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ANSWER BOOK

Electrode potentials and the standard hydrogen electrode

Electrochemistry · Unit C10

AQA 3.1.11.1 · OCR A 5.2.3

16 questions · 54 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 EPS-Q12

B1 copper is the positive electrode, as the right-hand half-cell with the more positive $E^{\ominus}$. **B1** electrons flow through the external wire from the magnesium to the copper. [2]

A2 EPS-Q14

B1 an oxide layer or grease on a metal strip, so the equilibrium at its surface is not the one intended. **B1** a voltmeter of too low a resistance, so a current flows and the reading falls below the EMF; or a dry or contaminated salt bridge. [2]

SECTION B · Standard, 3 to 5 marks

B1 EPS-Q1

B1 the solution contains H^+ ions at a concentration of 1.00 mol dm^{-3}, for example 1.00 mol dm^{-3} hydrochloric acid (allow 1 mol dm^{-3}). **B1** hydrogen gas is bubbled in at 100 kPa and the temperature is 298 K. **B1** the gas passes over a platinum electrode, coated with platinum black, that dips into the acid. **B1** platinum conducts and is inert, so it carries electrons to and from the H^+/H_2 equilibrium without reacting, since hydrogen cannot itself be an electrode. [4]

B2 EPS-Q6

B1 a high-resistance voltmeter allows almost no current to flow through the cell. **B1** no voltage is lost driving a current and the concentrations do not change, so the reading is the EMF; reject 'more accurate' alone. **B1** each end of a wire dipping into a solution would form a new metal–solution half-cell with its own electrode potential. **B1** those extra potentials would add to the reading, so the measured value would not be the EMF of the cell. [4]

B3 EPS-Q2

B1 the EMF, or potential difference, of a cell measured when no current flows (allow 'voltage'). **B1** in which the half-cell is connected to a standard hydrogen electrode; reject an answer with no reference electrode. **B1** with both half-cells under standard conditions: 298 K, 100 kPa and 1.00 mol dm^{-3} of each ion. [3]

B4 EPS-Q4

B1 the salt bridge allows ions to move between the two half-cells, completing the circuit; reject 'carries electrons'. **B1** the movement of ions keeps each solution electrically neutral without the two solutions mixing. **B1** potassium ions and nitrate ions do not react with the ions in either half-cell and form no precipitate. [3]

B5 EPS-Q7

B1 an equilibrium is set up at the surface of the metal, $Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$. **B1** zinc atoms leave the metal as Zn^{2+} ions and leave their electrons behind on the strip. **B1** the metal becomes negatively charged relative to the solution, giving a potential difference between them. [3]

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B6 EPS-Q8 **M1** silver has the more positive E°, so the silver half-cell is the right-hand, positive electrode. **M1** E°cell = E°right - E°left = (+0.80) - (-0.76). **A1** E°cell = +1.56 V, with the silver electrode positive. [3]

B7 EPS-Q10 **M1** E°cell = E°right - E°left = (+0.77) - (-2.37). **B1** $Mg(s) + 2Fe^{3+}(aq) \rightarrow Mg^{2+}(aq) + 2Fe^{2+}(aq)$, with the iron half-equation doubled and its E° not doubled. **A1** E°cell = +3.14 V. [3]

B8 EPS-Q11 **B1** the silver half-cell is on the right, written $|| Ag^{+}(aq) | Ag(s)$, because its E° is more positive. **B1** the iron half-cell is on the left, written $Pt(s) | Fe^{2+}(aq), Fe^{3+}(aq) ||$, with platinum at the outer end, a comma between the ions and Fe^{3+} next to the double line. **B1** EMF = 0.80 - 0.77 = +0.03 V, with the silver electrode positive. [3]

B9 EPS-Q15 **B1** chlorine gas at 100 kPa bubbled over a platinum electrode. **B1** in a solution of chloride ions at 1.00 mol dm^{-3}, such as potassium chloride solution, at 298 K. **B1** connected by a salt bridge and a high-resistance voltmeter to a standard hydrogen electrode; the reading is E°, with the chlorine electrode positive. [3]

B10 EPS-Q16 **B1** the zinc half-cell is a metal in a solution of its own ions, and the zinc metal is the electrode. **B1** the iron half-cell holds two ions, Fe^{3+} and Fe^{2+}, in the same solution, each at 1.00 mol dm^{-3}. **B1** neither iron species is a solid, so an inert platinum electrode is needed; in both, a redox equilibrium is set up at the electrode surface. [3]

B11 EPS-Q17 **B1** the statement is wrong: electrons flow only through the external wire and the electrodes. **B1** ions move through the salt bridge, anions towards the half-cell where oxidation occurs and cations towards the one where reduction occurs. **B1** that movement of ions keeps each solution electrically neutral, so the current can continue. [3]

B12 EPS-Q19 **B1** zinc has the more negative E°, so the equilibrium $Zn^{2+}(aq) + 2e^{-} \rightleftharpoons Zn(s)$ lies further to the left than the copper one and zinc releases electrons more readily. **B1** zinc is oxidised, $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$, and the electrons it leaves on the metal make it the negative electrode; electrons flow from zinc to copper through the external circuit. **B1** copper is the positive electrode, where Cu^{2+} is reduced, and E°cell = 0.34 - (-0.76) = +1.10 V comes out positive only with the cell written $Zn(s) | Zn^{2+}(aq) || Cu^{2+}(aq) | Cu(s)$, zinc on the left. [3]

SECTION C · Long, 6 marks or more

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C1 EPS-Q5

Indicative content [6]

B1 copper(II) ions are reduced and aluminium is oxidised, so the copper half-cell goes on the right and $E^\circ_{cell} = 0.34 - (-1.66) = +2.00$ V. **B1** E°_{cell} is positive, so the reduction of Cu^{2+} by aluminium is feasible under standard conditions and copper is predicted to form. **B1** the equation balances six electrons: $2Al(s) + 3Cu^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cu(s)$, with neither E° value multiplied. **B1** E° values predict whether a reaction can happen, not how fast, because they say nothing about the activation energy of the reaction. **B1** the aluminium is covered by a thin, unreactive layer of aluminium oxide that keeps the copper(II) ions off the metal, so at first the rate is negligible. **B1** chloride ions break down the oxide layer and expose the metal, so the feasible reaction now goes at a visible rate and the energy it releases warms the mixture.

Levels

Level 3 (5–6 marks) E°_{cell} is calculated correctly, the reaction is predicted feasible, the balanced six-electron equation is given, the limit of E° values to feasibility rather than rate is stated, and the oxide layer and its removal by chloride are used to explain both the delay and the later reaction.

Level 2 (3–4 marks) E°_{cell} is calculated, the reaction predicted feasible and the equation is right; the delay is explained only in part, such as the oxide layer with no role for chloride, or E° values are not separated from rate.

Level 1 (1–2 marks) the reaction is called feasible or the oxide layer mentioned; the E° values are typically taken to mean the reaction must start at once, and the equation does not balance the electrons.

C2 EPS-Q13

Indicative content [6]

B1 clean the zinc and copper strips with emery paper to remove the oxide layer, then rinse and dry them. **B1** stand the zinc in 1.00 mol dm^{-3} zinc sulfate and the copper in 1.00 mol dm^{-3} copper(II) sulfate, in separate beakers. **B1** join the solutions with a strip of filter paper soaked in saturated potassium nitrate solution as a salt bridge. **B1** connect the two metals to a high-resistance voltmeter, positive terminal to the copper, so that almost no current flows. **B1** read the voltmeter once the reading is steady, and record the temperature, which should be 298 K. **B1** repeat with fresh solutions and a fresh salt bridge, and take the mean of concordant readings.

Levels

Level 3 (5–6 marks) all the elements of a standard measurement are present: cleaned electrodes, 1.00 mol dm^{-3} solutions of each metal's own ions, a salt bridge and what it is made of, a high-resistance voltmeter with the polarity given, a steady reading at 298 K and repeats.

Level 2 (3–4 marks) the two half-cells, the salt bridge and the voltmeter are described correctly; the 1.00 mol dm^{-3} concentrations, the temperature, the high-resistance voltmeter or the cleaned electrodes are not mentioned.

Level 1 (1–2 marks) zinc and copper are dipped in solutions joined to a voltmeter, often in the same beaker or with a wire in place of the salt bridge.

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