Lab #7: Spectrophotometric Determination of Copper in the USA Coins

*** This experiment is to be done as a group. The report however is an individual effort and is a formal report***

Objectives:
At the end of this experiment you should be able to:
● Draw conclusions about the amount of copper used to produce of USA coins.
● Use a standard curve to determine the concentration of an analyte (i.e., copper) in various samples and express the results appropriately
● Calculate and report the copper in a coin (i.e., penny) in terms of:
  ❖ grams of copper per gram of a coin
  ❖ % copper in a USA penny
  ❖ Is the copper in a coin really worth its face value
● Understand the concepts of spectrophotometry and the Beer - Lambert Law.

Prelab Exercise:
Before coming to lab you must do the following:
➢ Read and understand the experiment and its background.
➢ Prepare a flow chart for the lab analysis.
➢ Calculate the mass of cupric nitrate trihydrate, Cu(NO₃)₂·3 H₂O, (molar mass 241.65) required to prepare the standard solutions.

Table 1. Safety notes for Lab 7: Copper Lab

<table>
<thead>
<tr>
<th>SAFETY NOTES</th>
<th>CHEMICALS</th>
<th>HAZARD</th>
<th>PRECAUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Copper (II) nitrate trihydrate</td>
<td>Danger! Strong oxidizer. Irritant to skin, eyes and respiratory tract.</td>
<td>Do not mix with strong reducing agents, or combustible materials. Avoid contact with skin. Wash hands well after use.</td>
</tr>
<tr>
<td></td>
<td>Nitric acid</td>
<td>Danger! Corrosive. Causes eye and skin burns. Toxic</td>
<td>Avoid contact with skin. Wash hands well after use.</td>
</tr>
<tr>
<td>DISPOSAL</td>
<td>Dispose of all solutions into the waste containers provided.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Introduction:**

Solutions of many compounds appear coloured to the human eye. The colour is characteristic of a specific compound in a particular solvent (e.g. aqueous copper nitrate solutions appear blue while aqueous solutions of cobalt chloride are pink). The colour that we see is a result of the solution absorbing some wavelengths (absorbed colour) with the rest being reflected back to us, we then see the complimentary colour (colour opposite it on a colour wheel). For example, copper nitrate solutions absorb light at a wavelength of about 600nm. The perceived colour is therefore blue (complimentary to the orange light absorbed).

We already know that an aqueous solution of copper nitrate appears blue. A dilute solution will appear a faint blue color; a more concentrated copper nitrate solution will be perceived as a darker, more intense, blue colour. This is because the more concentrated solution absorbs more light (around 600nm). This is, in fact, the basis of the Beer-Lambert law that you will use in this experiment (see below).

**Spectrophotometry** is one analytical technique used to give the lab analyst qualitative information (what compound is present) and quantitative information (how much compound is present). Spectrophotometry uses the spectrum (spectrophotometry) of light (spectrophotometry) by measuring (spectrophotometry) the type and amount of light absorbed by a compound in solution. The **actual wavelength** of light that is absorbed provides qualitative information; the **amount of light** at that wavelength, also known as the **intensity** of light absorption, is the basis for quantitative information.

Spectrophotometry is not used exclusively by chemists, but is a lab technique used widely by biologists, biotechnologists, gene jockeys, and many other scientists. To understand spectrophotometry one must usually think in terms of the intensity of light at the wavelength that is absorbed by the analyte. The intensity of the light that hits the sample is given by $I_0$ (which is **incident** on the sample). Some of the intensity of this light will be absorbed by the solution decreasing $I_0$ to $I$ (**$I$ represents the light that is transmitted through the sample**) without being absorbed.

![Fig. 1 Transmission of light through a solution](image)
These 2 terms ($I_0$ and $I$) are used to give % Transmittance ($%T$) using the following equation

$$%T = \frac{I}{I_0} \times 100\%$$

N.B. In all cases $I \leq I_0$.

Although some older instruments measure $%T$, most modern instruments instead use absorbance ($A$). Absorbance is the amount of light that is absorbed by the sample. Absorbance is related to $%T$ in the following way:

$$A = 2 - \log_{10} %T$$

The quantitative aspect of spectrophotometry is based on two laws: the Beer Law and the Lambert Law. The **Beer Law** states that there is a linear relationship between the absorbance of a solution and the concentration of that solution (within a range of 0-0.8 absorbance units). This relationship between concentration and absorbance is the basis for the linear standard curves that analysts use in spectrophotometric analyses.

The **Lambert Law** states that the absorbance increases with increasing distance that the light travels through the solution. Often this distance, or optical path, is kept constant by using a 1 cm cuvette to hold the sample solution.

Often scientists will combine these two laws and refer to them as the Beer-Lambert Law. The **Beer-Lambert Law** which states that the amount of light absorbed by a solution is directly proportional to the concentration of the absorbing material present in the solution and the length of the optical path through the solution.

The **Beer-Lambert Law** is written:

$$A = \varepsilon bc$$

Where, $A$ = Absorbance, $b$ = optical path length (usually 1 cm), $c$ = concentration of the compound (moles/L), and $\varepsilon$ = Molar absorptivity coefficient (a constant for each specific analyte that is related to the chemical and physical nature of the compound which allow it to absorb light).

As stated previously, this Beer-Lambert Law allows analysts to develop and use a linear standard curve. The plot of concentration (x-axis) vs absorbance (y-axis) is one type of **standard curve** (see Fig. 2, below). Standard curves are used to show the relationship (often linear) between an independent variable (i.e., concentration) and a dependent variable (i.e., absorbance). Standard curves are frequently used to determine the concentration of unknowns in science.
Fig. 2 Diagrammatic representation of a typical standard curve

**Procedure:**
Today you will work in groups of 4-6 students. Each group will do the following experiment.

1. **Preparation of Standards:**
As part of your prelab exercise, you have calculated the amount of cupric nitrate trihydrate required to prepare 100mL of each of the following copper standards. **NOTE:** The standards are to be prepared in terms of Cu. Remember that copper is only a portion of the copper nitrate. One way to do this would be to use the factor label method comparing Cu with cupric nitrate trihydrate OR you could first calculate the percentage of copper in cupric nitrate trihydrate and then use this to calculate the mass required to prepare the blank and standards in each case.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Concentration (g Cu/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>0</td>
</tr>
<tr>
<td>Standard #1</td>
<td>0.00157</td>
</tr>
<tr>
<td>Standard #2</td>
<td>0.00314</td>
</tr>
<tr>
<td>Standard #3</td>
<td>0.00953</td>
</tr>
<tr>
<td>Standard #4</td>
<td>0.0191</td>
</tr>
</tbody>
</table>

Using a 3-decimal place balance, obtain the appropriate amount of cupric nitrate trihydrate for each of the standards. Quantitatively transfer each to a separate 100mL volumetric flask and add approx. 50mL of distilled water. Using a re-pipette, CAREFULLY add 20mL of concentrated nitric acid slowly to the water and copper nitrate in the flask. Swirl to mix and cool. Use distilled water to carefully bring to volume; mix by inversion. (Each standard solution contain 20% (v/v) nitric acid which keeps the matrix of the standards the same as the sample solutions. Why do you think that this is important?)

2. **Preparation of Samples:**
Select 6 coins from those provided. Record the mass and date of issue of each coin. Place each coin in a separate 125mL Erlenmeyer flask. In the *fume hood*, add to the Erlenmeyer concentrated nitric acid from the re-pipette. Your Lab Instructor will guide you by suggesting an appropriate amount of nitric acid to achieve a complete reaction and dissolution of the metal in
the coin. You should leave your labelled Erlenmeyer flasks in the fume hood until the coin has completely dissolved as there will be **significant amounts of brown fumes evolved**. What are the brown fumes being given off? Do you have an idea about what is going on during this process? Write and equation and/or explain. Once the coins have completely dissolved prepare the samples according to the following directions.

The next step is to make the sample solution up to volume. **NOTE:** Once again, the Lab Instructor will suggest a suitable size of volumetric flask based upon the coins you have selected. **Remember to have some water in the volumetric flask BEFORE your transfer the sample** since the sample was dissolved in **concentrated acid**.

**Always add acid to water, never the other way around.**

For each sample, individually - quantitatively transfer the sample to a volumetric flask and make up to volume.

Read all the samples and the standards on the spectrophotometer at a wavelength of 620nm.

*Please ask the Lab Instructor for instructions on the proper use of the instrument.*

3: **Analysis of Data Collected:**

From the standards prepare a standard curve by plotting absorbance (y-axis) vs concentration of copper in g/mL (x-axis). Use Excel, Minitab or some other suitable computer software to prepare your curve. Include the equation of the line and your $R^2$ value on the curve. **Prior to leaving lab check with your Instructor that your standard curve meets the minimum requirements.** ($R^2$ value greater than 0.98)

From your standard curve, determine the concentration of copper in the coins (use the equation of the line to calculate this value). Remember that different masses (and perhaps different final volumes) were used for each sample. You must take these into consideration when calculating the concentration of copper in the individual samples.

Report your findings in the following ways

a) **grams of copper/gram of coin** for each coin,

b) **% copper in each coin**

c) **For each coin, calculate the value of the copper and state whether or not the coin is worth its face value with respect to the copper content only.**

Remember this is a formal report so all raw and calculated data must be included in the results section (masses, volumes, absorbance values etc.). Comment on the composition of American coins. Is this analysis for copper content precise?

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