# 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.

*Figure 1*

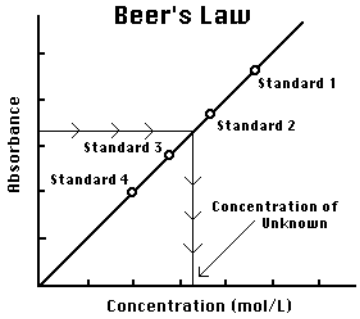


*Figure 2*

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.

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 2). The concentration of the unknown can also be found using the slope of the Beer's law curve.

## MATERIALS

LabPro
TI Graphing Calculator
DataMate program
Vernier Colorimeter
one cuvette
five large test tubes
30 mL of 0.40 M $NiSO_4$
5 mL of $NiSO_4$ unknown solution
pipet or pipet bulb
distilled water
test tube rack (or large beaker)
stirring rod
tissues (preferably lint-free)

## PROCEDURE

1. Obtain and wear goggles! **CAUTION:** *Be careful not to ingest any $NiSO_4$ solution or spill any on your skin. Inform your teacher immediately in the event of an accident.*

2. Add about 30 mL of 0.40 M $NiSO_4$ stock solution to a 100-mL beaker. Add about 30 mL of distilled water to another 100-mL beaker.

3. Label four clean, dry, test tubes 1-4 (the fifth solution is the beaker of 0.40 M $NiSO_4$). Pipet 2, 4, 6, and 8 mL of 0.40 M $NiSO_4$ 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 $NiSO_4$ 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) | $H_2O$ (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 |

4. Plug the Colorimeter into Channel 1 of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.

5. Prepare a *blank* by filling an empty cuvette ¾ 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 right of the cuvette slot on the Colorimeter.

6. Turn on the calculator and start the DATAMATE program. Press CLEAR to reset the program. Be sure that the Datamate program has recognized that the probe connected is a Colorimeter.

7. Calibrate the Colorimeter
   a. Open the Colorimeter lid.
   b. Holding the cuvette by the upper edges, place it in the cuvette slot of the Colorimeter. Close the lid.
   c. If your Colorimeter has a CAL button, Press the < or > button on the Colorimeter to select a wavelength of 635 nm (Red) for this experiment. Press the CAL button until the red LED begins to flash. Then release the CAL button. When the LED stops flashing, the calibration is complete.

8. Set up the data-collection mode.
   a. To select MODE, press [▲] once and press [ENTER].
   b. Select EVENTS WITH ENTRY from the SELECT MODE menu.
   c. Select OK to return to the main screen.

9. You are now ready to collect absorbance-concentration data for the five standard solutions.
   a. Select START from the main screen.
   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 calculator screen has stabilized, press [ENTER]. Enter "0.080" as the concentration in mol/L. 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 calculator screen to stabilize and press [ENTER]. 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 $NiSO_4$. **Note:** Wait until Step 10 to do the unknown.
   f. Press [STO▶] to stop data collection. The absorbance and concentration values have now been saved for the standard solutions.
   g. Examine the data points along the curve on the displayed graph. As you move the cursor right or left, the concentration (X) and absorbance (Y) values of each data point are displayed below the graph. Record the absorbance values in your data table (round to the nearest 0.001).
   h. Press [ENTER] to return to the main screen.

10. Determine the absorbance value of the unknown $NiSO_4$ solution. To do this:
   a. Obtain about 5 mL of the *unknown* $NiSO_4$ 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. Monitor the absorbance value displayed on the calculator. When this value has stabilized, record it in your data table (round to the nearest 0.001).
   d. Dispose of the remaining solution as directed by your instructor.

11. Discard the solutions as directed by your instructor. Proceed directly to Steps 1–2 of Processing the Data.

## DATA AND OBSERVATIONS

| 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 the unknown | | _____ mol/L |

## CALCULATIONS AND GRAPHS

1. Using graph paper, plot a graph of concentration vs. absorbance.
2. Plot the point for the absorbance of the unknown solution, and infer the value of the concentration from its placement on your graph.
3. Perform a regression analysis (method included in our first lab).
    a. Put the values for concentration in L1 and the values for absorbance in L2.
    b. Perform a linear regression on the list data, and record the results values for the equation, r, and $r^2$ in the calculations section of your lab book. 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. Use the equation generated by the regression to calculate a value for the concentration of the unknown solution.
4. Your instructor will provide you with the actual value for the concentration of the unknown. Calculate your relative (percent) error for each of the two methods used to determine concentration: graphical analysis and regression analysis.