Effects of concentration on the absorbance values

Abstract:

A 0. 2100 M stock solution of cobalt (II) chloride hexahydrate was analyzed using UV-Vis spectroscopy. A series of dilutions of the stock solution were made to analyze the effects of concentration on the absorbance values of cobalt (II) chloride hexahydrate using the UV-Vis spectrophotometer. The copper (II) chloride hexahydrate was found to have the highest absorbance value at an average wavelength of 511. 02 nm. The average molar extinction coefficient for copper (II) chloride hexahydrate was found to be 4. 5172. Spectroscopic analyses of dilutions of the stock solution were used to create a calibration curve of absorbance versus concentration of the cobalt chloride hexahydrate solution. A solution of unknown concentration was analyzed using the UV-Vis spectrophotometer. The calibration curve was used to determine that the unknown had a concentration of 0. 1250 M.

Introduction:

Ultraviolet/Visible (UV-Vis) spectroscopy analyzes electronic transitions between atoms and molecules. Spectra are produced when electrons in molecules or atoms move from one electronic energy level to another of higher energy. In doing so, the absorbed energy is equal to the difference between to the two levels. Compounds that absorb light in the visible region are colored . Compounds that absorb light only in the ultraviolet region are colorless .

Inside a UV-Vis spectrophotometer there are usually two light sources, a tungsten lamp for the visible region (380-800 nm) and a deuterium lamp for the ultraviolet region (10-380 nm). The light source produces a white light

ray which contains all wavelengths (all colors). The light ray directed to a monochromator by a mirror. The monochromator is used to separate light into specific wavelengths. Each wavelength corresponds to a different color . The instrument scans through the UV-Vis spectrum, sending different wavelengths of light through the sample. A single wavelength passes into the modulator, which consist of a rotor with mirrors that splits the light into two beams. One beam passes through the sample cell, while the other passes through the reference cell. Both sample and reference beams are redirected by mirrors into a detector. The detector compares their intensities of the two beams and sends a signal to the computer that controls the instrument. The signal is defined as absorbance, which is a measurement of how much light is being absorbed by the sample at that particular wavelength.

The Beer-Lambert law states that absorbance (A) is proportional to concentration of the absorbing species and path length of the medium over a certain time:

In equation 1, is the molar extinction coefficient and has units of, the path length of the medium or L, is reassured in centimeters or cm and the concentration of the absorbing species has units of molarity or M.

In this experiment a solution of cobalt (II) chloride hexahydrate was analyzed using UV-Vis absorption spectroscopy. The purpose of this experiment is to create a calibration curve of absorbance versus concentration by making series of dilutions of cobalt (II) chloride hexahydrate. The calibration curve will then be used to determine the concentration of an unknown sample. The

molar extinction coefficient for cobalt (II) chloride hexahydrate will also be determined using the absorption at the concentrations of each dilution.

Experimental Procedure:

Using the analytical balance, 2. 5072 g of cobalt (II) chloride hexahydrate were weighed and placed into a 50 mL beaker. The purple solid was dissolved inside the beaker using 15 mL of distilled water. The purple liquid was then transferred to a 50 mL volumetric flask with the aid of a funnel. The beaker was then rinsed with another 15 mL portion of distilled water to collect any remaining cobalt (II) chloride hexahydrate left behind and then was transferred to the 50 mL volumetric flask using the same funnel. Additional 20 mL of distilled water were added to the 50 mL volumetric flask to create the stock solution of cobalt (II) chloride hexahydrate.

Dilutions of the stock solution were made by transferring 2, 4, 6 and 8 mL of the stock solutions to four labeled 10 mL volumetric flasks. Distilled water was added to fill each flask to the line.

The absorbance for each solution was calculated using spectrophotometer . Before any samples were analyzed , a sample containing just water was used to blank the instrument. A quartz cuvette was filled with distilled water and covered. The blank sample was placed in the sample holder in the back of the spectrophotometer. Using the program, the spectrophotometer parameters were set to scan the sample from 650 nm to3 90 nm. The program was also designed to automatically let the user know which sample to place next into the sample holder.

After the blank sample was analyzed , the cuvette was rinsed with distilled water first and then with a small portion of the stock solution. The cuvette was then filled with a portion of the stock solution, covered and analyzed using the spectrophotometer. This procedure was repeated for all dilutions. After each analysis, the cuvette was first rinsed with distilled water and then rinsed with a small portion of the following sample.

Results:

In order to analyze the sample using the spectrophotometer, the compound needs to be present in the aqueous form. The copper (II) chloride hexahydrate appeared purple as a solid. After the 2. 507 grams of copper (II) chloride hexahydrate were dissolved in 50 mL of distilled water, the compound's color changed from a dark purple to a pink colored solution.

The concentration of the copper (II) chloride hexahydrate stock solution was found using the molecular weight of the compound, the amount of compound used and the amount of distilled water used to dissolve it. Table #1 shows the how the concentration of the copper (II) chloride hexahydrate stock solution was found.

When the dilutions were made by taking 8, 6, 4 and 2 mL of the stock solution, the concentration of each dilution decreased proportionally to the amount of stock being added. The intensity of the pink color of each dilution also decreased as the amount of milliliters of distilled water increased. Table # 2 shows how the concentration for each dilution of the stock solution was calculated.

The software was programmed to analyze the solutions in the following order, the blank sample, the stock solution (0. 2100 M), the 0. 1680 M dilution, the 0. 1260 M dilution, the 0. 0840 M dilution and 0. 0420 M dilution. All samples were analyzed in the spectrophotometer, by using quartz cuvettes. The blank sample had no visual results as expected. When the 0. 2100 M stock solution was analyzed by the spectrophotometer, the computer's monitor displayed the formation of a graph starting at 650. 00 nm on the x-axis and 0. 00 Absorbance on the y-axis. After the graph passed 580. 00 nm, the graph's absorbance values started to increase exponentially. The maximum absorbance value was recorded at 0. 9993 and it occurred at maximum wavelength of 511. 34 nm. After the was passed, the graph's absorbance values started to exponentially decreased until the graph reached 420. 00 nm, after 420. 00 nm the graphs absorbance values displayed a slightly constant pattern until the end of the graph at 380. 00 nm.

Similar results were observed for all the dilutions. The 0. 16800 M dilution analysis showed a maximum wavelength of 510. 92 nm and a maximum absorbance value of 0. 7266. The 0. 12600 M dilution analysis showed a maximum wavelength of 511. 11 nm and a maximum absorbance value of 0. 5703. The 0. 0840 M dilution analysis showed a maximum wavelength of 510. 98 nm and a maximum absorbance value of 0. 4024. The 0. 0420 M dilution analysis showed a maximum wavelength 510. 75 nm and a maximum absorbance value of 0. 1758. Table # 3 summarizes all the maximum wavelengths and absorbance values for the stock solutions and all

its dilutions. Figure # 1 (appendix-pg 14) illustrates the graph for each solution.

Using the data from table # 3, a calibration curve of absorbance versus concentration can be created. Figure # 2, the calibration curve can be found in the appendix section, page 13.

The molar extinction coefficient for copper (II) chloride hexahydrate can be found using data found in Table # 3 and the Beer-Lambert law. By algebraically manipulating the Beer-Lambert equation ($A = \varepsilon * L * c$), the molar extinction coefficient (ε) for copper (II) chloride hexahydrate can be determined by: $\varepsilon = A / L * c$. The molar extinction coefficient for all the solutions can be found in Table # 4. The average molar extinction coefficient for copper (II) chloride hexahydrate was found to be 30445.

A solution of unknown concentration was analyzed using the spectrophotometer following the same procedure as all other solutions. The solution of unknown concentration was found to have a maximum wavelength of 511. 49 nm and a maximum absorbance value of 0. 5715. The concentration of the unknown sample was determined using the equation of the line found on the calibration curve (page 13-Appendix). The unknown's absorbance value of 0. 5715 was used as the y -value and the equation was solved for its correspondent x-value or concentration. The unknown's concentration was found to be 0. 80 M. Table # 5 shows how the equation of the line from the calibration curve was used to determine the concentration of the unknown. Figure # 3 in the appendix section-pg 14, is a graph of all the solutions tested. In figure # 3, the unknown is easier to identify because

the graph is in a landscape format and the x-axis increases by a factor of 20 nm as opposed to a factor of 50 nm in Figure # 1.

Conclusion:

The spectroscopic analysis of copper (II) chloride hexahydrate made the students familiar with operating a spectrophotometer. Dilutions to a stock solution of copper (II) chloride hexahydrate were made to examine how different concentrations of the compound affected the absorbance values of each sample. The copper (II) chloride hexahydrate was found to have the highest absorbance value at an average wavelength of 511. 02 nm. A calibration curve for the concentration versus absorbance of copper (II) chloride hexahydrate was created using the data obtained from stock solution and dilutions using the spectrophotometer. A unknown sample was found to have a concentration of 0. 1250 M. The concentration of the unknown was determined by using the calibration curve along with the data obtained from the spectrophotometer. The average molar extinction coefficient for copper (II) chloride hexahydrate was found to be 4. 5172. The value for the molar extinction coefficient was determined using the theory behind Beer-Lambert law and maximum absorbance values from the spectrophotometer.

Discussion

A different approach to determine the concentration of the unknown involves using the average molar extinction coefficient for copper (II) chloride hexahydrate found in table # 4. By algebraically manipulating the Beer-Lambert equation a formula for concentration can be derived: c =

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