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

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.

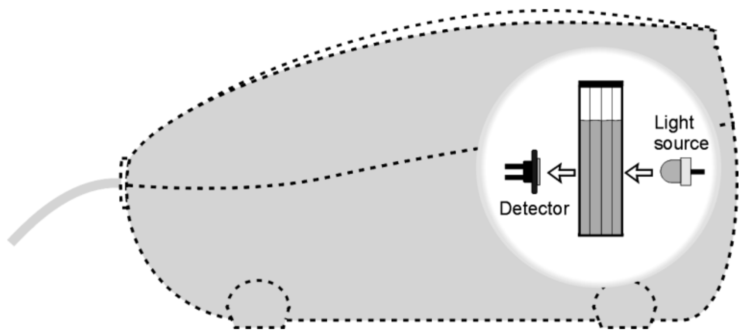

Figure 1

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

Vernier computer interface
computer
Vernier Colorimeter
one cuvette
five 20 × 150 mm test tubes
two 10 mL pipets or graduated cylinders
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 a Colorimeter to Channel 1 of the Vernier computer interface. Connect the interface to the computer using the proper cable.
5. Start the Logger *Pro* program on your computer. Open the file "17 Colorimeter" from the *Advanced Chemistry with Vernier* folder.
6. Calibrate the Colorimeter.
   a. Prepare a *blank* by filling an empty cuvette ¾ full with distilled water. Place the blank in the cuvette slot of the Colorimeter and close the lid.
   b. If your Colorimeter has a CAL button, set the wavelength on the Colorimeter to 635 nm, press the CAL button, and proceed directly to Step 7. If your Colorimeter does not have a CAL button, continue with this step to calibrate your Colorimeter.
   c. Choose Calibrate ▸ CH1: Colorimeter from the Experiment menu, then click Calibrate Now.
   d. Turn the wavelength knob on the Colorimeter to the "0% T" position.
   e. Type **0** in the edit box.
   f. When the displayed voltage reading for Reading 1 stabilizes, click Keep.
   g. Turn the knob of the Colorimeter to the Red LED position (635 nm).
   h. Type **100** in the edit box.
   i. When the voltage reading for Reading 2 stabilizes, click Keep, then click Done.

7. You are now ready to collect absorbance-concentration data for the five standard solutions.
   a. Click ▶ Collect.
   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 ¾ full. Wipe the outside with a tissue, place it in the Colorimeter, and close the lid.
   c. When the absorbance readings stabilize, click Keep, type "0.080" in the edit box, and press the ENTER key. The data pair should now be plotted on the graph.
   d. Discard the cuvette contents as directed. Using the solution in Test Tube 2, rinse and fill the cuvette ¾ full. Wipe the outside, place it in the Colorimeter, and close the lid. When the absorbance readings stabilize, click Keep, type "0.16" in the edit box, and press the ENTER key.
   e. Repeat the procedure for Test Tubes 3 and 4. Trial 5 is the original 0.40 M $CuSO_4$ solution. **Note:** Do not test the unknown solution until Step 9.
   f. When you have finished testing the standard solutions, click ■ Stop.
   g. Examine the graph of absorbance *vs.* concentration. Click the Linear Regression button. A best-fit linear regression line will be shown for your five data points.

8. Record the absorbance values, for each of the five trials, 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 ¾ full. Wipe the outside of the cuvette, place it into the Colorimeter, and close the lid.
   c. Read the absorbance value displayed in the meter. (**Important**: The reading in the meter is live, so it is not necessary to click ▶ Collect to read the absorbance value.) When the displayed absorbance value stabilizes, record its value as Trial 6 in your 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 ____	

DATA ANALYSIS

1. Calculate the linear regression (best-fit line) equation of absorbance *vs.* concentration for the five standard $CuSO_4$ solutions. Print 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.