Beer's Law and the Determination of Solution Concentration

Introduction

Substances that appear to have color absorb light at wavelengths that are visible. The color perceived is due to the wavelengths that are not absorbed. It is the light that is either transmitted or reflected that is sensed by the eye. The human eye is sensitive only to wavelengths from approximately 400 nm to 700 nm. An aqueous solution containing $CoCl_2$ will absorb light with a wavelength of 510 nm most strongly. This is within the range of wavelengths that are visible and the solution appears pink to red depending on its concentration. The more $CoCl_2$ present in solution the stronger the absorption and the deeper the color. This property is represented in Beer's Law: $A = \varepsilon bc$. The Law applied for a single wavelength of light; it relates the absorbance, A, to the concentration of the absorbing species, c, the thickness of the solution, b, and a characteristic of the absorbing species, the molar absorptivity, ε:

Percent transmittance, %T, is sometimes measured instead of absorbance. On instruments with scales rather than digital displays there is less error associated with reading the transmittance. It is also more directly related to the light level being measured. The absorbance and the percent transmittance are related as follows: $A = -\log(\%T/100)$.

Spectrophotometers are a type of instrument often found in chemistry laboratories. The instruments incorporate a light source, a means of selecting a single wavelength of light and a light sensitive measurement device. Most modern spectrophotometers have digital displays and can show either absorbance or percent transmittance. Instructions for the use of the spectrophotometers will be provided in the laboratory.

In this laboratory exercise Beer's Law will be used to determine concentrations. Based on your measurements you will prepare several solutions of particular concentrations.

I. Preparation of Calibration Curve

Measure the absorbance of the four standard solutions. These solutions have concentrations of 0.0300, 0.0600, 0.0900 and 0.150 M in $CoCl_2$. Then prepare a plot of absorbance (y-axis) versus concentration (x-axis). Place a linear regression line on the plot. This will be you calibration curve.

II. Determination of the Concentration of $CoCl_2$ in an Unknown

A sample of $CoCl_2$ solution of unknown concentration can be obtained from your teaching assistant. The will be referred to as the “unknown”. Place a portion of the unknown into a cuvette and measure the absorbance of the solution. If the absorbance of the unknown is greater that the most concentrated solution used to prepare the calibration curve it must be diluted. Perform dilutions until the absorbance is within the range of the standards. The table below is provided as a guide. Then use the calibration curve to determine the concentration of the diluted unknown. Based on the dilution used calculate the concentration of the undiluted unknown solution.

mL unknown solution	mL pure water added	Absorbance
10.0	0.0	
7.5	2.5	
5.0	5.0	

III. Dilution of the Unknown to Produce a Solution with a Specified Concentration or Transmittance

A. Calculate the absorbance that corresponds to a transmittance of 38.0%. Use this absorbance to determine the concentration of a solution with a transmittance of 38.0%. Then prepare 10 mL of the solution using you unknown and pure water. You may assume that volumes are additive. Measure the percent transmittance of the solution.

B. If a 1.5 mL portion of your unknown was diluted with pure water to exactly 10.0 mL, what concentration of $CoCl_2$ would result? Make the dilution and verify the concentration.

C. Prepare 25 mL of a solution with an absorbance of 0.25 from solid $CoCl_2$ 6 H_2O and deionized water. To make the solution: (1) weigh out the required amount of cobalt chloride hexahydrate (2) Dissolve the salt is about 15 mL of water in your graduated cylinder (3) Add water to the graduated cylinder until the volume of solution is 25 mL. Verify the absorbance by measurement.

Data Summary

Part I.

Standard	Absorbance
0.03	
0.06	
0.09	
0.15	

Part II.

Absorbance of diluted unknown _____

Concentration of unknown _____

Part III.A.

Absorbance corresponding to 38% transmittance _____

Concentration of solution _____

Measured transmittance _____

Part III.B.

Concentration of diluted unknown _____

Absorbance of diluted unknown _____

Part III.C.

Concentration of solution _____

Mass to prepare 25 mL of solution _____

Measured absorbance of solution _____