BEER'S LAW

Determining the Concentration of an Unknown

There are several ways to determine the concentration of solute in a solution. The most common technique is called titration. Titration is time consuming and glassware intensive. Another technique simply shines a light through the solution. A concentrated solution that is dark will absorb a greater amount of light than a dilute solution of light color. Beer's law states that there is a direct relationship between a solution's absorbance of light and its concentration. Mathematically the law is expressed as the absorbance A is equal to the product of abc, where a is an attenuation constant that describes the decreasing of transmitted light as increased light is absorbed for a given solution, b is the distance the light travels, and c is the concentration of the solution.

Beer's law $A = abc$ indicates that there is a linear relationship between Absorbance and Concentration. By plotting a calibration curve of solutions of known concentration and their respective absorbance, the concentration of an unknown can be determined.

Materials

- Spectrometer
- Cuvettes and Lids (6)
- Beakers (2), glass, 50-mL
- Volumetric flask (4), 100-mL
- Volumetric flask, 250-mL
- 0.32 M Copper(II) sulfate ($CuSO_4$)
- Distilled water

Chemical Preparation

- 0.32 M Copper(II) sulfate ($CuSO_4$)

Prepare 250 mL of 0.32 M copper(II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) by filling a 250-mL volumetric flask 1/3 full of distilled water. Add 19.975 g of copper(II) sulfate pentahydrate to the flask and swirl to dissolve. Fill flask to line with distilled water.

OTHER SOLUTIONS: Prepare 100 mL of 0.16 M copper(II) sulfate ($CuSO_4$) by adding 50.0 mL of the 0.32 M copper(II) sulfate stock solution to the flask. Fill the flask to the line with distilled water and swirl to dissolve. Use a similar procedure to prepare a 0.08M copper(II) sulfate solution from 0.16 M copper(II) sulfate, a 0.04M copper(II) sulfate from 0.08M copper(II) sulfate and a 0.02M copper(II) sulfate from 0.04M copper(II) sulfate.

Procedure

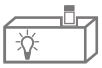
Calibration

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 the most concentrated solution to be analyzed into a cuvette, or if cuvettes have been prepared in advance obtain the cuvette containing the sample of highest concentration. 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.


CALIBRATE DARK


CALIBRATE REFERENCE


START RECORDING


STOP RECORDING


SCALE TO FIT

ANALYZE SOLUTION

CONCENTRATION


SHOW LINEAR FIT


ADD COORDINATE


EXPERIMENT OPTIONS

013-14597A

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.

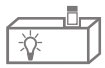
Creating Concentration-Absorbance Curve

6. Select ananlyze CONCENTRATION from the menu at the top of the screen. A table will appear on the left side of the screen that has columns for Concentration and Absorbance.
7. Highlight the concentrations in the column titled Concentration and type over the given values with the concentrations of the samples your instructor has prepared.
8. Select RECORD to start analyzing the solution.
9. Place the highest-concentration sample into the spectrometer and look at the cell in the Absorbance column that corresponds to the respective concentration. Once the absorbance stabilizes select the check mark next to the absorbance to record the value. A value of three indicates that the solution is too concentrated for the selected wavelength.
10. Place the samples of lesser concentration into the spectrometer and record their absorbance values.
11. Select STOP RECORDING to stop data collection.
12. You may wish to turn off Show Live Scan Display .
13. Use SCALE TO FIT to rescale your data.
14. Select SHOW LINEAR FIT to create a best fit line and display the equation for the line.
15. Place the cuvette containing a solution of unknown concentration into the spectrometer.
16. Select the box in the table titled Determine Unknown Concentration at the bottom of the screen under a column labeled Absorbance.
17. Select RECORD to start analyzing the solution.
18. Once the absorbance stabilizes select the check mark next to the absorbance to record the value.
19. Select STOP RECORDING to stop data collection.
20. Use EXPERIMENT OPTIONS to save your experiment.
21. Use either the graph or the equation for the line to determine the unknown concentration and type it into the box in the column titled Concentration.

Results

22. Make a mathematical argument with relevant scientific evidence as to the concentration of the unknown solution.


CALIBRATE DARK


CALIBRATE REFERENCE


START RECORDING


STOP RECORDING


SCALE TO FIT

ANALYZE SOLUTION

CONCENTRATION


SHOW LINEAR FIT


ADD COORDINATE


EXPERIMENT OPTIONS