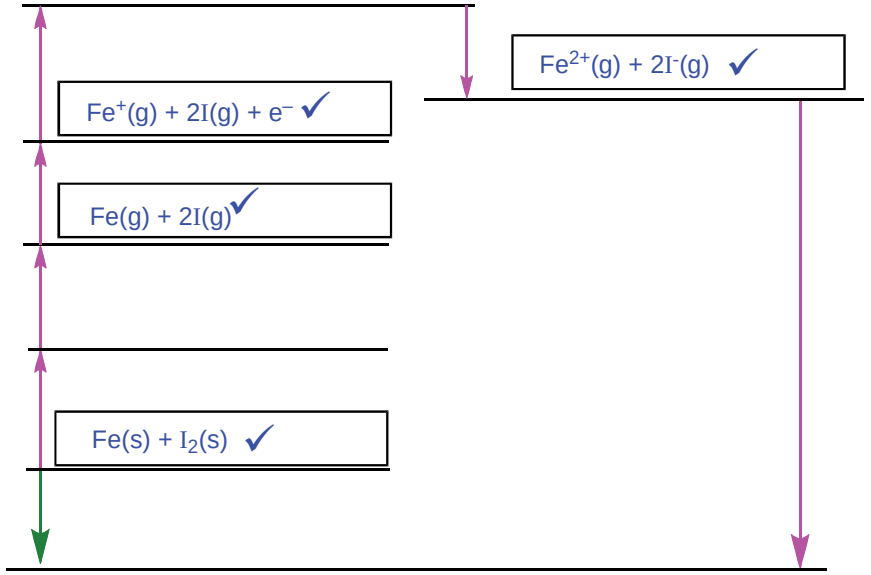
Question			Expected answers	Marks	Additional guidance
1	a		Complete circuit with electrodes to voltmeter **AND** salt bridge between solutions ✓ Fe^{3+}/Fe^{2+} half-cell with Pt electrode **AND** 1 mol dm^{-3}/ 1 M Fe^{2+} and 1 mol dm^{-3}/ 1 M Fe^{3+} ✓ Ni electrode in (1 mol dm^{-3}) Ni^{2+} half-cell ✓	3	circuit shown **must** be complete, *i.e. must be capable of working* salt bridge **must** be labelled. electrodes **AND** salt bridge **must** dip into/touch both solutions **ALLOW** cells drawn either way around **ALLOW** Fe^{3+}/Fe^{2+} 1 mol dm^{-3} / 1 M /1 molar **ALLOW BOTH** solutions same concentration/equimolar **DO NOT ALLOW** 1 mol **OR** 1 dm^{-3} **IGNORE** any temperature or pressure, even if wrong
		ii	1.02 V **AND** – sign ✓ 0.49 V **AND** + sign ✓	2	**IGNORE** any sign **BEFORE** cell potential **ALLOW 1 mark** for correct values **AND** signs **BOTH** the wrong way round: *i.e.*1.02 V **AND** + sign **AND** 0.49 V **AND** – sign
	b		**Cell A** (based on **1** and **2**) $Ni + 2Fe^{3+} \longrightarrow Ni^{2+} + 2Fe^{2+}$ ✓ **Cell B** (based on **1** and **3**) $2Cr + 3Ni^{2+} \longrightarrow 2Cr^{3+} + 3Ni$ ✓ **concentrations** (of the ions in each cell) change **OR** **concentrations** are not standard ✓	3	In equations, **ALLOW** equilibrium sign, ⇌ instead of → **Equations are required** for the first two marking points **ALLOW** $Ni \longrightarrow Ni^{2+} + 2e^-$ **ALLOW** $Ni^{2+} + 2e^- \longrightarrow Ni$ **ALLOW** any statement that a **concentration** is changing **IGNORE** 'non-standard conditions'
	c	i	$MH + OH^- \longrightarrow M + H_2O + e^-$ ✓	1	**ALLOW** $MH \longrightarrow M + H^+ + e^-$
		ii	adsorbed (on a solid) **OR** on the surface (of a solid) **OR** as a liquid under pressure ✓	1	**DO NOT ALLOW** adsorbed **into** the solid ***CON*** **DO NOT ALLOW** just 'as a liquid'
			Total	**10**	

Question			Expected answers	Marks	Additional guidance
2	a		$Fe_2O_3 + 6H^+ \longrightarrow 2Fe^{3+} + 3H_2O$ ✓	1	**ALLOW** $Fe_2O_3 + 6HCl \longrightarrow 2FeCl_3 + 3H_2O$ **OR** $Fe_2O_3 + 6HCl \longrightarrow 2Fe^{3+} + 6Cl^- + 3H_2O$ **ALLOW** correct multiples **IGNORE** state symbols **DO NOT ALLOW** Fe_2Cl_6 as a product
	b		$Sn^{2+} + 2Fe^{3+} \longrightarrow Sn^{4+} + 2Fe^{2+}$ ✓ $6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \longrightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$ ✓	2	**IGNORE** state symbols **ALLOW** overall equations: $SnCl_2 + 2FeCl_3 \longrightarrow SnCl_4 + 2FeCl_2$ $6FeCl_2 + K_2Cr_2O_7 + 14HCl \rightarrow 6FeCl_3 + 2CrCl_3 + 2KCl + 7H_2O$ **ALLOW** correct multiples

Question			Expected answers	Marks	Additional guidance
	c		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 54.6%, award **5 marks** --- **Amount Fe^{2+} in 250 cm^3 solution – 3 marks** amount $Cr_2O_7^{2-}$ used = $0.0200 \times \frac{26.5}{1000}$ $= 5.30 \times 10^{-4}$ (mol) ✓ amount Fe^{2+} = **6** × 5.30 x 10^{-4} $= 3.18 \times 10^{-3}$ mol ✓ amount Fe^{2+} in original 250 cm^3 = **10** × 3.18 x 10^{-3} $= 3.18 \times 10^{-2}$ (mol) ✓		***ANNOTATIONS MUST BE USED*** **IF** there is an alternative answer, 1st check common errors below. Then see if there is any **ECF** credit possible using working below --- **Working must be to at least 3 SF throughout** **BUT** ignore trailing zeroes, *i.e.* for 0.490 allow 0.49 **ALLOW ECF** from different Fe^{2+} ratio in equation from **8(b)** **BUT** still **ALLOW** 6 : 1 even from different ratio in equation If no equation use actual 6 : 1 ratio **DO NOT AWARD** 'ratio mark' at all for use of 1 : 1 ratio – *makes problem easier* **ECF** 10 × answer above
			% Fe in ore – 2 marks mass of Fe in ore = $55.8 \times 3.18 \times 10^{-2}$ g = 1.77444 g ✓		**ECF** 55.8 × answer above **IF** answer above has **not** been used **AND** × 55.8, **DO NOT ALLOW** this mark but do **ALLOW** final % **IF** answer above **AND** 55.8 are **BOTH not** used, then **DO NOT ALLOW ANY** further marks
			percentage Fe in ore = $\frac{1.77444}{3.25} \times 100$ = 54.6% ✓	**5**	**ECF** $\frac{\text{answer above}}{3.25} \times 100$ **ALLOW** 54.5% (from 1.77 g) **AND** any answer with > 1 decimal place that rounds back to 54.5 **OR** 54.6
					COMMON ERRORS 5.46 ✓✓✓✓ × *10 omitted* 51.5 ✓✓✓✓ *titre taken as 25.0* 156.2 ✓✓✓✓ × *159.6 instead of 55.8* 15.62 ✓✓✓ × *159.6 and* × *10 omitted* 45.5 ✓✓✓✓ *5 : 1 ratio* 1.52 ✓✓✓✓ ÷ 6 instead of × 6

Question			Expected answers	Marks	Additional guidance
	d		$E^{\ominus}$ for MnO_4^- is more positive/greater than Cl_2 **OR** $E^{\ominus}$ for $Cr_2O_7^{2-}$ is less positive/smaller than Cl_2 ✓ MnO_4^- reacts with Cl^- **OR** HCl (forming Cl_2 gas) **OR** $Cr_2O_7^{2-}$ does **not** react with Cl^- ions ✓	**2**	**ORA:** $E^{\ominus}$ for Cl_2 is less positive/smaller than MnO_4^- **OR** $E^{\ominus}$ for Cl_2 is more positive/greater than $Cr_2O_7^{2-}$
			Total	**10**	

Question			Answer	Mark	Guidance
3	(a)	(i)	Complete circuit with electrodes to voltmeter **AND** salt bridge between solutions ✓ Sn^{4+}/Sn^{2+} half cell with Pt electrode **AND** both solutions labelled as 1 mol dm^{-3} / 1M H^+/H_2 half cell with Pt electrode **AND** H^+ solution labelled as 1 mol dm^{-3} / 1M ✓	3	**ANNOTATE WITH TICKS AND CROSSES, etc** circuit shown **must** be complete, *ie* must be capable of working salt bridge **must** be labelled and must dip into both solutions **ALLOW** concentration label of 'equimolar' or similar wording for Sn^{4+}/Sn^{2+} half cell **ALLOW** any strong acid **IF** both half cells are correct with no concentrations, **ALLOW** 1 out of the 2 marks available for the 2 half cells **IGNORE** any stated temperature or pressure, even if wrong
		(ii)	$2Cr + 3Sn^{4+} \rightarrow 2Cr^{3+} + 3Sn^{2+}$ ✓ $Cr + 3Cu^{+} \rightarrow Cr^{3+} + 3Cu$ ✓ $Sn^{2+} + 2Cu^{+} \rightarrow Sn^{4+} + 2Cu$ ✓ Conditions not standard **OR** concentrations not 1 mol dm^{-3} ✓ High activation energy **OR** slow rate ✓	5	**ANNOTATE WITH TICKS AND CROSSES, etc** Correct species **AND** balancing needed for each mark **ALLOW** equations as shown with equilibrium sign **ALLOW multiples** but **electrons** must not be shown **IF** three equations have correct species but no balancing, **AWARD** 1 mark **ALLOW** not favoured kinetically
	(b)	(i)	$CH_3OH + 1½O_2 \rightarrow CO_2 + 2H_2O$ ✓	1	Correct species **AND** balancing needed **ALLOW** multiple, *ie* $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ **ALLOW** CH_4O for formula of methanol
		(ii)	$CH_3OH + H_2O \rightarrow 6H^+ + 6e^- + CO_2$ ✓	1	
		(iii)	less CO_2 **OR** less greenhouse gases ✓ greater efficiency ✓	2	**ALLOW** no CO_2 **OR** no greenhouse gases **ALLOW (**very) efficient **IGNORE** less pollution **OR** 'renewable fuels'
		(iv)	methanol is a **liquid** **AND** methanol is easier to store/transport ✓	1	**Both points required for mark** Response **MUST** state that methanol is a **liquid** **IGNORE** methanol has a higher boiling point Assume that '**it**' refers to methanol **IGNORE** safety issues, *eg* H_2 leakage, flammability, explosive
			Total	**13**	

Question			Answer	Marks	Guidance
4	(a)	(i)	 **Mark each marking point independently**	4	Correct species **AND** state symbols required for each marks **ALLOW** e for e^{-} **TAKE CARE**: In top left box, e^{-} may be in centre of response and more difficult to see than at end. There is only **ONE** correct response for each line *From the gaps in the cycle, there is **NO** possibility of any **ECF***

Question			Answer	Marks	Guidance
	(a)	(ii)	(The enthalpy change that accompanies) the **formation** of **one mole** of a(n ionic) compound from its **gaseous ions** (under standard conditions) ✓✓ Award marks as follows. **1st mark: formation** of **compound** from **gaseous ions** **2nd mark: one mole** for compound **only** **DO NOT ALLOW** 2nd mark without 1st mark **DO NOT ALLOW** any marks for a definition for enthalpy change of **formation BUT** note the two concessions in guidance	**2**	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW one mole** of compound is **formed/made** from its **gaseous ions** **ALLOW** as alternative for compound: lattice, crystal, substance, solid **IGNORE**: $Fe^{2+}(g) + 2I^{-}(g) \longrightarrow FeI_2(s)$ (Part of cycle) **ALLOW** 1 mark for absence of 'gaseous' only, i.e. the **formation** of **one mole** of a(n ionic) compound from its **ions** (under standard conditions) ✓ **ALLOW** 1 mark for ΔH_f definition with 'gaseous': the **formation** of **one mole** of a(n ionic) compound from its **gaseous** elements (under standard conditions) ✓

Question			Answer	Marks	Guidance
	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2473 (kJ mol^{-1}) award 2 marks** --- (–113) = 416 + (2 × +107) + 759 + 1561 + (2 × –295) + $\Delta H_{LE}(FeI_2)$ **OR** $\Delta H_{LE}(FeI_2)$ = –113 – (416 + (2 × +107) + 759 + 1561 + (2 × –295)) **OR** –113 – 2360 ✓ = – 2473 ✓ (kJ mol^{-1})	**2**	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **See list below for marking of answers from common errors** --- **ALLOW** for 1 mark: +2473 wrong sign –2661 107 and –295 used instead of **2 ×** 107 and **2 ×** –295 –236 +107 used instead of **2 ×** 107 –276 –295 used instead of **2 ×** –295 –365 wrong sign for 295 –224 wrong sign for 113 –164 wrong sign for 416 –204 wrong sign for 2 **×** 107 –95 wrong sign for 750 +64 wrong sign for 1561 –365 wrong sign for **2 ×** –295 Any other number: **CHECK** for **ECF** from 1st marking point for expressions with **ONE** error only e.g. one transcription error: e.g. +461 instead of +416
	(b)	**(i)**	Fe^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓ Br^-: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$ ✓	**2**	**ALLOW** 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$ **ALLOW** $1s^2$ written after answer prompt (*ie* $1s^2$ twice) **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_2 3D_1$ **ALLOW** for Fe^{2+} **……**$4s^0$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake

Question			Answer	Marks	Guidance
	(b)	(ii)	With Cl_2 **AND** Br_2 **AND** I_2 products are Fe^{2+} (AND halide ion) $FeCl_2$ **AND** $FeBr_2$ **AND** FeI_2 ✓ **OR** Evidence that **two** electrode potentials have been compared for at least **ONE** reaction, ✓ e.g. Fe –0.44 **AND** Cl_2 +1.36 e.g. Iron has more/most negative electrode potential With Cl_2 **AND** Br_2, products are Fe^{3+} (AND halide ion) $FeCl_3$ **AND** $FeBr_3$ ✓	**3**	**FULL ANNOTATIONS NEEDED** **ALLOW** products within equations (even if equations are not balanced) **IF stated, IGNORE reactants** **ALLOW** response in terms of positive 'cell reactions', e.g $Fe + Cl_2 \rightarrow Fe^{2+} + 2Cl^- \ E = (+)1.80$ V **IGNORE** comments about reducing and oxidising agents and electrons
	(c)		**BOTH EQUATIONS REQUIRE IONS PROVIDED IN QUESTION** **OR** **Reaction 1: 2 marks** **1st mark** for **ALL CORRECT species** e.g.: $Fe^{2+} + NO_3^- + H^+ \rightarrow Fe^{3+} + NO + H_2O$ **2nd mark** for **CORRECT balanced equation** $3Fe^{2+} + NO_3^- + 4H^+ \rightarrow 3Fe^{3+} + NO + 2H_2O$ ✓✓ --- **Reaction 2: 1 mark** $_2O)_6]^{2+} + NO \rightarrow [Fe(H_2O)_5NO]^{2+} + H_2O$ ✓	**3**	**ALLOW** correct multiples throughout **ALLOW equilibrium signs in all equations** **For 1st mark, IGNORE** e^- present **Check** carefully for correct **charges**
			[Fe(H **Total**	**16**	