

Galvanic cells, electrode potentials and electrolysis

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Lab

Name: _____ Date: _____ Class: _____

Can a handful of metal strips, a few beakers and a voltmeter reproduce the electrochemical series? You pair each metal with a copper half-cell, rank the metals by emf, compare the results with data-book values, and then watch what happens to a cell's voltage when one solution is diluted.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB R3.2

Aim

To measure the emf of cells made from copper and four other metals, compare the results with standard electrode potentials, and see how concentration changes the emf.

Equipment

- Strips of copper, zinc, magnesium, tin and an iron nail, cleaned with sandpaper
- 0.10 mol/dm³ solutions of each metal's sulfate (iron(II) sulfate freshly prepared), 1.0 mol/dm³ copper(II) sulfate and 1.0 mol/dm³ zinc sulfate
- High-resistance voltmeter, leads with crocodile clips, filter-paper strips soaked in potassium nitrate solution, small beakers

Safety

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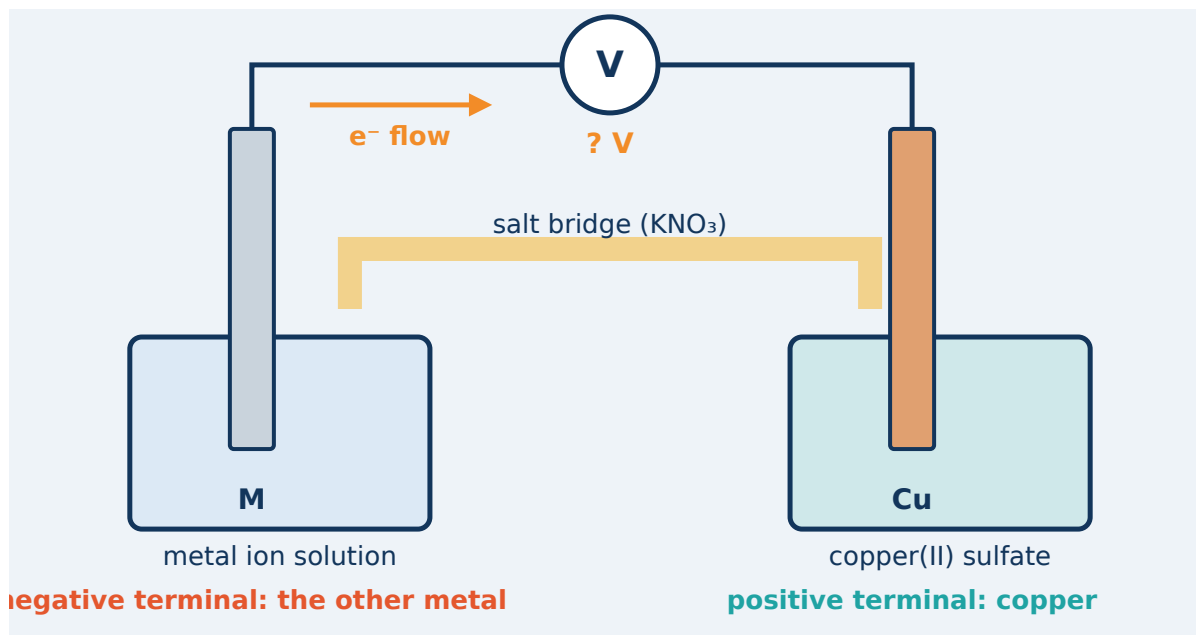
Wear eye protection. Copper(II) sulfate is harmful if swallowed and irritates eyes.

Magnesium and zinc strips are not hazardous but have sharp edges. Wash hands after the lab and do not use lead.

Method

1. Place a copper strip in 0.10 mol/dm³ copper(II) sulfate in one beaker. Put a magnesium strip in 0.10 mol/dm³ magnesium sulfate in another.
2. Join the solutions with a wet filter-paper salt bridge and connect the metals to the voltmeter.
3. Record the emf and which metal is connected to the negative terminal.

- Repeat with zinc, iron and tin against the same copper half-cell.
- Finally set up $\text{Zn} \mid \text{Zn}^{2+} (1.0 \text{ mol/dm}^3) \parallel \text{Cu}^{2+} \mid \text{Cu}$ with copper(II) sulfate of 1.0, 0.10, 0.010 and 0.0010 mol/dm^3 (make by dilution) and record the emf each time.



Results

Sample class data (about 22 °C):

Metal M	Measured emf of M Cu cell (V)	Standard E° cell (V)
Magnesium	2.60	2.71
Zinc	1.08	1.10
Iron	0.74	0.78
Tin	0.46	0.48

Zinc-copper cell with different copper(II) concentrations:

$[\text{Cu}^{2+}]$ (mol/dm^3)	1.0	0.10	0.010	0.0010
Measured emf (V)	1.10	1.07	1.04	1.02

Analysis questions

Question 1 Order of reactivity

Use the first table to list the four metals in order of how strongly they act as reducing agents when connected to copper.

Question 2 Electrode potentials

Taking $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34 \text{ V}$, calculate the electrode potential of each metal from your measured emf.

Question 3 Comparing with the data book

Calculate the percentage difference between the measured and standard emf for magnesium and for zinc.

Question 4 Why results differ

Suggest three reasons why the measured emf values are lower than the standard values.

Question 5 Concentration trend

Describe the trend in the second table and calculate the average fall in emf for each tenfold dilution of copper(II) sulfate.

Question 6 Explaining the trend

Explain the trend using the equilibrium $\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$.

Question 7 Equipment and improvement

Explain why a high-resistance voltmeter is used and suggest one way to improve the reliability of the readings.