Production of a vital industrial compound ($CuSO_4$)

Preparation of Copper(II) Sulfate by Electrolysis

Aim

To produce copper(II) sulfate solution using electrolysis with copper electrodes and dilute sulfuric acid.

Introduction

Copper sulfate is an essential chemical across the industrial sector. Its primary importance lies in its role as a fungicide in agricultural practices.

1. Agriculture (Most Common Use)

- Fungicides - It is the main ingredient in the "Bordeaux mixture" (copper sulfate and lime) used to prevent mildew and blight on grapes, tomatoes, and potatoes as well as stone fruit such as nectarines and peaches.
- Nutritional Supplement - Added to soil or animal feed to correct copper deficiencies in crops and livestock.
- Pest Control - Acts as a molluscicide to kill snails and slugs that carry parasites.

Figure – fungal disease of stone fruit

2. Metal and Mining Industry

Copper sulfate is crucial for high-scale mineral extraction and refining:

- Mining (Froth Flotation) - It is used as an "activator" to help separate valuable minerals like zinc, lead, and gold from raw ore.
- Electroplating - It serves as the electrolyte bath for coating steel or other metals with a thin layer of copper for electrical conductivity or decorative finishes.

3. Textiles and Wood Preservation

- Dyeing - Acts as a "mordant" (a fixative) to help dyes stick permanently to fabrics like leather and wool.
- Wood Preservative - It is impregnated into timber to prevent rotting and insect damage in construction.

Electrolysis uses electrical energy to drive a chemical reaction to produce a useful product. In this experiment, electrodes are placed into dilute sulfuric acid and connected to a DC power supply. The setup is shown below in fig 2.

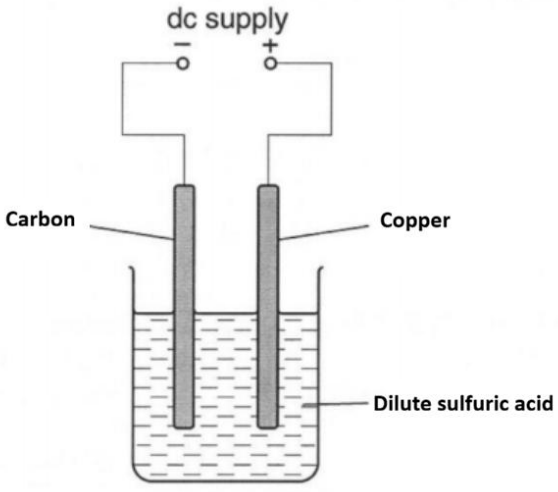

Figure 2 – the electrolytic setup for the formation of $CuSO_4$

Materials

- 100 mL dilute sulfuric acid (approximately 0.5 mol L^{-1})
- 1 copper electrode and 1 carbon electrode
- 250 mL beaker
- DC power supply
- Connecting wires and alligator clips
- Retort stand (optional)
- Safety glasses
- Gloves , lab-coat

Safety

- Wear, gloves, safety glasses and lab-coat, at all times.
- Dilute sulfuric acid is corrosive and may irritate skin and eyes.
- Wash spills immediately with plenty of water.
- Ensure electrical equipment remains dry.

Method

1. Pour approximately 100 mL of dilute sulfuric acid into a beaker.
2. Clean the electrodes to remove oxide or grease.
3. Place the electrodes into the solution without touching each other.
4. Connect the copper electrode to the positive terminal of the power supply.
5. Connect the carbon electrode to the negative terminal.
6. Turn on the power supply at a low voltage (approximately 4–6 V).
7. Allow electrolysis to continue for 10–15 minutes or until a reddish-brown copper coating is observed on the carbon electrode..
8. Observe any colour changes and changes to the electrodes.
9. Turn off the power supply and remove the electrodes after 10 minutes or until a red/pinkish deposit is seen on the carbon electrode.

Results / Observations

You should observe the following. Fill in the blanks to the sentences below with appropriate responses.

- Describe the colour change of the clear electrolyte solution.

_____

- Describe how the copper electrode has visibly changed throughout the course of the experiment.

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- Describe how the carbon electrode changed during the course of this experiment.

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Discussion Questions

1. At the end, how is it obvious that Cu^{2+} ions are present in the electrolyte? Justify your answer with a balanced half-equation.

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2. Which electrode loses mass? Explain why with a balanced half-equation.

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3. Name two roles that sulfuric acid plays in this experiment?

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4. What reaction occurs at the :
   - anode _____

   - cathode_____

5. Explain why the experiment should stop when a pink layer is seen to deposit on the carbon electrode. Give a balanced half-equation to enhance your explanation.

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Conclusion

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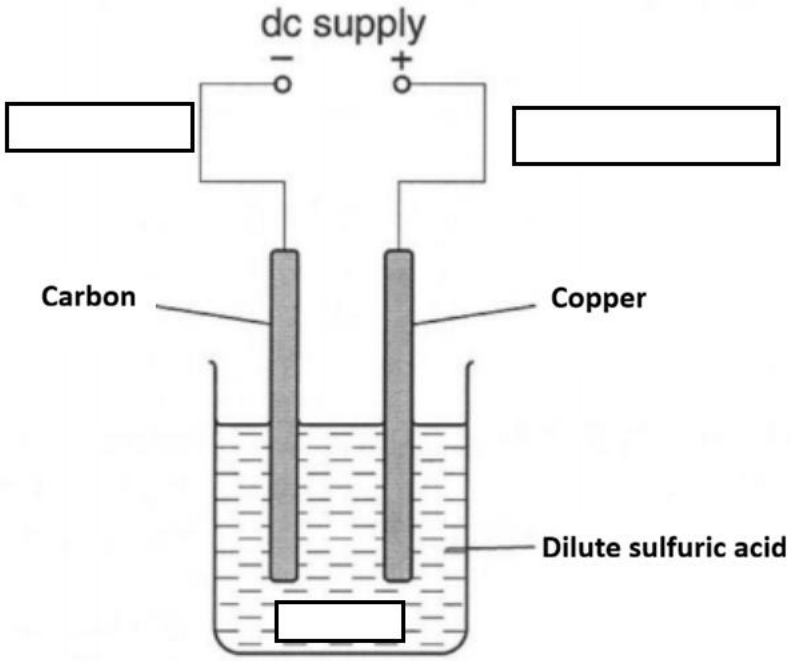
An industrial chemist is given the task to complete a small scale electrolysis experiment to form copper sulphate ($CuSO_4$) from recycled scrap copper metal from the scrapyard. The chemist uses the experimental setup shown below.



1. On the diagram shown above, clearly label and give the half reaction taking place at the:

- anode _____

- cathode _____

- label the direction of anion flow by placing an arrow in the box provided,

2. A volume of 100 mL of 0.500 M H_2SO_4 was placed in the beaker .

a. Calculate the amount, in mol, of H_2SO_4 present in the beaker. 2 marks

b. Calculate the amount, in mol, of Cu^{2+} ions needed to react exactly with all the SO_4^{2-} ions present in the beaker. 1 mark

c. When the circuit was switched on, a current of 1.5 amps was supplied at a voltage of 5.00 volts.

i. Write a balanced half-equation for the reaction at the anode

_____ 2 marks

ii. Calculate the time, in minutes, needed to completely convert all the SO_4^{2-} into $CuSO_4$. 3 marks

3. Is the synthesis of $CuSO_4$ an example of a linear or circular economy? Justify your answer.

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_____ 2 marks

4. Explain how the experiment would change if the carbon rod was replaced with a silver electrode.

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_____ 2 marks