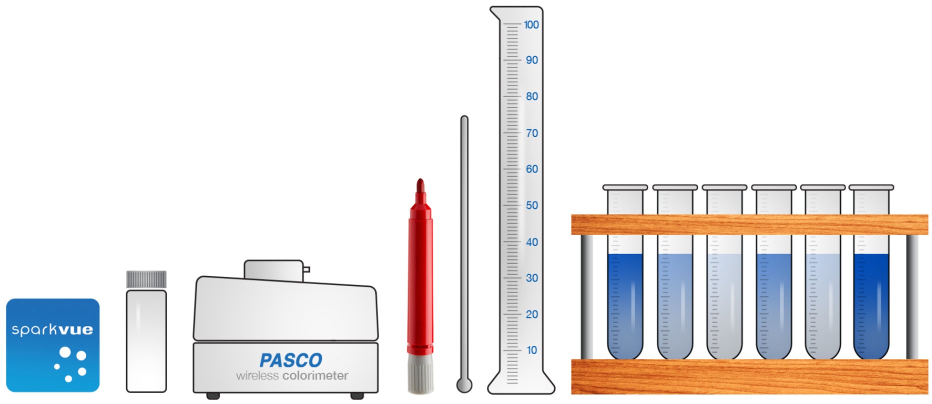
13B - SOLUTION CONCENTRATION

INQUIRY

How can you use light to determine the concentration of a solution?

MATERIALS

- Device with SPARKvue software
- Colorimeter
- 40.0 mL, copper(II) sulfate, 0.10M
- Test tubes, 20 mm x 150 mm (6)
- Graduated Cylinder, 100-mL (2)
- Marker
- Cuvettes (7)
- Test tube rack
- Stirring rod



BACKGROUND

Have you ever added more and more of an item and seen the color of the solution deepen? Analytical chemists, particularly in the agricultural and medical fields, routinely use a quantitative approach called spectroscopy to determine the concentration of solute in a solution as it relates to the color of the solution. While we can roughly tell how many items are dissolved based on color, spectroscopy allows us to assign numbers to the dissolved items. Beer's Law states that the absorbance of a solution (A) is directly proportional to its concentration (M). You will first determine the relationship between absorbance and molarity for a known concentration of $CuSO_4$. You will then use this relationship to construct a calibration curve. The standard curve will be used to determine the concentration of a solution of unknown molarity of copper(II) sulfate.

SAFETY

Follow these important safety precautions in addition to your regular classroom procedures.

- Wear safety goggles at all times.

PROCEDURE

Part 1 – Known concentrations

1. Open SPARKvue.

2. Connect the Colorimeter.

PROCEDURE

3. Add 3 mL of distilled water to a clean cuvette. This is your reference measurement.

4. Calibrate the colorimeter with the cuvette containing distilled water (the water sample is called a "blank").
   Note: It is important to wipe off the sides of the cuvette before placing it into the colorimeter!

5. Open the 13B Solution Concentration lab file in SPARKvue under Experiments > Essential Chemistry.

6. Obtain about 40 mL of a 0.20 M CuSO4(aq).

7. Prepare Solution A by filling a test tube with 10 mL of the 0.10 M $CuSO_4$(aq). Label the test tube "A."

8. Prepare Solution B by adding 8.0 mL of the 0.10 M $CuSO_4$(aq) to an empty 10-mL graduated cylinder. Fill to the 10-mL mark with water. Stir and transfer to a test tube. Label this test tube "B." Rinse and dry the graduated cylinder so you can prepare the next solution.

9. Prepare Solution C by adding 6.0 mL of the 0.10 M $CuSO_4$(aq) to an empty 10-mL graduated cylinder. Fill to the 10-mL mark with water. Stir and transfer to a test tube. Label this test tube "C." Rinse and dry the graduated cylinder so you can prepare the next solution.

10. Prepare Solution D by adding 4.0 mL of the 0.10 M $CuSO_4$(aq) to an empty 10-mL graduated cylinder. Fill to the 10-mL mark with water. Stir and transfer to a test tube. Label this test tube "D." Rinse and dry the graduated cylinder so you can prepare the next solution.

11. Prepare Solution E by adding 2.0 mL of the 0.10 M $CuSO_4$(aq) to an empty 10-mL graduated cylinder. Fill to the 10-mL mark with water. Stir and transfer to a test tube. Label this test tube "E."

12. Determine the molarity for all solutions. Solution A has a molarity of 0.20 M. For solution B (first dilution), the original molarity is M_1 = 0.20 M, and the volume is V_1 = 8.0 mL. We are solving for the new molarity (M_2). The final volume is V_2 = 10.0 mL. Record the molarities of all solutions in Table 1.

13. Place about 3 mL of each solution into a clean cuvette. Make sure the cuvette is at least ¾ full.

14. Start collecting data.

15. Insert the cuvette that contains Solution A and select the check mark to record the values for absorbance at all available wavelengths. Repeat this for each cuvette and transfer the data to Table 1.

PROCEDURE

16. Discard the solutions in the test tubes and the cuvettes.

17. Rinse the graduated cylinder, test tubes, cuvettes, and pipettes with clean water.

18. Stop data collection.

ANALYSIS

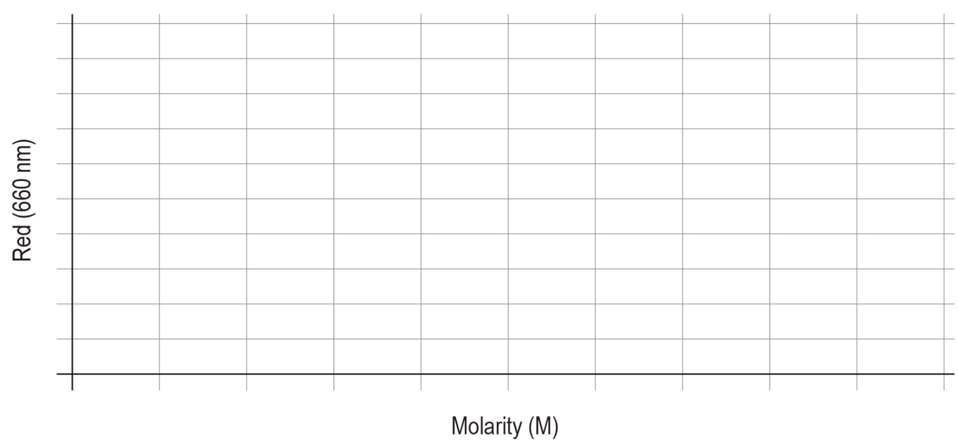
Table 1 – Known concentration and absorbance

Test tube label	Molarity (mol/L)	Red Abs 650 nm	Orange Abs 600 nm	Yellow Abs 570 nm	Green Abs 550 nm	Blue Abs 500 nm	Violet Abs 450 nm
A	0.20						
B							
C							
D							
E							

19. Referring to your data table, which color of light absorbs the most light at all the concentrations?

20. Go to Page 2 of the SPARKlab. You should see a graph of Red Absorbance (y-axis) vs Concentration. If necessary, change the y-axis to the color of light that absorbs the most light at all the concentrations. Sketch the graph below.

Graph 1 – Absorbance vs. Concentration



21. Apply a Linear fit to determine the slope and intercept of the graph. What is the line expression for the graph?

22. Based on the "r" value, was the linear relationship a good fit for the data?

PROCEDURE

Part 2 – Unknown concentration

1. Your teacher will provide you with a copper(II) sulfate solution that has an unknown concentration. If there is more than one unknown, record the solution label Table 2.

2. Obtain 10 mL of the unknown solution of $CuSO_4$ provided by your instructor. Put it in a clean cuvette, and make certain that the liquid is at the same level as the other cuvettes.

3. Go to the next page of the SPARKlab. You should see a digits display of Absorbance for all the colors of light.

4. Start data collection.

5. Find the color that matched the graph you made with known concentrations in the first part of the investigation. Record the Absorbance in Table 2.

ANALYSIS

Table 2 – Unknown concentration and absorbance

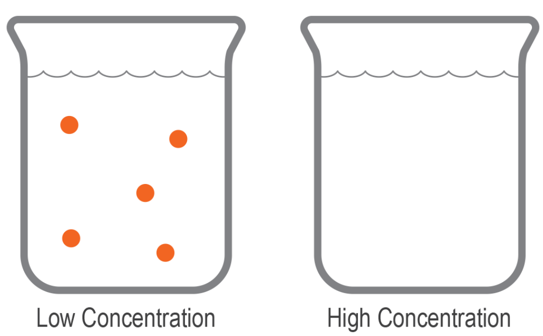
Test tube label	Absorbance	Molarity (mol/L)

6. Using the line expression from the first part of the investigation, calculate the molarity of the unknown solution. Your Absorbance is the y value. You will need to solve for x. Show you work!

QUESTIONS

Part 2 – Unknown concentration

1. The picture below represents the solute particles of a low concentration solution. In the empty space draw the solute particles if the concentration were doubled.



2. What happens to the absorbance of light as you increase the concentration of the substance?

QUESTIONS

3. Do you think this is a reliable method for determining the concentration of a known solution?

4. How do your results for the unknown compare to those of your classmates?

5. Your teacher will tell you the real concentration of the unknown solution. Determine the percent error for your experiment.

6. What would likely be the largest source of error? Explain.

SOLUTION CONCENTRATION

Analysis – Known Concentrations

Table 1 – Known concentration and absorbance

Test tube label	Molarity (mol/L)	Red Abs 650 nm	Orange Abs 610 nm	Yellow Abs 570 nm	Green Abs 550 nm	Blue Abs 500 nm	Violet Abs 450 nm
A							
B							
C							
D							
E							

19. Referring to your data table, which color of light absorbs the most light at all the concentrations?

Graph 1 – Absorbance vs. Concentration

21. Apply a Linear fit to determine the slope and intercept of the graph. What is the line expression for the graph?

22. Based on the “r” value, was the linear relationship a good fit for the data?

Analysis – Unknown concentrations

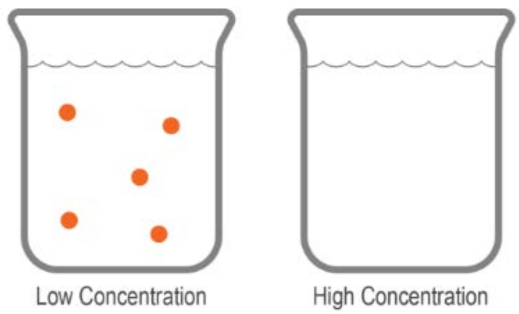
Table 2 – Unknown concentration and absorbance

Test tube label	Absorbance	Molarity (mol/L)

6. Using the line expression from the first part of the investigation, calculate the molarity of the unknown solution. Your Absorbance is the y value. You will need to solve for x. Show you work!

Questions – Unknown concentration

1. The picture below represents the solute particles of a low concentration solution. In the empty space draw the solute particles if the concentration were doubled.



2. What happens to the absorbance of light as you increase the concentration of the substance?

3. Do you think this is a reliable method for determining the concentration of a known solution?

❓ 4. How do your results for the unknown compare to those of your classmates?

❓ 5. Your teacher will tell you the real concentration of the unknown solution. Determine the percent error for your experiment.

❓ 6. What would likely be the largest source of error? Explain.