LabQuest

Determining the Concentration of a Solution: Beer's Law 17

The primary objective of this experiment is to determine the concentration of an unknown copper (II) sulfate solution. You will use a Colorimeter (a side view is shown in Figure 1) to measure the concentration of each solution. In this experiment, red light from the LED light source will pass through the solution and strike a photocell. A higher concentration of the colored solution absorbs more light (and transmits less) than a solution of lower concentration. The Colorimeter monitors the light received by the photocell as percent transmittance.

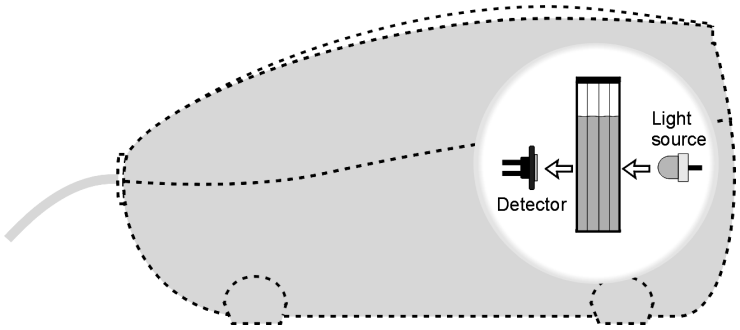

Figure 1

You will prepare five copper (II) sulfate solutions of known concentration (standard solutions). Each solution is transferred to a small, rectangular cuvette that is placed into the Colorimeter. The amount of light that penetrates the solution and strikes the photocell is used to compute the absorbance of each solution. When you graph absorbance *vs*. concentration for the standard solutions, a direct relationship should result. The direct relationship between absorbance and concentration for a solution is known as *Beer's law*.

You will determine the concentration of an unknown $CuSO_4$ solution by measuring its absorbance with the Colorimeter. By locating the absorbance of the unknown on the vertical axis of the graph, the corresponding concentration can be found on the horizontal axis. The concentration of the unknown can also be found using the slope of the Beer's law curve.

OBJECTIVES

In this experiment, you will

- Prepare and test the absorbance of five standard copper (II) sulfate solutions.
- Calculate a standard curve from the test results of the standard solutions.
- Test the absorbance of a copper (II) sulfate solution of unknown molar concentration.
- Calculate the molar concentration of the unknown $CuSO_4$ solution.

MATERIALS

LabQuest
LabQuest
Vernier Colorimeter
two 10 mL pipets or graduated cylinders
five 20 × 150 mm test tubes
one cuvette
two 100 mL beakers
0.40 M copper (II) sulfate, $CuSO_4$, solution
copper (II) sulfate, $CuSO_4$, unknown solution
pipet pump or pipet bulb
distilled water
test tube rack
stirring rod
tissues (preferably lint-free)

PROCEDURE

1. Obtain and wear goggles.
2. Obtain small volumes of 0.40 M $CuSO_4$ solution and distilled water in separate beakers.
3. Label four clean, dry, test tubes 1–4. Use pipets to prepare five standard solutions according to the chart below. Thoroughly mix each solution with a stirring rod. Clean and dry the stirring rod between uses.

Trial number	0.40 M $CuSO_4$ (mL)	Distilled H_2O (mL)	Concentration (M)
1	2	8	0.080
2	4	6	0.16
3	6	4	0.24
4	8	2	0.32
5	~10	0	0.40

4. Connect the Colorimeter to LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.
5. Calibrate the Colorimeter.
   a. Prepare a *blank* by filling an empty cuvette 3/4 full with distilled water.
   b. Place the blank in the cuvette slot of the Colorimeter and close the lid.
   c. Press the < or > buttons on the Colorimeter to set the wavelength to 635 nm (Red). Then calibrate by pressing the CAL button on the Colorimeter. When the LED stops flashing, the calibration is complete.
6. On the Meter screen, tap Mode. Change the data-collection mode to Events with Entry. Enter the Name (Concentration) and Units (mol/L). Select OK.
7. You are now ready to collect absorbance-concentration data for the five standard solutions.
   a. Start data collection.
   b. Remove the cuvette from your Colorimeter and pour out the water. Using the solution in Test Tube 1, rinse the cuvette twice with ~1 mL amounts, and then fill it 3/4 full. Wipe the outside with a tissue, place it in the Colorimeter, and close the lid.
   c. When the absorbance readings have stabilized, tap Keep and enter **0.080** as the concentration. Select OK. The absorbance and concentration values have now been saved for the first solution.
   d. Discard the cuvette contents as directed. Using the solution in Test Tube 2, rinse the cuvette twice with ~1 mL amounts, and then fill it 3/4 full. Wipe the outside, place it in the

Colorimeter, and close the lid. When the absorbance readings have stabilized, tap Keep and enter **0.16** as the concentration in mol/L. Select OK.

e. Repeat Part d of this step for Test Tube 3 (0.24 M), Test Tube 4 (0.32M), and the stock 0.40 M $CuSO_4$. **Note:** Do not test the unknown solution until Step 9.

f. Stop data collection to view a graph of absorbance *vs.* concentration.

g. To examine the data pairs on the displayed graph, select any data point. As you tap each point, the absorbance and concentration values of each data point are displayed to the right of the graph. Record the absorbance values in your data table.

8. Display a graph of absorbance *vs.* concentration with a linear regression curve.

   a. Choose Curve Fit from the Analyze menu.

   b. Select Linear as the Fit Equation. The linear-regression statistics for these two data columns are displayed for the equation in the form

   $$y = mx + b$$

   where x is concentration, y is absorbance, a is the slope, and b is the y-intercept. **Note:** One indicator of the quality of your data is the size of b. It is a very small value if the regression line passes through or near the origin. The correlation coefficient, r, indicates how closely the data points match up with (or *fit*) the regression line. A value of 1.00 indicates a nearly perfect fit.

   c. Select OK. The graph should indicate a direct relationship between absorbance and concentration, a relationship known as Beer's law. The regression line should closely fit the five data points *and* pass through (or near) the origin of the graph. Record the best-fit line equation for the standard solutions in your data table.

9. Determine the absorbance value of the unknown $CuSO_4$ solution.

   a. Obtain about 5 mL of the *unknown* $CuSO_4$ in another clean, dry, test tube. Record the number of the unknown in your data table.

   b. Rinse the cuvette twice with the unknown solution and fill it about 3/4 full. Wipe the outside of the cuvette, place it into the Colorimeter, and close the lid.

   c. Tap Meter and monitor the absorbance value displayed on the screen. When this value has stabilized, record it in the data table.

   d. Dispose of any of the remaining solutions as directed.

DATA TABLE

Trial	Concentration (mol/L)	Absorbance
1	0.080	
2	0.16	
3	0.24	
4	0.32	
5	0.40	
6	Unknown number ____	

Best-fit line equation: _____

DATA ANALYSIS

1. Calculate the linear regression (best-fit line) equation of absorbance *vs.* concentration for the five standard $CuSO_4$ solutions. Print or sketch a graph showing the data and linear-regression equation for the standard solutions.

2. Determine the concentration of the unknown $CuSO_4$ solution. Explain how you made this determination.

3. Describe an alternate method for determining the molar concentration of your unknown sample of copper (II) sulfate solution, using the standard data.