Question			er	Marks	Guidance
1	(a)		**Definition** The e.m.f. (of a half-cell) compared with a (standard) hydrogen half-cell/(standard) hydrogen electrode ✓ **Standard conditions** Temperature of 298 K / 25ºC **AND** (solution) concentrations of 1 mol dm^{-3} / 1M **AND** pressure of 101 kPa **OR** 100 kPa ✓	2	**ALLOW** voltage **OR** potential difference **OR** p.d. **OR** electrode potential **OR** reduction potential **OR** redox potential as alternative for e.m.f. **IGNORE** S.H.E. (as abbreviation for standard hydrogen electrode) **ALLOW** 1 atmosphere/1 atm **OR** 10^5 Pa **OR** 1 bar
	(b)		2.71 V ✓	1	**IGNORE** any sign
	(c)	(i)	$Al + 3Fe^{3+} \longrightarrow Al^{3+} + 3Fe^{2+}$ ✓ $2Al + 3I_2 \longrightarrow 2Al^{3+} + 6I^-$ ✓ $2I^- + 2Fe^{3+} \longrightarrow I_2 + 2Fe^{2+}$ ✓	3	Correct species **AND** balancing needed for each mark **IGNORE** state symbols **ALLOW** equilibrium sign (i.e. assume reaction is to right) **ALLOW** correct multiples **IF** there are **more than** three equations • mark a maximum of three equations • mark incorrect equations first
		(ii)	High activation energy **OR** slow rate ✓ Conditions not standard **OR** concentrations not 1 mol dm^{-3} ✓	2	 **DO NOT ALLOW** 'standard conditions' are different

Question			er	Marks	Guidance
	(d)		**ANNOTATE WITH TICKS, CROSSES, etc**	4 max	**ORA** throughout Minimum identification for system **6** is Cl^- Minimum identification for system **7** is ClO^- **Note**: Cl_2 is unsuitable as an identifier as it features in both system **6** and system **7** **IGNORE** reference to gaining and losing electrons; oxidation and reduction
			General (2 marks – assumed to be acid) • (E of) **7** (ClO^-/Cl_2) is more positive/less negative (than **6**) **OR** E_{cell} is (+)0.27 (V) **OR** E_{cell} is positive ✓ • **6** (Cl_2/Cl^-) moves to left **AND 7** (ClO^-/Cl_2) to right ✓		**---** **Note**: identification of systems 6 and 7 could be from use of relevant half equations/overall equation **ALLOW** 'greater' or 'higher' for 'more positive' **ALLOW** correct eqn: $Cl^- + ClO^- + 2H^+ \rightarrow Cl_2 + H_2O$ **IGNORE** uncancelled electrons **ALLOW** multiples, e.g. $2Cl^- + 2ClO^- + 4H^+ \rightarrow 2Cl_2 + 2H_2O$ **Note**: **IF** equilibrium shifts are correct, **IGNORE** incorrectly balanced equation but **CON** an equation in wrong direction
			--- **In alkali (3 marking points),** • H^+ in **7** (ClO^-/Cl_2) is removed by/reacts with OH^-/alkali ✓ • (E of) **7** (ClO^-/Cl_2) less positive/more negative (than **6**) ✓ • **6** (Cl_2/Cl^-) moves to right **AND 7** (ClO^-/Cl_2) to left ✓		**---** **ALLOW** correct eqn: $Cl_2 + H_2O \rightarrow Cl^- + ClO^- + 2H^+$ **IGNORE** uncancelled electrons **ALLOW** multiples, e.g. $2Cl_2 + 2H_2O \rightarrow 2Cl^- + 2ClO^- + 4H^+$ **Note**: **IF** equilibrium shifts are correct, **IGNORE** incorrectly balanced equation but **CON** an equation in wrong direction

Question			er	Marks	Guidance
	(e)	(i)	IO_3^- has removed/gained electrons from Sn^{2+} **OR** IO_3^- has been reduced to I_2 / reduced to 0 **OR** IO_3^- has oxidised Sn^{2+} ✓	1	**ALLOW** IO_3^- is the oxidising agent as I has been reduced **DO NOT ALLOW** just IO_3^- has been reduced **DO NOT ALLOW** I is the oxidising agent
		(ii)	$5Sn^{2+} + 2IO_3^- + 12H^+ \longrightarrow I_2 + 5Sn^{4+} + 6H_2O$ All chemical species correct with **no extra** chemical species ✓ Correct balancing with no electrons shown ✓	2	**ALLOW** correct multiples eg $2½\ Sn^{2+} + IO_3^- + 6H^+ \rightarrow ½\ I_2 + 2½\ Sn^{4+} + 3H_2O$ **IGNORE** e^- for 1st marking point
			Total	**15**	

Question			Answer	Marks	Guidance
2	(a)	(i)	complete circuit with **voltmeter** and **salt bridge** linking two half-cells ✓ Pt electrode in Fe^{3+}/Fe^{2+} half-cell with **same** concentrations ✓ Cr electrode in 1 mol dm^{-3} Cr^{3+} half-cell ✓	3	Salt bridge **MUST** be labelled **ALLOW** Fe^{2+} and Fe^{3+} with concentrations of 1 mol dm^{-3} **ALLOW** 1 M but **DO NOT ALLOW** 1 mol
		(ii)	$Cr + 3Fe^{3+} \longrightarrow Cr^{3+} + 3Fe^{2+}$ ✓	1	**ALLOW** $\rightleftharpoons$ sign **DO NOT ALLOW** if e^- shown uncancelled on both sides, e.g. $Cr + 3Fe^{3+} + 3e^- \longrightarrow Cr^{3+} + 3Fe^{2+} + 3e^-$
		(iii)	1.51 V ✓	1	**IGNORE** sign
	(b)		$Cr_2O_7^{2-}$ **AND** H^+ ✓	1	**ALLOW** acidified dichromate
	(c)		$Cr_2O_7^{2-}(aq) + 8H^+(aq) + 3HCOOH(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3CO_2(l)$ ✓✓ State symbols **not** required	2	**1st mark for ALL species correct and no extras:** $Cr_2O_7^{2-}$, H^+, HCOOH, Cr^{3+}, H_2O **AND** CO_2 **NOTE**: H^+ may be shown on both sides **ALLOW** $\rightleftharpoons$ sign **2nd mark** for correct balancing with H^+ cancelled down
	(d)	(i)	$E^{\ominus}$ for chromium (redox system) is more negative/lower/less (than copper redox system) **ORA** ✓ chromium system shifts to the left / $Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^-$ **AND** copper system shifts to the right / $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ ✓	2	**ALLOW** E_{cell} is +1.08 V (sign required) **ALLOW** Cr loses electrons more readily/more easily oxidised **OR** Cr is a stronger reducing agent **OR** Cu loses electrons less readily **OR** Cu is a weaker reducing agent

Question			Answer	Marks	Guidance
	(d)	**(ii)**	Cr reacts with H^+ ions/acid to form H_2 gas ✓	1	**ALLOW** equation: $2Cr + 6H^+ \longrightarrow 2Cr^{3+} + 3H_2$ (**ALLOW** multiples) **DO NOT ALLOW** just 'hydrogen forms', i.e. Cr, H^+/acid **AND** H_2 must **all** be included for the mark
	(e)	**(i)**	1.45 V ✓	1	**IGNORE** sign
		(ii)	**2 marks**, ✓ ✓, for **two** points from the following list: **1.** Methanoic acid is a liquid **AND** easier to store/transport **OR** hydrogen is a gas **AND** harder to store/transport **OR** hydrogen as a liquid is stored under pressure **2.** Hydrogen is explosive/more flammable **3.** HCOOH gives a greater cell potential/voltage **4**. HCOOH has more public/political acceptance than hydrogen as a fuel	2	**ASSUME** 'it' refers to HCOOH **DO NOT ALLOW** 'produces no CO_2' **IGNORE** comments about biomass and renewable *HCOOH and H_2 are **both** manufactured from natural gas*
			Total	**14**	

Question			er	Mark	Guidance
3	(a)		**Definition** The e.m.f. (of a half-cell) compared with a standard hydrogen half-cell/standard hydrogen electrode ✓ **Standard conditions** Temperature of 298 K / 25ºC **AND** (solution) concentrations of 1 mol dm^{-3} **AND** pressure of 101 kPa **OR** 100 kPa ✓	**2**	**ALLOW** voltage **OR** potential difference **OR** p.d. **OR** electrode potential **OR** reduction potential **OR** redox potential as alternative for e.m.f. **IGNORE** S.H.E. (as abbreviation for standard hydrogen electrode) **ALLOW** 1 atmosphere/1 atm **OR** 10^5 Pa **OR** 1 bar
	(b)		1.25 (V) ✓	**1**	**IGNORE** any sign
	(c)	(i)	$Cd + 2NiO(OH) + 2H_2O \longrightarrow Cd(OH)_2 + 2Ni(OH)_2$ LHS: correct species and correctly balanced ✓ RHS: correct species and correctly balanced ✓	**2**	**2 marks for correct equation** **ALLOW** NiOOH OR NiO_2H **ALLOW** ⇌ sign for equation (*ie* assume reaction goes from left to right) **ALLOW** 1 mark for correctly balanced equation with e^- and/or OH^- shown e.g.: $Cd + 2NiO(OH) + 2H_2O + 2OH^- + 2e^- \longrightarrow Cd(OH)_2 + 2Ni(OH)_2 + 2OH^- + 2e^-$ **ALLOW** 1 mark for balanced correct reverse equation with OH^- **AND** e^- cancelled: $Cd(OH)_2 + 2Ni(OH)_2 \longrightarrow Cd + 2NiO(OH) + 2H_2O$
		(ii)	oxidation: Cd from 0 to +2 ✓ '+' sign **not** required reduction: Ni from +3 to +2 ✓'+' sign **not** required	**2**	**ALLOW** $Cd^0 \rightarrow Cd^{2+}$ (shows 0 and 2+) **ALLOW** $Ni^{3+} \rightarrow Ni^{2+}$ (shows 3+ and 2+) **ALLOW ECF** from **(c)(i)** equation written 'wrong way around'.
	(d)	(i)	reverse reactions to charging **OR** $Cd(OH)_2 + 2e^- \longrightarrow Cd + 2OH^-$ $Ni(OH)_2 + OH^- \longrightarrow NiO(OH) + H_2O + e^-$ **OR** reaction that is reverse to reaction given in **c(i):** $Cd(OH)_2 + 2Ni(OH)_2 \longrightarrow Cd + 2NiO(OH) + 2H_2O$ ✓	**1**	If half-equations are given, then **BOTH** equations required **ALLOW** ⇌ sign for equation (*ie* assume reaction goes from left to right)

Question			er	Mark	Guidance
	(d)	(ii)	$4OH^- \longrightarrow O_2 + 2H_2O + 4e^-$ ✓ $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$ ✓	2	**ALLOW** multiples; **ALLOW** ⇌ sign for each equation **Note**: These are the **only** correct responses
			Total	10	

Question			Expected Answers	Marks	Additional Guidance
4	**a**		Complete circuit (with voltmeter) and salt bridge linking two half-cells ✓ Pt electrode in solution of Fe^{2+}/Fe^{3+} ✓ Ag in solution of Ag^{+} ✓	3	**DO NOT ALLOW** 'solution of a silver halide', e.g. AgCl (as these are insoluble) but **DO ALLOW** any solution of any other silver salt (whether insoluble or not) **IF** candidate has used incorrect redox systems, then mark ECF as follows: **(i) each** incorrect system will cost the candidate **one** mark **(ii)** if species have been quoted (see Additional Guidance below) **(iii)** for equation **(iv)** for cell potential ***YOU MAY NEED TO WORK OUT THESE ECF RESPONSES YOURSELF DEPENDING ON THE INCORRECT REDOX SYSTEMS CHOSEN***
		ii	electrons **AND** ions ✓	**1**	For electrons, **ALLOW** e^{-} For 'ions', **ALLOW** formula of an ion in one of the half-cells or salt bridge, e.g. Ag^{+}, Fe^{2+}, Fe^{3+} **ALLOW ECF** as in **(i)**
		iii	$Ag + Fe^{3+} \longrightarrow Ag^{+} + Fe^{2+}$ ✓	1	**ALLOW ECF** as in **(i)** **ALLOW** equilibrium sign
		iv	0.43 V ✓	1	**ALLOW ECF** as in **(i)**
	b	**i**	Cl_2 **OR** O_2 **AND** H^{+} ✓	1	**ALLOW** chlor**ine** **ALLOW** O_2 **AND** $4H^{+}$ **ALLOW** O_2 **AND** acid **DO NOT ALLOW** O_2 alone **DO NOT ALLOW** equation or equilibrium
		ii	I^{-} ✓	1	**ALLOW** $2I^{-}$ **OR** iod**ide** **DO NOT ALLOW** equation or equilibrium

Question			Expected Answers	Marks	Additional Guidance
	c		A fuel cell converts energy from reaction of a fuel with oxygen into a voltage/electrical energy ✓ $2H_2 + O_2 \rightarrow 2H_2O$ ✓ Two from: • under pressure **OR** at low temperature **OR** as a liquid • adsorbed on solid • absorbed within solid ✓✓ Energy is needed to make the hydrogen **OR** energy is needed to make fuel cell ✓	5	***ANNOTATIONS MUST BE USED*** **ALLOW** combustion for reaction of fuel with oxygen/reactants **ALLOW** a fuel cell requires constant supply of fuel **OR** operates continuously as long as a fuel (and oxygen) are added **ALLOW** multiples, e.g. $H_2 + ½O_2 \rightarrow H_2O$ **IGNORE** state symbols **ALLOW** 'material' **OR** metal for solid **ALLOW** as a metal hydride
			Total	**13**	

Question			Expected Answers	Marks	Additional Guidance
5	a		$H_2O_2 \longrightarrow O_2 + 2H^+ + 2e^-$ ✓✓	2	All other multiples score 1 mark e.g. ½ $H_2O_2 \longrightarrow$ ½ $O_2 + H^+ + e^-$ $5H_2O_2 \longrightarrow 5O_2 + 10H^+ + 10e^-$
	b		**Marks are for correctly calculated values.** **Working shows how values have been derived.**		***ANNOTATIONS MUST BE USED***
			$n(KMnO_4) = \frac{0.0200 \times 23.45}{1000} = 4.69 \times 10^{-4}$ (mol) ✓		**DO NOT ALLOW** 4.7×10^{-4}
			$n(H_2O_2) = 5/2 \times 4.69 \times 10^{-4} = 1.1725 \times 10^{-3}$ (mol) ✓		**ALLOW** 1.173×10^{-3} OR 1.17×10^{-3} (i.e. 3 significant figures upwards) **ALLOW** by **ECF**: 5/2 × ans above
			$n(H_2O_2)$ in 250 cm^3 solution $= 10 \times 1.1725 \times 10^{-3} = 1.1725 \times 10^{-2}$ (mol) ✓		**ALLOW** by **ECF** 10 × ans above **ALLOW** concentration $H_2O_2 = 0.0469$ mol dm^{-3}
			concentration in g dm^{-3} of original H_2O_2 $= 40 \times 1.1725 \times 10^{-2} \times 34 = 15.9$ (g dm^{-3}) ✓	4	**ALLOW** by **ECF** $40 \times n(H_2O_2) \times 34$ **ALLOW** $0.0469 \times 10 \times 34 = 15.9$ g dm^{-3} ✓ **ALLOW** two significant figures, 16 (g dm^{-3}) up to calculator value of 15.946 g dm^{-3}
			$n(O_2) = 5/2 \times 4.69 \times 10^{-4} = 1.1725 \times 10^{-3}$ (mol) ✓		**ALLOW** 0.028 dm^3 **OR** 0.02814 dm^3 **ALLOW** 28 cm^3 **OR** 28.14 cm^3 Value **AND** units required **DO NOT ALLOW** 0.03 dm^3
			volume $O_2 = 24.0 \times 1.1725 \times 10^{-3} = 0.0281$ dm^3 ✓	2	**ALLOW** by **ECF**: 24.0 × calculated moles of O_2 (2 significant figures up to calculator value)
			Total	**8**	