

Galvanic cells, electrode potentials and electrolysis

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

Name: _____ Date: _____ Class: _____

These problems train you to build and describe galvanic cells, calculate cell emf from electrode potentials, judge feasibility, work with fuel cells and apply Faraday's law in electrolysis. They progress from definitions to multi-step calculations.

The level suits A Level, IB Chemistry, CBSE Class 11-12 and senior WAEC and NECO students. Use $F = 96\,500\text{ C/mol}$ and quote answers to three significant figures.

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

Problem 1 Anode, cathode and salt bridge (easy)

A teacher in Kampala builds a simple galvanic cell from magnesium and copper.

1. State which electrode is the anode and which process takes place there.
2. State the direction of electron flow in the external wire.
3. State the job of the salt bridge.

Problem 2 Writing cell notation (easy)

Chiamaka builds a nickel-magnesium cell. $E^\circ(\text{Mg}^{2+}/\text{Mg}) = -2.37\text{ V}$ and $E^\circ(\text{Ni}^{2+}/\text{Ni}) = -0.26\text{ V}$.

1. Identify the anode and the cathode.
2. Write the cell notation, anode on the left.
3. Calculate E°_{cell} .

Problem 3 The reference electrode (easy)

All electrode potentials are measured against the standard hydrogen electrode.

1. State the three standard conditions for the electrode.
2. Write the half-equation for the hydrogen electrode.
3. State the value of its potential.

Problem 4 Emf of a zinc-silver cell (easy)

Aarav in Pune has a zinc half-cell ($E^\circ = -0.76\text{ V}$) and a silver half-cell ($E^\circ = +0.80\text{ V}$).

1. Calculate E°_{cell} .
2. Write the overall equation.
3. State which metal dissolves.

Problem 5 Charge and moles of electrons (easy)

A current of 0.250 A passes through a cell for 90.0 minutes ($F = 96\,500\text{ C/mol}$).

1. Calculate the charge in coulombs.
2. Calculate the moles of electrons.

Problem 6 Will Fe^{3+} or H^+ oxidise the metal? (medium)

Use E° : $\text{Fe}^{3+}/\text{Fe}^{2+} +0.77\text{ V}$, $\text{Cu}^{2+}/\text{Cu} +0.34\text{ V}$, $\text{Ag}^+/\text{Ag} +0.80\text{ V}$, $\text{H}^+/\text{H}_2 0.00\text{ V}$.

1. Calculate E°_{cell} for Cu reducing Fe^{3+} and state whether the reaction is feasible.
2. Calculate E°_{cell} for silver reacting with dilute acid and state whether it is feasible.
3. Write the equation for any feasible reaction.

Problem 7 Halogens and halide ions (medium)

Diego in Texas adds chlorine to pool water that contains traces of bromide and iodide. E° :

$\text{Cl}_2/\text{Cl}^- +1.36\text{ V}$, $\text{Br}_2/\text{Br}^- +1.07\text{ V}$, $\text{I}_2/\text{I}^- +0.54\text{ V}$.

1. Calculate E°_{cell} for $\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$.
2. Calculate E°_{cell} for $\text{I}_2 + 2\text{Cl}^- \rightarrow 2\text{I}^- + \text{Cl}_2$.
3. Arrange the three halogens from strongest to weakest oxidising agent.

Problem 8 Hydrogen fuel cell half-equations (medium)

A hydrogen-oxygen fuel cell with acid electrolyte powers a bus in Singapore.

1. Write the half-equation at the anode.
2. Write the half-equation at the cathode.
3. Combine them into the overall equation and calculate E°_{cell} ($\text{O}_2/\text{H}_2\text{O } E^\circ = +1.23\text{ V}$).

Problem 9 Hydrogen consumed by a fuel cell (medium)

Bilal in Lahore runs a hydrogen fuel cell scooter motor at 5.0 A for 1.0 hour ($A_r\text{ H} = 1.008$; 1 mol gas = 24.0 dm^3 at room temperature).

1. Calculate the charge passed.
2. Calculate the moles of hydrogen consumed.
3. Calculate the mass and volume of hydrogen.

Problem 10 Plating copper (medium)

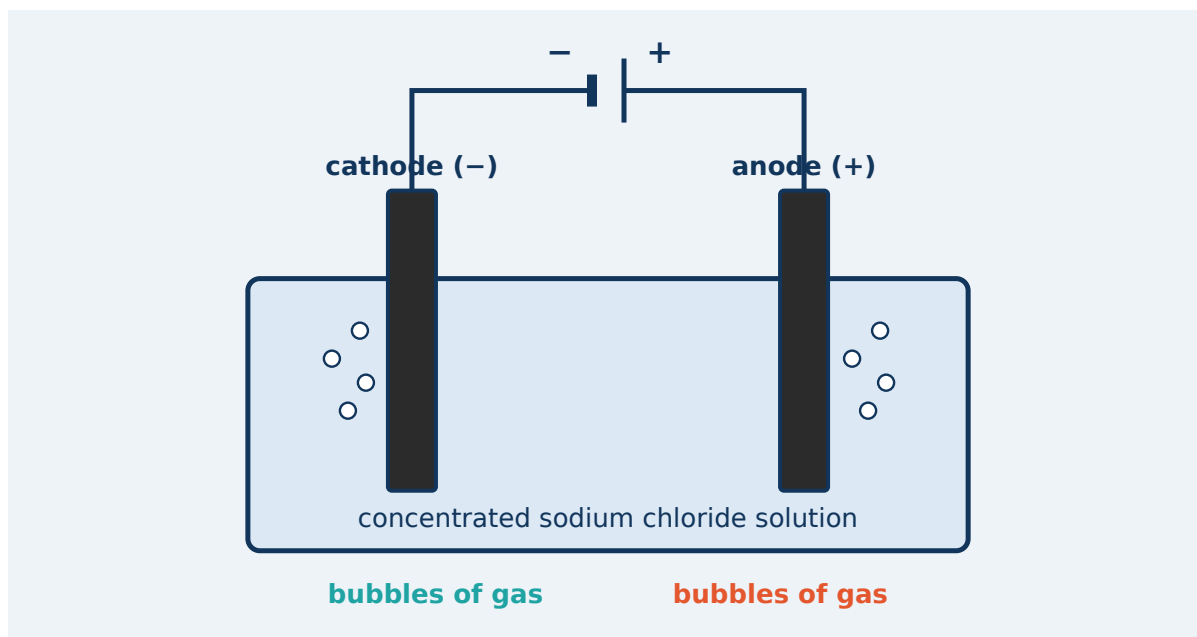
Wanjiru in Nairobi plates a brass key with copper using a current of 1.25 A for 25.0 minutes ($A_r\text{ Cu} = 63.5$).

1. Calculate the charge passed.
2. Calculate the moles of electrons and of copper.
3. Calculate the mass of copper deposited.

Problem 11 Electrolysis of brine (medium)

Mei in Singapore electrolyses concentrated sodium chloride solution with graphite electrodes, as shown. E° : $\text{Na}^+/\text{Na} -2.71 \text{ V}$, $\text{H}_2\text{O}/\text{H}_2 -0.83 \text{ V}$.

1. Name the product at each electrode.
2. Write the half-equation at each electrode.
3. Explain why sodium metal is not formed.
4. Identify the solution that remains.



Gas bubbles form at both electrodes.

Problem 12 Diluting one half-cell (medium)

Emma in Leeds measures the emf of $\text{Zn(s)} \mid \text{Zn}^{2+}(1.0 \text{ mol/dm}^3) \parallel \text{Cu}^{2+}(c) \mid \text{Cu(s)}$ for different concentrations c of copper(II) ions.

1. State what happens to the emf when c is reduced from 1.0 to 0.010 mol/dm³.
2. Use the equilibrium $\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$ to explain.

Problem 13 Identify metals from cell voltages (medium)

Kofi connects three unknown metals X, Y, Z to a copper half-cell ($E^\circ = +0.34 \text{ V}$) under standard conditions. $\text{X}|\text{Cu}$: 1.10 V, X negative. $\text{Y}|\text{Cu}$: 0.47 V, Y negative. $\text{Z}|\text{Cu}$: 0.46 V, copper negative. Candidates and E° : Zn -0.76 V , Pb -0.13 V , Ag $+0.80 \text{ V}$, Fe -0.44 V .

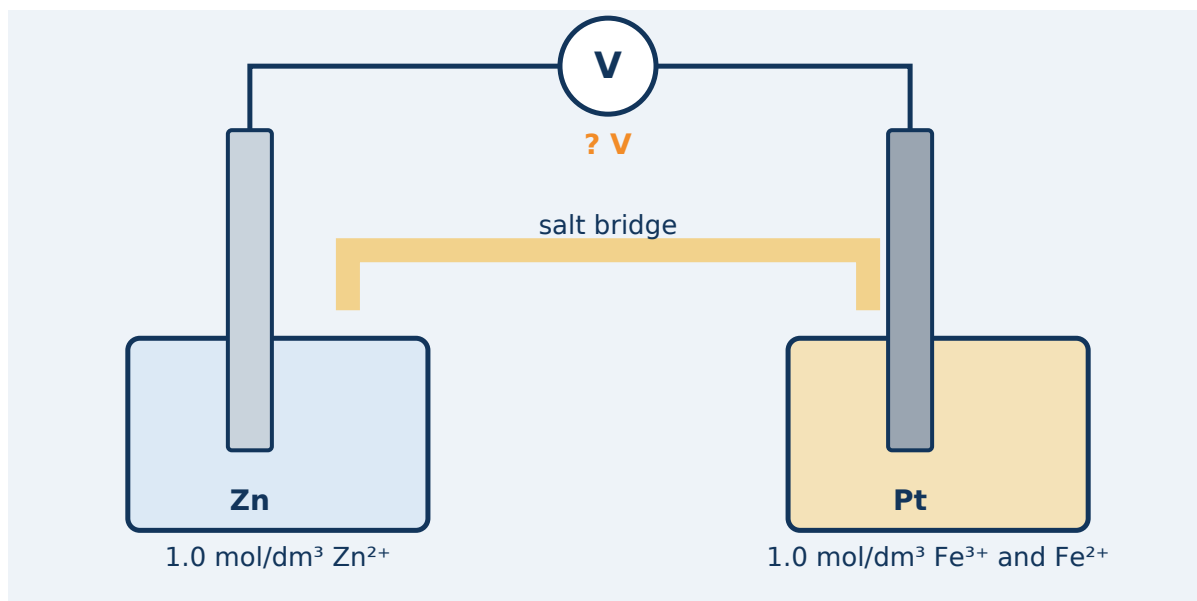
1. Calculate E° of X, Y and Z.
2. Identify each metal.

Problem 14 A cell with a platinum electrode (medium)

Aarav sets up the cell in the diagram. E° : $\text{Zn}^{2+}/\text{Zn} -0.76 \text{ V}$, $\text{Fe}^{3+}/\text{Fe}^{2+} +0.77 \text{ V}$.

1. Explain why platinum is used in the right-hand half-cell.
2. Calculate the voltmeter reading.

3. State the direction of electron flow and write the overall equation.



Zn|Zn²⁺ half-cell linked to a Pt|Fe³⁺, Fe²⁺ half-cell.

Problem 15 Ion movement in the salt bridge (medium)

Emma in Leeds uses a potassium nitrate salt bridge in the cell $\text{Zn(s)} \mid \text{Zn}^{2+}(\text{aq}) \parallel \text{Cu}^{2+}(\text{aq}) \mid \text{Cu(s)}$.

1. State which half-cell gains positive charge as the cell operates.
2. State the direction in which K^+ and NO_3^- ions move.
3. Explain why a second copper wire cannot replace the salt bridge.

Problem 16 Silver nitrate electrolysis (hard)

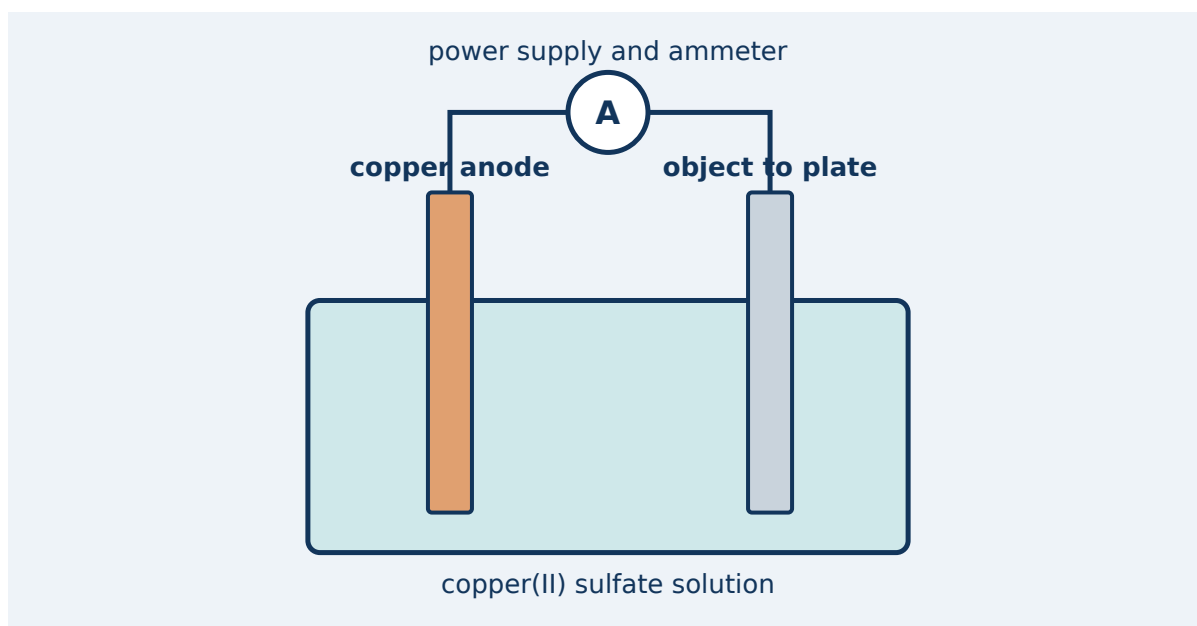
Mei passes 0.250 A for 3.00 hours through silver nitrate solution with inert electrodes (A, Ag = 107.9; F = 96 500 C/mol; 1 mol gas = 24.0 dm³).

1. Calculate the charge passed and the moles of electrons.
2. Calculate the mass of silver deposited at the cathode.
3. Write the anode half-equation and calculate the volume of oxygen formed.

Problem 17 Charge on a metal ion (hard)

A student plates an unknown metal M of molar mass 112.4 g/mol. A current of 0.800 A for 25.0 minutes deposits 0.699 g of M on the cathode, as in the apparatus shown.

1. Calculate the charge passed and the moles of electrons.
2. Calculate the moles of M deposited.
3. Find the ratio electrons : atoms and deduce the charge on the ion.



Plating set-up: the object is the cathode.

Problem 18 Efficiency of copper plating (hard)

Chiamaka plates a spoon with copper using 2.00 A for 20.0 minutes. The mass of copper on the spoon rises by 0.760 g ($A_r \text{ Cu} = 63.5$).

1. Calculate the theoretical mass of copper deposited.
2. Calculate the percentage current efficiency.
3. Suggest two reasons why the efficiency is below 100 %.

Problem 19 Alkaline hydrogen fuel cell (hard)

An alkaline fuel cell uses potassium hydroxide as electrolyte. Anode: $\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$ ($E^\circ = -0.83 \text{ V}$). Cathode: $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$ ($E^\circ = +0.40 \text{ V}$).

1. Combine the half-equations into the overall equation.
2. Calculate E°_{cell} .
3. State the direction in which hydroxide ions move and explain why.
4. Explain one advantage of a fuel cell over burning hydrogen in an engine.

Problem 20 Spot the errors (hard)

A student writes: "For Zn/Cu, $E^\circ_{\text{cell}} = E^\circ(\text{anode}) - E^\circ(\text{cathode}) = -0.76 - 0.34 = -1.10 \text{ V}$, so the cell does not work. Also, if I write the copper half-equation as $2\text{Cu}^{2+} + 4\text{e}^- \rightarrow 2\text{Cu}$, E° doubles to +0.68 V and the cell emf is 1.44 V."

1. Identify the error in the formula used.
2. Give the correct value of E°_{cell} .
3. Explain why doubling the half-equation does not change E° .