

Determining the Concentration of a Solution: Beer's Law

The primary objective of this experiment is to determine the concentration of an unknown nickel (II) sulfate solution. You will be using the Colorimeter shown in Figure 1. In this device, red light from the LED light source will pass through the solution and strike a photocell. The NiSO_4 solution used in this experiment has a deep green color. 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 either an *absorbance* or a *percent transmittance* value.

You are to prepare five nickel sulfate solutions of known concentration (standard solutions). Each 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 a graph of absorbance vs. concentration is plotted for the standard solutions, a direct relationship should result, as shown in Figure 2. The direct relationship between absorbance and concentration for a solution is known as Beer's law.

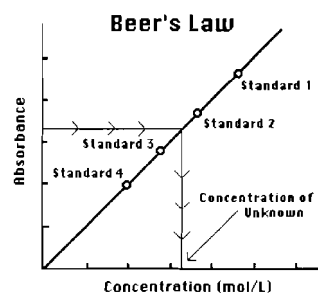


Figure 1

The concentration of an *unknown* NiSO_4 solution is then determined 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 (follow the arrows in Figure 1). 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 NiSO_4 standard solution.
- Use a Colorimeter to measure the absorbance value of each standard solution.
- Find the relationship between absorbance and concentration of a solution.
- Use the results of this experiment to determine the unknown concentration of another NiSO_4 solution.

MATERIALS

LabQuest	two 10 mL pipets (or graduated cylinders)
LabQuest App	two 100 mL beakers
Vernier Colorimeter	pipet or pipet bulb
one cuvette	distilled water
five 20 x 150 mm test tubes	test tube rack
30 mL of 0.40 M NiSO ₄	stirring rod
5 mL of NiSO ₄ unknown solution	tissues (preferably lint-free)

PROCEDURE

- Obtain and wear goggles! **CAUTION:** *Be careful not to ingest any NiSO₄ solution or spill any on your skin. Inform your teacher immediately in the event of an accident.*
- Add about 30 mL of 0.40 M NiSO₄ stock solution to a 100 mL beaker. Add about 30 mL of distilled water to another 100 mL beaker.
- Label four clean, dry, test tubes 1–4 (the fifth solution is the beaker of 0.40 M NiSO₄). Pipet 2, 4, 6, and 8 mL of 0.40 M NiSO₄ solution into Test Tubes 1–4, respectively. With a second pipet, deliver 8, 6, 4, and 2 mL of distilled water into Test Tubes 1–4, respectively. *Thoroughly* mix each solution with a stirring rod. Clean and dry the stirring rod between stirrings. Keep the remaining 0.40 M NiSO₄ in the 100 mL beaker to use in the fifth trial. Volumes and concentrations for the trials are summarized below:

Trial number	0.40 M NiSO ₄ (mL)	Distilled H ₂ O (mL)	Concentration (M)
1	2	8	0.08
2	4	6	0.16
3	6	4	0.24
4	8	2	0.32
5	~10	0	0.40

- Connect the Colorimeter to LabQuest and choose New from the File menu.
- Prepare a *blank* by filling an empty cuvette 3/4 full with distilled water. Seal the cuvette with a lid. To correctly use a Colorimeter cuvette, remember:
 - All cuvettes should be wiped clean and dry on the outside with a tissue.
 - Handle cuvettes only by the top edge of the ribbed sides.
 - All solutions should be free of bubbles.
 - Always position the cuvette with its reference mark facing toward the white reference mark at the top of the cuvette slot on the Colorimeter.
- Calibrate the Colorimeter.
 - Place the blank in the cuvette slot of the Colorimeter and close the lid.
 - 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.

7. Set up the data-collection mode.
 - a. On the Meter screen, tap Mode. Change the mode to Events with Entry.
 - b. Enter the Name (Concentration) and Units (mol/L). Select OK.
8. You are now ready to collect absorbance-concentration data for the five standard solutions.
 - a. Start data collection.
 - b. Empty the water from the cuvette. 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 value displayed on the screen has 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 by your instructor. Using the solution in Test Tube 2, rinse the cuvette twice with ~1 mL amounts, and then fill it 3/4 full. After closing the lid, wait for the value displayed on the screen to stabilize and tap Keep. Enter **0.16** as the concentration in mol/L.
 - e. Repeat the procedure for Test Tube 3 (0.24 M) and Test Tube 4 (0.32M), as well as the stock 0.40 M NiSO₄. **Note:** Wait until Step 10 to do the unknown.
 - f. Stop data collection.
 - g. To examine the data pairs on the displayed graph, tap any data point. As you tap each data point, the absorbance and concentration values are displayed to the right of the graph. Record the absorbance and concentration data values in your data table.
9. Display a graph of absorbance vs. concentration with a linear regression curve.
 - a. Choose Graph Options from the Graph menu.
 - b. Select Autoscale from 0 and select OK.
 - c. Choose Curve Fit from the Analyze menu.
 - d. Select Linear for 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.
 - e. 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.
10. Determine the absorbance value of the unknown NiSO₄ solution.
 - a. Tap the Meter tab.
 - b. Obtain about 5 mL of the *unknown* NiSO₄ in another clean, dry, test tube. Record the number of the unknown in your data table.
 - c. 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.
 - d. Monitor the absorbance value. When this value has stabilized, record it in your data table.

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- Discard the solutions as directed by your instructor and proceed to Step 1 of Processing the Data.

PROCESSING THE DATA

- To determine the concentration of the unknown NiSO_4 solution, interpolate along the regression line to convert the absorbance value of the unknown to concentration.
 - Tap the Graph tab.
 - Choose Interpolate from the Analyze menu.
 - Interpolate along the regression curve to determine the concentration of the unknown solution. Tap any point on the regression curve (or use the ► or ◀ key of LabQuest) to advance to the absorbance value that is closest to the absorbance reading you obtained in Step 10. The corresponding NiSO_4 concentration, in mol/L, will be displayed to the right of the graph.
 - Record the concentration value in your data table.
- (optional) Print a graph of absorbance vs. concentration, with a regression line and interpolated unknown concentration displayed.

DATA AND CALCULATIONS

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