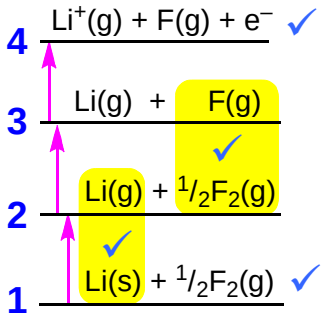
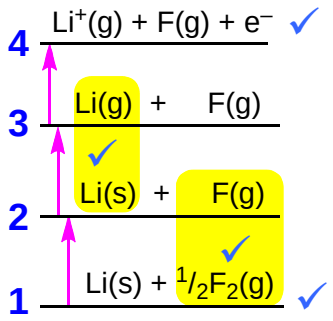
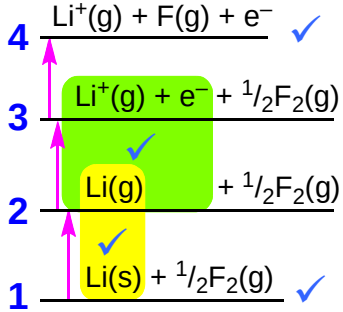
Question			Answer	Marks	Guidance
1	(a)		(The enthalpy change that accompanies) the formation of **one mole** of a(n ionic) compound ✓ from its **gaseous ions** ✓ (under standard conditions)	2	**IGNORE** 'Energy needed' **OR** 'energy required' **ALLOW** as alternative for compound: lattice, crystal, substance, solid, product **Note**: 1st mark requires **1 mole** **2nd mark** requires **gaseous ions** **IF** candidate response has '1 mole of gaseous ions', award 2nd mark but **NOT** 1st mark **IGNORE** reference to 'constituent elements' **IGNORE**: $Li^+(g) + F^-(g) \longrightarrow LiF(s)$ *Question asks for a definition, not an equation*

Question			Answer	Marks	Guidance
1	(b)	(i)	**1**. Mark **Line 1** first as below (right or wrong) **2**. Mark **Line 4** as below (right or wrong) **3**. Mark difference in species on **Line 1** and **Line 2** **MUST** match one of the enthalpy changes in the table: atomisation of Li(s) atomisation of ½F_2(g) first ionisation energy of Li(g) **4**. Repeat for differences on **Line 2** and **Line 3**		***ANNOTATIONS MUST BE USED*** --- **ALLOW** marks by **ECF** as follows: Follow order at top of Answer column
			 Correct species **and** state symbols required for all marks **IF** an electron has formed, it **MUST** be shown as e^- **OR** e	4	**ALLOW** atomisation of ½F_2(g) before atomisation of Li(s):  **ALLOW** ionisation of Li(g) before atomisation of ½F_2(g):  e^- required for marks involving **Line 3 AND Line 4** **Common errors** **Line 4**: Missing e^- and rest correct 3 marks **Line 1**: **IF** ½F_2(g) is **NOT** shown 2 max [**Line 4** and Li(s) → Li(g)] e.g., for F(g), F(s), F(l), F(aq), F_2(g) **DO NOT ALLOW** F*I* when first seen but credit subsequently

Question			Answer	Marks	Guidance
1	(b)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –1046 (kJ mol^{-1}) award 2 marks** --- (–616) = (+159) + (+79) + (+520) + (–328) + ΔH_{LE}(LiF) **OR** ΔH_{LE}(LiF) = (–616) –[(+159) + (+79) + (+520) + (–328)] ✓ = –616 – 430 = –1046 (kJ mol^{-1}) ✓	2	**IF** there is an alternative answer, check **the list below for marking of answers from common errors** --- **ALLOW** for **1 mark**: +1046 wrong sign –186 +430 instead of –430 +186 +616 instead of –616 –1006.5 (+79) ΔH_{at}(F) halved to +39.5 –1702 wrong sign for 328 Any other number: **CHECK** for **ECF** from 1st marking point for expressions with **ONE** error only e.g. one transcription error: e.g. +195 instead of +159
	(c)		$\Delta H < T\Delta S$ ***OR*** $\Delta H - T\Delta S < 0$ **OR** ΔH is more negative than $T\Delta S$ **OR** Negative value of ΔH is more significant than negative value of $T\Delta S$ ✓ ——————— **NOTE** **IGNORE** comments about ΔG	1	***ANNOTATIONS MUST BE USED*** **ALLOW** 'exothermic' for negative **ALLOW** a negative lattice energy value **ALLOW** ΔH is negative **AND** magnitude of ΔH > magnitude of $T\Delta S$ **IGNORE ONLY** magnitude of ΔH > magnitude of $T\Delta S$

Question			Answer	Marks	Guidance
1	(d)		For **FIRST TWO** marking points, assume that the following refer to 'ions', Mg^{2+}, etc. For 'ions', **ALLOW** 'atoms' For Mg^{2+}, Na^{+}, Cl^{-} and F^{-}, **ALLOW** symbols: Mg, Na, Cl and F **ALLOW** names: magnesium, sodium, chlorine, chloride, fluorine, fluoride *i.e.* **ALLOW** Mg has a smaller (atomic) radius For **THIRD** marking point, **IONS** must be used		**DO NOT ALLOW** molecules **ALLOW** F*l* for F
			Comparison of size of anions Chloride ion **OR** Cl^{-} is larger (than F^{-}) **OR** Cl^{-} has smaller charge density (than F^{-}) ✓ ***Comparison of size AND charge of cations*** Mg^{2+} is smaller (than Na^{+}) **AND** Mg^{2+} has a greater charge (than Na^{+}) ✓ ***Comparison of attraction between ions*** F^{-} has greater attraction for Na^{+} / + ions **AND** Mg^{2+} has greater attraction for F^{-} / – ions ✓ **Quality of Written Communication**: --- Third mark needs to link ionic size and ionic charge with the attraction that results in lattice enthalpy	3	***ANNOTATIONS MUST BE USED*** --- **ORA** F^{-} is smaller **OR** F^{-} has a larger charge density ✓ **IGNORE** just Cl^{-} is large *comparison required* **ORA**: Na^{+} is larger **AND** Na^{+} has a smaller charge ✓ **IGNORE** just Mg^{2+} is small *comparison required* **ALLOW** 'greater charge density' for 'greater charge' but **NOT** for smaller size + ***AND*** – ***IONS must be used for this mark*** **IGNORE** greater attraction between **ions** in NaF **AND** MgF_2 + ***AND*** – *ions* ***OR*** *oppositely charged ions are required* **ASSUME** attraction to be electrostatic unless stated otherwise: e.g. **DO NOT ALLOW** nuclear attraction **ALLOW** pull for attraction **ALLOW** 'attracts with more force' for greater attraction **IGNORE** just 'greater force' (*could be repulsion*) **IGNORE** comparison of bond strength/energy to break bonds **IGNORE** comparisons of numbers of ions **IGNORE** responses in terms of packing
			Total	**12**	

Question			Answer	Marks	Guidance
2	(a)	(i)	(K_c =) $\frac{[CO_2]^2\ [N_2]}{[CO]^2\ [NO]^2}$ ✓	1	Square brackets required for **ALL** four concentrations
		(ii)	$dm^3\ mol^{-1}$ ✓	1	**ALLOW** $mol^{-1}\ dm^3$

Question			Answer	Marks	Guidance
2	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 0.95 award **4 marks** --- ***Equilibrium amounts:*** $n(CO) = 0.46 - 0.20 = 0.26$ mol ✓ $n(CO_2) = 0.2(0)$ mol ✓ $n(N_2) = 0.1(0)$ mol ✓ **K_c calculation** **Must** use calculated equilibrium amounts **AND** 0.25 $(K_c =) \frac{0.20^2 \times 0.10}{0.26^2 \times 0.25^2} = 0.95$ (dm^3 mol^{-1}) ✓	4	***ANNOTATIONS MUST BE USED*** **IF** there is an alternative answer, apply **ECF** by checking working for intermediate marks --- **APPLY ECF** from incorrect starting $n(CO)$ By **ECF**, $n(N_2) = n(CO_2)/2$ For **all** parts, **ALLOW** numerical answers from 2 significant figures up to the calculator value **Correct numerical answer with no working scores 4 marks** **ALLOW** calculator value: 0.946745562 down to 0.95 (2SF), correctly rounded, e.g. 0.947 **IGNORE** units, even if incorrect --- **Common errors** 1.89 3 marks use of $n(N_2) = 0.2(0)$ mol $(K_c =) \frac{0.20^2 \times 0.20}{0.26^2 \times 0.25^2} = 1.893491124$ (dm^3 mol^{-1}) ✓ 1.29 3 marks 0.45 and 0.46 swapped over $n(CO) = 0.45 - 0.21 = 0.24$ mol ✓ $n(CO_2) = 0.21$ mol ✓ $n(N_2) = 0.105$ mol ✓ $(K_c =) \frac{0.21^2 \times 0.105}{0.24^2 \times 0.25^2} = 1.28625$ (dm^3 mol^{-1}) ✓ 1.024 3 marks 0.45 used twice $n(CO) = 0.45 - 0.20 = 0.25$ mol ✓ $n(CO_2) = 0.2(0)$ mol ✓ $n(N_2) = 0.1(0)$ mol ✓ $(K_c =) \frac{0.20^2 \times 0.10}{0.25^2 \times 0.25^2} = 1.024$ (dm^3 mol^{-1}) ✓ 1.185 3 marks 0.46 used twice $n(CO) = 0.46 - 0.21 = 0.25$ mol ✓ $n(CO_2) = 0.21$ mol ✓ $n(N_2) = 0.105$ mol ✓ $(K_c =) \frac{0.21^2 \times 0.105}{0.25^2 \times 0.25^2} = 1.185408$ (dm^3 mol^{-1}) ✓

Question			Answer	Marks	Guidance
2	(a)	(iv)	Mark **ECF** from **(iii)** **IF** K_c from **(iii)** < 1 equilibrium to left/towards reactants **OR** **IF** K_c from **(iii)** > 1 equilibrium to right/towards products ✓	1	**First look at K_c value for (iii) at bottom of cut** **----------** **ALLOW** favours reverse reaction For correct K_c value in **(iii)** of 0.95, **ALSO ALLOW** equilibrium position near to centre ✓
	(b)	(i)	K_c has decreased **AND** ΔH is negative **OR** (forward) reaction is exothermic ✓	1	Statement **AND** reason required for mark **ALLOW** for reason: reverse reaction is endothermic
		(ii)	**Effect of *T* and *P* on equilibrium** (increased) temperature shifts equilibrium to left **AND** (increased) pressure shifts equilibrium to right **AND** fewer (gaseous) moles on right-hand side ✓ **Overall effect on equilibrium** Difficult to predict relative contributions of two opposing factors ✓	2	**Reason ONLY** required for pressure Temperature and ΔH had been *required in (i)* **ALLOW** ratio of (gas) moles is 4:3 **ALLOW** opposing effects may not be the same size **ALLOW** effects could cancel each other out **ALLOW** effects oppose one another **DO NOT ALLOW** just 'it is difficult to predict equilibrium position' (*in question*) *For the 2nd mark, we are assessing the idea that we don't know which factor is dominant*
			Total	**10**	

Question			Answer	Marks	Guidance
3	(a)	(i)	$(K_a =) \dfrac{[H^+][CH_3(CH_2)_2COO^-]}{[CH_3(CH_2)_2COOH]}$ ✓	1	**ALLOW** $CH_3CH_2CH_2COOH$ **OR** C_3H_7COOH in expression **DO NOT ALLOW** use of HA and A^- in this part. **DO NOT ALLOW**: $\dfrac{[H^+][CH_3(CH_2)_2COO^-]}{[CH_3(CH_2)_2COOH]} = \dfrac{[H^+]^2}{[CH_3(CH_2)_2COOH]}$: **CON**
		(ii)	$pK_a = -\log K_a = 4.82$ ✓	1	**ALLOW** 4.82 up to calculator value of 4.821023053 **DO NOT ALLOW** 4.8
		(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 2.71 award **3 marks** --- $[H^+] = \sqrt{[K_a][CH_3(CH_2)_2COOH]}$ **OR** $\sqrt{1.51\times10^{-5}\times0.250}$ ✓ $[H^+] = 1.94 \times 10^{-3}$ (mol dm^{-3}) ✓ $pH = -\log[H^+] = 2.71$ ✓	3	**IF** alternative answer to more or fewer decimal places, check calculator value and working for 1st and 2nd marks --- **ALLOW** use of HA and A^- in this part **Calculator**: $1.942935923 \times 10^{-3}$ **ALLOW** use of calculated K_a value, either calculator value or rounded on script. pH **must** be to 2 decimal places **ALLOW ECF** from incorrectly calculated $[H^+]$ and pH **ONLY** when values for both K_a **AND** $[CH_3CH_2CH_2COOH]$ have been used, i.e. 1.5×10^{-5} **AND** 0.250. e.g.: pH = 5.42 2 marks $-\log(1.51 \times 10^{-5} \times 0.250)$ *No* √ pH = 2.11 2 marks $-\log(\sqrt{\dfrac{1.51\times10^{-5}}{0.250}})$ pH = 4.22 1 mark $-\log(\dfrac{1.51\times10^{-5}}{0.250})$ *No* √ **DO NOT ALLOW** just $-\log(1.51 \times 10^{-5}) = 4.82$ **NO MARKS**

Question			Answer	Marks	Guidance
3	(b)	(i)	$Mg + 2H^+ \longrightarrow Mg^{2+} + H_2$ ✓	1	**IGNORE** state symbols **ALLOW** $Mg + 2\ CH_3(CH_2)_2COOH \longrightarrow 2CH_3(CH_2)_2COO^- + Mg^{2+} + H_2$ **DO NOT ALLOW** on RHS: $(CH_3(CH_2)_2COO^-)_2Mg^{2+}$ ***Ions must be shown separately***
		(ii)	$CO_3^{2-} + 2H^+ \longrightarrow H_2O + CO_2$ ✓	1	**IGNORE** state symbols **ALLOW** $CO_3^{2-} + 2\ CH_3(CH_2)_2COOH \longrightarrow 2\ CH_3(CH_2)_2COO^- + H_2O + CO_2$ **ALLOW** as product H_2CO_3
	(c)	(i)	$CH_3(CH_2)_2COONa$ **OR** $CH_3(CH_2)_2COO^-$ forms **OR** $CH_3(CH_2)_2COOH + OH^- \rightarrow CH_3(CH_2)_2COO^- + H_2O$ ✓ $CH_3(CH_2)_2COOH$ is in excess **OR** acid is in excess **OR** some acid remains ✓	2	**ALLOW names throughout** **ALLOW** '**sodium** salt of **butanoic acid**' **ALLOW** $CH_3(CH_2)_2COOH + NaOH \rightarrow CH_3(CH_2)_2COONa + H_2O$ **DO NOT ALLOW** just 'forms a salt/conjugate base' i.e. identity of product is required

Question			Answer	Marks	Guidance
3	(c)	(ii)	**Moles (2 marks)** amount $CH_3(CH_2)_2COOH$ = 0.0100 (mol) ✓ amount $CH_3(CH_2)_2COO^-$ = 0.0025 (mol) ✓ **Concentration (1 mark)** $[CH_3(CH_2)_2COOH]$ = 0.100 mol dm^{-3} **AND** $[CH_3(CH_2)_2COO^-]$ = 0.025 mol dm^{-3} ✓ **$[H^+]$ and pH (2 marks)** $[H^+] = 1.51\times10^{-5} \times \frac{0.100}{0.025}$ = 6.04 x 10^{-5} (mol dm^{-3}) ✓ pH = –log 6.04 x 10^{-5} = 4.22 ✓ **pH to 2 DP**	2 1 2	***ANNOTATIONS MUST BE USED*** --- **ALLOW** HA and A^- throughout **Mark** by **ECF** throughout **ONLY** award final 2 marks via a correct pH calculation via $K_a \times \frac{[CH_3(CH_2)_2COOH]}{[CH_3(CH_2)_2COO^-]}$ using data derived from that in the question (i.e. not just made up values)
			ALLOW alternative approach based on Henderson–Hasselbalch equation for final 2 marks $pH = pK_a + \log\frac{0.025}{0.100}$ **OR** $pK_a - \log\frac{0.100}{0.025}$ ✓ pH = 4.82 – 0.60 = 4.22 ✓ **ALLOW** $-\log K_a$ for pK_a		
			TAKE CARE with awarding marks for pH = 4.22 There is a mark for the concentration stage. If this has been omitted, the ratio for the last 2 marks will be 0.0100 and 0.0025. **4 marks max.** **Common errors** **pH = 5.42** As above for 4.22 but with acid/base ratio inverted. Award 4 **OR** 3 marks **Award zero marks for:** 4.12 from no working or random values pH value from K_a square root approach (weak acid pH) pH value from K_w /10^{-14} approach (strong base pH)		**Common errors** **pH = 4.12** use of initial concentrations: 0.250 and 0.050 given in question. **Award last 3 marks for:** 0.250/2 **AND** 0.050/2 = 0.125 **AND** 0.025 ✓ $1.51\times10^{-5} \times \frac{0.125}{0.025}$ = 7.55 x 10^{-5} (mol dm^{-3}) ✓ pH = –log$[H^+]$ = 4.12 ✓ **Award last 2 marks for:** $1.51\times10^{-5} \times \frac{0.250}{0.050}$ = 7.55 x 10^{-5} (mol dm^{-3}) ✓ pH = –log$[H^+]$ = 4.12 ✓ **pH = 5.52** As above for 4.12 but with acid/base ratio inverted. Award 2 **OR** 1 marks as outlined for 4.12 above

Question			Answer	Marks	Guidance
3	(d)		$HCOOH + CH_3(CH_2)_2COOH \rightleftharpoons HCOO^- + CH_3(CH_2)_2COOH_2^+$ ✓ acid 1 base 2 base 1 acid 2 ✓ **CARE:** Both + and – charges are required for the products in the equilibrium **DO NOT AWARD** the 2nd mark from an equilibrium expression that omits either charge	2	State symbols **NOT** required **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 For 1st mark, **DO NOT ALLOW** $COOH^-$ (i.e. H at end rather than start) but within 2nd mark **ALLOW** $COOH^-$ by **ECF** **IF** proton transfer is wrong way around then **ALLOW** 2nd mark for idea of acid–base pairs, i.e. $HCOOH + CH_3(CH_2)_2COOH \rightleftharpoons HCOOH_2^+ + CH_3(CH_2)_2COO^-$ × base 2 acid 1 acid 2 base 1 ✓ For H_2COOH^+ shown with wrong proton transfer, **DO NOT ALLOW** an **ECF** mark for acid–base pairs
			Total	**16**	

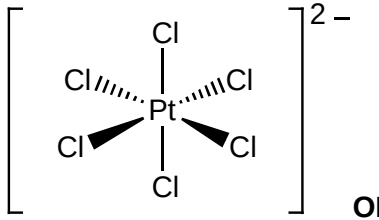
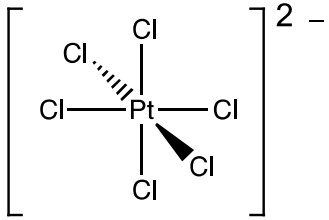
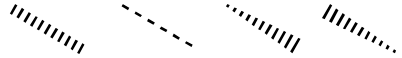
Question			Answer	Marks	Guidance
4	(a)	(i)	***initial rates data:*** **From Experiment 1** to **Experiment 2** **AND** $[NO_2]$ x 1.5, rate x 1.5 ✓ 1st order with respect to NO_2 ✓ **From Experiment 2** to **Experiment 3** **AND** $[O_3]$ is doubled, rate x 2 ✓ 1st order with respect to O_3 ✓ ***rate equation and rate constant:*** *rate* = $k[NO_2]\,[O_3]$ ✓ $k = \frac{rate}{[NO_2][O_3]}$ **OR** $\frac{4.80 \times 10^{-8}}{0.00150 \times 0.00250}$ ✓ = 0.0128 ✓ $dm^3\ mol^{-1}\ s^{-1}$ ✓	8	***ANNOTATIONS MUST BE USED*** **Quality of Written Communication**: --- Changes **MUST** be linked to Experiment numbers **in writing** (*Could be described unambiguously)* **IGNORE** annotations in the table --- For 2nd condition, **ALLOW** 'when $[NO_2]$ increases by half, rate increases by half **NOTE**: Orders may be identified within a rate equation **ALLOW**: working from any of the Experiments : All give the same calculated answer 0.0128 subsumes previous rearrangement mark **ALLOW**: $mol^{-1}\ dm^3\ s^{-1}$ ✓ **DO NOT ALLOW** 0.013 *over-rounding* --- **ALLOW ECF** from inverted *k* expression: $k = \frac{[NO_2][O_3]}{rate}$: *k* = 78.125 ✓ **ALLOW** 3 SF or more **NOTE** units must be from rate equation ✓

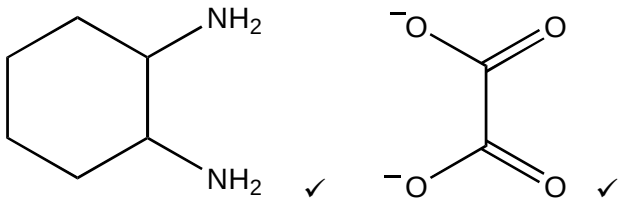
Question			Answer	Marks	Guidance
4	(a)	(ii)	**step 1**: $NO_2 + O_3$ LHS of step one ✓ $\longrightarrow NO_3 + O_2$ **step 2**: $NO_2 + NO_3 \longrightarrow N_2O_5$ rest of equations for step 1 **AND** step 2 ✓ **CHECK** that each equation is balanced **CARE:** **Step 1 AND Step 2** must add up to give overall equation In **Step 2**, **IGNORE** extra species shown on both sides, e.g. $NO_2 + NO_3 + O_2 \longrightarrow N_2O_5 + O_2$ **Step 2** can only gain a mark when **Step 1** is correct	2	State symbols **NOT** required For 'rest of equations', **ALLOW** other combinations that together give the overall equation, *e.g.*: $\longrightarrow NO_5$ $NO_2 + NO_5 \longrightarrow N_2O_5 + O_2$ *e.g.*: $\longrightarrow NO + 2O_2$ $NO + NO_2 + O_2 \longrightarrow N_2O_5$ **DO NOT ALLOW** use of algebraic species, e.g. X
	(b)	(i)	3 **gaseous** moles $\longrightarrow$ 2 **gaseous** moles ✓ Less randomness **OR** becomes more ordered ✓	2	**ALLOW** products have fewer **gaseous** moles **ORA** **ALLOW** 'molecules' instead of 'moles' **ALLOW** fewer ways of distributing energy **OR** fewer degrees of freedom **OR** fewer ways to arrange
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = –148 award **3 marks** --- $\Delta G = \Delta H - T\Delta S$ ✓ = –198 – (298 x –168/1000) ✓ = –148 (kJ mol^{-1}) ✓	3	**IF** there is an alternative answer, check calculator value and working for intermediate marks by **ECF** --- 2nd mark subsumes 1st mark for $\Delta G = \Delta H - T\Delta S$ **ALLOW** –148 to calculator value of –147.936 **ALLOW for 2 marks:** 49866 (kJ mol^{-1})*: not converting ΔS from J to kJ (no ÷ 1000)* –193.8 (kJ mol^{-1}) *use of 25 instead of 298*

Question			Answer	Marks	Guidance
4	(b)	(iii)	**CARE: responses involve changes of negative values** --- **Feasibility with increasing temperature** Reaction becomes less feasible/not feasible **AND** ΔG increases **OR** ΔG becomes less negative **OR** $\Delta G = 0$ **OR** $\Delta G > 0$ **OR** ΔG is positive **OR** ΔG approaches zero ✓ ***IF a candidate makes a correct statement about the link between ΔG and feasibility, **IGNORE** an incorrect ΔH and $T\Delta S$ relationship **IF** there is no ΔG statement, then mark any ΔH and $T\Delta S$ relationship in line with the mark scheme **----------** **Effect on $T\Delta S$** $T\Delta S$ becomes more negative **OR** $T\Delta S$ decreases **OR** $-T\Delta S$ increases **OR magnitude** of $T\Delta S$ increases ✓ ---	2	***ANNOTATIONS MUST BE USED*** --- As alternative for 'not feasible' **ALLOW 'not** spontaneous' **OR** a comment that implies 'reaction does not take place' **ALLOW for ΔG increases** $\Delta H = T\Delta S$ **OR** $\Delta H > T\Delta S$ **OR** $\Delta H - T\Delta S$ is positive **OR** $T\Delta S$ becomes more significant than ΔH **OR** $T\Delta S$ becomes the same as ΔH **OR** $T\Delta S$ becomes more negative than ΔH **NOTE Last statement will also score 2nd mark** **----------** **DO NOT ALLOW** $T\Delta S$ increases --- ***APPROACH BASED ON TOTAL ENTROPY:*** **Feasibility with increasing temperature** Reaction becomes less feasible/not feasible **AND** $\Delta S - \Delta H/T$ **OR** ΔS_{total} decreases/ less positive **OR** ΔS outweighs/ is less significant than $\Delta H/T$ ✓ **Effect on $\Delta H/T$** $\Delta H/T$ is less negative **OR** $\Delta H/T$ increases **OR** $-\Delta H/T$ decreases **OR** magnitude of $\Delta H/T$ decreases ✓
			Total	**17**	

Question			Answer	Marks	Guidance
5	(a)		(A transition element) has (at least) one **ion** with a partially filled d sub-shell/ d orbital ✓ Fe **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ ✓ Fe(II) / Fe^{2+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓ Fe(III) / Fe^{3+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ ✓	4	**ALLOW** incomplete for partially filled **DO NOT ALLOW** d shell **ALLOW** 4s before 3d, i.e. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ **IF** candidate has used subscripts **OR** caps **OR** [Ar], **DO NOT ALLOW** when first seen but credit subsequently, i.e. $1s_2 2s_2 2p_6 3s_2 3p_6 3d_6 4s_2$ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3D^6$ $[Ar]4s^2 3d^6$ For Fe^{2+} and Fe^{3+}, **ALLOW** $4s^0$ in electron configuration **IGNORE** electron configurations of elements other than Fe
	(b)		**EXAMPLES MUST REFER TO Cu^{2+} FOR ALL MARKS** **PRECIPITATION** **Reagent** NaOH(aq) **OR** KOH(aq) ✓ States not required **Transition metal product AND observation** $Cu(OH)_2$ **AND** blue precipitate/solid ✓ **Correct balanced equation** $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$ ✓ state symbols **not** required **IF more than one example shown, mark example giving lower mark**	3	***ANNOTATIONS MUST BE USED*** **ALLOW** NaOH in equation if 'reagent' not given in description **ALLOW a small amount** of NH_3/ammonia **DO NOT ALLOW** concentrated NH_3 **DO NOT ALLOW** just OH^- **ALLOW** $Cu(OH)_2(H_2O)_4$ **ALLOW** any shade of blue **ALLOW** (s) as state symbol for ppt (may be in equation) **ALLOW** $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2(H_2O)_4 + 2H_2O$ For NH_3, also **ALLOW:** $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2(H_2O)_4 + 2NH_4^+$ **ALLOW** full equation, e.g. $CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$ $CuCl_2 + 2NaOH \rightarrow Cu(OH)_2 + 2NaCl$

Question			Answer	Marks	Guidance
5	(b)		**LIGAND SUBSTITUTION – 2 likely** **Reagent** NH_3(aq)/ammonia ✓ State not required **Transition metal product AND observation** $[Cu(NH_3)_4(H_2O)_2]^{2+}$ **AND** deeper/darker blue (solution) ✓ **Correct balanced equation** $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ✓ **OR** ---------- **Reagent** Concentrated HCl **OR** (dilute) HCl(aq) **OR** NaCl(aq) ✓ State not required **Transition metal product AND observation** $[CuCl_4]^{2-}$ **AND** yellow (solution) ✓ **Correct balanced equation** $[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$ ✓	3	**IF more than one example shown, mark example giving lower mark** **ALLOW** NH_3 in equation if 'reagent' not given in description **DO NOT ALLOW** precipitate **ALLOW** royal blue, ultramarine blue or any blue colour that is clearly darker than for $[Cu(H_2O)_6]^{2+}$ ✓ ---------- **ALLOW** $CuCl_4^{2-}$ i.e. no brackets **ALLOW** any shades of yellow, e.g. yellow–green **DO NOT ALLOW** precipitate **ALLOW other correct ligand substitutions using same principles for marking as in two examples given**
	(c)	(i)	Pt oxidised from 0 +4 ✓ N reduced from +5 to +4 ✓	2	**ALLOW** 1 mark for Pt from 0 to +4 **AND** N from +5 to +4 i.e. oxidation and reduction not identified or wrong way round **DO NOT ALLOW** Pt is oxidised and N reduced with no evidence **DO NOT ALLOW** responses using other incorrect oxidation numbers **(CON)**

Question			Answer	Marks	Guidance
5	(c)	(ii)	$Pt + 6HCl + 4HNO_3 \longrightarrow H_2PtCl_6 + 4NO_2 + 4H_2O$ ✓✓	2	**1st mark for ALL species correct and no extras:** i.e: $Pt + HCl + HNO_3 \longrightarrow H_2PtCl_6 + NO_2 + H_2O$ **DO NOT ALLOW** charge on Pt, e.g. Pt^{2+} **2nd mark** for correct balancing **ALLOW** correct multiples
	(d)		 **OR**  **3-D Shape 1 mark** Correct 3-D diagram of Pt surrounded by 6Cl **ONLY** ✓ **Bond angle 1 mark** bond angle of 90º on diagram or stated ✓ **Charge 1 mark** 2– charge shown outside of brackets ✓	3	Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper **OR** 4 lines, 1 'out wedge' and 1 'in wedge' For bond into paper, **ALLOW**:  **IGNORE** charges on Pt and Cl for this mark The 2 marks for charge **AND** bond angle are **ONLY** available from a diagram showing Pt bonded to 6 Cl **ONLY** **ALLOW ONLY** if diagram has Pt surrounded by 6Cl **ONLY** **BUT** 3-D shape may not be correct **DO NOT ALLOW** if **ANY** charges shown on Pt or Cl within brackets

Question			Answer	Marks	Guidance
5	(e)	(i)	Donates **two** electron pairs to a **metal** (ion) ✓ forms **two** coordinate bonds ✓	2	**ALLOW** lone pairs for electron pairs **ALLOW** dative (covalent) bond for coordinate bond **ALLOW** 1 mark for a full definition of a ligand (without reference to 2: **i.e.** Donates **an** electron pair to a metal (ion) forming **a** coordinate bond ✓
		(ii)	 ✓ ✓	2	**ALLOW** displayed formulae '– charges' essential in $(COO^-)_2$ structure **DO NOT ALLOW** $–H_2N$
			Total	**21**	

Question			Answer	Marks	Guidance
6	(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
6	(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			Answer	Marks	Guidance
7	(a)		$MnO_2 + 4OH^- \longrightarrow MnO_4^{2-} + 2H_2O$ **+ 2e⁻** ✓ $3H_2O + ClO_3^-$ **+ 6e⁻** ✓ $\longrightarrow 6OH^- + Cl^-$	2	**ALLOW** 'e': i.e. – sign not required
	(b)		**Role of CO_2** CO_2 reacts with H_2O forming an acid **OR** carbonic acid/H_2CO_3 forms **OR** CO_2 is acidic ✓ **Equation involving OH^-** $H_2CO_3 + OH^- \longrightarrow H_2O + HCO_3^-$ **OR** $H_2CO_3 + 2OH^- \longrightarrow 2H_2O + CO_3^{2-}$ **OR** $CO_2 + OH^- \longrightarrow CO_3^{2-} + H^+$ **OR** $CO_2 + OH^- \longrightarrow HCO_3^-$ **OR** $CO_2 + 2OH^- \longrightarrow CO_3^{2-} + H_2O$ **OR** $H^+ + OH^- \longrightarrow H_2O$ ✓ **Effect on equilibrium with reason** equilibrium shifts to right **AND** to restore OH^- ✓	3	***ANNOTATIONS MUST BE USED*** --- **ALLOW** equation: $CO_2 + H_2O \longrightarrow H_2CO_3$ **OR** $CO_2 + H_2O \longrightarrow H^+ + HCO_3^-$ **OR** $CO_2 + H_2O \longrightarrow 2H^+ + CO_3^{2-}$ **ALLOW** for 'restores OH^-' the following: 'makes more OH^-', 'OH^- has been used up' **DO NOT ALLOW** just 'equilibrium shifts to right'

Question			Answer	Marks	Guidance
7	(c)		**FOLLOW through stages to mark** --- **Moles in titration** $n(KMnO_4) = 0.0200 \times \frac{26.2}{1000} = 5.24 \times 10^{-4}$ mol ✓ $n(SO_3^{2-}) = 1.31 \times 10^{-3}$ mol ✓ **Scaling** $n(SO_3^{2-})$ in original 100 cm^3 $= 4 \times 1.31 \times 10^{-3} = 5.24 \times 10^{-3}$ mol ✓ **Mass** Mass of Na_2SO_3 in sample $= 126.1 \times 5.24 \times 10^{-3}$ g = 0.660764 g ✓ **Percentage** $\%\ Na_2SO_3 = \frac{0.660764}{0.720} \times 100 = 91.8\%$ ✓	5	***ANNOTATIONS MUST BE USED*** ***AT LEAST 3 SF for each step*** --- **ECF** 2.5 x answer above **ECF** 4 x answer above **ECF** 126.1 x answer above **ALLOW** 0.661 g up to calculator value **ECF** $\frac{\text{calculated mass above}}{0.720} \times 100$ **ALLOW** 91.8% (1 DP) up to calculator value of 91.77277778 i.e. **DO NOT ALLOW** 92%
			ALLOW alternative approach based on theoretical content of Na_2SO_3 for last 2 marks **Theoretical amount, in moles, of Na_2SO_3 in sample** $n(Na_2SO_3) = \frac{0.720}{126.1} = 5.71 \times 10^{-3}$ mol ✓ **Percentage** $\%\ Na_2SO_3 = \frac{5.24 \times 10^{-3}}{5.71 \times 10^{-3}} \times 100 = 91.8\%$ ✓		**COMMON ERRORS**: 36.8(1)% 4 marks no 2.5 factor 22.9(4)% 4 marks no scaling by 4 9.18% 3 marks no 2.5 and no x 4 Watch for random ECF %s for % from incorrect $M(Na_2SO_3)$, e.g. use of $M(SO_3^{2-})$ = 80.1 giving 58.3%
			Total	**10**	