EXPERIMENT 4:

Exploring Le Chatelier's Principle: What Factors Control the Equilibrium of Cobalt Complex Ions?[1]

INTRODUCTION

Coordination Complexes of Co^{2+}

Structures with a central transition metal atom or ion bonded to an array of molecules or ions called ligands are known as coordination complexes (or complex ions). These structures are stable because the central, positively charged metal atom or ion can form strong chemical bonds with the negatively charged (electron-rich) portions of the coordination species. The charge and size of the metal ion and the coordinating species will determine the overall structure of the coordination complex. This will then influence properties like the optical absorbance spectrum (or color) of the solution.

This lab focuses on cobalt (II), which forms complex ions in solution. When dissolved, the Co^{2+} ion will be surrounded by either four or six ligands yielding tetrahedral or octahedral structures, respectively. Complexes with tetrahedral geometry such as $[CoCl_4]^{2-}$ are blue or violet in color while complexes with octahedral geometry (ex. $[Co(H_2O)_6]^{2+}$) are pink. In this lab alcohols will be used as the ligands.

Dissolving cobalt (II) chloride in water will form a pink solution of $[Co(H_2O)_6]^{2+}$, which consists of a Co^{2+} ion surrounded by six water molecules in an octahedral arrangement. The electronegative oxygen atoms are positioned toward the positively charged Co^{2+} ion (**Figure 2**). The equilibrium can be shifted to favor the blue tetrahedral attangement (**Figure** 1) by adding the negatively charged Cl^- ion. Though this lab will use alcohols as ligands instead of Cl^- and H_2O, this can be used to explain what happens in solution. When ligands have similar charges, the larger ligands prefer tetrahedral structures rather than octahedral complexes to minimize repulsive forces and steric hindrance. Although both the chloride ion and the oxygen atom (in H_2O) are both attracted to the Co^{2+} ions, the Cl^- has a fully negative charge of one while the oxygen atoms has only a partial negative charge. In addition the Cl^- is "larger" owing to its extra electron. Therefore, the ligand-metal bond is stronger and shorter for Cl^-. The tetrahedral configuration minimizes these effects. In the case of the smaller H_2O, the metal-ligand bond is weak and long. Therefore, the repulsion between water molecules is small regardless of the configuration. As a result, Co^{2+} attracts 6 H_2O molecules to form the octahedral structure. ***Figures 1 and 2*** show the detailed geometric structures between Co^{2+} and these coordination species:

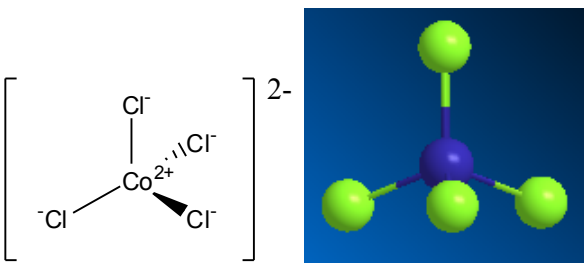


Figure 1: A tetrahedral Co^{2+} coordination complex

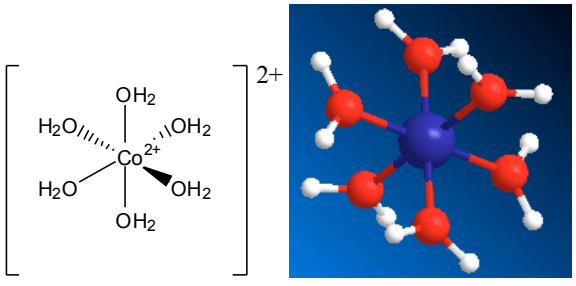


Figure 2: An octahedral Co^{2+} coordination complex

[1] The new green chemistry procedures were developed by Allison Lawman (UTRA) and Professor Li-Qiong Wang at Brown University (Summer/Fall 2012). Thank Ning Huo, Dylan Cofer-Shabica Christine Buehler for the help.

This experiment explores the equilibrium of cobalt (II) coordination complexes in alcohol solvents: Methanol (CH_3OH) and 2-propanol ($CH_3CHOHCH_3$).

Equilibrium Between Tetrahedral and Octahedral Co2+ Coordination Complexes in Solution

When 2-propanol (also known as isopropanol), $CH_3CHOHCH_3$, is used as a solvent, cobalt (II) chloride retains one chloride ion and complexes three 2-propanol molecules to form the blue tetrahedral complex $[CoCl(CH_3CHOHCH_3)_3]^+$. Conversely, if a smaller alcohol such as methanol (CH_3OH) is used as the solvent, cobalt (II) chloride complexes six total molecules to form a pink octahedral complex ion $[CoCl(CH_3CHOHCH_3)_2(MeOH)_3]^+$.[2] An equilibrium between the tetrahedral and octahedral coordination complexes is established when methanol is added to a solution of $CoCl_2$ dissolved in 2-propanol. This reaction is given below:

$$\underset{\text{(Blue, tetrahedral)}}{[CoCl(CH_3CHOHCH_3)_3]^+} + 3\ CH_3OH \rightleftharpoons \underset{\text{(Octahedral, light pink)}}{[CoCl(CH_3CHOHCH_3)_2(MeOH)_3]^+} + CH_3CHOHCH_3 \quad \textbf{(Eq. 1)}$$

This reaction can written more simply if P and M are used to represent 2-propanol and methanol molecules, respectively:

$$\underset{\text{(Blue, tetrahedral)}}{[CoCl(P)_3]^+} + 3\ M \rightleftharpoons \underset{\text{(Octahedral, light pink)}}{[CoCl(P)_2(M)_3]^+} + P \quad \textbf{(Eq. 2)}$$

The equilibrium constant expression for this reaction is shown below:

$$K_{eq} = \frac{[Co_{(oct)}][P]}{[Co_{(tet)}][M]^3} \quad \textbf{(Eq. 3)}$$

As is the case for all equilibrium constants, this equilibrium constant depends only on the temperature of the system and not on the absolute concentrations of 2-propanol and methanol present. The relative proportions of the two coordination complexes sets the solution color.
Le Chatelier's Principle states that a change made to a chemical system at equilibrium will cause the equilibrium position to shift in a way that will reduce the effect of the change. For example, if methanol is added to the equilibrium mixture, the equilibrium position will shift to the right. This will increase the relative proportion of the octahedral complex ion, and thus shift the equilibrium toward the octahedral (pink) side.

THEORY OF SPECTROSCOPY[3,4]

Although light exhibits both wave-like and particle-like properties, absorption spectroscopy takes advantage of its wave properties. In this view, light is considered to be waves of electromagnetic energy moving through space ***(Figure 3)***. Light is characterized by its wavelength (λ), frequency (ν), and speed (c). The wavelength is the distance between the crests of a wave. Wavelength is typically measured in units of nanometers (1 nm = 10^{-9} m). The frequency is the number of crests passing a given point in space per second and is given by $\nu = c / \lambda$.

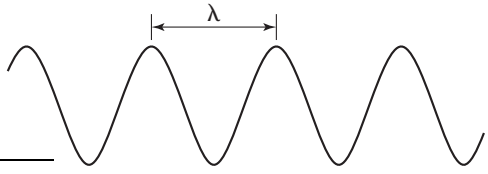


Figure 3: A Wavelength

[2] Nyasulu, F.; Nething, D.; Barlag, R.; Wise, L.; Arthasery, P. *J. Chem. Educ.* **2012**, *89*, 536-539.
[3] Parts of this section are from Professor Joseph Stein's Chemistry 33 Lab Manuals, Brown University.
[4] Other parts of this section are from Zumdahl *Chemical Principles* 6th ed. For more information about spectral analysis refer to the appendix in the textbook.

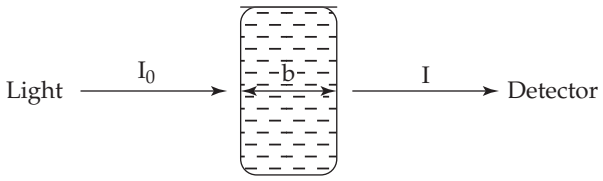
The visible region of the electromagnetic spectrum occupies the region from about 380 to 720 nm. The wavelength of light that reaches the eye determines the color the brain perceives. White light is a mixture of all wavelengths (all the colors) in the visible region. Colorless solutions do not absorb light at any visible wavelength. However, when white light passes through a colored solution, certain wavelengths are absorbed. Wavelengths that are not absorbed are transmitted and meet the eye resulting in the perception of color. The wavelengths that are not absorbed are known as complimentary colors. A table of colors, complementary colors, and wavelengths is given below in **Table 1**. Based on the table, a solution that appears to be blue when seen in white light takes its color because the yellow wavelengths are absorbed, leaving only the blue light to be transmitted.

Table 1**:** *Wavelengths, colors and complementary colors*

Wavelength Range/nm	Color	Complementary color
380–435	Violet	Yellow-green
435–480	Blue	Yellow
480–490	Green-blue	Orange
490–500	Blue-green	Red
500–560	Green	Purple
560–580	Yellow-green	Violet
580–595	Yellow	Blue
595–610	Orange	Green-blue
610–750	Red	Blue-green

A *spectrophotometer* is a device that measures the absorption of light by a solution as a function of wavelength. A basic spectrophotometer consists of a white light source, a prism, a sample chamber, and a detector. The prism provides a monochromatic (single wavelength) beam of light by splitting the spectrum. A detector behind the sample measures the intensity of the light passing through the sample and a meter on the instrument reports the output of the detector. ***Figure 4*** shows a diagram of this light absorption.

Figure 4: A diagram of a sample absorbing light



The initial intensity of the light entering the sample is represented as I_o. The intensity of the light leaving the sample after some has been absorbed is I,the signal that the detector receives. I is dependent on the absorbing species and the path length, b (in cm)of the sample. The relationship between absorbance and incoming and outgoing intensity is given by the Beer-Lambert Law:

(Eq. 4)

$$-\log I/Io = \varepsilon\ b\ c = A$$

A is absorbance and ε is the molar absorptivity (or the molar extinction coefficient). This constant of proportionality is specific to a particular absorbing species. c is the concentration (molarity) of the absorbing species. This equation shows that absorbance is proportional to the concentration of the species in the sample.

Absorbance measurements are commonly used in two ways:

1. Single point measurements: When the wavelength (λ) and the path length (b) are fixed, the absorbance value is proportional to concentration. This can be used for measuring concentration.
2. Full spectrum measurement: When concentration and path length are fixed, but the wavelength varies, the absorbance changes with wavelength because ε depends on λ. A plot of A against λ is called an absorption spectrum and is used to determine the wavelength of the maximum absorption, λ_{max}.

In this experiment, absorbance measurements are taken both ways.

EXPERIMENTAL OVERVIEW

Measuring the Concentrations of Tetrahedral Coordinated Co^{2+}, $[Co_{(tet)}]$ (Part B):

A provided stock solution is prepared by dissolving solid $CoCl_2$ in 2-propanol. The wavelength of maximum absorbance (λ_{max}) for this solution is experimentally determined and used later as the analytical wavelength for all other absorbance measurements. In the stock solution, the tetrahedral coordination $[CoCl(P)_3]^+$ will dominate. Therefore, it is assumed that the concentration of the tetrahedral coordinated complex is equal to the total cobalt concentration, i.e. $[Co_{(tet)}] = [Co^{2+}]$. λ_{max} for this blue solution will be around 650-660 nm.

Different concentrations of $[Co_{(tet)}]$ will be made by diluting the stock solution with different amounts of 2-propanol. The absorbance at λ_{max} for Co^{2+} in 2-propnaol is proportional to the concentration of $[Co_{(tet)}]$ present. The general relationship between absorbance (A) and concentration (c) of the absorbing species is known as Beer's Law:

$$A = \varepsilon c \qquad \textbf{Eq. 5}$$

ε is a proportionality constant that relates absorbance to concentration for solutions measured at fixed path lengths. In this experiment, path length is held constant by using the same cuvette for all solutions. Beer's law can then be rewritten for solutions of tetrahedrally coordinated Co^{2+} in a 2-propanol at λ_{max}:

$$A = \varepsilon [Co_{(tet)}] \qquad \textbf{Eq. 6}$$

For different concentrations of $[Co_{(tet)}]$ in the same 2-propanol environment, each absorbance is plotted as a function of the corresponding $[Co_{(tet)}]$ concentration. The slope of the line yields ε.

Measuring the Equilibrium Constant For Co^{2+} Complexes (Part C):

In Part C of this experiment, Le Chatelier's Principle will be explored, and the equilibrium constant for the conversion of tetrahedrally coordinated Co^{2+} to octahedrally coordinated Co^{2+} (**Eq. 1**) will be determined. A series of solution mixtures are prepared by varying the amount of 2-propanol and methanol added to the stock solution. From the reaction equation (**Eq. 1 and 2**), it can be seen that adding more methanol relative to 2-propnaol will shift the equilibrium to the right. As more methanol is added relative to 2-propnaol, an obvious color change will occur as the cobalt coordination shifts from the blue tetrahedral arrangement to the pink octahedral arrangement. The absorbance of each diluted solution will be measured at the previously recorded λ_{max}, and based on Beer's Law (**Eq. 5**), the absorbance will be related to the corresponding concentration of tetrahedrally coordinated Co^{2+}. The concentration of each component of the equilibrium constant (**Eq. 2**) can be derived after measuring the absorbance at the previously determined λ_{max}. The equilibrium constant (**Eq. 3**) will be calculated for a variety of concentrations.

Example Calculations:

Example Parameters:
λ_{max} is determined to be 650.16 nm
$\varepsilon = 338.51\ M^{-1}$
For the original stock solution $[Co^{2+}_{total}] = 0.00375$ M,

A solution is made of combining 2.000 mL stock, 0.750 mL 2-propanol, and 0.250 mL methanol (the density of methanol is 0.791 g/mL and that of 2-propanol is 0.786 g/ml). Absorbance at λ_{max} of 650.16 nm is 0.670:

$$[Co_{(tet)}] = Abs_{650.16} / \varepsilon = 0.670 / (338.51\ M^{-1}) = 0.00198\ M$$

$[Co^{2+}_{(total)}] = [Stock]*(V_{stock}/V_{total}) = (0.00375\ M)*(2.000mL/3.000mL) = 0.0025\ M$
$[Co_{(oct)}] = [Co^{2+}_{total}] - [Co_{(tet)}] = 0.00052\ M$
$[P] = ((V_{stock} + V_{2\text{-propanol}}) * 0.786\ g/mL) / (60.09\ g/mol * V_{total})*(1000\ mL/1\ L) = ((2.000\ mL + 0.750\ mL) * 0.785\ g/mL) / (60.09\ g/mol * 3.000\ mL) *(1000\ mL/1\ L) = 11.98\ M$
$[M] = (V_{methanol} * 0.791\ g/mL) / (32.04\ g/mol * V_{total}) *(1000\ mL/1\ L) = (0.250\ mL * 0.791\ g/mL) / (32.04\ g/mol * 3.000\ mL) *(1000\ mL/1\ L) = 2.06\ M$
Substitute $[Co_{(tet)}]$, $[Co_{(oct)}]$, [P], and [M] values into Eq. 3 to calculate K_{eq}.

This redesign of this experiment was made possible with the support of the UTRA program (Summer/Fall 2012). The new procedure aims to highlight important chemical concepts while simultaneously reducing tedious redundancy in the procedure. Additionally, the new version minimizes the usage of chemicals in order to promote green chemistry and help save the environment. Please do not waste the chemicals.

PROCEDURE (WORK IN PAIRS)

Safety Precautions: Cobalt (II) chloride ($CoCl_2$) is toxic and an irritant. 2-propanol, also called isopropanol, is the major component of drugstore rubbing alcohol. 2-propanol is an irritant and methanol is toxic. Methanol and 2-propanol are volatile and flammable. To prevent vaporization, which will alter concentrations, cover all beakers with a watch glass. Avoid contact with the solutions, and promptly wash any contaminated skin. Wear goggles and aprons at all times.

Materials

General Equipment	Special Equipment	Reagents
2 x automatic pipette (1 mL adjustable volume)	LabQuest with Vernier SpectroVis Spectrophotometer	0.00375 M Co^{2+} stock solution ($CoCl_2$ dissolved in 2-propanol)
3 x small beakers (25, 50 or 150 mL range)	Plastic cuvette with cap	2-propanol, $CH_3CHOHCH_3$
2 x 250 mL beaker	3 x plastic pipette tip (1 mL volume)	Methanol, CH_3OH
1 x large waste beaker	Digital thermometer	
Ring stand with three fingered (or utility) clamp and clamp holder		
3 x watch glass		
USB flash drive		

Part A: Calibration and Use of the Automatic Pipette

1. An automatic pipette dispenses small (<1 mL) volumes of liquids more quickly and with comparable accuracy compared to more cumbersome methods like burets and graduated pipettes. To minimize time spent dispensing solution, each set of partners should have two automatic pipettes. Before using the pipette obtain three 1 mL plastic pipette tips from the back of the lab. Attach a tip to each pipette and temporarily set the other one aside.

2. The volume of the pipette can be adjusted by turning the dial at the top. Adjust the dials on both pipettes so that one is set to dispense 1.000 mL and the other 0.250 mL To fill the tip, use the following directions: Push the plunger down until it hits the first stop of resistance. Immerse the tip just below the surface of liquid. Gradually release the thumb pressure to allow the plunger to rise. Do not raise the plunger so rapidly that the liquid squirts up inside the transparent plastic tip. Never lay the pipette down or hold it upside down if there is liquid in the tip. To dispense the liquid depress the plunger until it reaches the second stop. Practice this technique several times with distilled water in a small beaker.
3. The actual volume of the pipette can be determined by weighing dispensed distilled water on an analytical balance. A small beaker or watch glass may be used as a container. Use the density of distilled water at room temperature (1.00 g/mL) to calculate the actual volume of the pipette. For calibration purposes, make sure the weighed water mass is within 0.002 g of the desired volume (you may need to adjust the dial to achieve this). Record the mass and volume of the weighed water.
4. Calibrate the first pipette to 1.000 mL. Repeat step 3 two more times (for a total of three) and write down the average exact mass of the dispensed distilled water after calibration.
5. Calibrate the second pipette to 0.250 mL. Repeat step 3 three times. Write down the average exact mass of the dispensed distilled water after calibration.
6. To avoid contamination, use a different pipette tip for each reagent (stock solution, 2-propanol, and methanol). Since 2-propnaol and methanol are both colorless, it is important to use labeling to distinguish the pipette tips. Use a permanent marker to label each tip near where it attaches to the pipette. Make sure not to put ink anywhere that will contact solution. This will affect the results. Alternatively, label a paper towel with the three solutions and lay each pipette tip by its corresponding spot.

Part B: Identifying λ_{max} and ε

1. Use the same SpectroVis spectrophotometer and LabQuest for the entire experiment. Refer to Figure 5 for a visual representation of the equipment. Record the SpectroVis number in the lab notebook. Turn on the LabQuest and choose "New" from the File menu. Obtain a square cuvette labeled as "2-propanol" from the back of the lab. Place the clear sides of the cuvette facing the light source in the SpectroVis cuvette slot. Avoid touching the clear side as fingerprints on the cuvette might affect your results. Always hold cuvettes by the frosted sides. Please remember to return the 2-propanol cuvette to the back bench as soon as you finish the calibration.

Figure 5: LabQuest, SpectroVis Spectrophotometer, and 3 mL cuvette

2. Touch the words "USB: ABS" in the red-orange box and tap "Calibrate." After the 60 second warm up period touch the highlighted box, "Finish Calibration." Then tap "OK."
3. Obtain two small beakers (25 mL to 50 mL volume) and collect 20 mL of the stock solution (0.00375 M $CoCl_2$ dissolved in 2-propanol), and 8.0 mL of 2-propanol, respectively. Label the beakers using a permanent marker. Record the exact concentration of the stock solution. Place a watch glass on top of both beakers to reduce evaporation. Evaporation will change the concentration by an unknown amount and affect results.
4. Use the 1.000 mL calibrated pipette to dispense 3.000 mL of the stock Co^{2+} solution into a new cuvette by pipetting three times. Before measuring the spectrum, cap the cuvette to avoid evaporation.

5. Place the square cuvette containing the stock solution into the SpectroVis slot. ***Make sure that the clear side is facing the light source***. Set the Mode to "Full Spectrum." Start the data collection by touching the green button on the lower left side. After the full spectrum of absorbance vs. wavelength appears, touch the red stop button.
6. To find λ_{max}, tap the graph twice to obtain a pointer. Select the wavelength of maximum absorption. Alternatively, tap the table icon to the right of the graph icon to display the data in table form. Record this λ_{max} value in the lab notebook. Since the data is needed to complete the report, you must save the data to your USB flash drive. Do not save the data onto the LabQuest. The whole spectrum is needed for the lab report. Simply writing down the λ_{max} is not enough. To save the data to a USB drive, insert the flash drive into the LabQuest's USB port and select the "save" (data can only be read by LoggerPro) or "export" (text file) option from the file menu. You may check if the data are saved by uploading the data to your labtop in the classroom area. Plug the spectrophotometer back into the LabQuest and calibrate it using the 2-propanol blank as outlined in steps 1 and 2.
7. After determining λ_{max}, use this as the experimental wavelength throughout the remainder of the lab. Now find ε for $Co_{(tet)}$ in this 2-propanol environment. To do this, measure the absorbance of different concentrations of $Co_{(tet)}$ in the same 2-propanol conditions at the previously determined λ_{max}. The solutions and their respective $[Co_{(tet)}]$ concentrations to be measured are:

Solution	V_{stock}, mL	$V_{2\text{-propanol}}$, mL	Total Volume, mL	$[Co_{(tet)}]$, M
1	3.000	0.000	3.000	0.00375
2	2.000	1.000	3.000	0.00250
3	1.000	2.000	3.000	0.00125

These solutions will be prepared in the cuvette one at a time. The first solution is the prepared stock solution. The calibrated 1.000 mL pipette and the different pipette tips will be used to measure and dispense the solutions. After preparing each solution, cap the cuvette and gently shake the contents to mix and make sure that no soultion is spilled out. Before reading the absorbance be sure that none of the solution is stuck in the cap. If there is any residual solution on the cap of the cuvette, carefully use the pipette to transfer it back to the cuvette. Record the color of the solution in the lab notebook and then measure the absorbance at the previously determined λ_{max}.

8. To measure the absorbance, change the Mode to "Events with Entry" on the LabQuest. Once tapping this icon set the event as "concentration" with units "mol/L." Then touch "USB: ABS" in the orange box and tap "Change Wavelength." Type in the previously determined λ_{max} value and then hit "OK." Once changed, the display should include the new wavelength in the orange box as "USB:ABS@# nm." Place the filled cuvette in the proper slot of the spectrophotometer. Once the reading stabilizes, tap "Keep" and then enter the $[Co_{(tet)}]$ concentration. Record the saved value in the laboratory notebook. Additionally, record the color of the solution. Prepare the next solution as outlined in step 7.

   Note: The same cuvette is used for all the solutions so after measuring the absorbance of one solution, dump the contents into the waste beaker before making the next solution. Rinse the cuvette with 1-2 mL of 2-propanol and dump the contents into the waste beaker. Residual solution left inside the cuvette or cap ***will*** *affect results. Use a KimWipe™ to absorb residual solution.*
9. When all three samples have been measured, touch the red stop button to stop the data collection. Leave the spectrophotometer on. Review the data by looking at the graph on the LabQuest. If a linear plot is shown, save the data to a USB flash drive using the method outlined above in step 6. Make sure that all the absorbance values are also recorded directly in the laboratory notebook. If a linear plot is not shown, check with your TA. Rinse the cuvette with ~3-4 mL of 2-propanol three times. Discard all rinses in the waste beaker.
10. Plug the spectrophotometer back into the LabQuest and recalibrate it using the 2-propanol blank as outlined in steps 1 and 2.

Part C: Equilibrating Co^{2+} Tetrahedral and Octahedral Coordination Complexes

1. Ensure that the spectrophotometer is still set at the correct λ_{max} and the Mode is set at "Events with Entry" to read the absorbance. For this part of the experiment, the absorbance values will be read directly and not

entered into the LabQuest. To read the absorbance, stay on the Meter icon screen. All data must be recorded in the lab notebook.

2. Obtain 5 mL of methanol in a small (25 mL-50 mL) beaker. Since 2-propanol is also colorless, it is important to use proper labeling to distinguish the two chemicals. Methanol is extremely volatile, so cover the beaker with a watch glass.
3. The following solutions below will be prepared.

Solution	V_{stock}, mL	$V_{2\text{-propanol}}$, mL	$V_{Methanol}$, mL	V_{Total}, mL
A	2.000	0.750	0.250	3.000
B	2.000	0.500	0.500	3.000
C	2.000	0.250	0.750	3.000
D	2.000	0.000	1.000	3.000

4. Prepare Solution A in the rinsed cuvette. Use the appropriate calibrated pipette for each solution. For example, to dispense 0.500 mL use the 0.250 mL calibrated pipette twice. To avoid contamination, use three different plastic pipette tips (one for each solution). Be sure that the tips are labeled and kept separate. Before reading the absorbance, cap the cuvette and gently shake the contents to mix and make sure that no soultion is spilled out. Insert the cuvette into the SpectroVis slot and measure the absorbance at λ_{max}. Record this value and the color of the solution. The same cuvette is used for all the solutions so after measuring one solution, dump the contents into the waste beaker before preparing the next solution. Residual solution left inside the cuvette or cap **will** affect results. Use a KimWipe™ to absorb visible residual solution.
5. Repeat Step 4 for Solutions B and C. Record the color of each solution and its respective absorbance at λ_{max} in the laboratory notebook.
6. In an empty and dry cuvette, prepare Solution D using the automatic pipettes. Cap the solution, shake the contents gently, and record the color. Insert the cuvette into the proper slot in the spectrophotometer and record the absorbance. ***Note: The absorbance for Solution D will be very low.*** Remove the cuvette. Choose "New" from the File menu. The mode should automatically switch to read "Full Spectrum." If this does not occur, manually change the mode. Calibrate the spectrophotometer using Steps 1 and 2 in Part B.
7. Once the calibration is complete, place the cuvette containing Solution D back into the proper slot of the spectrophotometer. Start the data collection by touching the green button on the lower left side. After the full spectrum of absorbance vs. wavelength appears, touch the red stop button.
8. Determine a new λ_{max} for solution D from either the graph or the table. Record this value in the laboratory notebook. Note the differences between this full spectrum and the spectrum obtained earlier for the $CoCl_2$ in 2-propanol stock solution. Since the data is needed to complete the lab report, save the data to a USB flash drive. Do not save the data on the LabQuest.
9. After saving the data, check to make sure that no data is saved on the LabQuest. Delete all other files listed on the LabQuest. Turn off the LabQuest by pushing down the top silver button. Pour the solutions into the waste beaker and rinse the cuvette three times with 2-propanol. Return the rinsed cuvette and thermometer to the supplies bench. Wash all glassware thoroughly.

Disposal:

Collect all used solutions in a waste beaker in your hood. After completing the experiment, dispose all used and unused solutions in the waste container in the hood in the back of the room.. Put the pipette tips into the black "medical waste" containers on the supplies table in the back of the room.