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

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)	Distilled 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. Connect the Colorimeter to LabQuest and choose New from the File menu.

5. 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.

6. Calibrate the Colorimeter.
   a. Place the blank in the cuvette slot of the Colorimeter and close the lid.
   b. 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 $NiSO_4$. **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 $NiSO_4$ solution.
    a. Tap the Meter tab.
    b. 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.
    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.

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

PROCESSING THE DATA

1. 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.
   a. Tap the Graph tab.
   b. Choose Interpolate from the Analyze menu.
   c. 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.
   d. Record the concentration value in your data table.
2. (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

TEACHER INFORMATION

Experiment
11

Determining the Concentration of a Solution: Beer's Law

1. The student pages with complete instructions for data-collection using LabQuest App, Logger *Pro* (computers), EasyData or DataMate (calculators), and DataPro (Palm handhelds) can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. The light source for the nickel (II) sulfate solution is the red LED (635 nm). Since the $NiSO_4$ is green in color, the nearly monochromatic red light is readily absorbed by the solution.

3. The 0.40 M $NiSO_4$ solution can be prepared by using 10.51 g of $NiSO_4 \cdot 6H_2O$ per 100 mL. **HAZARD ALERT:** Toxic; avoid dispersing this substance; dispense with care; Nickel dust is a *possible carcinogen*. Hazard Code: B—Hazardous.

   The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual,* (800) 452-1261, www.flinnsci.com. See *Appendix D* of this book, *Chemistry with Vernier*, for more information.

4. Solutions of $Ni(NO_3)_2$ also work well, and can be prepared by using 11.63 g of solid $Ni(NO_3)_2 \cdot 6H_2O$ per 100 mL of solution.

5. Unknowns can be prepared by doing dilutions starting with the 0.40 M $NiSO_4$ stock solution. For example, to prepare a 0.22 M unknown, use 55 mL of the standard plus 45 mL of water:

   $$(55 \text{ mL} / 100 \text{ mL})(.40 \text{ M}) = 0.22 \text{ M}$$

6. This experiment works well using solutions of green food coloring. A solution with an absorbance similar to 0.40 M $NiSO_4$ can be prepared by dissolving 8–9 drops of green Schilling Food Coloring in 1 liter of water. Check to see that the absorbance of this stock solution falls in the range of 0.40 to 0.80. Assign this solution a concentration of 100%. Students will follow the same procedure to dilute the stock solution to 80%, 60%, 40%, and 20%. If you use this method, have your students load the Exp 11b Colorimeter in the Experiment 11 folder in *Chemistry with Vernier*. This file has concentration scaled from 0 to 100% on the horizontal axis.

7. The cuvette must be from 55% to 100% full in order to get a valid absorbance reading. If students fill the cuvette 3/4 full, as described in the procedure, they should easily be in this range. To avoid spilling solution into the cuvette slot, remind students not to fill the cuvette 8. Since there is some variation in the amount of light absorbed by the cuvette if it is rotated 180°, you should use a water-proof marker to make a reference mark on the top edge of one of the clear sides of all cuvettes. Students are reminded in the procedure to align this mark with the white reference mark at the top of the cuvette slot on the Colorimeter.

8. The use of a single cuvette in the procedure is to eliminate errors introduced by slight variations in the absorbance of different plastic cuvettes. If one cuvette is used throughout the experiment by a student group, this variable is eliminated. The two rinses done prior to adding a new solution can be accomplished very quickly.

9. There are two models of Vernier Colorimeters. The first model (rectangular shape) has three wavelength settings, and the newest model (a rounded shape) has four wavelength settings. The 635 nm wavelength of either model is used in this experiment. The newer model is an auto-ID sensor and supports automatic calibration (pressing the CAL button on the

Colorimeter with a blank cuvette in the slot). If you have an older model Colorimeter, see www.vernier.com/til/1665.html for calibration information.

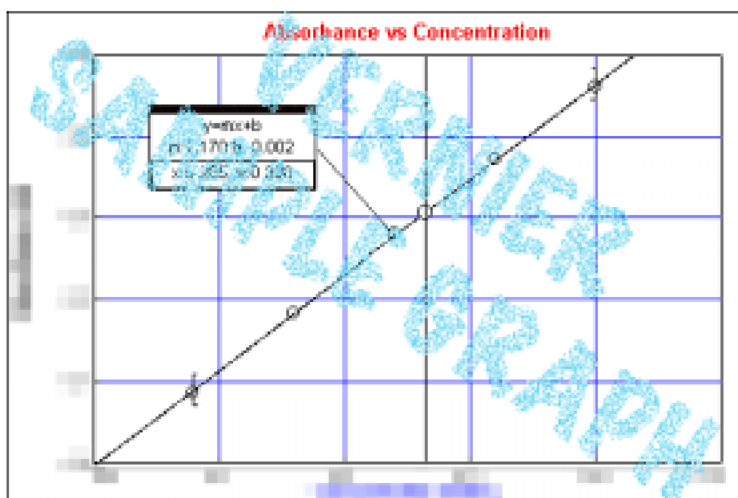
10. This experiment gives you a good opportunity to discuss the relationship between percent transmittance and absorbance. At the end of the experiment, students can click the Absorbance vertical-axis label of the graph, and choose Transmittance. The graph should now be transmittance *vs.* concentration. You can also discuss the mathematical relationship between absorbance and percent transmittance, as represented by either of these formulas:

$$A = \log(100/\%T) \text{ or } A = 2 - \log\%T$$

SAMPLE RESULTS

Trial	Concentration (mol / L)	Absorbance
1	xxxx	xxxx
2	xxxx	xxxx
3	xxxx	xxxx
4	xxxx	xxxx
5	xxxx	xxxx
6	xxxx	xxxx

Concentration of the unknown	xxxx mol/L



Absorbance vs. concentration for $NiSO_4$
with interpolation of the unknown displayed