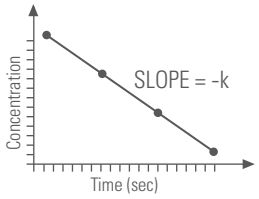
KINETICS

Determining the Order of a Reaction

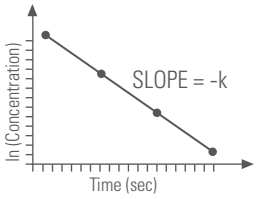
Chemical kinetics is the study of chemical reactions with respect to reaction rates. This is often expressed as a concentration unit per time, for example mol/(L s). According to Beer's Law there is a direct relationship between a solution's concentration and the absorbance of light that passes through it. The means absorbance per sec can be used as a unit for reaction rate as in the following procedure.

Rate laws describe the relationship between concentration and reaction rate. A rate law for a reaction that has two reactants will be expressed as the following, $\text{Rate} = k[A]^n[B]^m$. The concentrations of the reacting species are shown as [A] and [B]. The rate constant "k" is a proportionality constant and has derived units. The exponents "n" and "m" are the order for that reactant in that specific reaction. The order of a chemical species describes the way that reactant affects the reaction rate. For example, if the order is zero, $n = 0$, that reactant mathematically drops out of the expression and therefore has no effect on the reaction rate. When the reactant is first order, $n = 1$, the reactant has a direct relationship with the recreation rate. For example, when the reactant is doubled the rate also doubles. When the reactant is second order, $n = 2$, the reactant has an exponential relationship with the recreation rate. For example, when the reactant is doubled the rate gets four times faster.



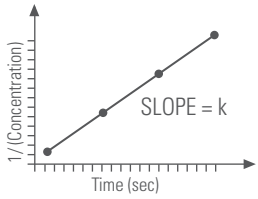
ZERO ORDER

When the concentration or absorbance for a specific reactant is plotted against time and the resulting graph is linear, this indicates the reaction is zero order with respect to that reactant. The slope of the line is the negative value of the rate constant k.



FIRST ORDER

When the ln (concentration) or ln (absorbance) for a specific reactant is plotted against time and the resulting graph is linear, this indicates the reaction is first order with respect to that reactant. The slope of the line is the negative value of the rate constant k.



SECOND ORDER

When the 1/ (concentration) or 1/ (absorbance) for a specific reactant is plotted against time and the resulting graph is linear, this indicates the reaction is second order with respect to that reactant. The slope of the line is the rate constant k.

Materials

- Spectrometer
- Beakers (3), glass, 50-mL
- Graduated cylinder (2),10 mL
- Volumetric flask, 100-mL or 250-mL
- 5.0 x 10^{-5} M Crystal violet, 8 mL
- 0.2 M Sodium hydroxide (NaOH), 2.0 mL
- Distilled water

INQUIRY SECTION

- 3.1 × 10^{-3} M Phenolphthalein, 2.0mL
- 95% Ethyl alcohol, 500mL

Chemical Preparation

2.5 × 10^{-3} M Crystal violet stock solution:
Because the students' solution is so dilute, it is necessary to make a stock solution first and then dilute that solution to the final concentration. Wear gloves to avoid staining your hands. Dissolve 0.1 g of solid crystal violet in about 200 mL of distilled water in a 1-L volumetric flask and then fill it to the line with distilled water. Alternatively, starting from a 1% solution of crystal violet, place 50 mL of 1% solution in a 1 L volumetric flask and fill it to the line with distilled water.

5.0 × 10^{-5} M Crystal violet:
Measure 20.0 mL of the 2.5 × 10^{-3} M stock solution into a 1 L volumetric flask and fill to the line with distilled water.

0.2 M NaOH (500 mL):
Place 4.0 g of solid NaOH in about 100 mL of distilled water in a 500-mL volumetric flask. Stir it well and let it sit (dissolving NaOH evolves a significant amount of heat). When the solid has completely dissolved, fill it to the line with distilled water.

INQUIRY SECTION

3.1× 10^{-3} M Phenolphthalein (500 mL):
Fill a 1000-mL volumetric flask 1/3 full of 95% ethanol. Add 0.485 g of sodium hydroxide to the flask and swirl to dissolve. Fill the flask to the line with 95% ethanol.

Procedure

Calibration

1. Plug the spectrometer into your computer using the USB cable or wirelessly associate the spectrometer using Bluetooth.
2. Open the spectrometry application.
3. Select ANALYZE SOLUTION from the menu at the top of the screen.
4. Select CALIBRATE DARK from the Menu at the bottom of the screen. The Spectrometer will turn off all of its lights and perform the calibration. A check mark will appear when the calibration is finished.
5. Put distilled water into a cuvette. This should be the same distilled water that was used as a solvent for the solutions being analyzed. Always handle the cuvette by the ridged sides. Wipe off any fingerprints using a lint free wipe. Place the cuvette into the spectrometer so that the ridged sides are facing the violet and green light icons and clear sides face the white light and absorbance spectrum icons.
6. Select CALIBRATE REFERENCE from the menu at the bottom of the screen. A check mark will appear when the calibration is complete.

Finding a Wavelength to Analyze

1. Place 4 mL of 5.0×10^{-5} M crystal violet solution into a cuvette. Always handle the cuvette by the ridged sides. Wipe off any fingerprints using a lint free wipe. Place the cuvette into the spectrometer as you did in the calibration.
2. Select the red RECORD circle at the bottom left of the screen to start analyzing the solution. (It changes into a square while data is being collected.) Select the red STOP RECORDING square to stop data collection.
3. Select SCALE TO FIT to rescale your data.
4. Use the ADD COORDINATE to locate a wavelength to analyze on the curve.
   a. A small hand will replace your cursor. Move it to the box that has appeared on the graph and drag the box slowly toward the curve. As you get near the curve an arrow will appear that indicates a specific wavelength on the curve. Releasing the box will snap the box to the point on the curve the arrow is pointing to.
   b. Drag the box along the curve to find a desirable wavelength to analyze. This is usually a high point on the curve. If your curve plateaus near the top of the graph, the absorbance is too large in that area to be used for analysis and another wavelength should be selected.
5. Once you have found a desirable wavelength, select the blue check mark to the left of the selected wavelength value.

Determine Reaction Order

1. Select analyze over TIME from the menu at the top of the screen.
2. Use a 50mL beaker to place 2.0mL of 5.0×10^{-5} M crystal violet into a graduated cylinder.
3. Use a different 50mL beaker to place 2.0 ml 0.2 M sodium hydroxide (NaOH) into a graduated cylinder.
4. Pour the contents of both graduated cylinders into a third 50mL beaker. Then put that solution into a cuvette and quickly put it into the spectrometer and start data collection .
5. Use SCALE TO FIT to rescale your data. Allow the spectrometer to collect data for at least 90 seconds, then stop data collection.
6. You may wish to turn off Show Live Scan Display.
7. Select SHOW LINEAR FIT to create a best fit line and display the equation for the line. It will display the r value for the line at the bottom of the pop up box that will appear.
8. Use QUICKCALCS (located near the top of the Y-axis) to cycle the Y axis between Absorbance vs. Time, ln(Absorbance) vs. Time and 1/Absorbance vs. Time.
9. You may wish to use Experiments Options to save your experiment.

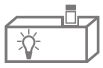
Results

10. Make a mathematical argument with relevant scientific evidence as to the order of reaction for crystal violet and sodium hydroxide.

Inquiry

11. Determine the order for the reaction of phenolphthalein and sodium hydroxide.
12. What solvent should you use to calibrate the spectrometer?
13. What wavelength is best for the analysis of phenolphthalein?


CALIBRATE DARK


CALIBRATE REFERENCE


START RECORDING


STOP RECORDING

ANALYZE SOLUTION

CONCENTRATION

TIME


SCALE TO FIT


ADD COORDINATE


SHOW LINEAR FIT


EXPERIMENT OPTIONS


QUICKCALCS