

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. The NiSO_4 solution used in this experiment has a blue color, so Colorimeter users will be instructed to use the red LED. Spectrometer users will determine an appropriate wavelength based on the absorbance spectrum of the solution. A higher concentration of the colored solution absorbs more light (and transmits less) than a solution of lower concentration.

You will prepare five nickel (II) sulfate solutions of known concentration (standard solutions). Each solution is transferred to a small, rectangular cuvette that is placed into the Colorimeter or Spectrometer. 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*.

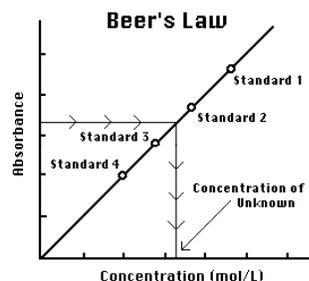


Figure 1

You will determine the concentration of an unknown NiSO_4 solution by measuring its absorbance. 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.

MATERIALS

Vernier Graphical Analysis App
Chromebook or 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 nickel (II) sulfate, NiSO_4 , solution
nickel (II) sulfate, NiSO_4 , unknown solution
pipet pump or pipet bulb
distilled water
test tube rack
stirring rod
tissues (preferably lint-free)

Caution: Nickel (II) sulfate should be handled with care. Should you get the solution on your skin, wash it off immediately with a steady flow of water. Your instructor will provide a container for discarding the used solutions. Under no circumstances are you to pour used, or unused, solution down the drain.

PROCEDURE

1. Obtain and wear goggles.
2. Obtain small volumes of 0.40 M NiSO₄ solution and distilled water in separate beakers.
3. Label five clean, dry, test tubes 1–5. 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.

Test Tube	0.40 M NiSO ₄ (mL)	Distilled H ₂ O (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. Prepare a *blank* by filling a cuvette 3/4 full with distilled water. To correctly use cuvettes, remember:
 - Wipe the outside of each cuvette with a lint-free tissue.
 - Handle cuvettes only by the top edge of the ribbed sides.
 - Dislodge any bubbles by gently tapping the cuvette on a hard surface.
 - Always position the cuvette so the light passes through the clear sides.
5. Log into your account on your Chromebook. Go to the Web Store and install “Vernier Graphical Analysis” if you have not already done so. Connect the Colorimeter to the Chromebook using a Go!Link and launch the Graphical Analysis app.
6. Calibrate the Colorimeter.
 - a. Place the blank in the cuvette slot of the Colorimeter and close the lid.
 - b. Press the < or > button on the Colorimeter to select the wavelength of 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 bottom left of the screen, select Mode. Change the mode to Event Based, and the Event Mode to “Events with Entry”.
 - b. Enter the Event Name (Concentration) and Units (mol/L). Select DONE.
 - c. Proceed to Step 8.
8. You are now ready to collect absorbance-concentration data for the five standard solutions.
 - a. 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 and place it in the device. (Close the lid of the Colorimeter.)
 - b. Select “Collect”. When the value displayed on the screen has stabilized, tap Keep and enter **0.080** as the concentration in mol/L. Select OK. The absorbance and concentration values have now been saved for the first solution.
 - c. Discard the cuvette contents as directed. Using the solution in Test Tube 2, rinse and fill the cuvette 3/4 full. Wipe the outside and place the cuvette in the device (close the lid of the Colorimeter). Wait for the value displayed on the screen to stabilize, and tap Keep. Enter **0.16** as the concentration in mol/L.
 - d. Repeat the procedure for Test Tubes 3 and 4. Trial 5 is the original 0.40 M NiSO₄ solution. **Note:** Do not test the unknown solution until Step 11.
 - e. When you have finished testing the standard solutions, stop data collection.
 - f. 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.

9. Write down the absorbance values, for each of the five trials, in your data table. Be sure you are getting “Absorbance” not “% Transmittance” – it is the third column in the data table on your Chromebook.
11. Determine the absorbance value of the unknown NiSO_4 solution.
 - a. Using the same procedure as before, wash a your cuvette with a small sample of the unknown.
 - b. Place the sample in the colorimeter, and determine the absorbance value. Record this in your data table. You do not have a concentration, so you cannot enter it as a data point.
12. Clean all of your glassware and lab tools and return them to the table where you found them. Be certain that all of the NiSO_4 solution is discarded in the waste container, NOT down the sink!

DATA TABLE

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

13. Determine the concentration of the unknown using regression analysis. Obtain a TI-83plus graphing calculator.

Step 1: Enter the data in a list

STAT → “EDIT” → 1:Edit → ENTER This opens the list window. If there are contents in the lists, then use the “up” cursor to move into the uppermost field – the list header ($L_1, L_2, L_3 \dots$). Once there, press CLEAR and then the “down” cursor. This clears the list field.

Now enter the values for concentration in L_1 and absorbance in L_2 .

Step 2: Turn on Diagnostics

In order to analyze the linearity of our data, we need to turn on the statistical diagnostics. This will provide us with correlation coefficients when we perform a linear regression.

Open the Catalog function: 2nd → 0 and then scroll down to “DiagnosticOn” and press ENTER, and then ENTER a second time. The diagnostic functions are now on.

Step 3: Perform Linear Regressions

Press STAT > CALC, press ENTER. Scroll down to 4:LinReg(ax+b) and press ENTER

We will now perform a linear regression on the contents of L_1 and L_2 . We would also like to store the resulting linear equation for later use. We will store it in under the Y= function. The homescreen should now say “LinReg(ax+b)”. Press 2nd 1, 2nd 2, VARS > (Y-VARS, 1:Function) ENTER and Select “1:Y1”. Press ENTER. The screen should now appear as it does to the right.

LinReg(ax+b) L1,
L2:Y1

Press ENTER once again, the screen should look (somewhat) like it does below:

```
LinReg
y=ax+b
a=-1.720636E-5
b=.4505445079
r2=.9011585514
r=-.9492937119
```

The values of r^2 and r give us a sense of how closely our data correlates to a linear equation. The closer these values are to 1, the better the correlation. In this case, the correlation is not very close. This indicates that there is not a linear relationship between our variables, or that our data is inaccurate.

Record the table (similar to above) ON your lab paper.

Now, using the equation in the form $y = mx + b$, plug in your absorbance for the unknown as the value for “y”, and use the “a” and “b” values from your regression. SOLVE FOR ‘x’, which will be the concentration of your unknown.

Show your work, and be sure to report the value obtained for the concentration of your unknown in your abstract, as well as the linearity of your results based on the regression analysis.