Question			Answer	Marks	
1	(a)		<table><tr><td>E^o</td><td>redox system</td></tr><tr><td>Most negative</td><td>**E**</td></tr><tr><td></td><td>**C**</td></tr><tr><td>Least negative</td><td>**D**</td></tr></table> ✓	1	**ALL** 3 correct for 1 mark
	(b)	(i)	pH = 0 ✓	1	**Guidance**
	(b)	(ii)	H redox system is more negative (e.g. has a more –ve *E* **OR** less +ve *E* **OR** is –ve electrode) **OR** H redox system releases electrons (May be in equation, e.g. $H_2 \rightarrow 2H^+ + 2e^-$) ✓ Equilibrium **shifts** to increase [H^+] **OR** H^+ **OR** standard hydrogen equation **shifts** to increase [H^+] **OR** H^+ ✓	2	**ALLOW ORA**, *ie* Ag redox system (D) has more positive *E* / less negative *E* **ALLOW** equilibrium sign **IGNORE** H is more reactive **ORA** **IGNORE** direction of equilibrium shift
	(b)	(iii)	$H_2 + 2Ag^+ \rightarrow 2Ag + 2H^+$ ✓	1	**ALLOW** multiples e.g. $\frac{1}{2}H_2 + Ag^+ \rightarrow Ag + H^+$ State symbols **NOT** required **ALLOW** equilibrium sign
	(c)	(i)	CN^- + H_2O ⇌ **HCN** + **OH^-** **AND** Base 2 Acid 1 Acid 2 Base 1 ✓	1	State symbols **NOT** required **ALLOW** CNH and HO^- (i.e. any order) **ALLOW** 1 **and** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels throughout if linked by lines so that it is clear what the acid-base pairs are.

Question			Answer	Marks	Guidance
	(c)	**(ii)**	H^+ reacts with CN^- **OR** HCN forms **OR** equation: $H^+ + CN^- \rightarrow HCN$ (**ALLOW** $\rightleftharpoons$) **OR** CN^- accepts a proton/H^+ **OR** equilibrium shifts right **AND** CN^- is removed ✓	**1**	**ALLOW** Acid reacts with/removes OH^- ions (to form HCN) **ALLOW** CNH (i.e. any order) **IGNORE** other equilibrium comments
	(d)	**(i)**	Fuel reacts with oxygen/oxidant to give **electrical** energy**/**voltage✓	**1**	**ALLOW** named fuel. e.g. hydrogen/H_2; ethanol; methanol, etc **ALLOW** fuel cell requires constant supply of fuel **AND** oxygen/an oxidant **OR** fuel cell operates continuously as long as a fuel **AND** oxygen/an oxidant are added **IGNORE** 'reactants' 'products' and comments about pollution and efficiency
	(d)	**(ii)**	ethanol is a **liquid OR** is **less** volatile **OR** ethanol is easier to store/transport/stored more safely **OR** hydrogen is explosive/more flammable **OR** ethanol has more public/political acceptance ✓	**1**	Assume that '**it**' refers to ethanol **ALLOW** ORA throughout **IGNORE** ethanol has a higher boiling point **IGNORE** H_2 is a gas **IGNORE** 'produces no CO_2' **OR** less pollution **IGNORE** comments about efficiency **IGNORE** comments about biomass and renewable
	(d)	**(iii)**	$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ ✓	**1**	Correct species **AND** balancing needed **ALLOW** multiples **ALLOW** C_2H_6O for formula of ethanol **IGNORE** state symbols
	(d)	**(iv)**	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ ✓	**1**	Correct species **AND** balancing needed **ALLOW** multiples, e.g. $3O_2 + 12H^+ + 12e^- \rightarrow 6H_2O$ $\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$ **ALLOW** e (*ie* no – sign) **ALLOW** $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ **OR 3**$O_2 + 6H_2O + 12e^- \rightarrow 12OH^-$ **IGNORE** state symbols

Question			Answer	Marks	Guidance
	(d)	**(v)**	oxidation: C from –2 to +4 ’+’ sign **not** required ✓ reduction: O from 0 to –2 ✓	**2**	**ALLOW** 2– and 4+ **ALLOW** $C^{2-} \rightarrow C^{4+}$ **ALLOW** 0 and 2– **ALLOW** $O^{0} \rightarrow O^{2-}$ **ALLOW** 1 mark if correct oxidation numbers shown for **BOTH** C and O but wrong way around (*ie* C on reduction line and O on oxidation line) **IGNORE** O_2 reduced **IGNORE** any reference to electron transfer (*not in question*)
			Total	**13**	

Question			Answer	Marks	Guidance
2	**(a)**		**Equations can be in either order** $Na_2O + H_2O \rightarrow 2NaOH$ ✓ $NaFeO_2 + 2H_2O \rightarrow Fe(OH)_3 + NaOH$ ✓	**2**	**ALLOW** multiples throughout **IGNORE** state symbols **ALLOW** $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ **DO NOT ALLOW** equations with uncancelled species. e.g. $Na_2O + 2H_2O \rightarrow 2NaOH + H_2O$ **ALLOW** $2NaFeO_2 + H_2O \rightarrow Fe_2O_3 + 2NaOH$ **OR** $2NaFeO_2 + H_2O \rightarrow Fe_2O_3 + 2Na^+ + 2OH^-$ ✓

Question			Answer	Marks	Guidance
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 33.7%, award **6 marks.** **IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- amount $S_2O_3^{2-}$ used = $0.1000 \times \frac{25.50}{1000}$ = **2.550×10^{-3}** (mol) ✓ amount I_2 = 2.550×10^{-3} **÷ 2** **1.275×10^{-3}** (mol) ✓ amount CrO_4^{2-} **2/3 ×** 1.275×10^{-3} **OR** 1.275×10^{-3} ÷ **1.5** = **$8.5(00) \times 10^{-4}$** (mol) ✓ amount CrO_4^{2-} in original 1000 cm^3 = **40 ×** $8.5(00) \times 10^{-4}$ = **$3.4(00) \times 10^{-2}$** mol ✓ Mass of Cr/Cr^{3+} in ore = **52.0** × $3.4(00) \times 10^{-2}$ g **1.768 g** ✓ percentage Cr in ore = $\frac{1.768}{5.25} \times 100$ = **33.7%** ✓ **MUST** be to **one** decimal place (in the question)	6	***FULL ANNOTATIONS MUST BE USED*** **IF** a step is omitted but subsequent step subsumes previous, then award mark for any missed step **Working: at least 3 SF throughout until final % mark** BUT ignore trailing zeroes, ie for 0.490 allow 0.49 --- **ECF** answer above ÷ **2** **ECF** answer above ÷ **1.5** **ECF** answer above **×** 40 **ECF** answer above × 52.0 **IMPORTANT**: The last two marks are **ONLY** available by using 52.0 for Cr **---** **Common ECFs:** **0.8%** x 40 missing 5 marks (scaling error) **0.84%** x 40 missing 4 marks (scaling error and 2 DP) **33.68%** 5 marks (2 DP) **16.8%** 5 marks (divide Cr somewhere by 2) **144.9%; 72.5%** 4 marks (**Final 2 marks unavailable**) Use of $M(Fe(CrO_2)_2)$ = 223.8 instead of M(Cr).

Question			Answer	Marks	Guidance
	(c)		*Overall*: $CrO_4^{2-} + 3I^- + 4H_2O \rightarrow Cr^{3+} + 1½\ I_2 + 8OH^-$ ✓ *Half equations*: $CrO_4^{2-} + 4H_2O + 3e^- \rightarrow Cr^{3+} + 8OH^-$ ✓ $2I^- \rightarrow I_2 + 2e^-$ ✓	3	**ALLOW multiples and equilibrium signs throughout** **IGNORE** state symbols throughout e.g. $2CrO_4^{2-} + 6I^- + 8H_2O \rightarrow 2Cr^{3+} + 3I_2 + 16OH^-$ **ALLOW** equation using H^+. i.e. $CrO_4^{2-} + 3I^- + 8H^+ \rightarrow Cr^{3+} + 1½\ I_2 + 4H_2O$ **OR** $2CrO_4^{2-} + 6I^- + 16H^+ \rightarrow 2Cr^{3+} + 3I_2 + 8H_2O$ **ALLOW** CrO_4^{2-} half equation using H^+. i.e. $CrO_4^{2-} + 8H^+ + 3e^- \rightarrow Cr^{3+} + 4H_2O$
			Total	**11**	

Question			Answer	Marks	Guidance
3	(a)		**Definition** The e.m.f. (of a half-cell) compared with/connected to a (standard**)** hydrogen half-cell/(standard**)** hydrogen electrode ✓ **Standard conditions** *Units essential* Temperature of 298 K / 25ºC **AND** (solution) concentrations of 1 mol dm^{-3} **AND** pressure of 100 kPa **OR** 10^5 Pa **OR** 1 bar ✓	2	As alternative for e.m.f., **ALLOW** voltage **OR** potential difference **OR** p.d. **OR** electrode potential **OR** reduction potential **OR** redox potential **ALLOW** /(standard) hydrogen cell **IGNORE** S.H.E. (as abbreviation for standard hydrogen electrode) **ALLOW** 1M **DO NOT ALLOW** 1 mol **ALLOW** 1 atmosphere/1 atm **OR** 101 kPa **OR** 101325 Pa
	(b)	(i)	$2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$ ✓	1	State symbols **not** required **ALLOW** $\rightleftharpoons$ provided that reactants on LHS
	(b)	(ii)	**Assume Cu^{2+}|Cu OR Cu half cell unless otherwise stated.** $[Cu^{2+}]$ decreases **OR** < 1 mol dm^{-3} **AND** Equilibrium (shown in table) shifts to left ✓ more electrons are released by Cu ✓ The cell has a bigger **difference** in *E* ✓	3	***FULL ANNOTATIONS MUST BE USED*** -- **ALLOW** $[Cu^{2+}]$ less than standard concentration/1 mol dm^{-3} **DO NOT ALLOW** water reacts with Cu^{2+} **OR** Cu **ALLOW** *E* (for Cu^{2+}|Cu) is less positive / more negative /decreases **IGNORE standard** electrode potential (*Cell no longer standard*) **IGNORE** $E^{\ominus}$ decreases **CARE** **DO NOT ALLOW** statements about silver *E* changing (**CON**) **IGNORE** just 'cell potential increases' (in the question) *The final mark is more subtle and is a consequence of the less positive E value of the copper half cell*

	(c)	**(i)**	no/less CO_2 **OR** H_2O is **only** product **OR** greater efficiency ✓	**1**	**IGNORE** less pollution **IGNORE** less carbon emissions **IGNORE** less fossil fuels used **IGNORE** no/less greenhouse gas **OR** no global warming (*H_2O vapour is a greenhouse gas)*
	(c)	**(ii)**	liquefied/as a liquid **AND** under pressure/pressurised ✓	**1**	**IGNORE** adsorption or absorption **IGNORE** low temperature **DO NOT ALLOW** liquidise *processes are described in the question*
	(d)	**(i)**	E = –2.31 (V) ✓	**1**	– sign **AND** 2.31 **required** for the mark
	(d)	**(ii)**	$4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4^-(aq)$ species ✓ balance ✓	**2**	**IGNORE** state symbols **ALLOW** multiples **ALLOW** 1 mark for an equation in which OH^- are balanced but have not been cancelled, e.g. $4Al(s) + 16OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4^-(aq) + 12OH^-(aq)$ **ALLOW** 1 mark if charge on $Al(OH)_4$ is omitted, i.e $4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l) \rightarrow 4Al(OH)_4(aq)$ **ALLOW** 1 mark for an 'correct equation' reversed, i.e. $4Al(OH)_4^-(aq) \rightarrow 4Al(s) + 4OH^-(aq) + 3O_2(g) + 6H_2O(l)$
			Total	**11**	

Question			Answer	Marks	Guidance
4	(a)		$Fe_2O_3 + 3Cl_2 + 10OH^- \rightarrow 2FeO_4^{2-} + 6Cl^- + 5H_2O$ ✓✓ First mark for all 6 species Second mark for balancing	2	**ALLOW** multiples **ALLOW** oxidation half equation for two marks $Fe_2O_3 + 10OH^- \rightarrow 2FeO_4^{2-} + 5H_2O + 6e^-$ Correct species would obtain 1 mark – *question: equation for oxidation* **ALLOW variants forming H^+ for 1 mark, e.g:** $Fe_2O_3 + 3Cl_2 + 5OH^- \rightarrow 2FeO_4^{2-} + 6Cl^- + 5H^+$ $Fe_2O_3 + 3Cl_2 + 5OH^- \rightarrow 2FeO_4^{2-} + 5HCl + Cl^-$
	(b)		$Ba^{2+}(aq) + FeO_4^{2-}(aq) \rightarrow BaFeO_4(s)$ ✓	1	Balanced **ionic** equation **AND** state symbols required **DO NOT ALLOW** +2 or –2 for ionic charges
	(c)		**Reason can ONLY be correct from correct reducing agent** --- ***reducing agent***: I^- **OR** KI ✓ I^- adds/donates/loses electrons **AND** to FeO_4^{2-} **OR** to $BaFeO_4$ **OR** to Fe(VI) or to Fe(+6) ✓ ***ALLOW*** *Fe(6+)* ***OR*** *Fe^{6+}*	2	**IGNORE** H^+ **OR** acidified **ALLOW** iodide/potassium iodide but **DO NOT ALLOW** iodine **ALLOW** I^- loses electrons **AND** to form I_2 **ALLOW** Fe(6+) **OR** Fe^{6+}

	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 51.8%, award **4 marks.** --- $n(S_2O_3^{2-})$ used = $0.1000 \times \frac{26.4}{1000}$ = 2.64×10^{-3} (mol) ✓ $n(FeO_4^{2-})$ = ½ x 2/3 x 2.64×10^{-3} = $8.8(0) \times 10^{-4}$ (mol) ✓ Mass $BaFeO_4$ in sample = $8.8 \times 10^{-4} \times 257.1$ g = 0.226248 g ✓ % purity = $\frac{0.226248}{0.437} \times 100$ = 51.8% ✓ **MUST** be to **one** decimal place (in the question) --- As an alternative for the final two marks, **ALLOW**: Theoretical amount of $BaFeO_4$ = $\frac{0.437}{257.1}$ = 0.00170 (mol) ✓ % purity = $\frac{8.8 \times 10^{-4}}{1.70 \times 10^{-3}} \times 100$ = 51.8% ✓	4	***FULL ANNOTATIONS MUST BE USED*** **---** For alternative answers, look first at common **ECFs** below. Then check for **ECF** credit possible using working below **IF** a step is omitted but subsequent step subsumes previous, then award mark for any missed step --- **Working must be to at least 3 SF throughout until final % mark** **BUT** ignore trailing zeroes, ie for 0.880 allow 0.88 **ECF** answer above × ½ × 2/3 This mark may be seen in 2 steps via I_2 but the mark is for both steps combined **ECF** 257.1 × answer above **ECF** $\frac{\text{answer above}}{0.437} \times 100$ **ALLOW** 51.7% FROM 0.226 g $BaFeO_4$ (earlier rounding) -- **Common ECFs:** No × 2/3 for $n(FeO_4^{2-})$: % purity = 77.7%/77.6% 3 marks No ÷ 2 for $n(FeO_4^{2-})$: % purity = 25.9% 3 marks 24.6 used instead of 26.4: % purity = 48.2% 3 marks

	(e)		**gas**: O_2 ✓ **precipitate**: $Fe(OH)_3$ ✓ **equation**: $2FeO_4^{2-} + 5H_2O \rightarrow 1½O_2 + 2Fe(OH)_3 + 4OH^-$ **OR** $2FeO_4^{2-} + H_2O + 4H^+ \rightarrow 1½O_2 + 2Fe(OH)_3$ ✓	**3**	**DO NOT ALLOW** names **IGNORE** a balancing number shown before a formula **ALLOW** $Fe(OH)_3(H_2O)_3$ **ALLOW** multiples **ALLOW** $2FeO_4^{2-} + 11H_2O \rightarrow 1½O_2 + 2Fe(OH)_3(H_2O)_3 + 4OH^-$
			Total	**12**	