Determination of the Mass Percentage
of Copper in a Penny

Introduction

This experiment will cost you one penny ($0.01). The penny must be minted after 1983. Any penny will do; for best results the penny should be relatively clean and bright, with very little staining or gross physical damage. Modern pennies are described as "sandwich" coins, having a center of zinc covered by a thin copper shell (Figure 1).

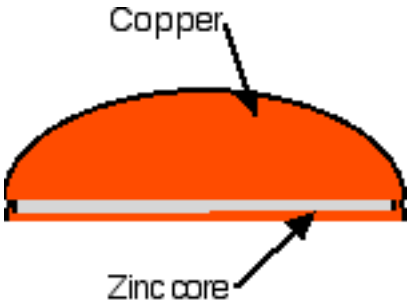


Figure 1. Cross-section of a modern (post 1983) penny.

The purpose of this experiment is to give you practice using the Spec 20 spectrophotometer. You will also get extensive practical work in working with volumetric glassware, especially pipets and volumetric flasks. This experiment is relatively "forgiving", since the solutions are stable for several days. Not all spectroscopic experiments are as student friendly!

You will dissolve the penny, and prepare copper amine complexes, which are blue. You will calibrate the spectrometer using solutions made from pure copper. Using the calibration curve, you will determine the concentration of copper from the dissolved penny, and ultimately the mass percentage of copper.

Solutions needed for this experiment:

Solutions prepared by the student	Solutions provided by the instructor
1:1 Nitric acid	Concentrated nitric acid
6 M ammonium hydroxide	Concentrated hydrochloric acid
	Concentrated ammonium hydroxide

Specialized equipment needed for this experiment.

I will provide a pair of metal shears for all students to use. For anyone who has never seen metal shears, they look like very heavy-duty scissors. These shears are sharp so be careful.

You will be using a Spec20 spectrophotometer. Detailed instructions for setting up the spectrometer are at the end of this experiment. Please read these instructions before attending the lab briefing.

Experimental Procedure

Preparation of standards:

1. Use the shears to cut a piece of copper weighing about 0.25 gram from the copper foil provided. (Alternatively, copper shot may be provided. You will need 0.25 grams of copper shot.) When you have a piece of copper metal approximately 0.25 gram in mass, weigh the copper metal on the analytical balance, recording the mass to four decimal points.

2. Perform this step in the hood. In a 600 mL beaker dissolve the copper metal in 10 mL of 1:1 nitric acid. **A REDDISH BROWN GAS WILL BE PRODUCED. THIS GAS IS A MIXTURE OF NITROGEN OXIDES. IT IS TOXIC, AND WILL INJURE YOU IF YOU BREATHE IT.**

3. After the copper has completely dissolved, add about 100 mL of deionized water. Boil this solution for a few minutes to remove all nitrogen oxides.

4. Quantitatively transfer the solution to a clean 250.0 mL volumetric flask and QS (Latin, *quantum satis* – the amount which is needed) with deionized water. Store this solution in a clean plastic bottle.

5. All liquid wastes generated in preparing the standards, except copper containing wastes, can be flushed down the sink with tap water. All solid wastes, including leftover copper metal, can be disposed of in the trashcan.

6. If exactly 0.2500 gram of copper was used, then 1.00 mL of your standard solution will contain 1.00 mg of copper, and the copper concentration is 1000 mg/L. If you used some other mass of copper, then your solution will have some other concentration of copper. **This solution is called the "stock solution".**

Preparation of unknown (the penny):

1. Use the shears to cut a penny into four quarters. Measure the mass of penny quarters on the analytical balance (measure the total mass, not the individual masses). Record this mass in your notebook.

2. Perform this step in the hood. Put the penny quarters into a clean 250 mL beaker and add 20 mL of concentrated hydrochloric acid. Hydrogen gas will be produced as the hydrochloric acid dissolves the zinc core of the penny. Allow at least one hour for the zinc to dissolve.

   Note to student: this reaction generally starts rapidly, but slows dramatically. Patience is required – eventually the zinc will completely dissolve. Hydrochloric acid will NOT dissolve copper, but will dissolve any copper oxide on the surface of the penny. Some students have success leaving their penny to dissolve overnight: others have the penny completely dissolve. This appears to be due to oxygen dissolving in the acid. Under these conditions, copper oxychloride ($CuCl_2 \cdot 3Cu(OH)_2$) has probably formed. If your penny dissolves completely, you have no choice but to start this part of the experiment over again.

3. When all of the zinc has dissolved, filter the solution through filter paper. Discard the liquid, and transfer the relatively thin copper metal pieces into a clean 150 mL beaker.

4. Working in the hood, add about 4 mL of concentrated nitric acid. **ONCE AGAIN, A REDDISH BROWN TOXIC GAS WILL BE PRODUCED.**

5. While the copper is dissolving, prepare about 200 mL of 6 M ammonium hydroxide, using concentrated ammonium hydroxide and deionized water. You can prepare and store the 6 M ammonium hydroxide in a small clean plastic bottle.

6. When the copper has dissolved, add 30 mL of 6 M ammonium hydroxide, drop wise (one drop at a time!). Once sufficient ammonium hydroxide has been added to neutralize the nitric acid, you will see a deep and distinct blue color. Continue the drop wise addition of ammonium hydroxide until all 30 mL has been added.

7. Quantitatively transfer the copper/ammonia solution to a 100.00 mL volumetric flask and QS with DI water. If it has to be stored for any significant length of time (for example, overnight), it should be stored in a clean plastic bottle.

8. All liquid wastes generated by this preparation can be disposed of in the sink. All solids can be disposed of in the trashcan.

9. **This solution is called the "penny solution".**

Preparation of calibration standards:

You must prepare at least 4 different calibration standards covering the range from 50.0 to 200 mg/L. The exact concentrations of your calibration standards will depend on the concentration of your stock solution, and the exact details of the dilutions that you make. Make sure that the 4 calibration standards reasonably cover the entire range; don't bunch two or three of the standards at one end of the range. I would suggest making standards around 200, 150, 100, and 50-mg/L copper.

It absolutely does not matter which specific concentration values are achieved, provided that they uniformly cover the indicated range. A set of calibration standards at 209.0, 154.0, 103.0, and 52.0 mg/L would be just as acceptable and provide results just as good as the suggested standards. In the final analysis, it is not important which specific concentrations are prepared. **IT IS EXTREMELY IMPORTANT THAT YOU KNOW THE CONCENTRATION AS SPECIFICALLY AS POSSIBLE!!!!**

1. Use appropriate pipets and 100.00 mL volumetric flasks for preparing your calibration standards. Use only class A transfer pipets and do NOT use serological or Mohr pipets. Do NOT use a burette, and do NOT use micropipettes. Use of any volumetric glassware other than class A transfer pipets and class A volumetric flasks will result in SEVERE grading penalties for this experiment.

2. Pipet the appropriate amount of **stock solution** into the volumetric flask. Add sufficient DI water to produce about 50 mL of solution. Add 6 M ammonium hydroxide, drop wise, until the nitric acid has been neutralized. Typically, a bluish precipitate will form which dissolves upon addition of excess ammonium hydroxide, forming a deep blue solution. Once this deep blue solution has formed, add 10 mL of excess ammonium hydroxide and QS to 100.00 mL with DI water. Label the volumetric flask.

3. Pipet 20.00 mL of the **penny solution** into a 100.00 mL volumetric flask. Add 10 mL of ammonium hydroxide and QS to 100.00 mL with DI water. Clearly label this solution. **This solution is called the "unknown solution".**

4. Prepare a blank solution using 10 mL of ammonium hydroxide and QS to 100.00 mL with DI water. Clearly label this solution.

Spectrophotometric measurements:

1. Set up the spectrometer following the instructions given in the section entitled "Spectronic 20 Operations", located at the end of this experiment. Set the wavelength to 650 nM.

2. Rinse the cuvette 3 times with DI water (1 – 2 mL), pouring each rinse into a convenient waste beaker (one of your own).

3. Rinse the cuvette 3 times with the blank solution (1 – 2 mL), pouring each rinse into the waste beaker.

4. Fill the cuvette almost full. There should be about 1 cm of empty space at the top of the cuvette. Wipe the sides of the cuvette with a Kimwipe® and insert the cuvette into the spectrometer with the frosted side of the cuvette facing towards you.

5. Close the cover, allow the instrument reading to stabilize, and measure the % transmission to one decimal place. Record % transmission in your notebook.

6. Empty the cuvette into the waste beaker, refill with blank solution, re-wipe the sides of the cuvette, and re-measure the % transmission. Repeat this process a third time.

7. Repeat steps 2 – 6, using your calibration standards. Start with the lowest concentration calibration standard and proceed, in order, to the highest. Make 3 separate measurements of % transmission, on 3 separate portions of each calibration standard.

8. When you have finished making measurements of your calibration standards, measure the % transmission of your **unknown solution** sample. Use the same procedure that you used for measuring your calibration standards.

When you are finished, you should have a data table resembling the one shown below.

Sample	Measurement 1	Measurement 2	Measurement 3
Blank	99.9%	99.8%	99.9%
51.3 mg/L	85.6%	85.4%	86.0%
Etc.			

Data treatment

Convert all of your % transmission values into absorbance values. The mathematical formula for this conversion is:

$$A = -\log\left(\frac{\%transmission}{100}\right)$$

Prepare a calibration curve of copper concentration (mg/L) versus absorbance. Plot ALL of your data points as separate, independent measurements. DO NOT AVERAGE YOUR THREE MEASUREMENTS TO PLOT ONLY ONE POINT.

Refer to Chapter 4 in your textbook. You must use linear regression (the method of least squares) to determine the slope and intercept for your calibration curve. However, if you use a computer program to plot your data, you may use the built in linear regression feature (if the program has such a feature).

Finally, from the three measured values for your penny solution, calculate the average % copper and the sample deviation, using the corrected slope and intercept values. If you have plotted absorbance on the y-axis, and concentration in mg/L on the x-axis, then the formula

$$y = mx + b$$

can be used to determine the amount of copper in your unknown solution. In the formula, y is the absorbance of the unknown, m is the slope of the straight line from the calibration curve, x is the concentration in mg/L (for your unknown), and b is the intercept. Plug the three values you know (absorbance, slope, and intercept) into the equation and solve for x.

Include your calibration curve with your lab report.

Lab report

A sample report is included at the end of this experiment.

WASTE DISPOSAL: All copper solutions go in the aqueous metals container. This includes the waste liquid from your spectrometer measurements. All other solutions can go down the sink. Solid wastes go into the trashcan.

Spectronic 20 Operations

Please look at the diagram of the instrument shown below.

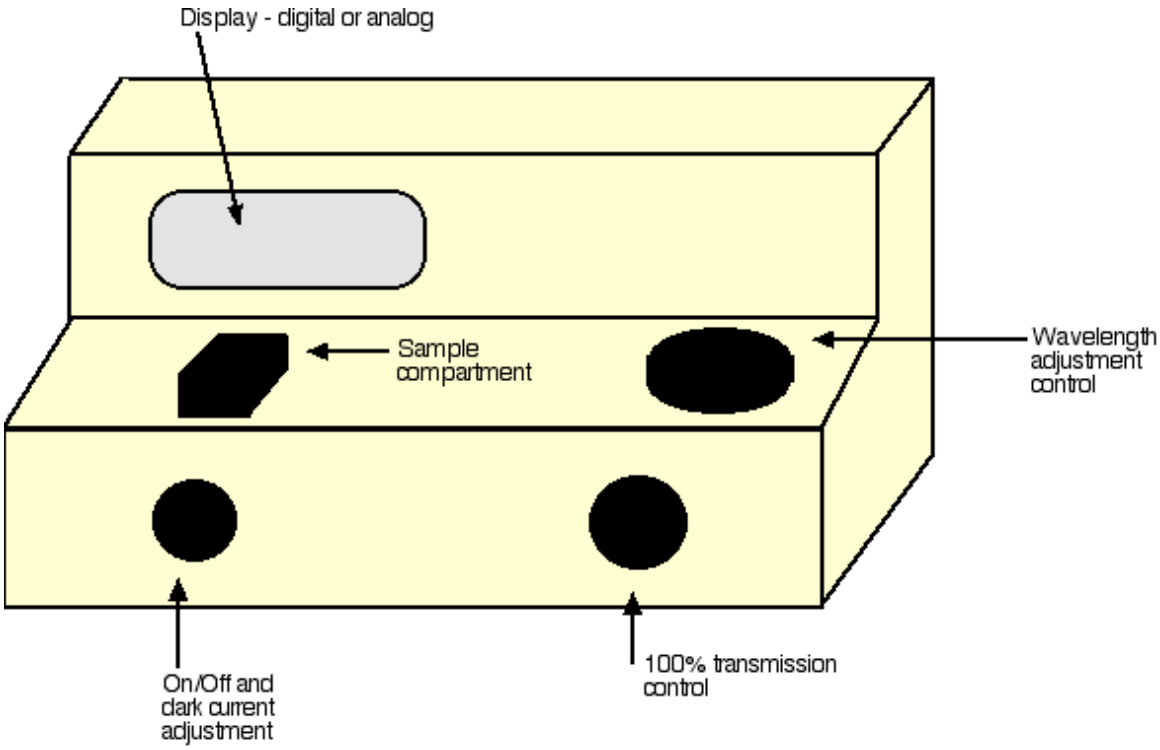


Figure 2. Spectronic 20 spectrophotometer.

Procedure:

1. Using the left hand knob on the front of the instrument as you are facing towards it, turn the spectrometer on. Allow it to warm up at least 30 minutes.

2. Set the wavelength adjustment, using the knob on the top of the instrument deck, opposite of the sample holder, and on the right hand side of the instrument.

3. After the instrument has warmed up, set the dark current. Leave the cover of the sample holder closed, and use the left hand knob on the front of the instrument. Set this so that the indicator needle reads 0% transmission.

4. Fill a cuvette with DI water. Wipe the clear sides of the cuvette with a Kimwipe® tissue. Put the cuvette in the sample holder, with the frosted sides facing towards you, and the transparent sides facing left and right. Close the

hatch, and use the right hand knob on the front of the instrument. Set 100% transmission.

5. Remove the cuvette, and check to make sure that the dark current is still at 0% transmission.

6. The spectrometer is now ready for use.

7. Any and all problems must be brought to the attention of your lab instructor immediately.

SAMPLE REPORT – ALL NUMERICAL VALUES ARE FICTITIOUS!
% Copper in a penny

Name: Joe Bagodonuts

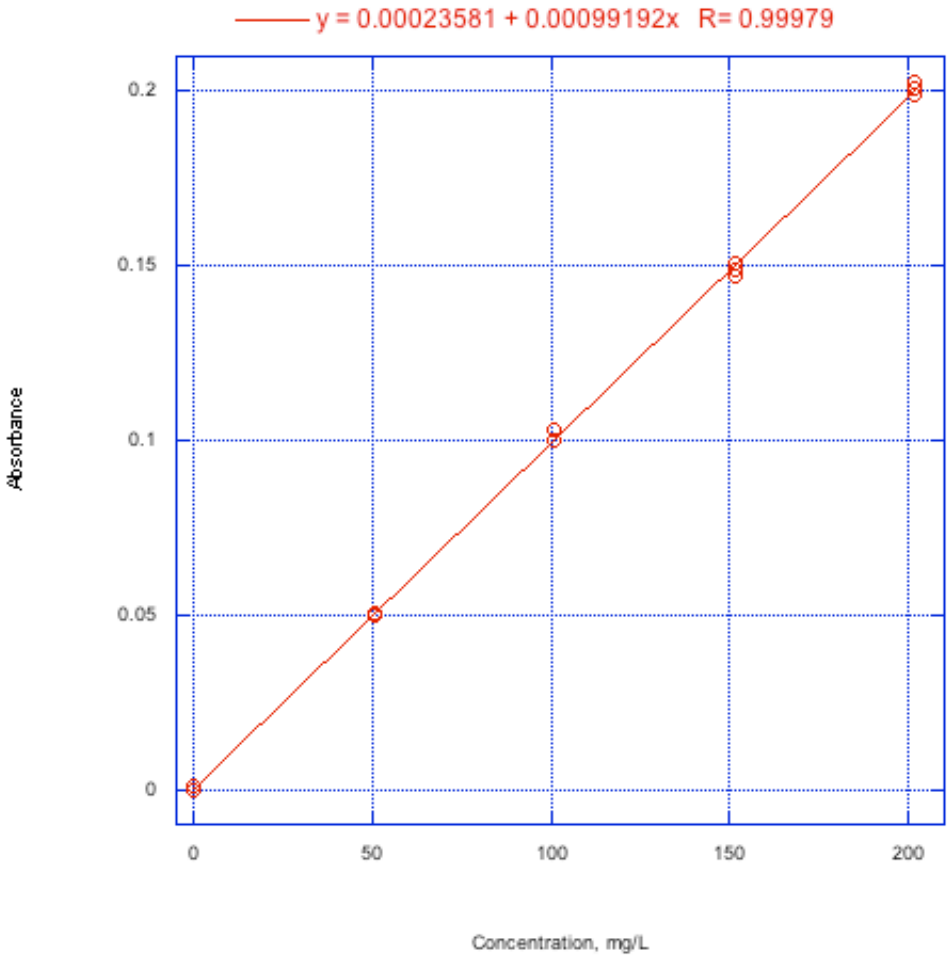
Mass of penny 2.5093 g
Mass of copper metal 1.0087 g

Calibration data:

Sample	Measured % Transmission		
Blank	99.9	99.8	100.0
50.4 mg/L	89.1	89.1	89.0
100.9 mg/L	79.4	78.9	79.5
151.3 mg/L	70.6	71.0	71.3
201.7 mg/L	63.0	63.2	62.7
Unknown sol.	66.8	66.4	66.7

Sample	Absorbances		
Blank	0.000434	0.000869	0.000
50.4 mg/L	0.0501	0.0501	0.0506
100.9 mg/L	0.100	0.103	0.0996
151.3 mg/L	0.151	0.149	0.147
201.7 mg/L	0.201	0.199	0.203
Unknown sol.	0.175	0.178	0.176
Unknown solution, mg/L	176.2	179.2	177.2
Penny solution, mg/L	881.0	896.0	886.0
Total mass of copper, mg	88.10	89.60	88.60
% Copper in penny	3.511	3.571	3.531

Mean % copper in penny: 3.54%
Sample deviation: $\pm$0.03%


y = 0.00023581 + 0.00099192x R= 0.99979
Absorbance
0.2
0.15
0.1
0.05
0
0
50
100
150
200
Concentration, mg/L