ELECTROPLATING

OBJECTIVE:

You will understand the process of electroplating and will use electricity to plate a key with copper. You will then compare experimental findings with those predicted from Faraday's laws of electrolysis.

INTRODUCTION:

Electroplating is the process of applying a thin coating of one metal onto an object made of another metal. It works by electrolysis, in which an electric current is passed through a solution called an electrolyte, causing a chemical reaction. Metal ions pass from the positive electrode (anode) to the negative electrode (cathode). The metal for the coating forms the anode, and the metal object to be plated forms the cathode.

The process was discovered in 1800 by German physicist Johann Ritter (1776–1810), who electroplated copper. In 1833 English physicist Michael Faraday (1791–1867) published the results of two series of experiments. These results formed the basis for what later became known as Faraday's laws of electrolysis. The first series of experiments showed that the amount of metal deposited during electrolysis is proportional to the current passed—the greater the current, the heavier the deposit. The second showed that the mass of metal deposited by a given amount of electricity is related to the "chemical equivalent" of that element. In today's language, the chemical equivalent is the atomic weight or relative atomic mass of the element divided by its valency (its combining power). These two findings provided the first quantitative information about electrolysis, and helped inventors design effective electroplating apparatus. In 1839 patents for electroplating were granted to Carl Jacobi and Werner Siemens, two German scientists, and by the early 1840s electroplating was established commercially in England.

Today, electroplating is used to apply a wide range of metals—chromium, copper, nickel, zinc, cadmium, tin, gold, silver, and platinum, to name a few—in a thin, even coating onto a base metal. This has a wide range of applications in manufacturing, including coating base metals with copper to create circuit boards for electronic appliances, plating steel cans with tin, and plating automobile parts with chromium. In most cases, electroplating is done to improve the appearance or prevent corrosion of the base metal.

TIME NEEDED:

1 hour

MATERIALS:

- 250ml beaker containing 200 ml of 10% solution of copper sulfate crystals in dilute sulfuric acid
- 10 cm x 2 cm strip of thin copper sheet
- metal door key
- DC power pack (0–50 V)
- 2 20cm lengths of bell wire
- 15cm length of bell wire
- 2 alligator clips
- electronic scale weighing to the nearest 0.01 g
- multimeter
- 250ml beaker containing 150 ml water
- 250ml beaker containing 150 ml acetone
- stopwatch
- safety gloves
- wire strippers

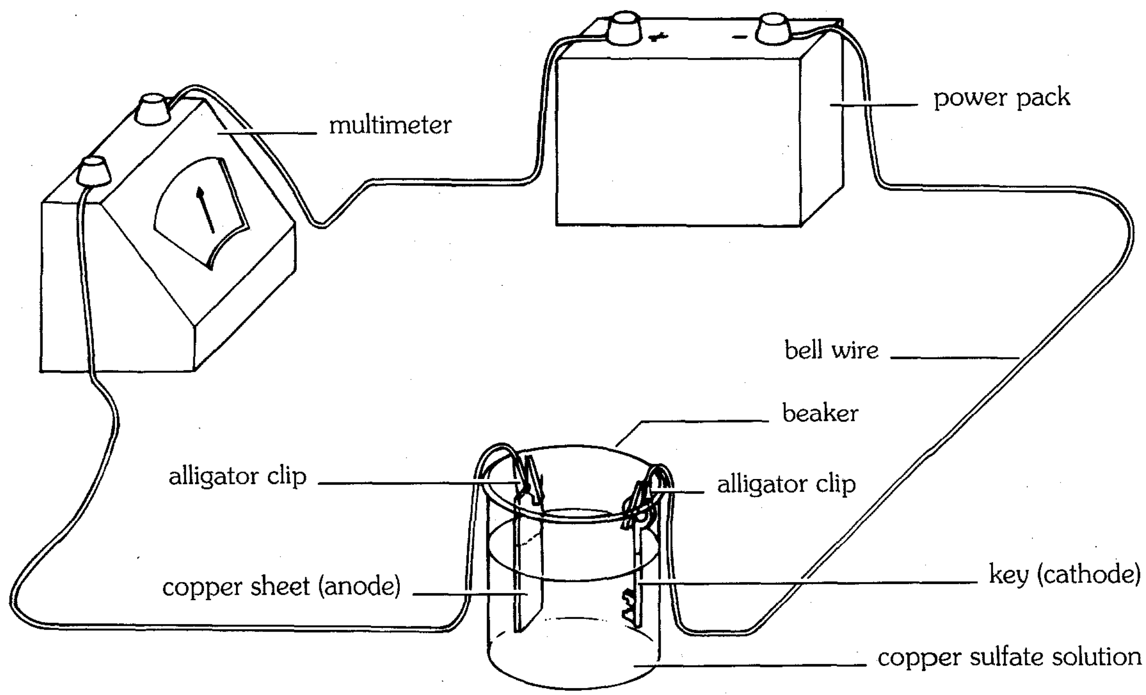
Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Electricity can cause dangerous shocks. Do not touch the apparatus when the electrical circuit is complete and current is flowing. Safety gloves should be worn when handling the copper sulfate solution. Take care not to allow the copper sulfate solution to come in contact with your skin. If you do, wash it off immediately under running water. Acetone is flammable and should be used with care.

PROCEDURE:

1. Weigh the copper strip on the electronic scale and enter this figure in the first line of the Data Table in the column headed Mass before electrolysis. Repeat this procedure with the key and enter the figure in the second line of the Data Table.
2. Use the wire strippers to strip 3 cm of insulation from both ends of the three wires. Attach one end of the 15cm wire to the positive terminal of the power pack, and the other end to the negative terminal of the multimeter. Attach one end of one 20cm wire to the positive terminal of the multimeter and the other end to the strip of copper sheet, using an alligator clip. Attach one end of the other 20cm wire to the remaining terminal on the power pack, and the other end to the key, using an alligator clip.
3. Wearing gloves, place the copper strip and key into the beaker containing the copper sulfate solution so that they are facing each other and are each submerged to about two-thirds of the beaker's depth. Fold the wires over the beaker rim so that the strip and key are held in place (see figure 1). Make sure the alligator clips do not get wet.

Figure 1



4. Switch on the electricity supply and adjust the power pack voltage supply so that no more than 1 amp flows. Allow the current to flow for precisely 30 minutes. Do not tamper with the apparatus during this time. You should be able to observe the pink color of copper being deposited on the key.
5. At the end of the 30 minutes, turn off the power pack. Holding the alligator clips, carefully lift the copper strip and key out of the copper sulfate solution, and dip the copper strip and key into a beaker of water and then into a beaker of acetone. Hold them in the air for a few seconds over the beaker of acetone to allow the acetone to completely evaporate.
6. Carefully detach the copper strip and key from the wires and alligator clips, being careful not to disturb the surfaces that were dipped in the copper sulfate solution. Weigh the copper strip and enter this figure in the first line of the Data Table in the column headed Mass after electrolysis. Repeat this procedure with the key and enter the figure in the second line of the Data Table.
7. For the copper strip, subtract the mass before electrolysis from the mass after electrolysis, and enter the figure in the first line of the Data Table in the third column. Repeat this procedure for the key, and enter the figure in the second line of the Data Table.

DATA TABLE

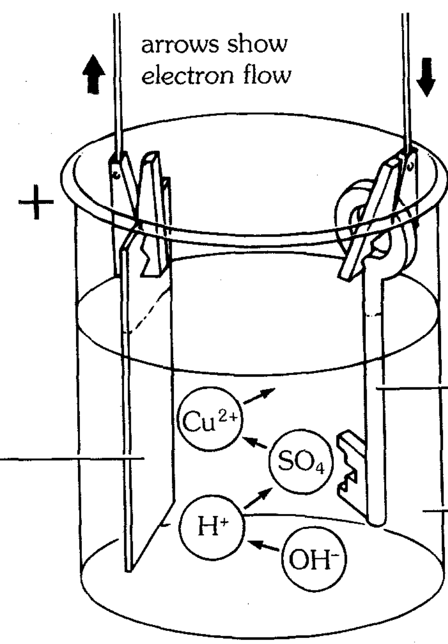
	Mass before electrolysis (g)	Mass after electrolysis (g)	Difference in mass
Copper strip (anode)			
Key (cathode)			

ANALYSIS:

1. Did the copper strip weigh more or less after electrolysis? Did the key weigh more or less? Explain your findings.

2. Figure 2 illustrates what was happening when the current was flowing through the copper sulfate solution. The solution contains copper ions (Cu^{2+}) and sulfate ions (SO_4^{2-}) from the copper sulfate, and hydrogen ions (H^+) and hydroxide ions (OH^-) from water. When the current flows, ions carry the current through the solution. When the ions arrive at one or other of the electrodes, they give up or receive electrons and undergo a chemical change. It is Cu^{2+} ions which carry the bulk of the current from the anode (the copper strip) to the cathode (the key).

Figure 2



a) Do some research. Both sulfate ions (SO_4^{2-}) and hydroxide ions (OH^-) are attracted to the anode, and yet it is copper atoms which undergo chemical change here. Why is this?

b) Both Cu^{2+} and H^+ ions are attracted to the cathode, yet it is Cu^{2+} ions which undergo chemical change. Why is this?

3. Michael Faraday's first law states that the weight of a substance produced during electrolysis is directly proportional to the quantity of electricity passed through the electrolyte. A modern

interpretation of Faraday's second law is that when the quantity of electricity used is 1 Faraday (26.8 ampere hours) then one mole of monovalent (single-charged) ions, or half a mole of divalent (double-charged) ions are discharged. You can check to what extent your findings agree with those predicted by Faraday's laws as follows. According to Faraday's second law, 64 g (1 mole) of copper atoms would be discharged by 2 Faradays or 53.6 ampere hours of electricity. You can calculate the amount of electricity used in your experiment by using the equation:

quantity of electricity (ampere hours) = current (amps) x time (hours)

For a current of 1 amp flowing for 30 minutes, the quantity of electricity is 0.5 ampere hours.

To estimate how much copper should have been deposited by this amount of electricity (according to Faraday's second law), use the following equation:

$$\frac{\text{predicted mass of copper deposited}}{\text{amount of electricity used}} = \frac{64\ (\text{g})}{53.6\ (\text{ampere hours})}$$

$$\text{predicted mass of copper deposited} = \frac{64 \times 0.5}{53.6} = 0.60\ \text{g}$$

Look at your Data Table. Compare the predicted amount of copper deposited on the key with the actual amount deposited.

a) How closely does the predicted amount compare with the actual amount? If there is a difference, how do you account for this?

b) Is the mass lost from the copper anode the same as that gained by the copper key? If not, can you account for the difference?

4. Electropolishing is the opposite process to electroplating. Electropolishing uses the process of electrolysis to remove irregularities from the surface of plated materials and give them a polished finish. How could you modify your electrolysis apparatus to electropolish a tarnished copper medallion?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES