

# Electrochemistry: Molar Mass

## Of Cu by Electrodeposition/Electroplating

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### Objective

The goal of this experiment is:

- to learn Faraday's two laws of electrolysis.
- to relate an electric current to the passage of an amount of electric charge.
- to discuss electrolysis in molten salts and in aqueous solutions.
- to determine the molar mass of copper by electrodeposition from an aqueous solution.
- to copper into gold (**please bring to lab with you a penny that is pre-1982**)

### Grading

You will be assessed on:

- completion of the prelab.
- completion of the report form.
- TA evaluation of lab procedure.

**The pre-lab assignment must be completed and handed in to your TA at the beginning of lab. You will not be allowed to begin the lab until this assignment is complete.**

**Link to the Report Form here. This report is due at the beginning of the next lab period. Click here for Background Information and Calculation of the Molar Mass.**

# Introduction

**Electrochemistry** describes the interaction between electrical energy and chemical processes. Electricity continues to intrigue us, as it has since people first observed the sky shattered by bolts of lightning. Electrochemistry is of great practical value to contemporary living. Consider the number of batteries used for powering the many portable items of pleasure and need – everything from cassette recorders to hearing aids, from calculators, from calculator to pacemakers. Pure metals are produced from natural ores, inorganic and organic compounds are synthesized, metal surfaces are plated with other metals or coated with paint to enhance their value and utility – all through electrochemistry.

Electricity is a moving stream of electrical charges. This flow, or **electric current**, can occur as electrons moving through a wire or as ions flowing through an aqueous solution. If the electrons lost and gained in a spontaneous reaction can flow through a wire on their pathway from the substance oxidized to the substance reduced, the energy of the reaction is released as electrical energy. Conversely, a non-spontaneous redox reaction can be driven forward by the introduction into the system of electrical energy from another source. Any device in which either process can occur is called an **electrochemical cell**.

There are two types of electrochemical cells. The first type generates electrical energy from a spontaneous redox reaction. These are called **voltaic** or **galvanic cells**, common household batteries are classic examples. An Italian physicist, Allesandro Volta in 1800 explained that electricity is generated by connection of two dissimilar metals separated by any moist body not necessarily organic. A simple voltaic cell, similar to that made by Volta, can be assembled using twelve pennies and twelve nickels. By making a column of alternating pennies and nickels, each coin separated by disk-size pieces of wet filter paper soaked in salt water.

In the second type of electrochemical cell, called an electrolytic cell, a non-spontaneous redox reaction is caused by the addition of electrical energy from a direct current source such as a generator or a storage battery. The process of generating a non-spontaneous redox reaction by means of electrical energy is called **electrolysis**.

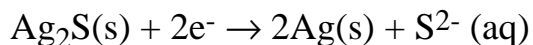
## [Click here for Background Information](#)

Electrolysis can be used for purifying a metal through the electrolytic dissolution of an impure anode and the subsequent recrystallization of the pure metal on the cathode. The impurities are left behind in solution. Copper is refined commercially by this electrolytic technique.

Electrolysis is often used for electroplating a metal to another material acting as the cathode. The other material must also be electrically conducting. Nonconducting materials, such as leaves, can also be plated by first being painted with a metallic conductive paint. Silver plating can be done with a silver anode and the object to be plated as the cathode.

Electrolytic reduction (**cathodic reduction**) has developed into a useful technique for the restoration of artifacts such as corroded nails and encrusted silver. In the case of silver, the degradation is usually due to the surface formation of insoluble (black) silver sulfide ( $\text{Ag}_2\text{S}$ ). The artifact (a silver coin, for example) is attached to the negative electrode of the electrolysis cell. The  $\text{Ag}^+$  ions of the silver sulfide

pick up electrons and are converted back to metallic silver:



The sulfide ions are swept away by the water and the surface of the object is restored.

In this experiment, firstly you will electroplate copper quantitatively to a copper cathode. The anode is also composed of copper. The current is measured over an interval of approximately one hour so that the amount of charge passing through the cell is known. The molar mass of copper is calculated from its equivalent mass using Faraday's second law. Secondly, you will use the same principles to etch a design on a piece of stainless steel metal by deposition of copper

## Experimental Procedure

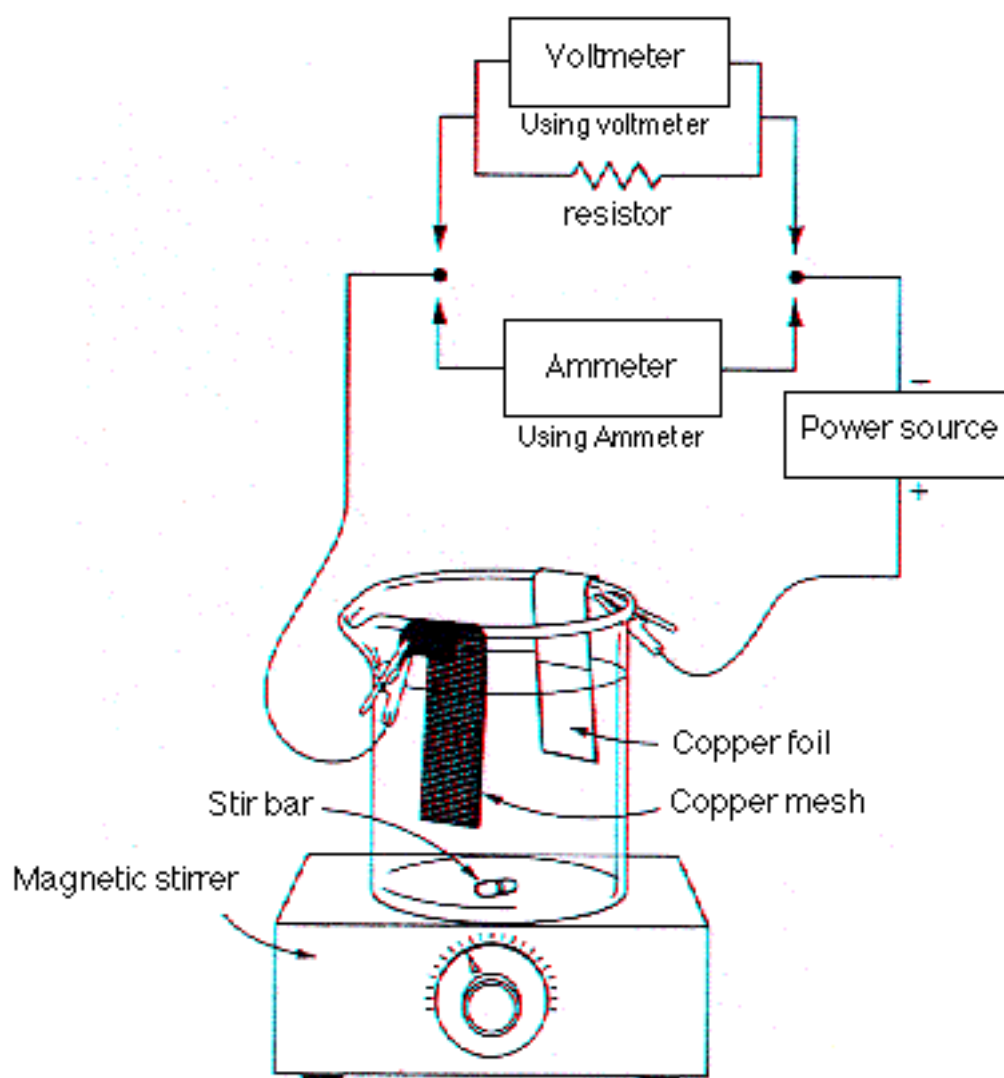


Figure 1

**CAUTION WEAR EYE PROTECTION!**

**CAUTION THE 6 M nitric acid used in the next step will burn and stain the skin as well as damage clothing. In case of skin or clothing contact, wash the area immediately with large amounts of water.**

1. Obtain a piece of copper foil (about 2 cm x 8 cm). Holding the foil with tweezers or tongs, dip it into 6 M nitric acid several times until its surface is bright and shiny. Do not allow tweezers or tongs to touch the acid solution. Rinse the foil in de-ionized water and set it aside. This is the anode. Set the nitric acid aside to use in the electroplating exercise.
2. Obtain a piece of copper mesh (about 5 cm x 8 cm) and remove any loose pieces of copper. Clean and rinse it as in step 1. Place the copper mesh on a watch glass in the drying oven. Be careful not to touch the cleaned surfaces. This is the cathode.
3. Add 350 mL 1.0 M  $\text{KNO}_3$  solution to a 400 mL beaker.

**CAUTION The copper sulfate used in the next step is toxic. Avoid skin contact**

4. To this solution, add about 5 mL of 1 M  $\text{H}_2\text{SO}_4$  and 10 g of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ . Stir until the copper sulfate pentahydrate is fully dissolved.
5. Assemble the apparatus shown in Figure 1, but leave the copper mesh electrode in the oven. Add a magnetic stirring bar to the beaker. If necessary, add additional 1.0 M  $\text{KNO}_3$  to bring solution level in the beaker within 2 cm of the rim. You will either measure the electric directly with an ammeter in series with the electrolytic cell or you will measure the current indirectly by measuring the voltage across a resistor of known value (about 10 ohms).
6. Remove the copper mesh electrode from the oven, let it cool, and determine its mass to the nearest milligram.
7. Attach the copper mesh electrode to the negative terminal of your power supply using an alligator clip. Turn on the magnetic stirrer.
8. Turn on the low voltage power supply and adjust the current until about 140 mA are flowing through the cell. Record the time and current.
9. Record the time and current every five minutes for an hour.
10. After the last reading, gently remove the cathode from the solution while yet attached to the power supply. After the copper mesh has cleared the solution, remove the wire and turn off the power supply.
11. Gently dip-rinse the copper mesh electrode several times in a beaker of deionized water, and place it on a watch glass in the drying oven.
12. When dry, remove the electrode from the oven and let it cool. Reweigh the mesh electrode.
13. Remove the magnetic stirring bar from your beaker and dispose of the solution in the sink.

**[Click here for the Calculation of the Molar Mass.](#)**

# Alchemy: Copper into Gold

Here you will place your pre-1982 copper penny in an evaporating dish and heat with a mixture that first turns it silver, then suddenly turns it gold when the penny is then heated on a hot plate.

## Experimental Procedure

**Caution: Wear safety goggles and gloves, do the reaction in the fume hood with the sash down.**

**Note step 10: special disposal**

1. Place approximately 5 g of zinc in an evaporating dish.
2. Add enough NaOH solution to cover the zinc and fill the dish about one-third.
3. Place the dish on a hot plate and heat until the solution is near boiling.
4. Prepare a copper penny (pre-1982) by cleaning it thoroughly with a light abrasive (steel wool pads work well).
5. Using crucible tongs or tweezers, place the cleaned penny in the mixture in the dish.
6. Leave the penny in the dish for 3-4 min. You will be able to tell when the silver coating is complete.
7. Remove the penny, rinse it, and blot dry with paper towels. (Do not rub.) Remove particles of zinc.
8. Using crucible tongs or tweezers, place the coated penny on the hot plate. The gold color appears immediately.
9. When the gold color forms, remove the coin, rinse it, and dry it with paper towels.
10. Special disposal procedures: Do not discard the waste zinc in the trash container. When zinc dries, it forms a powder that may spontaneously ignite. Rinse the NaOH-zinc mixture several times with water. Then add the solid to a beaker that contains 200 mL of 1 M H<sub>2</sub>SO<sub>4</sub>. When all of the solid dissolves, flush the zinc sulfate solution down the drain.