

Galvanic cells, electrode potentials and electrolysis

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

Each answer shows the subtraction or formula, the substitution and the result with its unit in bold. When a problem asks for an explanation, the key idea is given in a sentence you can compare with your own wording.

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

Problem 1 Anode, cathode and salt bridge

1. The anode is the **magnesium** electrode, where **oxidation** happens ($\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$).
2. Electrons flow **from magnesium (anode) to copper (cathode)** through the wire.
3. The salt bridge **completes the circuit and lets ions move** to keep both half-cells electrically neutral.

Problem 2 Writing cell notation

1. Magnesium has the more negative E° , so it is the **anode**; nickel is the **cathode**.
2. **$\text{Mg(s)} \mid \text{Mg}^{2+}(\text{aq}) \parallel \text{Ni}^{2+}(\text{aq}) \mid \text{Ni(s)}$** .
3. $E^\circ_{\text{cell}} = -0.26 - (-2.37) = \mathbf{+2.11 \text{ V}}$.

Problem 3 The reference electrode

1. **298 K, 1.00 mol/dm³ H⁺ and 100 kPa hydrogen gas** (with a platinum electrode).
2. $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$.
3. $E^\circ = \mathbf{0.00 \text{ V}}$ by definition.

Problem 4 Emf of a zinc-silver cell

1. $E^\circ_{\text{cell}} = +0.80 - (-0.76) = \mathbf{+1.56 \text{ V}}$.
2. $\text{Zn} + 2\text{Ag}^+ \rightarrow \text{Zn}^{2+} + 2\text{Ag}$.
3. **Zinc** dissolves, because it is oxidised at the anode.

Problem 5 Charge and moles of electrons

1. $t = 90.0 \times 60 = 5400 \text{ s}$; $Q = 0.250 \times 5400 = \mathbf{1350 \text{ C}}$.
2. $n(\text{e}^-) = 1350 \div 96\,500 = \mathbf{0.0140 \text{ mol}}$.

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

1. Reduction Fe^{3+} (+0.77), oxidation Cu (+0.34): $E^\circ_{\text{cell}} = +0.43 \text{ V}$, feasible.
2. Reduction H^+ (0.00), oxidation Ag (+0.80): $E^\circ_{\text{cell}} = 0.00 - 0.80 = -0.80 \text{ V}$, not feasible.
3. $2\text{Fe}^{3+} + \text{Cu} \rightarrow 2\text{Fe}^{2+} + \text{Cu}^{2+}$.

Problem 7 Halogens and halide ions

1. $E^\circ_{\text{cell}} = 1.36 - 1.07 = +0.29 \text{ V}$, feasible.
2. $E^\circ_{\text{cell}} = 0.54 - 1.36 = -0.82 \text{ V}$, not feasible.
3. **Cl_2 , then Br_2 , then I_2** , in order of decreasing E° .

Problem 8 Hydrogen fuel cell half-equations

1. $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$.
2. $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$.
3. Double the first equation: **$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$** ; $E^\circ_{\text{cell}} = 1.23 - 0.00 = +1.23 \text{ V}$.

Problem 9 Hydrogen consumed by a fuel cell

1. $Q = 5.0 \times 3600 = 18\,000 \text{ C}$.
2. $n(\text{e}^-) = 18\,000 \div 96\,500 = 0.1865 \text{ mol}$; each H_2 gives 2e^- , so $n(\text{H}_2) = 0.0933 \text{ mol}$.
3. $m = 0.0933 \times 2.016 = 0.188 \text{ g}$; $V = 0.0933 \times 24.0 = 2.24 \text{ dm}^3$.

Problem 10 Plating copper

1. $t = 1500 \text{ s}$; $Q = 1.25 \times 1500 = 1875 \text{ C}$.
2. $n(\text{e}^-) = 1875 \div 96\,500 = 0.01943 \text{ mol}$; $n(\text{Cu}) = 0.01943 \div 2 = 0.009715 \text{ mol}$.
3. $m = 0.009715 \times 63.5 = 0.617 \text{ g}$.

Problem 11 Electrolysis of brine

1. Cathode: **hydrogen**; anode: **chlorine**.
2. Cathode: $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$. Anode: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$.
3. Water (-0.83 V) is reduced more easily than Na^+ (-2.71 V), since the higher E° is reduced first.
4. Aqueous **sodium hydroxide**, from Na^+ and OH^- .

Problem 12 Diluting one half-cell

1. The emf **decreases** a little (it is about 0.06 V lower).
2. Lower $[\text{Cu}^{2+}]$ shifts the equilibrium to the left, so Cu^{2+} is less strongly attracted to electrons and the copper half-cell becomes less positive. The difference between the two half-cells is smaller, so the emf falls.

Problem 13 Identify metals from cell voltages

1. X: $E^\circ = 0.34 - 1.10 = -0.76 \text{ V}$. Y: $0.34 - 0.47 = -0.13 \text{ V}$. Z is the cathode against negative copper: $E^\circ = 0.34 + 0.46 = +0.80 \text{ V}$.
2. X is **zinc**, Y is **lead**, Z is **silver**.

Problem 14 A cell with a platinum electrode

1. Both Fe^{3+} and Fe^{2+} are in solution, so an **inert conducting electrode** is needed to carry electrons.
2. $E^\circ_{\text{cell}} = 0.77 - (-0.76) = +1.53 \text{ V}$.
3. Electrons flow **from Zn to Pt**. Overall: $\text{Zn} + 2\text{Fe}^{3+} \rightarrow \text{Zn}^{2+} + 2\text{Fe}^{2+}$.

Problem 15 Ion movement in the salt bridge

1. Zn becomes Zn^{2+} , so the **zinc half-cell** gains positive charge; the copper half-cell loses Cu^{2+} and becomes negative.
2. **K^+ moves towards the copper half-cell** and **NO_3^- moves towards the zinc half-cell**.
3. A metal wire carries electrons only; the solutions need ions to flow to complete the circuit and cancel the charge build-up.

Problem 16 Silver nitrate electrolysis

1. $t = 10\,800 \text{ s}$; $Q = 0.250 \times 10\,800 = 2700 \text{ C}$; $n(e^-) = 2700 \div 96\,500 = 0.02798 \text{ mol}$.
2. $\text{Ag}^+ + e^- \rightarrow \text{Ag}$, so $n(\text{Ag}) = 0.02798 \text{ mol}$; $m = 0.02798 \times 107.9 = 3.02 \text{ g}$.
3. $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4e^-$; $n(\text{O}_2) = 0.02798 \div 4 = 0.006995 \text{ mol}$; $V = 0.006995 \times 24.0 = 0.168 \text{ dm}^3 = 168 \text{ cm}^3$.

Problem 17 Charge on a metal ion

1. $t = 1500 \text{ s}$; $Q = 0.800 \times 1500 = 1200 \text{ C}$; $n(e^-) = 1200 \div 96\,500 = 0.01244 \text{ mol}$.
2. $n(\text{M}) = 0.699 \div 112.4 = 0.006219 \text{ mol}$.
3. Ratio = $0.01244 \div 0.006219 = 2.00$, so each atom needs 2 electrons: the ion is **M^{2+}** .

Problem 18 Efficiency of copper plating

1. $Q = 2.00 \times 1200 = 2400 \text{ C}$; $n(e^-) = 0.02487 \text{ mol}$; $n(\text{Cu}) = 0.012435 \text{ mol}$; $m = 0.790 \text{ g}$.
2. Efficiency = $0.760 \div 0.790 \times 100 = 96.2 \%$.
3. Some current reduces H^+ to hydrogen at the cathode; some copper may fall off the spoon or dissolve again; the current may not have been steady.

Problem 19 Alkaline hydrogen fuel cell

1. Double the anode equation: $2\text{H}_2 + 4\text{OH}^- \rightarrow 4\text{H}_2\text{O} + 4e^-$. Add the cathode equation and cancel: **$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$** .
2. $E^\circ_{\text{cell}} = 0.40 - (-0.83) = +1.23 \text{ V}$, the same as in acid.

3. OH^- moves **from the cathode to the anode**, because OH^- is made at the cathode and used up at the anode.
4. A fuel cell converts chemical energy directly into electrical energy with fewer losses (typically 40–60 % efficient) than burning hydrogen to produce heat and then work.

Problem 20 Spot the errors

1. The formula is **upside down**: it must be $E^\circ(\text{cathode}) - E^\circ(\text{anode})$.
2. $E^\circ_{\text{cell}} = 0.34 - (-0.76) = \mathbf{+1.10\text{ V}}$, so the cell works.
3. E° is a potential per unit charge, an **intensive property**. Doubling the amounts of Cu^{2+} and electrons doubles the energy but not the energy per coulomb, so E° stays +0.34 V and the emf stays 1.10 V.