Determination of Weight Percentage of Copper in Penny using Ordinary Linear Calibration and Standard Addition Methods by Atomic Absorption Spectrometry

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*Performed September 28, 2020; submitted October 4, 2020.*

**Abstract**: The weight percentage of a copper coin was found by dissolving a copper coin in 10 mL of HCl and 15 mL HNO3. Then, this solution was diluted to 100 mL with ionized water. Furthermore, a stock solution of 100 ppm Cu2+ was prepared with Cu(NO3)2**·**3H2O, with the two solutions to be used in two methods, Ordinary Linear Calibration and Standard Addition. In the former method, the stock solution was used to prepare solutions of 1.00, 2.00, 3.00, 5.00, and 8.00 ppm Cu2+, which were aspirated to form a linear absorption calibration plot. Then, a diluted sample of the dissolved penny was aspirated to plot on the linear regression to determine the concentration of the penny solution. In the latter method, a small sample of the dissolved penny solution was added to four beakers, to which increasing amounts of stock solution were added. After aspirating each solution, a linear regression on the absorption plot was recovered, and the initial concentration of the penny solution was calculated. The weight percentage of copper in penny was measured to be 1.42% and 1.47% in the two methods, respectively.

**Introduction**

Atomic Absorption Spectrometry (AAS) is a common method used to determine the concentration of certain substances in solid, liquid, or gaseous form, most commonly used to find the concentration of ions in solution. AAS is carried out by aspirating a solution through a flame and measuring the absorption of certain wavelengths caused by the excitation of molecules when burned. Each ion has a certain wavelength, so filtering out other wavelengths with a monochromator allows for the measurement of the absorption corresponding to only the desired ion. Thus, by measuring increasing absorption with increasing concentration, the unknown concentration of certain ions in solution can be determined.

Two methods using AAS to determine concentration of an ion are Ordinary Linear Calibration and Standard Addition. In Ordinary Linear Calibration, calibration solutions of known concentration are prepared to create a linear calibration curve on an absorption plot. Then, by aspirating the unknown solution and measuring the absorption, the concentration can be interpolated using the regression equation. The second method, Standard Addition, takes advantage of a linear increase in absorption as known concentrations of solution are added to an unknown. By adding different amounts of known concentration solution, a similar calibration curve can be plotted, however, with the y-intercept of the plot far above zero. Using the regression equation, taking the absorption to be zero solves for the negative concentration of the unknown solution.

In this experiment, AAS will be used to determine the concentration of the copper (II) ion. To derive the copper (II) ion from the elemental copper found in pennies, the penny is dissolved in excess HNO3, a strong acid, according to equation 1:

Equation 1: Reaction of Copper to its Ion with Nitric Acid

A standard US penny also contains zinc, which will be reacted with excess HCl, according to the following equation 2:

Equation 2: Reaction of Zinc with Hydrochloric Acid

Thus, the penny will be dissolved completely into solution. Then, by preparing a standard solution of 100ppm Cu2+ with Cu(NO3)2**·**3H2O, the two aforementioned methods can be used to determine the concentration of the penny solution, which will recover the weight percentage of copper in the original penny.

**Experimental**

A standard US penny was used for this experiment. Concentrated HNO3 (CAS#: 7697-37-2), HCl (CAS#: 7647-01-0), Copper Nitrate Trihydrate (CAS: 10031-43-3) were all provided by the TAs, and a light sources designed for the measuring of copper ions was used in the AAS setup, which was a Perkin Elmer AAnalyst 200 model.

To begin, Cu(NO3)2**·**3H2O (0.038 g) was accurately weighed out and dissolved to make a 100.00 mL solution of 100 ppm Cu(NO3)2**·**3H2O. This served as the standard solution for both sections of the experiment. Then, a 50.00 mL buret was filled with the stock solution, and into five different beakers, 1.00 mL, 2.00 mL, 3.00 mL, 5.00 mL, and 8.00 mL of the stock solution was transferred and diluted with deionized water to make 100 mL of 1, 2, 3, 5, and 8 ppm Cu2+ solutions, respectively.

Next, a copper penny was weighed (2.4815 g) and dissolved into a beaker with 10 mL HCl and 15 mL HNO3. The mixture was brought to a boil on a hot plate inside of a fume hood to rid the mixture of the toxic NO2 byproduct seen in Equation 1. The heat was reduced when rigorous reaction started and continued until the coin was completely dissolved. Then, the solution was cooled and diluted with deionized water to a total volume of 100.00 mL with a volumetric flask. 1.00 mL of this solution was transferred to another 100 mL volumetric flask and diluted again with deionized water to create a dilute dissolved penny solution.

All six solutions (five calibration, one unknown) were aspirated for 15 seconds each through the AAS machine by transferring the solution from the volumetric flasks into the beaker connected to the machine, and then transferred back after the 15 seconds. The absorptions of the solutions, as measured by the computer, were recorded. Each sample was measured three times, for a total of 18 recorded data points.

The second method began with 1.00 mL of the diluted dissolved penny solution being transferred into four 100 mL volumetric flasks each. Then, the four flasks were labeled 0, 2, 4, and 6 ppm, and 0.00, 2.00, 4.00, and 6.00 mL of the stock solution was added to each flask, respectively. Each flask was filled to the mark with deionized water.

All four of these solutions were then aspirated for 15 second in the same procedure as the first part of this experiment, and the absorptions were recorded. Each sample was measured three times, for a total of 12 recorded data points.

**Results and Discussion**

From the absorptions measured in the Ordinary Linear Calibration method portion of this experiment, the following plot and regression equation was obtained:

Figure 2: Graph of Ordinary Linear Calibration Method of copper (II) ion

The average absorption reading of the unknown solution over three trials was 0.492. Plugging this into the regression equation for y(absorbance) recovers a concentration of 3.52 ppm. Multiplying this by the amount of liters in the solution (0.100 L) yields the mass of copper in the solution, which is 0.352 mg. Then, dividing the amount of dilute solution added (1.00 mL) over the total volume of the solution (100.00 mL) yields the original mass of the copper, which is 35.231 mg, which is 1.42% of the original mass.

From the absorptions measured in the Standard Addition method portion of the experiment, the following plot and regression equation was obtained:

Figure 3: Graph of Standard Addition Method of copper (II) ion in Diluted Penny Solution

To derive the concentration of the original solution, the following equation is used:

Figure 4: Derivation of Formula for Recovering Concentration of Unknown in Standard Addition

where A is the absorption, a is the absorptivity, b is the path length, Cx is the concentration of the unknown, and Cs is the concentration of the standard. Setting A to 0 designates a point of the graph where the concentration of the unknown is exactly equal to the “projected” concentration of the standard, which will be negative. Thus, following this methodology, setting y = 0 and solving for x recovers the value -3.65 ppm, which means the unknown solution has a concentration of 3.65 ppm Cu2+. Solving the same way done in the previous calculations, this recovers a percent mass of 1.47% copper in the penny.

This result signifies that the penny originated after the shift to creating 2.5% copper pennies in 1982. However, the results from the experiment contain a significant difference to the expected 2.5% copper by mass. Some explanations would include corrosion or scraping of the outer layer of copper over time since the manufacturing of the penny, combined with extra non-copper mass left by residue on the coin during weighing. Both these factors would lower the percent mass of copper calculated, as the first would lower the ppm of the dissolved penny solution, and the second would increase the measured mass of the penny.

**References**

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