Mass Percent of Copper in Brass Lab

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Introduction

Much of what we know about the structure of atoms has been obtained by studying the interaction between atoms and light, or electromagnetic radiation, and this interaction allows us to observe information about an atom. This is called spectroscopy. There are many types of spectroscopy, including mass spectrometry, ultraviolet-visible spectroscopy, infrared spectroscopy, and nuclear magnetic resonance spectroscopy, with each type allowing scientists to glean different information (Organic Chemistry). In this lab, you will be using ultraviolet-visible spectroscopy. All matter absorbs and reflects certain frequencies of light. Absorbance is the specific amount of light that is absorbed by a sample, which in this lab is liquid Copper II Nitrate. Using a spectrometer, or in this lab, a colorimeter, one can observe the absorbance of a certain wavelength of light in a solution (Reusch, 2013).

This absorbance can be implemented into Beer-Lamberts law that relates molar absorptivity (a ratio of absorbance to molarity of a solution), the absorbance of a solution, and the concentration of the solution, which is shown below (Helmenstine, 2013).

\[ A = \varepsilon bc \]

A is the measured absorbance, \( \varepsilon \) is the molar absorptivity (with unit M\(^{-1}\) cm\(^{-1}\)), b is the path length of light through the sample (or in this lab the length of the cuvette, 1cm) and c is the concentration or molarity (Tissue, 2000). This law when rearranged to solve for \( \varepsilon \) as shown below:

\[ \frac{A}{bc} = \varepsilon \]
shows a direct proportion between absorbance and concentration (b can be ignored because in this case it is equal to 1cm). This proportion allows us to solve absorbance/concentration of other solutions of the same composition using:

\[ M_1V_1 = M_2V_2 \]

Where \( M_1 \) is the concentration of the original solution, \( V_1 \) is the volume (in mL) of the solution, \( M_2 \) is the concentration of the second solution, and \( V_2 \) is the volume of the second solution.

**Purpose**

In this lab, you will determine the mass percent of copper in a sample of brass using the relation between absorbance and concentration.

**Methods**

1. Obtain 5.20 grams of the sample of brass and 13.8 mL of Nitric acid (HNO₃)
2. UNDER A FUME HOOD, put the sample of brass in one 250 mL volumetric flask and add the Nitric acid. CAUTION- The reaction creates extremely poisonous fumes, so make sure the hood is functional and not inhale any of the fumes. The reaction is written:

\[
3\text{Cu(s) + 8 HNO}_3(\text{aq}) \rightarrow 3\text{Cu(NO}_3)_2(\text{aq}) + 2\text{ NO(g) + 4 H}_2\text{O(l)}
\]

where “Cu” is substituted for “brass” as a reactant in order to solve for the actual percent of copper in brass later.
3. After the reaction has occurred (when the brass screws are completely dissolved), you should be left with a solution of Cu(NO₃)₂. Add 50 mL of distilled water.
4. Remove the volumetric flask. Rinse the beaker with 5mL of distilled water and add this washing to the flask. Fill the flask to 250 mL with distilled water. Note: this solution will be referred to as the “unknown”. It is Copper II Nitrate. By now, there should be 250 mL of the “unknown” solution.

5. Obtain 25 mL of the .4 M solution of Cu(NO$_3$)$_2$ and 50 mL of distilled water.

6. Calibrate the colorimeter by using a pipette and filling one cuvette 75% full with water and placing the cuvette in the colorimeter. The absorbance should be 0.00. (Note: the colorimeter should be set at 635 nm because of the blue color of the Cu(NO$_3$)$_2$ solution)

7. Obtain 7 more cuvettes and 6 Erlenmeyer flasks. Using the .4 M solution of Cu(NO$_3$)$_2$, create the following 6 dilutions of Cu(NO$_3$)$_2$ solution/ distilled water: 5 mL/0 mL, 4 mL/1 mL, 3 mL/2mL, 2 mL/3 mL, 1 mL/4 mL, and 0 mL/5 mL. (Note: The first volume denotes the amount of Cu(NO$_3$)$_2$ solution and the second denotes the amount of distilled water in each dilution.

8. Fill 6 of the cuvettes about 75% with each of the different dilutions of Cu(NO$_3$)$_2$ solution using 6 different pipettes. Place each dilution in the colorimeter and record the absorbance of each. In addition, find the absorbance of the unknown by filling a 7th cuvette 75% of the unknown and placing it in the colorimeter. Record this data.

9. Find the concentration of each of the dilutions using the formula: $M_1V_1 = M_2V_2$. Of course, this is not applicable to the unknown. (Note: The first dilution is essentially only .4 M Cu(NO$_3$)$_2$ solution; this information can be used in the equation to calculate the concentrations of the other dilutions.)

10. Once you have created a chart with the absorbance and the concentration of each dilution, create a graph of concentration vs. absorbance.
11. Find the equation of the trend line of the graph. Make sure the correlation of this trend line (R^2) is above .95. (This and the previous step can be done on Excel.)

12. Since the independent variable, x, is concentration, and the dependent variable, y, is absorbance, insert the absorbance of the unknown into the equation of the trend line as y and solve for x, the concentration of the unknown.

13. Using this concentration of the unknown solution of Cu(NO_3)_2, find the moles of Cu(NO_3)_2 in this solution. Then, determine the moles of copper in the unknown solution of Cu(NO_3)_2. Convert this value to grams of copper using the molar mass of copper. This gram amount is the amount of copper in the 5.20 g sample of brass.

14. To find the mass percent of copper in the original sample of brass, divide the amount of copper by the amount of brass originally used (5.20 g) and multiply by 100. This should be the mass percent of copper in the sample of brass.

Data

Table 1- Absorbance and Concentration of Solutions of Cu(NO_3)_2

<table>
<thead>
<tr>
<th>Dilution (mL of Cu(NO_3)_2 / mL of H_2O)</th>
<th>Absorbance</th>
<th>Concentration (Molarity/M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5mL/0mL</td>
<td>0.878</td>
<td>0.4 M</td>
</tr>
<tr>
<td>4mL/1mL</td>
<td>0.649</td>
<td>0.32 M</td>
</tr>
<tr>
<td>3mL/2mL</td>
<td>0.528</td>
<td>0.24 M</td>
</tr>
<tr>
<td>2mL/3mL</td>
<td>0.387</td>
<td>0.16 M</td>
</tr>
<tr>
<td>1mL/4mL</td>
<td>0.186</td>
<td>0.08 M</td>
</tr>
<tr>
<td>0mL/5mL</td>
<td>0.000</td>
<td>0.00 M</td>
</tr>
<tr>
<td>Unknown</td>
<td>.437</td>
<td>(?</td>
</tr>
</tbody>
</table>

(.199 M when calculated)
Calculations

- Concentrations of Dilutions: (Known information: Concentration of 5 mL/ 0 mL = .4 M)
  - Using $M_1V_1 = M_2V_2$:
    - 4 mL/ 1 mL: $(.4\ M)(4\ mL) = (?\ M)(5\ mL)$; $\frac{(4\ M)(4\ mL)}{5\ mL} = ?\ M = .32\ M$
    - 3 mL/ 2 mL: $(.4\ M)(3\ mL) = (?\ M)(5\ mL)$; $\frac{(4\ M)(3\ mL)}{5\ mL} = ?\ M = .24\ M$
    - 2 mL/ 3 mL: $(.4\ M)(2\ mL) = (?\ M)(5\ mL)$; $\frac{(4\ M)(2\ mL)}{5\ mL} = ?\ M = .16\ M$
    - 1 mL/ 4 mL: $(.4\ M)(1\ mL) = (?\ M)(5\ mL)$; $\frac{(4\ M)(1\ mL)}{5\ mL} = ?\ M = .08\ M$
    - 0 mL/ 5 mL: $(.4\ M)(0\ mL) = (?\ M)(5\ mL)$; $\frac{(4\ M)(0\ mL)}{5\ mL} = ?\ M = .00\ M$
Equation/ Correlation ($R^2$) of Trend Line (Found in Excel)

- $y = 2.1168x + 0.0161$
- $R^2 = 0.9925$

Concentration of “unknown” solution of Cu(NO$_2$)$_3$

- Using above trend line
  - $y = \text{absorbance of unknown solution} = .437$
  - $x = M \text{ of unknown solution} = ?$
  - $x \times 2.1168 + 0.0161 = .437$
  - $x = \frac{.437 - 0.0161}{2.1168}$
  - $x = ? = .199 M$

Grams of Copper in Original Sample of Brass

- $g \text{ of Cu} = ?$
  - $\frac{.199 \text{ mol Cu(NO}_2\text{)}_3}{1 \text{ L}} \times \frac{250 \text{ L}}{1 \text{ mol Cu(NO}_2\text{)}_3} = .04975 \text{ mol Cu(NO}_2\text{)}_3$
  - $\times .04975 \text{ mol Cu(NO}_2\text{)}_3 \times \frac{1 \text{ mol Cu}}{1 \text{ mol Cu(NO}_2\text{)}_3} = .04975 \text{ mol Cu}$
  - $\times .04975 \text{ Cu(NO}_2\text{)}_3 \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} = 3.161 \text{ g Cu}$
  - $g \text{ of Cu} = ? = 3.161 \text{ g Cu}$

Mass Percent of Copper in Original Sample of Brass

- $\frac{3.161 \text{ g Cu}}{5.29 \text{ g of brass}} \times 100 = 60.7 \% \text{ of Cu}$
Analysis/Discussion

The mass percent of copper I found to be in the original sample of brass was 60.7% copper. This was obtained using several processes. First, in order to confirm only the copper was being measured from the 5.20 g sample of brass, I had to react the brass with Nitric acid to create Copper II Nitrate. This Cu(NO₃)₂ had an unknown concentration, and to find this value, I had to use a known .4 molar solution of Cu(NO₃)₂. I made several dilutions of this known Cu(NO₃)₂ and measured their absorbance, as well as the absorbance of the unknown (Table 1). Given the proportional relationship between absorbance and concentration, and the fact that the 5 mL/0 mL dilution of Cu(NO₃)₂ was a known .4 M, I was able to use \( M_1 V_1 = M_2 V_2 \). To utilize this information, I had to understand that, to obtain the concentration of the 4 mL/1 mL dilution, \( M_1 \) was .4 (for the 5/0 dilution), and the volume of this .4 solution in the second dilution was 4 mL. Therefore, \( M_2 \) was unknown, and the total amount of the second dilution was 5 mL. From there, I simply had to solve for \( M_2 \) to obtain the concentration of the 4 mL/1 mL dilution. This same principle could be applied to all the rest of the dilutions until I had obtained the concentration of all 6 dilutions (Table 1). Then, using this data, I could construct a graph of concentration vs. absorbance of the dilutions of Cu(NO₃)₂ (Figure 1), and find the line of best fit for this graph. Using this best fit line and the absorbance of the unknown, I could then solve for the concentration of the unknown, as both the unknown and the dilutions were solutions of Cu(NO₃)₂. I found the concentration of Cu(NO₃)₂ in the unknown solution to be .199 M. I could then find the moles of Cu(NO₃)₂ in the solution of .199 M Cu(NO₃)₂ by multiplying .199 M by .250 L (amount of unknown), as the unit for molarity is nothing more than mol/L. The obtained moles was .04975 mol Cu(NO₃)₂. Using this data, I could convert this value into moles of copper (using the 1 to 1 molar ratio of Cu(NO₃)₂ to Cu) and then therefore obtain the grams of copper.
by multiplying the moles of copper (0.04975 mol Cu) by the gram to mole ratio of copper (63.55 g/mol). Finally, I took this value, 3.161 g Cu, and divided it by the original amount of brass (5.20 g) and multiplied by 100. I found this value, the mass percent of copper in the brass sample, to be 60.7% Cu, meaning that in the original sample of brass, 60.7% of the brass was made of copper.

While my findings are all calculated correctly, there may be some experimental errors on account of myself and my lab partners. However, the mass percent obtained is completely sound when compared to the collected data and calculations.

**Conclusion**

After the full lab procedure and appropriate calculations, the mass percent of copper in the original sample of brass was found to be 60.7% Cu.
References


