Student Pages

FLINN SCIENTIFIC

Electroplating with Copper

Introduction

Coat your keys or another metal object with a thin layer of copper using an electrolytic process called electroplating. *Electroplating* is a technique used to deposit a layer of metal—such as copper, chromium, silver, gold or nickel—onto the surface of another metal. The deposit can provide both a protective and decorative coating for the metal which lies beneath it. Chrome plating (on car bumpers) or silver plating (on serving dishes) are common electroplating processes.

Concepts

- Electrolysis/electroplating
- Oxidation–reduction
- Faraday's law

Background

Electrochemistry is the study of the interconversion of electrical and chemical energy. Two types of cell processes can result in the interconversion of these two energy sources—voltaic cells and electrolytic cells. *Voltaic cells* use a spontaneous chemical reaction to generate electrical energy. *Electrolytic cells* use electrical energy (e.g., from a battery) to make a nonspontaneous chemical reaction take place. A nonspontaneous process requires energy from an external source in order to drive the reaction to occur. The electroplating reaction performed in this lab activity is an example of an electrolytic nonspontaneous process.

The chemical reactions that take place in electrochemical cells are *redox* reactions. Reduction occurs at the cathode (negative [–] electrode) and oxidation occurs at the anode (positive [+] electrode). Within an electrochemical cell, positive ions (cations) move toward the cathode and negative ions (anions) move toward the anode.

Since the charge on an electron is 1.6022×10^{-19} coulombs and there are 6.022×10^{23} e^-/mole, then one mole of electrons carries a total charge of 96,485 coulombs (1 mole e^- = 96,485 coul or C). The constant 96,485 C/mol is called the *Faraday constant* in honor of Michael Faraday, who did extensive research on electrochemical cells. Michael Faraday observed that the amount of substance undergoing oxidation or reduction at each electrode during electrolysis is directly proportional to the amount of electricity that passes through the cell. This is known as *Faraday's Law of Electrolysis*. The rate at which electrical charge moves through a circuit is most commonly measured in amperes (amps or A). One ampere of current equals one coulomb of charge passing a given point in one second, or 1 amp = C/sec. Hence, 1 Faraday = 6.022×10^{23} e^- = 96,485 C.

In the electrolytic cells used in this lab activity, the nonspontaneous oxidation–reduction reactions occurring at the electrodes are the result of the transfer of electrons by the power supply. The power supply acts as an electron pump, pushing electrons into the cathode and removing them from the anode. Electrical neutrality, however, must be maintained; therefore, some process must consume electrons at the cathode and generate them at the anode.

The half-reaction occurring at the anode (the copper electrode) is the oxidation of copper to Cu^{2+}. When copper is oxidized to copper(II) ions, two electrons are produced according to Equation 1.

$$\text{Oxidation at Anode:} \quad Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

Equation 1.

The half-reaction occurring at the cathode (the metal key or object) is the reduction of copper(II) ions to copper. When copper(II) ions are reduced to copper metal, two electrons are consumed according to Equation 2.

$$\text{Reduction at Cathode:} \quad Cu^{2+} + 2e^- \rightarrow Cu(s)$$

Equation 2.

When the combined oxidation–reduction reaction is carried out in an electrolytic (nonspontaneous) cell, the process is called *electrolysis* (see Figure 1).

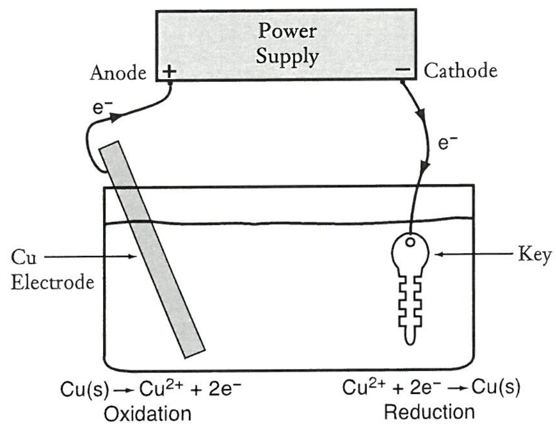

Figure 1. Electrolysis

In this laboratory activity, a metallic object (a key) will be electroplated with a copper coating. The energy needed to perform the oxidation–reduction reaction will come from an external power source. The mass change at each electrode (the copper electrode and the metal key) will be investigated. The reactions occurring at each electrode will be observed and written. The charge on the copper ion will then be calculated by applying Faraday's Law.

Materials

Copper electrode, 1.2 cm x 15 cm strip

Copper plating solution, 200 mL

Copper wire, 5-cm length (to hold key)

Sodium hydroxide solution, NaOH, 3 M, 30 mL

Sulfuric acid solution, H_2SO_4, 3 M, 30 mL

Water, distilled or deionized

Ammeter, 0–1 A

Balance, 0.01 g readability

Beaker, 50-mL (to clean key)

Beaker, 250-mL

DC power supply, variable, low voltage

Detergent

Glass rod (to support key)

Key (or other metal object such as a coin or a nail)

Steel wool pad, fine

Timer or timing device

Wires, insulated, with alligator clips (to hook up power supply), 3

Safety Precautions

Sodium hydroxide solution and sulfuric acid solution are corrosive to eyes, skin and other tissues. Copper plating solution is an acidic solution consisting of cupric sulfate and sulfuric acid; it is moderately toxic by ingestion and inhalation and is a skin and respiratory irritant. Avoid skin contact with all chemicals. Do not operate a power supply with wet hands or in wet areas. Be sure the area is dry before turning on the power supply or closing the circuit. Follow additional safety precautions as appropriate to your power supply. Wear chemical splash goggles, chemical-resistant gloves and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part 1. Cleaning the Electrodes

1. Clean a key and a copper electrode by rubbing with fine steel wool. Wash the key and the copper electrode with detergent and rinse both with tap water.
2. Attach a 5-cm length of copper wire to the key. The wire will serve as a handle to remove it from the cleaning solutions and to support it during the electrolysis.
3. Soak the key and copper electrode for a few minutes in 30 mL of 3 M sodium hydroxide solution. Remove the key and rinse it with distilled or deionized water.
4. Soak the key and copper electrode for a few minutes in 30 mL of 3 M sulfuric acid solution. Remove the key and rinse it with distilled or deionized water.
5. Remove the wire from the key. Save the wire for use in step 9. Dry the key and the copper electrode thoroughly for Part 2.

Part 2. Copper Plating the Key

6. Determine the mass of the key to the nearest 0.01 g. Determine the mass of the copper electrode to the nearest 0.01 g. Record both initial masses in the Data Table.
7. Pour approximately 200 mL of copper plating solution into a 250-mL beaker. **Note:** Copper plating solution is an acidic solution consisting of cupric sulfate and sulfuric acid. Avoid all skin contact. Rinse skin immediately if any contact is made.
8. Place the copper electrode into the beaker. Bend the copper strip to fit over the top of the beaker (see Figure 2).

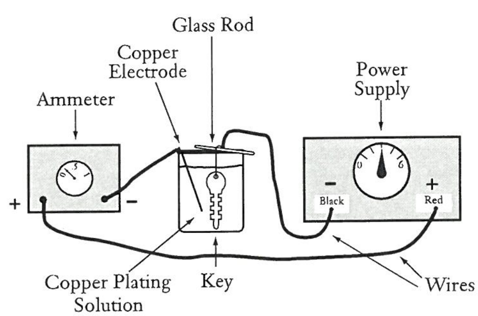

Figure 2.

9. Reattach the 5-cm length of wire to the key. Suspend the key in the beaker by wrapping the wire around a glass rod. Rest the rod on top of the beaker. Be sure the copper electrode and key are not touching.

10. Hook up the variable DC power supply. Wire the key directly to the negative (black) terminal of the power supply. Wire the positive (red) terminal of the power supply to the positive terminal of the ammeter. Wire the negative terminal of the ammeter to the copper electrode.
11. **Note:** Before turning on the power supply, be sure the area is dry. Read the *Safety Precautions*. Turn on the power supply and use a timer to begin timing. Adjust the current to approximately 0.50 amps (A). Monitor the current to maintain a constant reading throughout the electroplating. (**Note:** Current may vary as the copper is removed from the electrode and plated onto the key.) Record the exact current in A in the Data Table.
12. Turn off and unplug the power supply after approximately 10–15 minutes and stop the timer. Record the exact time for electrolysis in minutes in the Data Table. Convert the electrolysis time to seconds. Record the seconds in the Data Table.
13. Remove the key and copper electrode from the solution.
14. Carefully rinse the key with distilled water and gently pat it dry. Remove the wire from the key. Be careful to minimize the rubbing of the key or some copper may flake off and alter the final mass.
15. Determine the final mass of the key to the nearest 0.01 g. Record the final mass in the Data Table.
16. Rinse the copper electrode with distilled water, dry it off, and determine its final mass. Record the final mass of the copper electrode in the Data Table.
17. Disconnect the wires from the power supply and return the copper plating solution to the reagent table for reuse.
18. Complete the *Calculations and Post-Lab Questions*.
19. Optional Trial II—Repeat steps 1–18 using another metal object such as a coin or a nail.
20. Consult your instructor for appropriate disposal procedures.

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