Determining the Concentration of a Solution: Beer's Law

The primary objective of this experiment is to determine the concentration of an unknown cobalt (II) chloride, $CoCl_2$, solution. You will use a Vernier Spectrometer or a Vernier SpectroVis to measure the concentration of each solution. You will first measure the absorbance of a standard solution over the visible light spectrum and select the wavelength of maximum absorbance (λ max). A higher concentration of the solution absorbs more light (and transmits less) than a solution of lower concentration.

You will prepare five cobalt (II) chloride solutions of known concentration (standard solutions) and measure the absorbance of the standard solutions at the λ max. The graph of absorbance *vs.* concentration for the standard solutions will describe a direct relationship, known as *Beer's law*.

Finally, you will determine the concentration of an unknown $CoCl_2$ solution by measuring its absorbance with a spectrometer and using the best-fit line equation of the Beer's law curve to calculate the unknown's concentration.

OBJECTIVES

In this experiment, you will

- Measure and analyze the visible light absorbance spectrum of a standard cobalt (II) chloride solution to determine the maximum wavelength of absorbance.
- Prepare and test the absorbance of five standard cobalt (II) chloride solutions.
- Calculate a standard curve from the test results of the standard solutions.
- Test the absorbance of a cobalt (II) chloride solution of unknown molar concentration.

MATERIALS

Vernier Spectrometer or SpectroVis
computer
Vernier Logger *Pro* 3 software
pipet pump or pipet bulb
one cuvette
two 10 mL pipets or graduated cylinders
five 20 × 150 mm test tubes
0.20 M cobalt (II) chloride, $CoCl_2$, solution
cobalt (II) chloride, $CoCl_2$, unknown solution
distilled water
test tube rack
stirring rod
tissues (preferably lint-free)
two 100 mL beakers

PROCEDURE

1. Obtain and wear goggles.
2. Obtain ~30 mL of 0.20 M $CoCl_2$ solution and distilled water.
3. Label four clean, dry, test tubes 1–4. Use pipets to prepare the 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 number	0.20 M $CoCl_2$ (mL)	Distilled H_2O (mL)	Concentration (M)
1	10	0	0.20
2	8	2	0.16
3	6	4	0.12
4	4	6	0.08

4. Use a USB cable to connect a spectrometer to the computer.
5. Start the Logger *Pro* 3 (version 3.6 or newer) program on your computer.
6. Calibrate the spectrometer.
   a. Prepare a *blank* by filling an empty cuvette ¾ full with distilled water. Place the blank cuvette in the spectrometer.
   b. Select Calibrate ► Spectrometer from the Experiment menu. The calibration dialog box will display the message: "Waiting …seconds for lamp to warm up." The minimum warm up time is 90 seconds. Follow the instructions in the dialog box to complete the calibration. Click OK.
7. Determine the maximum wavelength for $CoCl_2$ (aq) and set up the data collection mode.
   a. Empty the blank cuvette and rinse it twice with small amounts of the 0.20 M $CoCl_2$ solution in Test Tube 1. Fill the cuvette ¾ full with the 0.20 M $CoCl_2$ solution and place it in the spectrometer.
   b. Click Collect. A full spectrum graph of the $CoCl_2$ solution will be displayed. Note that one area of the graph contains a peak absorbance. Click Stop to complete the analysis.
   c. To save your graph of absorbance *vs*. wavelength, select Store Latest Run from the Experiment menu.
   d. Click the Configure Spectrometer Data Collection icon,  , on the toolbar. A dialog box will appear.
   e. Select Abs *vs*. Concentration under Set Collection Mode. The wavelength of peak absorbance (λ max) will be automatically selected. If you wish to select a new wavelength, click on the graph or check the box next to the desired wavelength. Click OK to proceed.
8. Collect absorbance-concentration data for the five standard solutions.
   a. Leave the cuvette in the spectrometer. Click Collect. When the absorbance reading stabilizes, click Keep. Enter "0.20" as the concentration of the solution and click OK.
   b. Discard the cuvette contents as directed. Using the solution in Test Tube 2, rinse and fill the cuvette ¾ full. Wipe the cuvettee and place it in the spectrometer. When the absorbance reading stabilizes, click Keep. Enter "0.16" as the concentration.
   c. Repeat Step 8b for the remaining test tubes of the standard $CoCl_2$ solution. When you have finished testing the standard solutions, click Stop.

9. To determine the best-fit line equation for the $CoCl_2$ standard solutions, click the linear fit button,  , on the toolbar. Write down the equation for the standard solutions in your data table or lab book.

10. Determine the concentration of the unknown $CoCl_2$ solution.
    a. Obtain about 5 mL of the *unknown* $CoCl_2$ solution.
    b. Rinse the cuvette twice with the unknown solution and fill it about ¾ full. Wipe the outside of the cuvette and place it into the spectrometer.
    c. Select Interpolation Calculator from the Analyze menu. A dialog box will appear that displays the concentration of your unknown at the measured absorbance.
    d. Click OK. Write down the absorbance and the concentration of the unknown in your data table or lab book.
    e. Dispose of any of the remaining solutions as directed.

11. (optional) Print a copy of your graphs and/or data table.

12. (optional) Select Save As… from the File menu and save your experiment file.

DATA TABLE

Test Tube	Concentration (mol/L)	Absorbance
1	0.20	
2	0.16	
3	0.12	
4	0.08	
5	Unknown number ____	

DATA ANALYSIS

Your lab report should contain the following information:

- a graph showing the data and linear-regression equation for the standard solutions
- the molar concentration of your unknown $CoCl_2$ solution
- an explanation of your calculation of the unknown's concentration