

Cells, cell potential and electrolysis

AP Chemistry · Worksheet

Name: _____ Date: _____ Class: _____

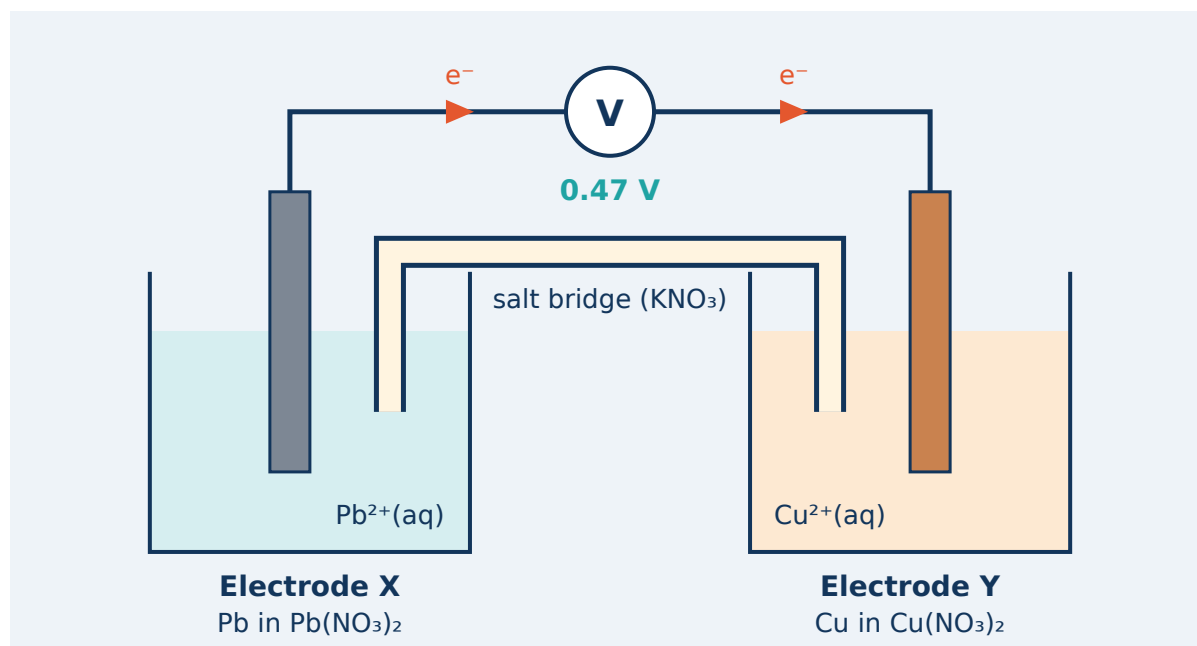
These 20 problems train the Unit 9 skills: labelling cells, calculating E°_{cell} , linking voltage to ΔG° and K , applying the Nernst equation and using Faraday's law for electrolysis.

They climb from recall through multi-step calculations to AP-style reasoning, suitable for AP Chemistry and first-year university courses. Use the table of potentials from the lesson when a value is not given.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 9

Problem 1 Reading a lead-copper cell (easy)

Emma in Leeds builds the cell in the diagram. The voltmeter reads 0.47 V.



Cell for Problem 1.

1. Identify the anode and write its half-reaction.
2. State the direction of electron flow in the wire.
3. State which way nitrate ions move in the salt bridge.

Problem 2 Magnesium and silver cell (easy)

Kofi in Accra looks up $E^\circ(\text{Mg}^{2+}/\text{Mg}) = -2.37 \text{ V}$ and $E^\circ(\text{Ag}^+/\text{Ag}) = +0.80 \text{ V}$.

1. Decide which half-cell is the cathode.
2. Calculate E°_{cell} .

3. Write the balanced overall equation.

Problem 3 Will the iron nail react? (easy)

Bilal in Lahore drops one iron nail into zinc sulfate solution and another into copper(II) sulfate solution. E° : $\text{Fe}^{2+}/\text{Fe} = -0.44 \text{ V}$, $\text{Zn}^{2+}/\text{Zn} = -0.76 \text{ V}$, $\text{Cu}^{2+}/\text{Cu} = +0.34 \text{ V}$.

1. Calculate E° for $\text{Fe} + \text{Zn}^{2+} \rightarrow \text{Fe}^{2+} + \text{Zn}$.
2. Calculate E° for $\text{Fe} + \text{Cu}^{2+} \rightarrow \text{Fe}^{2+} + \text{Cu}$.
3. State which nail changes and describe what Bilal sees.

Problem 4 From current to electrons (easy)

Wanjiru in Nairobi passes 0.250 A through a cell for 2.00 h. Use $F = 96\,485 \text{ C/mol}$ and $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$.

1. Convert the time to seconds.
2. Calculate the charge in coulombs.
3. Calculate the moles of electrons.
4. Calculate the number of electrons.

Problem 5 Balancing aluminium and copper (easy)

Mei in Singapore pairs aluminium ($E^\circ = -1.66 \text{ V}$ for Al^{3+}/Al) with copper(II) ($E^\circ = +0.34 \text{ V}$).

1. Write the oxidation and reduction half-reactions.
2. Multiply them so the electrons cancel and write the overall equation.
3. State n and calculate E°_{cell} .

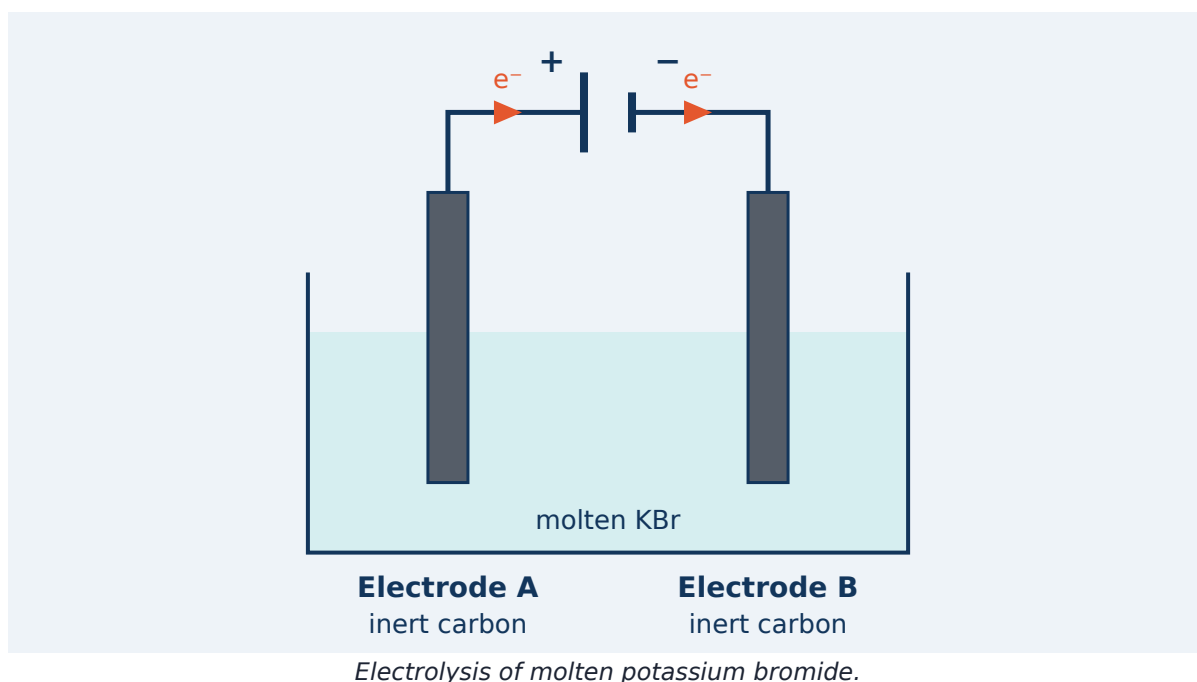
Problem 6 The hydrogen electrode (easy)

Aarav in Pune is told that all reduction potentials are measured against the standard hydrogen electrode (SHE).

1. State the standard conditions of the SHE.
2. In a cell of SHE and Cu^{2+}/Cu ($E^\circ = +0.34 \text{ V}$), identify the cathode.
3. Use $E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76 \text{ V}$ to decide if zinc reacts with 1.0 mol/dm^3 hydrochloric acid.

Problem 7 Electrolysis of molten potassium bromide (easy)

Diego in Texas electrolyses molten KBr with inert electrodes, as in the diagram.



1. State the sign of electrodes A and B.
2. Write the half-reaction at each electrode.
3. Explain why a battery is needed.

Problem 8 Free energy of a copper-silver cell (medium)

$\text{Cu} + 2\text{Ag}^+ \rightarrow \text{Cu}^{2+} + 2\text{Ag}$. $E^\circ(\text{Ag}^+/\text{Ag}) = +0.80 \text{ V}$, $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34 \text{ V}$.

1. Calculate E°_{cell} .
2. State n .
3. Calculate ΔG° in kJ/mol.

Problem 9 Equilibrium constant for iron and copper (medium)

$\text{Fe} + \text{Cu}^{2+} \rightarrow \text{Fe}^{2+} + \text{Cu}$. $E^\circ(\text{Cu}^{2+}/\text{Cu}) = +0.34 \text{ V}$, $E^\circ(\text{Fe}^{2+}/\text{Fe}) = -0.44 \text{ V}$. Use $\log K = nE^\circ/0.0592$.

1. Calculate E°_{cell} .
2. Calculate $\log K$ and K .
3. Comment on the extent of reaction.

Problem 10 Nickel plating a bracket (medium)

Chiamaka in Lagos nickel-plates a brass bracket with $\text{Ni}^{2+} + 2\text{e}^- \rightarrow \text{Ni}$, using 1.50 A for 25.0 min. $M(\text{Ni}) = 58.69 \text{ g/mol}$.

1. Calculate the charge passed.
2. Calculate the moles of nickel deposited.
3. Calculate the mass of nickel.

Problem 11 How long to deposit silver? (medium)

Mei in Singapore wants 5.00 g of silver from $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$ at a steady 2.00 A. $M(\text{Ag}) = 107.87 \text{ g/mol}$.

1. Calculate the moles of silver needed.
2. Calculate the charge required.
3. Calculate the time in minutes.

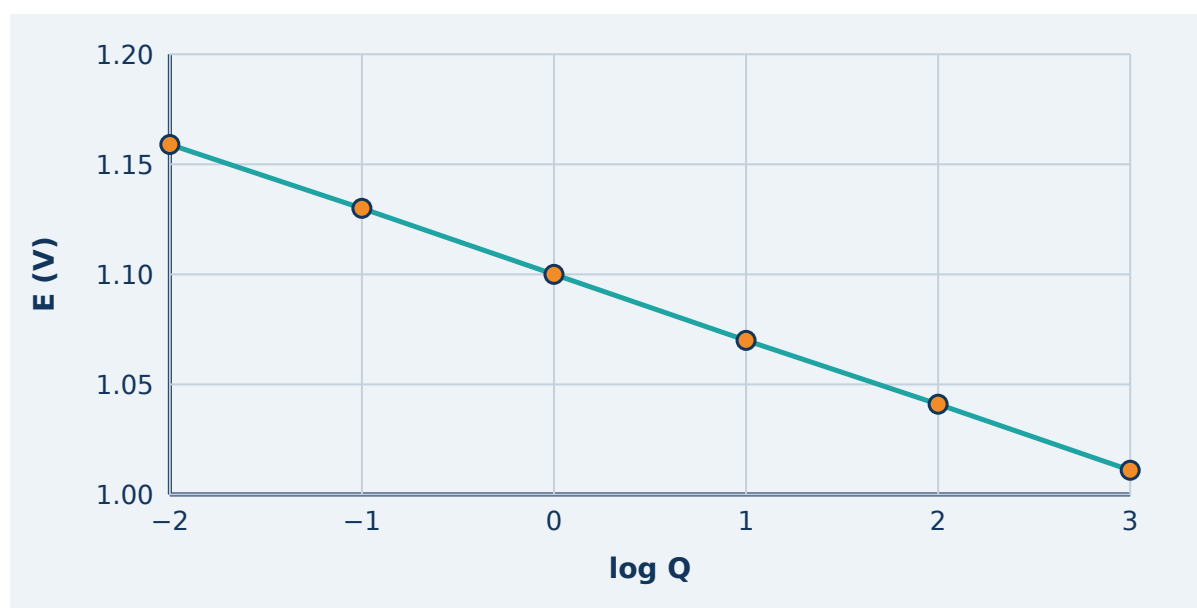
Problem 12 Cell voltage at other concentrations (medium)

A Zn/Cu cell at 25 °C has $[\text{Zn}^{2+}] = 0.050 \text{ mol/dm}^3$ and $[\text{Cu}^{2+}] = 0.80 \text{ mol/dm}^3$. $E^\circ = 1.10 \text{ V}$ and $n = 2$.

1. Write the expression for Q.
2. Calculate Q and log Q.
3. Use the Nernst equation to find E.

Problem 13 Reading a Nernst graph (medium)

The graph shows E against log Q for one cell at 25 °C.



Cell potential against log Q for one cell at 25 °C.

1. Read E° from the graph.
2. Use the points $(-2, 1.16)$ and $(2, 1.04)$ to find the slope.
3. Use $\text{slope} = -0.0592 / n$ to find n.

Problem 14 Galvanic against electrolytic (medium)

Compare a galvanic cell and an electrolytic cell. Cover the energy change, the sign of the anode, the sign of ΔG° and the source of the electrons.

Problem 15 Galvanised and tin-plated steel (medium)

Wanjiru in Nairobi compares a galvanised (zinc-coated) roofing sheet with a tin-plated can, both scratched to expose the iron. E° : $\text{Zn}^{2+}/\text{Zn} = -0.76 \text{ V}$, $\text{Fe}^{2+}/\text{Fe} = -0.44 \text{ V}$, $\text{Sn}^{2+}/\text{Sn} = -0.14 \text{ V}$.

1. Explain which coating still protects the iron.
2. Explain what happens to the iron under the tin.

Problem 16 Permanganate and iron(II) titration cell (hard)

Aarav in Pune builds a cell with platinum electrodes in acidified $\text{MnO}_4^-/\text{Mn}^{2+}$ ($E^\circ = +1.51 \text{ V}$) and $\text{Fe}^{3+}/\text{Fe}^{2+}$ ($E^\circ = +0.77 \text{ V}$).

1. Explain why platinum electrodes are used.
2. Write the balanced overall equation in acid.
3. Calculate E°_{cell} and ΔG° in kJ/mol.

Problem 17 Aluminium smelting (hard)

A smelter reduces Al^{3+} to Al in molten cryolite with a steady $5.00 \times 10^4 \text{ A}$ for 1.00 h. $M(\text{Al}) = 26.98 \text{ g/mol}$.

1. Calculate the mass of aluminium in kilograms.
2. Calculate the moles of O_2 released if $2\text{O}^{2-} \rightarrow \text{O}_2 + 4\text{e}^-$ is the anode reaction.
3. Explain why aqueous Al^{3+} cannot be electrolysed to give aluminium, using $E^\circ(\text{H}_2\text{O}/\text{H}_2 \text{ in base}) = -0.83 \text{ V}$ and $E^\circ(\text{Al}^{3+}/\text{Al}) = -1.66 \text{ V}$.

Problem 18 A concentration cell (hard)

A cell has two copper electrodes, one in $0.0010 \text{ mol/dm}^3 \text{ Cu}^{2+}$ and the other in $1.0 \text{ mol/dm}^3 \text{ Cu}^{2+}$, joined by a salt bridge. $n = 2$.

1. State E°_{cell} and explain why the cell still gives a voltage.
2. Identify the anode.
3. Calculate E at 25°C .
4. Predict E after a long time.

Problem 19 Spot the errors (hard)

A student writes: " $\text{Zn} + 2\text{Ag}^+ \rightarrow \text{Zn}^{2+} + 2\text{Ag}$, so $E^\circ_{\text{cell}} = 2(0.80) - (-0.76) = 2.36 \text{ V}$. Then $\Delta G^\circ = -1 \times 96\,485 \times 2.36 = -228 \text{ kJ/mol}$."

1. Identify the two mistakes.
2. Give the correct E°_{cell} .
3. Give the correct ΔG° in kJ/mol.

Problem 20 Two cells in series (hard)

The same current passes through two electrolytic cells in series, one of $\text{CuSO}_4(\text{aq})$ and one of $\text{AgNO}_3(\text{aq})$. In the first, 0.640 g of copper is deposited in 30.0 min. $M(\text{Cu}) = 63.55 \text{ g/mol}$,

$M(\text{Ag}) = 107.87 \text{ g/mol}$.

1. Calculate the moles of electrons passed.
2. Calculate the mass of silver in the second cell.
3. Calculate the current in amperes.