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Beer's Law: Determining the Concentration of $CoCl_2$ Solution

Purpose

The purpose of this experiment is to determine the concentration of an unknown cobalt (II) chloride, $CoCl_2$, solution.

Safety

Splashing of cobalt (requires safety goggles, long pants, and close-toed shoes)

Procedure	Observations
1. Obtain small volumes of 0.20 M CoCl2 solution and distilled water in separate beakers.	This is the set-up for creating the solutions needed.
2. Label five clean, dry, test tubes 1–5. Use pipets to prepare four standard solutions with a 0.1M $CoCl_2$ solution. Start with 2mL of $CoCl_2$, and increase by 2mL for each tube. Except for the 5th tube, fill to the 10mL line with DI water.	As the volume of $CoCl_2$ in each test tube increased, the pink/red color got progressively darker. In other words, the more diluted the cobalt solution, the lighter and clearer the color.
3. Prepare a blank cuvette by filling it ¾ full with DI water. Seal the cuvette with a lid. Fill the remaining 5 cuvettes with the diluted solution from the test tubes, keeping track of which cuvette holds which test tube's solution.	The blank cuvette will be used to calibrate the colorimeter. When the blank cuvette is inserted into the colorimeter, the absorption should be 0.
4. Calibrate the calorimeter with the blank cuvette, making sure the outside of the cuvette is dry.	The colorimeter was set to 470 nm.
5. Wipe the outside of the cuvette holding solution from test tube #1, and place the cuvette into the cuvette holder. Collect the absorption data, and repeat this step for the remaining $CoCl_2$ solutions inside each cuvette.	The more $CoCl_2$ in the test tube (and thus the cuvette), the higher the absorption of the solution. The absorption value seemed to waver between a few different consecutive values, not completely settling on one.
6. Calculate the concentration of each diluted $CoCl_2$ solution. Plot this data on a graph, with the x-axis being concentration (M) and the y-axis being absorption. Create a line of best fit and determine the equation of the line. If the R^2 value is greater than 0.95, this equation can be used to find the	The concentrations tested increase linearly, with a 0.02M difference between each solution.

concentration of the unknown $CoCl_2$ solution.

7.	Pipette the solution of unknown concentration into a cuvette, and repeat step 5 for this cuvette. Plug in the absorption value for the unknown concentration into the linear equation for *y*, and determine *x*. This is the concentration (M) for the solution.	The higher the R^2 value of the linear equation, the more accurate the concentration of the mystery solution will be.

Results & Calculations

Concentration (M)	Absorption
0.02	0.041
0.04	0.115
0.06	0.153
0.08	0.228
0.10	0.287

Fig. 1: Table of the absorption of solutions with different $CoCl_2$ concentrations.

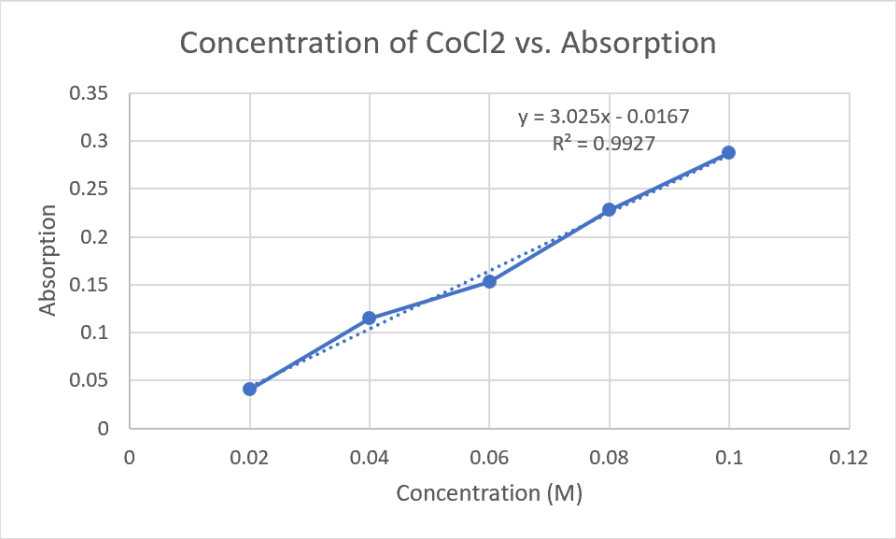

Fig. 2: Graph of table in Fig. 1—concentration of $CoCl_2$ solution vs. the absorption of the solution.

Calculations for concentrations in table:

$$\mathbf{0.1M \times 0.002L = m_2 \times 0.01L.} \qquad \boldsymbol{m_2 = 0.02M}$$

$$\mathbf{0.1M \times 0.004L = m_2 \times 0.01L.} \qquad \boldsymbol{m_2 = 0.04M}$$

$$\mathbf{0.1M \times 0.006L = m_2 \times 0.01L.} \qquad \boldsymbol{m_2 = 0.06M}$$

$$\mathbf{0.1M \times 0.008L = m_2 \times 0.01L.} \qquad \boldsymbol{m_2 = 0.08M}$$

Calculations for mystery solution:

$$\mathbf{0.193\ absorption = 3.025x - 0.0167}$$

$$\boldsymbol{x = 0.0693M}$$

Calculations for Cooperative Farms Inc:

$$\boldsymbol{m_1v_1 = m_2v_2}$$

$$\boldsymbol{m \times (10{,}000L) = (0.0693 mol/L) \times (1L)}$$

$$\boldsymbol{m = \frac{0.0693 mol}{10{,}000L} = 0.00000693M}$$

$$\boldsymbol{\frac{0.00000693 mol}{1L} \times \frac{1L}{1} = 0.00000693 mol}$$

$$\boldsymbol{0.00000693 mol \times \frac{58.93 g}{1 mol} = 0.0004083 g}$$

$$\boldsymbol{0.0004083 g \times \frac{1000 mg}{1 g} = 0.4083849 mg}$$

$$\boldsymbol{\frac{0.4083849 mg\ Co(II)}{40 kg} = 0.0102\ mg/kg}$$

$$\boldsymbol{0.0102\ mg/kg < 0.13\ mg/kg}$$

Discussion & Conclusion

The concentration of each diluted $CoCl_2$ solution was calculated by using the equation $m_1v_1=m_2v_2$. These concentrations were graphed with their corresponding absorptions (Fig. 2), and the equation of the best fit line was used to calculate the molarity of the mystery solution: 0.0693 mol/L. This result means that there are 0.0693 moles of $CoCl_2$ in one liter of diluted $CoCl_2$ solution. Furthermore, this concentration was used to calculate the amount of mg of cobalt (II) per kg of soil, which was determined to be 0.0102 mg/kg. Because the acceptable range of cobalt (II) in soil is between 0.13 – 0.30 mg/kg, there is not enough cobalt (II) in the soil for the cows. Cooperative Farms Inc. needs to add more cobalt (II) to the soil to ensure the cows are healthy.

Without any theoretical value for the concentration of the mystery solution, the percent error of the measured concentration or the calculations regarding cobalt (II) in soil cannot be determined. However, the R^2 value obtained, 0.9927, is greater than 0.95. Such a high R^2 value indicates that the data collected was precise. Consequently, the dilutions of $CoCl_2$ were performed precisely as well.

Potential sources of error include a potential slightly inaccurate reading on the colorimeter. Even with proper calibration, the colorimeter's absorption values wavered between 2-3 consecutive values, without settling on one exact value. Thus, this small inaccuracy could change the equation of the best fit line in the graph of concentration vs. absorption, and thus calculations regarding concentration of the mystery solution and the amount of cobalt (II) in the soil.

If this experiment were to be repeated in the future, multiple dilutions for each concentration of $CoCl_2$ could be performed, so that multiple absorption values would be recorded for the same concentration. By comparing these absorption values, the precision of the measurements can be measured, and the numbers can be averaged to collect a more accurate result.