violet are eye irritants.
  Crystal Violet can stain your skin or clothes.

Clean up

- Return cleaned 10.0 mL volumetric flasks to front hood at the end of the period
- Czar duty: Hood# 4&5
  - Wipe down hoods and sashes

Reminders

- Notebook pages are due Dec 2nd (Mon) at 1:25 PM to the drop box.

- Last day to turn in Assignments: Dec 2nd (Mon)
- Last day to report mistakes on Sakai: Dec 9th (Mon)