NAME PERIOD DATE

SOLUTION CONCENTRATION: BEER'S LAW

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

Objectives

- Determine the relationship between light absorption and solution concentration.
- Use a concentration calibration curve to determine the unknown concentration of a known solution.

Materials and Equipment

- Data collection system
- Colorimeter
- Cuvettes (7)
- Test tubes (6), 2 cm × 15 cm
- Graduated cylinder, 10-mL
- Stirring rod
- Test tube rack
- 0.20 M Copper(II) sulfate[1], $CuSO_4$, 40.0 mL
- $CuSO_4$ solution of unknown concentration
- Distilled water
- Permanent marker or grease pencil
- Lint-free, scratch-free wipes

Safety

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

- Wear safety goggles at all times

Procedure

1. Fill a clean cuvette 3/4 full of distilled water. Always handle cuvettes only by the ribbed side and wipe the clear sides with a lint-free, scratch-free wipe before placing in the colorimeter.

2. Open the Quick Start Labs > Beer's Law PASCO experiment file in SPARKvue.

3. Connect the colorimeter to your device. You will be prompted to calibrate the colorimeter. Use the cuvette filled with distilled water.

   a. Orient the cuvette inside the colorimeter so the arrow shown in the diagram passes through the clear sides of the cuvette.

   b. Close the lid and complete the calibration.

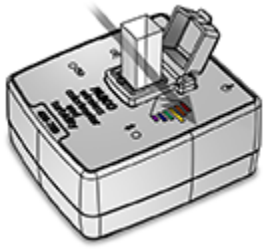


Figure 1: Cuvette placement

4. Obtain about 40 mL of a 0.20 M $CuSO_4$ solution.

5. Fill a test tube with 10 mL of the 0.20 M $CuSO_4$ solution. Label the test tube "0.20 M."

6. Prepare a 0.16 M $CuSO_4$ solution by adding 8.0 mL of the 0.20 M $CuSO_4$ solution to a 10-mL graduated cylinder. Fill to the 10-mL mark with distilled water. Stir and transfer to a test tube. Label this test tube "0.16 M." Rinse the graduated cylinder with distilled water.

7. Use 6.0 mL of the 0.20 M $CuSO_4$ solution to prepare 10 mL of a 0.12 M $CuSO_4$ solution in a similar manner.

8. Use 4.0 mL of the 0.20 M $CuSO_4$ solution to prepare 10 mL of a 0.080 M $CuSO_4$ solution in a similar manner.

9. Use 2.0 mL of the 0.20 M $CuSO_4$ solution to prepare 10 mL of a 0.040 M $CuSO_4$ solution in a similar manner.

10. Fill 5 individual cuvettes 3/4 full of each solution. Label cuvette lids with each concentration.

11. Enter the $CuSO_4$ solution concentrations in the Concentration column in SPARKvue.

12. Start collecting data.

13. Insert the 0.20 M cuvette into the colorimeter. Close the lid and select the check mark to record the absorbance value in SPARKvue.

14. Repeat this step for each cuvette in order of decreasing concentration. Transfer data to Table 1.

15. Stop collecting data.

16. Scale the graph and apply a linear fit. Record the linear fit values in Table 2.

17. Sketch the data points and linear fit in Graph 1. Add labels and values to the x- and y-axes.

18. Fill a test tube with a $CuSO_4$ solution of unknown concentration. Pour the solution into a cuvette. Record the solution letter in Table 3.

19. Start collecting data. Select the check mark to record the absorbance value for the solution.

20. Use the Coordinates tool in SPARKvue to find the x-y coordinate values for the unknown solution data point on the graph. Record the y-axis absorbance value in Table 3.

21. Draw a straight horizontal dotted line through the unknown solution data point on Graph 1. This dotted line should be parallel to the x-axis. Find the intersection point of the dotted line and the best fit line. Draw a vertical dotted line from the intersection point down to the x-axis. Record the x-axis value in Table 3 as the graphically determined concentration.

22. Stop collecting data. Clean the lab station according to your teacher's instructions.

Data Collection

Table 1: Solution concentrations

Concentration (mol/L)	Absorbance at 600 nm
0.20	
0.16	
0.12	
0.080	
0.040	

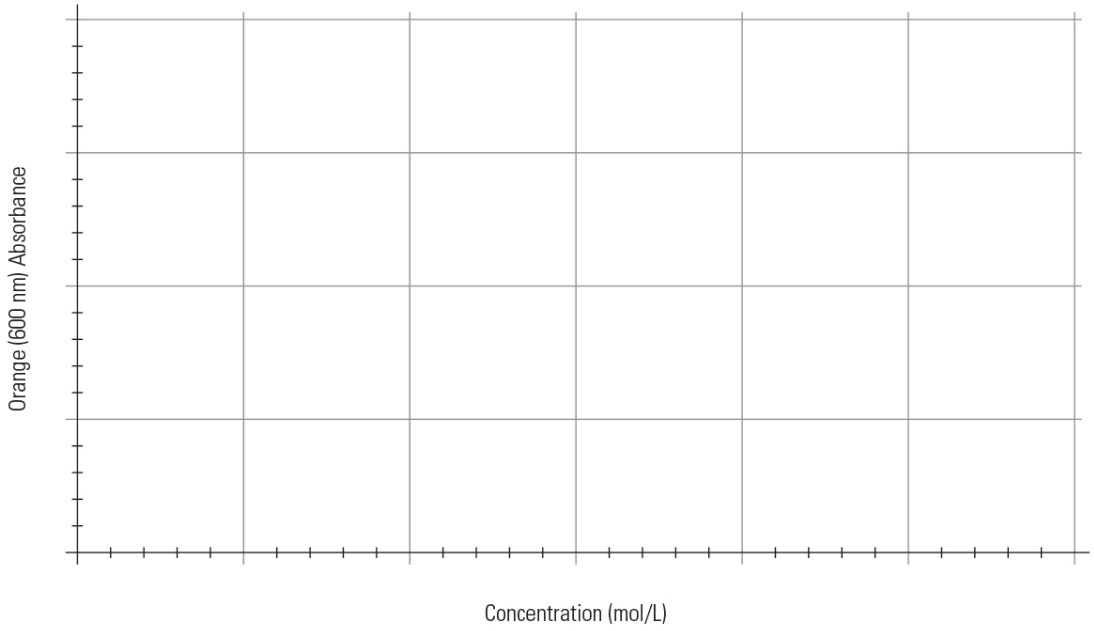
Table 2: Linear fit results

Variable	Value
Slope (m)	
y-intercept (b)	
Correlation coefficient (r)	

Table 3: Unknown concentration

Variable	Value
Unknown solution label	
Absorbance (y-axis value)	
Concentration (M) determined from graph	

Graph 1: Solution concentration versus absorbance

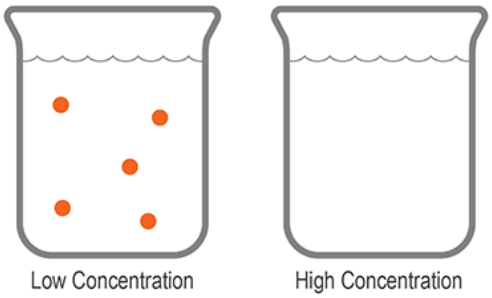


Questions and Analysis

1. The correlation coefficient (r) in Table 2 indicates whether x- and y-variables in a graph are related. An r-value is always between -1.00 and +1.00. Exactly -1.00 or +1.00 indicates a strongly linear relationship, and exactly 0.00 indicates zero relationship. Describe the relationship (or lack of relationship) between absorbance and concentration based on your r-value.

2. What happens to the absorbance of light as you increase the concentration of a substance? Support your answer with evidence from this investigation.

3. 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.



4. Perform a calculation to show how the dilution completed at Procedure Step 6 resulted in the 0.16 M $CuSO_4$ solution. Show your work and include units.

5. You are familiar with the line equation $y = mx + b$ from previous math classes. When applied to the line in Graph 1, if y refers to the absorbance from the colorimeter, what does x refer to?

6. Solve for x in the line equation. Use m and b values from Table 2 and the y value from Table 3.

7. Compare the calculated $CuSO_4$ solution concentration with the graphically determined concentration from Table 3. Which value is likely the most accurate, and which value should you use as the experimental value in a percent error calculation? Explain your answers.

8. Your teacher will tell you the actual concentration of the unknown solution. Determine the percent error for the unknown concentration. Show your work and suggest the most likely source of error.