

ChE-455/555: Analysis of Electrochemical Systems

Experiment 2: Copper Electroplating

1. Introduction

The process of electroplating is one of the most important applications of electrolytic cells. Electroplating is the deposition of a metallic coating onto an object by putting a negative charge onto the object and immersing it into a solution. In electroplating, the metal to be plated is used as the cathode and the electrolytic solution contains an ion derived from that metal. In this experiment, two copper electrodes will be used in an aqueous solution of copper sulfate CuSO_4 , which contains the ions $\text{Cu}^{2+}(\text{aq})$ and $\text{SO}_4^{2-}(\text{aq})$. Copper will be plated out onto the copper strip at the cathode. The anode is connected to the positive terminal of the power supply and the cathode copper strip is connected to the negative terminal. The external power supply causes a constant current to flow through the cell. The current is carried in the external circuit (wires) by the movement of electrons and in the solution by the movement of ions. The movement of positively charged cations in one direction in the solution is equivalent electrically to the movement of negatively charged electrons in the opposite direction in the wires.

Copper ions in the solution migrate to the negative electrode where they are reduced and deposited as elemental copper, according to the half-reaction: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$. The electrode at which the reduction occurs is called the cathode. At the other electrode, the anode, copper from the electrode is oxidized and goes into solution according the half-reaction: $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$.

The amount of Cu deposited is determined by weighing the electrode before and after the plating. The total electrical charge or number of coulombs passed during the plating can be calculated by using the formula, $Q = I \times t$, where Q is the charge in coulombs, I is the average current in amperes, and t is the time in seconds. From the coulombs of charge that pass through the cell, we can calculate the numbers of copper that theoretically can be plated out according to Faraday's equation. Ideally, the anode loses mass and the cathode gains an equal mass, as copper is transferred from the anode into solution and from solution to the cathode.

Using the initial and final weight of the copper electrode the mass difference of copper plated out can be calculated: $m_{(\text{Cu})} = m_{(\text{final})} - m_{(\text{initial})}$. Faraday's equation along with the experimental results can also be used to estimate the molecular weight of unknown materials during plating.

2. Purpose

The purpose of this experiment is to demonstrate different aspects involved during electroplating. The specific objectives include:

1. Construct an electroplating device.
2. Describe chemical changes that involve the transfer of electrons.
3. Describe the procedures used and the reactions occurring during the electroplating of a metal.
4. Determine the molar mass of copper by electro-deposition from an aqueous solution.

3. Materials

1M CuSO_4 electrolyte solution (25g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ with enough distilled water to make 100 ml of solution).

Two copper strips; stirring rod; 250ml beaker;

Power supply; Potentiostat Instrument with 4 wires;

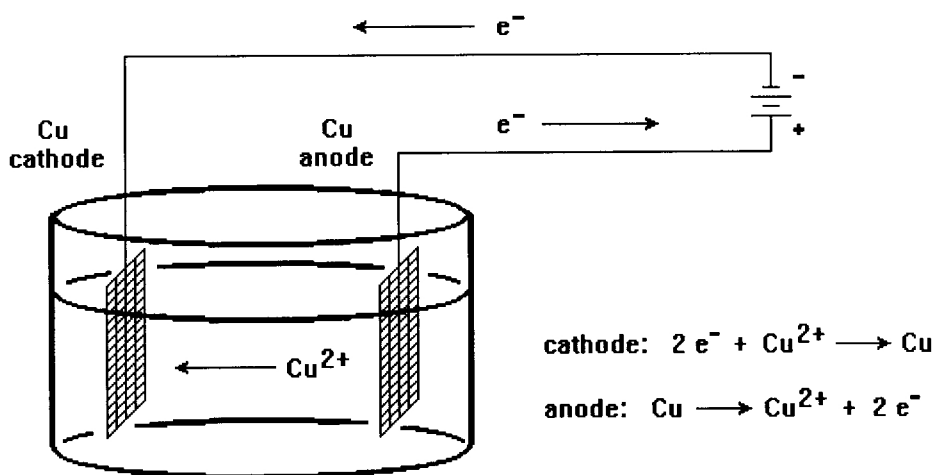
4. Procedure

- a. Prepare 100 ml 1M CuSO_4 electrolyte solution into the 250ml beaker.

- Clean carefully a pair of copper strip electrodes with distilled water and allow the electrodes to air dry, and then weigh each of them.
- Connect one copper strip to the red and white wires of Potentiostat Instrument and the other one to the black and green wires. Note that the red and white wires are the positive terminal, the black and green wires are the negative terminal. Support the electrodes as indicated in Figure1. The beaker can be raised and lowered while the two electrodes remain stationary. The electrodes almost touch the bottom of the beaker and extend above the liquid level.
- Check your set up carefully to verify that it is correct. Then set a stable DC power to the electroplating through the Potentiostat Instrument. Adjust the power supply to the given voltage that is assigned to your group and allow the time for electroplating running to half an hour. The Potentiostat Instrument will record the current and data automatically and stop.
- When the electroplating stops, get your file from the computer. Raise the electrodes out of the solution, disconnect the cathode and the anode copper, and rinse them thoroughly in a separate beaker with distilled water twice. Allow them to air dry and weigh them.

Item	amount	
	anode	cathode
mass of copper initial	g	g
mass of copper after	g	g
difference in mass	g	g
time	sec	
average current	A	

Figure1. Schematic of Apparatus for copper electroplating



5. Hazards

Although the power source is relatively weak, the electrodes and connecting wires should not be handled when the cell is operating. Goggles and gloves must be worn throughout the experiment.

6. Discussion

- Calculate the total number of coulombs passing through the cell (total charge).
- Calculate the theoretical mass of copper that should be plated out onto the cathode.

3. Compare the actual mass of copper plated out with the theoretical value.
4. Compare the mass difference at cathode and anode. Is it equal to each other? Discuss what would you expect?
5. Calculate the moles of copper plated out onto the cathode and the molar mass of copper
6. Compare the calculated value of molar mass of copper (molecular weight) to the accepted molar mass of copper. Remember that the accepted molar mass of copper is 63.55g/mol.
7. If the Potentiostat Instrument supplied a lower average current but the overall time remained the same, how would this affect the following measurement of calculation?

Item	more	same	less
mass of copper lost from the anode			
moles of electrons moving through the cell			
Coulombs generated			
The value of copper molar mass			

NOTE: Make sure to report uncertainties in your data and calculations.