Objectives

- Develop a method for determining the concentration of copper (II) ion solution based on Beer-Lambert law.
- Determine the amount of copper and zinc (in mass percent's) in one-cent coins minted before 1983 and after 1984.
- Report your findings as directed by your instructor.

Introduction

Over decades the composition of one cent coin (penny) has been changed several times. Due to the increasing cost of copper, a major composition change took place in 1983. In this experiment, you may assume that both pre-1983 and post-1984 pennies consist of copper and zinc however mass %'s of copper and zinc are considerably different. Thus, your objective is to devise an experiment to determine the mass percents of copper and zinc for both pre-1983 and post-1984 pennies by taking advantage of the *Beer-Lambert Law* and *PASCO Spectrometer system*.

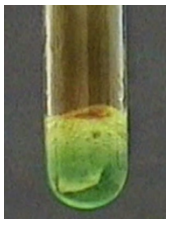
Background information

Chemical reaction

In order to determine the mass percent's of copper and zinc in pennies, you will need to dissolve penny samples in concentrated nitric acid solution. For example, metallic copper is known to dissolve in concentrated nitric acid by going through the following reaction:

$$\mathrm{Cu(s)} + 4\mathrm{HNO_3}\ (aq) \rightarrow \mathrm{Cu(NO_3)_2}(aq) + 2\mathrm{NO_2}(g) + 2\mathrm{H_2O}(l)$$

(The photo on the right shows the actual reaction between copper and nitric acid)



The blue-ish color of the solution is due to dissolved copper (Cu^{2+} ions) and the brown gas above the solution is nitrogen dioxide gas which is toxic.

Zinc will likewise dissolve in nitric acid, however Zn^{2+}(aq) is transparent and does not absorb visible spectrum.

***Safety tips**: Consider dissolving penny in a fume hood to avoid inhaling nitrogen dioxide. Also, nitric acid will be very concentrated (6M) and quite corrosive. Wearing proper safety gears (lab coat, safety goggle, gloves) will be absolutely essential for this experiment.*

Question to consider:

$Cu^{2+}(aq)$ appears blue to our eyes. Is it absorbing blue color of visible spectrum or is it absorbing some other color? Do an online search about the topic "complementary colors." This is a possible lab final question!

Beer-Lambert Law

According to Beer-Lambert Law, for a fixed path-length (distance the light travels), the amount of light absorbed by light-absorbing chemicals (such as Cu^{2+}) is directly proportional to the concentration (molarity):

$$Absorbance \propto [Cu^{2+}]$$

Absorbance of solutions can be measured readily by using *PASCO Spectrometer* system. The relationship between absorbance and copper ion concentration will give us a great strategy to estimate the amount of copper in a solution (see below)!

Experimental suggestions (for your lab proposal)

Based on the brief experimental suggestions (rough outline) below, write your own "detailed" lab procedures (including numbers and calculations) and report it in your lab proposal.

1. Preparation and measurements of standard $Cu^{2+}(aq)$ solutions
   - To determine the unknown $Cu^{2+}(aq)$ in penny solutions, first you must prepare the standard $Cu^{2+}(aq)$ solutions of "known" concentrations. Devise a procedure to prepare three or four $Cu^{2+}(aq)$ solutions of different molarities from copper (II) nitrate trihydrate [$Cu(NO_3)_2 \bullet 3H_2O$, the molar mass of this compound is 241.62 g] and DI water. Due to the sensitivity of PASCO Spectrometer, the molarities of standard solutions should "not" exceed 0.0500 M. The molarity of standard solution must be 0 – 0.0500M. **Note:** your instructor may opt to prepare the standard solutions for you in advance (not guaranteed at all so come prepared to make your own solutions). Ask your instructor on the day of the experiment for the availability of pre-made standard solutions.
   - Once standard $Cu^{2+}(aq)$ solutions are prepared, measure the absorbances of these solutions by PASCO Spectrometer. From the absorbance data, construct a graph (Absorbance vs $[Cu^{2+}]$). Perform a curve fitting (trendline) to obtain the slope formula ($y = ax + b$, "a" is the slope and "b" is the y-intercept). From this slope formula, you should be able to calculate the unknow Cu^{2+} molarity in penny solutions. See the accompanying Lab 2 PowerPoint file for a sample graph.

2. Preparation of pre-1983 and post-1984 penny solutions
    - Prepare the pre-1983 penny solution by putting a pre-1983 penny in 6M nitric acid. Be sure to carry out the reaction under fume hood since the reaction will produce toxic NO_2 gas. Due to high copper content in pre-1983 penny, the reaction will take place very slowly. To speed up the reaction, warm (not boil) the solution on a hot plate. "After" the penny dissolves completely in nitric acid, bring the solution back to the room temperature (very important!) and measure the accurate volume of the penny solution. You will need to accurate volume of the solution for the calculations later. Measuring the accurate volume of the nitric acid before the reaction is not recommenced since the volume of the solutions decreases during the heated reaction due to evaporation of water. Design this reaction so that nitric acid is the excess reactant. How much 6M nitric acid should you use?
    - Prepare the post-1984 penny solution by putting a post-1984 penny in 6M nitric acid. This reaction should take place quickly (10-15 min) under room temperature due to higher zinc content. Again, carry out the reaction in the fume hood to avoid inhaling NO_2 gas. You will need to record the accurate volume of the penny solution for later calculations. Again, design this reaction so that nitric acid is the excess reactant. How much 6M nitric acid should you use?
    - Measure the absorbances of both penny solutions with PASCO Spectrometer in the same way you measured the standard Cu^{2+} solutions. One (or both) of the solutions may be too concentrated so that the absorption peak is cut-off (maxed out). If so, carryout the quantitative dilution of the penny solution until the absorption reading is not maxed out and cut off. Do not forget to multiply the factor to estimate the original concentration (before dilution) of the penny solutions. Do you recall quantitative dilution formula from general chemistry I?
3. Calculating mass percent of copper and zinc in pre-1983 and post-1984 pennies.
    - From the slope formula obtained from the standard Cu^{2+} solutions, convert the absorbance of penny solution to Cu^{2+} concentration (molarity) for both pennies. How do you rearrange the slope formula so that you can calculate the unknown Cu^{2+} concentrations?
    - Carry out the stoichiometric calculations to determine the mass percent's of copper and zinc in both pennies. Refer to accompanying Lab 2 PowerPoint file for key equations. Which equations to use and how?

Appendix – How to set up and use PASCO Spectrometer

(Part of this appendix was adapted from PASCO documentation "Beer's Law: Determining the Concentration of an Unknown")

In this experiment, you will be measuring absorbance of Cu^{2+} ion with a ***PASCO Spectrometer***. The output of the Spectrometer will be recorded and process by ***SpectrometerApp*** that is pre-installed in an ***iPad***. The solution will be placed in a plastic cuvette for measurements.

> ***Caution:*** *You may only* ***Kimwipes*** *to wipe a cuvette in order to avoid scratches on the cuvette surface which will affect absorbance.*

PASCO Spectrometer and a cuvette

Syncing iPad and Spectrometer via Bluetooth

1. Turn on both the iPad and the Spectrometer.
2. Record the device ID number which is located on the bottom surface of the Spectrometer.
3. Open "Settings" on the iPad. Locate "Bluetooth" and make sure that it is set to "On."
4. Click "Bluetooth." If your Spectrometer is turned on, it should appear under "MY DEVICES." You may see multiple Spectrometer on this screen, click the Spectrometer with the correct device ID to sync it via Bluetooth.
5. Exit Settings and click on the SpectrometerApp icon.

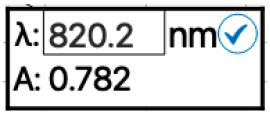
Settings

SpectrometerApp

Calibrating Spectroscope

1. Select "Analyze Solution" option at the top of the screen
2. Select "Calibrate Dark" option at the bottom of the Screen. This will turn the light off, thus calibrating the machine to 0% transmitted light setting.
3. Put deionized (DI) water into a cuvette. Be sure to handle the cuvette by the ridged sides. Wipe off any fingerprints using a Kimwipe since fingerprints will affect absorption. Place the cuvette into the spectrometer so that ridged sides are facing violet and green light signs and clear sides face the white light and absorbance spectrum icons.

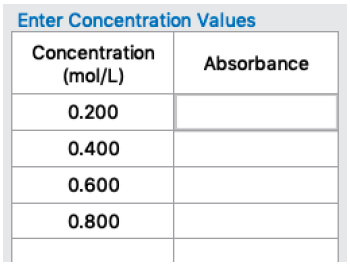
Calibrate Dark

4. Select "Calibrate Reference" option at the bottom of the screen. This will calibrate the machine to 100% transmitted light setting. 5. When both calibrations are complete, you should see check marks next to "Calibration Dark" and "Calibration Reference." When you see check marks, proceed to the next step.	Calibrate Reference  Calibrations are complete
<u>Determining the wavelength to analyze</u> 1. Place 4mL of the most concentrated "standard" Cu^{2+} (aq) solution into a cuvette. Place the cuvette into the Spectrometer as you did in the calibration. Be sure to wipe off fingerprints with Kimwipe before placing the cuvette into the Spectrometer. 2. Select the red "Record" circle at the bottom left of the screen. It should change into red "Stop Recording" square. 3. Select "Scale to Fit" at the bottom of the screen to rescale your data. 4. Use the "Add Coordinate Tool" to locate a wavelength to analyze on the curve. You should move the tool to the peak (the highest point) since this is the wavelength at which maximum absorption of light takes place. When you bring your cursor to the "Add coordinate Tool," a small hand icon will replace your cursor. With the hand icon drag the box slowly toward the curve. As you get closer to the curve, an arrow will appear that indicate a specific wavelength on the curve. Releasing the box at the desired the desired wavelength to be measured. 5. Once the desired wavelength is selected, lock it by clicking the blue check mark in the wavelength box. Once locked, all the following absorption measurement will be performed at this wavelength. 6. Click "Stop Recording" square on the bottom left.	 Record  Stop Recording  Scale to Fit  Add Coordinate Tool  Select the blue check mark to lock the wavelength

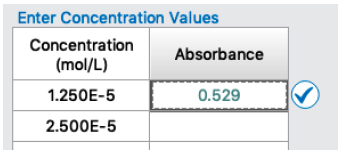
Creating Concentration-Absorption Curve

> ***Caution:*** *This segment should be performed by using your* ***standard Cu^{2+} (aq) solutions****. Do not use your penny solutions!*

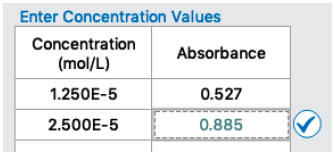
1. Select "Concentration" from the menu at the top of the screen. A table will appear on the left side of the screen that has columns for Concentration (mol/L) and Absorbance. This table has default (dummy) concentration values to be replaced.
2. Type over the default concentration values with your own standard Cu^{2+}(aq) concentrations (lower concentration to higher concentration is recommended).
3. Click on the top empty cell on the Absorbance column then, after placing the standard Cu^{2+}(aq) of the corresponding concentration, click on the "Record" red circle on the bottom left. Once the absorbance stabilizes, record the absorbance by clicking the blue check mark on the right. **Note:** absorbance data shown on the right are fictitious numbers and your numbers will be different.
4. Once you record the first absorbance data, the next absorbance data will be ready to be recorded automatically. Place the second standard Cu^{2+}(aq) solution, and likewise record the absorbance by pressing the blue check mark on the right side.
5. Repeat the procedure until absorbances of all standard Cu^{2+}(aq) solutions were recorded. Then press the "Stop Recording" red square on the bottom left.
6. Turn off the "Show Live Scan Display" by clicking the icon.
7. Rescale your graph by selecting "Scale to fit" button on the bottom of the screen.
8. Select "Show Linear Fit" on the bottom of screen to determine the best fitting linear curve through data.
9. The slope formula for this best fitting linear curve appears in a box on the graph (**Note:** the number shown in the picture is fictitious. Your numbers will be different). For the equation ($mC + b$), m represents the slope (in 1/M), C is the molarity (M) and b represent the y-intercept (dimensionless).



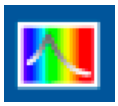
Data table with defaut values



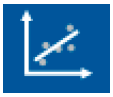
Click the blue check mark to record the absorbance data



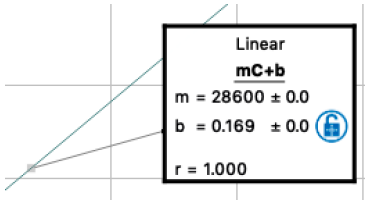
Record the second data



Show Live Scan Display



Show Linear Fit



10. At this point, the Spectrometer is ready for analyzing unknown penny solutions.

Equation for the best fitting linear curve in the box.

Analysis of unknown penny solutions

1. Click on the "Absorbance" cell in the "Determine Unknown Concentration" table on the lower left of the screen.
2. Place 4mL of the pre-1983 penny solution in a clean cuvette and place it in the Spectrometer.
3. Click on the "Record" red circle on the bottom left.
4. When the absorbance reading stabilizes, record it by clicking the blue check mark on the right. **Record this absorbance data in your lab notebook!**
5. Place 4mL of the post-1984 penny solution in a clean cuvette and place it in the Spectrometer.
6. Click on the same "Absorbance" cell on the "Determine Unknown Concentration" table again and the cell will be ready to accept the second data on the lower right (red colored data in the picture). Record the absorbance of the post-1984 data by clicking "Stop Recording" red square on the bottom left. Also record this new absorbance data in your lab notebook! **Note:** all data shown in pictures are fictitious numbers. Your actual data will be different.
7. This concludes data acquisition section of the experiment. Proceed to data analysis (calculations) section of the experiment after you put away equipment, solutions and wastes to appropriate locations. Be sure to clean your lab station and present it to your lab instructor.