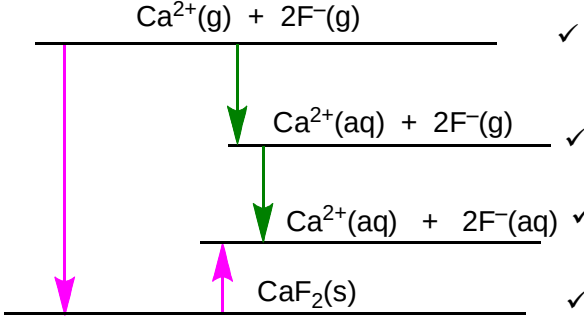


1	(a)	(i)	<i>Equation</i> $\text{Ba}(\text{NO}_3)_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{NaNO}_3(\text{aq}) \checkmark$ <i>Entropy change and explanation</i> entropy decreases OR entropy change negative AND (BaSO₄) solid/ppt has less disorder/ more order/ fewer ways of arranging energy/ less freedom/ less random particles/dispersal of energy ✓	2		ALLOW multiples M2 is dependent on BaSO₄(s) (even if formula is incorrect – eg Ba(SO₄)₂(s)) seen as a product in the attempted equation as long as reactants are not solid. BaSO₄ solid/ppt may be assumed from BaSO₄(s) seen in the attempted equation.
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Question			Answer	Marks		Guidance
1	(a)	(ii)	<i>Equation</i> $\frac{1}{2} \text{I}_2(\text{s}) \rightarrow \text{I}(\text{g})$ ✓ <i>state symbols required</i> <i>Entropy change and explanation</i> entropy increases OR entropy change positive AND gas has more disorder/ less order/ more ways of arranging energy/ more freedom/ more random particles / more dispersal of energy ✓	2		DO NOT ALLOW $\text{I}_2(\text{s}) \rightarrow 2\text{I}(\text{g})$ DEPENDENT on $\frac{1}{2} \text{I}_2(\text{s}) \rightarrow \text{I}(\text{g})$ OR $\text{I}_2(\text{s}) \rightarrow 2\text{I}(\text{g})$
			Total	12		

Question			Answer	Marks	Guidance
2	(a)		$\Delta G = \Delta H - T\Delta S$ linked to $y = mx + c$ (somewhere) ✓ gradient = $-\Delta S$ ✓ P: ΔH / enthalpy change ✓ Q: (temperature) for reaction to be feasible/unfeasible OR (temperature) at which feasibility changes ✓	4	Could be: $\Delta G = -\Delta S T + \Delta H$ – sign required ALLOW $\Delta S = -\text{gradient}$ ALLOW ‘point of feasibility’ For Feasibility: ALLOW can take place/happen OR is spontaneous IGNORE ‘minimum/maximum temperature’
	(b)	(i)	(Species have) different states/phases ✓	1	
		(ii)	$(K_p =) p(\text{CO(g)})^4$ ✓	1	Allow species without state symbols and without brackets, e.g. p_{CO}^4 , $pp\text{CO}^4$, PCO^4 , $p(\text{CO}^4)$ etc. DO NOT ALLOW square brackets
		(iii)	ΔG at 25 C $\Delta G = \Delta H - T\Delta S = 676.4 - (298 \times 0.7031)$ = (+) 467 (kJ mol ⁻¹) OR (+) 466876 (J mol ⁻¹) ✓ <i>Non-feasibility statement</i> Non-feasible when $\Delta G > 0$ OR $\Delta G > 0$ OR $\Delta H > T\Delta S$ ✓ <i>Minimum temperature</i> minimum temperature = $\frac{\Delta H}{\Delta S} = \frac{676.4}{0.7031}$ = 962(.0) K ✓	3	IGNORE units ALLOW (+) 467 up to calculator value of 466.8762 correctly rounded ECF for any positive value determined in M1 ALLOW 962 up to calculator value of 962.0253165 correctly rounded

Question	Answer	Marks	AO element	Guidance
3	A	1	AO1.2	

Question			Answer	Marks	Guidance
4	(a)	(i)	(enthalpy change when) 1 mole of gaseous ions react OR 1 mole of hydrated/aqueous ions are formed ✓ gaseous ions dissolve in water OR gaseous ions form aqueous/hydrated ions ✓	2	IGNORE 'energy released' OR 'energy required'
	(a)	(ii)		4	Correct species AND state symbols required for each mark. (mark independently) On 2nd line, ALLOW $\text{Ca}^{2+}(\text{g}) + 2\text{F}^{-}(\text{aq})$ (i.e. F^{-} hydrated before Ca^{2+}) On 3rd line, ALLOW $\text{CaF}_2(\text{aq})$ DO NOT ALLOW when first seen but ALLOW ECF for '2' missing and for use of the following ions Fl^{-} F_2^{-} $\text{Ca}^{+/3+}$

Question			Answer	Marks	Guidance
	(a)	(iii)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-504 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks IF answer = $-1008 \text{ (kJ mol}^{-1}\text{)}$ award 1 mark ----- $2 \times \Delta_{\text{hyd}}H(\text{F}^-)$ $= [-2630 + 13] - (-1609)$ OR $-2617 + 1609$ OR $-1008 \text{ (kJ mol}^{-1}\text{)}$ ✓ $\Delta_{\text{hyd}}H(\text{F}^-) = \frac{-1008}{2} = -504 \text{ ✓ (kJ mol}^{-1}\text{)}$	2	IF alternative answer, check to see if there is any ECF credit possible using working below. ‘-’ sign is needed. COMMON ERRORS for 1 mark: (+)2694: <i>signs all reversed</i> -2113: <i>sign wrong for -1609</i> -2126: <i>sign wrong for 2630</i> -517: <i>sign wrong for 13</i> +504: <i>sign wrong</i> IF ALL 3 relevant values from the information at the start of Q16a(iii) have NOT been used, award zero marks unless one number has a transcription error, where 1 mark can be awarded ECF
	(a)	(iv)	Correct comparison of Δ_{hyd} linked to sizes $\Delta_{\text{hyd}}H(\text{F}^-)$ more negative/exothermic (than $\Delta_{\text{hyd}}H(\text{Cl}^-)$) AND F^- has smaller size (than Cl^-) ✓ Comparison of attraction between ions and water F^- OR smaller sized ion linked to greater attraction to H_2O ✓	2	ORA IGNORE ‘atomic’ before radius when comparing size of ions IGNORE charge density IGNORE electronegativity IGNORE nuclear attraction DO NOT ALLOW ‘forms stronger hydrogen bonds with water’ OR ‘forms stronger van der Waals’ forces with water’ ALLOW ‘forms bonds’ for attraction’ DO NOT ALLOW F^- greater attraction to H_2O if given as larger ion Assume ‘F’ / ‘Fluorine’ means ‘ions’ but DO NOT ALLOW ‘F molecules’

Question			Answer	Marks	AO element	Guidance
5	(a)	(i)	Energy level diagram showing the formation of $2\text{K}^+(\text{g}) + \text{O}^{2-}(\text{g})$ from $2\text{K}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g})$. The diagram shows four energy levels. The lowest level is $2\text{K}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g})$ ✓. An upward arrow leads to a level above it. From there, an upward arrow leads to $2\text{K}(\text{g}) + \text{O}(\text{g})$ ✓. From $2\text{K}(\text{g}) + \text{O}(\text{g})$ ✓, a downward arrow leads to $2\text{K}^+(\text{g}) + \text{O}^-(\text{g}) + \text{e}^-$ ✓, and another downward arrow leads to the highest level, $2\text{K}^+(\text{g}) + \text{O}^{2-}(\text{g})$ ✓. A long downward arrow also goes from $2\text{K}^+(\text{g}) + \text{O}^{2-}(\text{g})$ ✓ to the level of $2\text{K}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g})$ ✓.	4	1.2 × 4	Mark each marking point independently Correct species AND state symbols required for each mark For e^-, ALLOW e For e^- only, IGNORE any state symbols added
5	(a)	(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $-2277 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks	2	2.2 × 2	IF there is an alternative answer, check to see if there is any ECF credit possible using

Question			Answer	Marks	AO element	Guidance
			$-363 - (2 \times +89 + 249 + 2 \times 419 - 141 + 790) \checkmark$ $-363 - 1914$ $= -2277 \checkmark \text{ (kJ mol}^{-1}\text{)}$			working below See list below for marking of answers from common errors ALLOW for 1 mark ONE mistake with sign OR use of 2 $\times$: +2277 (wrong sign) -601 (2×-419 instead of $2 \times +419$) -697 (-790 instead of $+790$) -1551 ($+363$ instead of -363) -1858 ($2 \times +419$ not used for K) -1921 (2×-89 instead of $2 \times +89$) -2152.5 or -2153 ($+249 \div 2$) -2188 ($2 \times +89$ not used for K) -2280 (rounded to 3SF) -2559 ($+141$ instead of -141) For other answers, check for a single transcription error or calculator error which could merit 1 mark
5	(b)	(i)	For sodium atomic radius smaller	2	1.1 $\times 2$	ALLOW 'Na/sodium is smaller' IGNORE smaller radius / fewer shells / less

Question			Answer	Marks	AO element	Guidance
			OR fewer shells ✓ nuclear attraction increases OR (outer) electron(s) experience more attraction ✓			shielding if applied to ions but DO NOT ALLOW responses which refer to ions losing electrons DO NOT ALLOW molecules ALLOW energy levels for shells IGNORE fewer orbitals OR fewer sub-shells ALLOW less (electron) shielding OR electron repulsion between shells IGNORE just 'shielding' ALLOW more/stronger/bigger nuclear attraction etc IGNORE 'pull' for attraction IGNORE electrons more tightly held IGNORE 'nuclear charge' for 'nuclear attraction' IGNORE more energy (in question) ALLOW reverse argument for potassium throughout
5	(b)	(ii)	Comparison of size of cations For sodium ions	2	1.2 x2	comparison of IONS is essential

Question			Answer	Marks	AO element	Guidance
			ionic radius of sodium / Na^+ is smaller ✓ <i>Comparison of attraction of cation and anion</i> Na^+ has stronger attraction to O^{2-} ✓			ALLOW Na^+ has a larger charge density IGNORE 'Na has smaller atomic radius' but DO NOT ALLOW contradictory sentences eg ' Na^+ ions have smaller atomic radius' IGNORE pull for attraction ALLOW 'sodium ion' and 'oxygen ion' IGNORE just 'oxygen' or just 'O' for oxygen ion ALLOW stronger attraction between

Question			Answer	Marks	AO element	Guidance
6	(a)	(i)	More energy is released by forming bonds than energy required when breaking bonds OR bond enthalpy of bonds being made is higher than bond enthalpy of bonds being broken ✓	1	1.2	Response needs link between energy, breaking and making bonds Eg 'bond breaking is endothermic' AND 'bond making is exothermic' AND 'exothermic change outweighs endothermic change' IGNORE more bonds made than broken
		(ii)	FIRST CHECK ΔG If $\Delta G = -1010 \text{ (kJ mol}^{-1}\text{)}$ award first 3 marks $\Delta S = (2 \times 248 + 2 \times 70) - (2 \times 206 + 3 \times 205)$ $= -391 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ OR $-0.391 \text{ (kJ K}^{-1} \text{ mol}^{-1}\text{)}$ ✓ $\Delta G = \Delta H - T\Delta S = -1125 - (293 \times -0.391)$ ✓ $= -1010 \text{ (kJ mol}^{-1}\text{)}$ ✓ Feasible AND $\Delta G < 0$ OR ΔG is negative ✓	4	2.2 x3 3.2 x1	ALLOW ecf ALLOW $-1010000 \text{ (J mol}^{-1}\text{)}$ ALLOW 3 SF up to calculator value -1010.437 Common errors ALLOW: Two calculation marks for: -1117 to 3 SF up to calculator value of -1117.179865 (use of 20 instead of 293) $(+)$$113438 \text{ (kJ mol}^{-1}\text{)}$ or 113000, 113400, 113440 (mix of J and kJ) -1008 up to calculator value of -1008.482 (use of $T = 298$) -1018 up to calculator value of -1018.257 (use of $T = 273$) ALLOW ECF for from incorrect ΔG,

Question			Answer	Marks	AO element	Guidance
7	(a)	(i)	$\text{Mg}^{2+}(\text{g}) + 2\text{Br}(\text{g}) + 2\text{e}^- \checkmark$ $\text{Mg}(\text{s}) + \text{Br}_2(\text{l}) \checkmark$	2	1.2×2	State symbols required. CARE: Liquid state symbol for Br ₂
		(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = –346.5 award 2 marks ----- $2\Delta H_{\text{hyd}} =$ $-525 - 186 - (2 \times 112) - 148 - 736 - 1450 + (2 \times -325)$ $+ 1926$ OR $-525 - 186 - 224 - 148 - 736 - 1450 + 650 + 1926$ OR $= -693 \checkmark$ $\Delta H_{\text{hyd}} = -346.5 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	2.2×2	ALLOW -347 (kJ mol⁻¹) for 2 marks. ALLOW for 1 mark ONE error with sign OR use of 2: –693 (not divided by 2 at the end) 346.5 (wrong sign on answer) Common errors for 1 mark –2272.5 (–1926 instead of 1926) –1386 (2 × –693 instead of –693) –996.5 (–650 instead of 650) –509 (2 × 325 not used) –290.5 (2 × 112 not used) –198.5 (148 instead of –148) –160.5 (186 instead of –186) –122.5 (224 instead of –224) 178.5 (525 instead of –525) 389.5 (736 instead of –736) 1103.5 (1450 instead of –1450) For other answers, check for a single transcription error or calculation error which could merit 1 mark DO NOT ALLOW any answer which involves two errors e.g. –453 (2 × 325 not used AND 2 × 112 not used)

Question			Answer	Marks	AO element	Guidance
7	(a)	(iii)	Equation: $\text{Mg}^{2+}(\text{g}) + 2\text{Br}^{-}(\text{g}) \rightarrow \text{MgBr}_2(\text{s})$ ✓ CHECK THE ANSWER ON ANSWER LINE If answer = -2433 award 2 marks ----- Lattice enthalpy = $\Delta_{\text{hy}}H(\text{Mg}^{2+}) + 2 \times \Delta_{\text{hy}}H(\text{Br}^{-}) - \Delta_{\text{sol}}H(\text{MgBr}_2)$ OR $-1926 + (2 \times -346.5) - (-186)$ OR $\Delta_{\text{f}}H(\text{MgBr}_2) - 2\Delta_{\text{at}}H(\text{Br}) - \Delta_{\text{at}}H(\text{Mg})$ $- 1\text{st IE}(\text{Mg}) - 2\text{nd IE}(\text{Mg}) - 2\Delta_{\text{ea}}H(\text{Br})$ OR $-525 - (2 \times 112) - 148 - 736 - 1450 - (2 \times -325)$ ✓ Lattice enthalpy = $-2433 \text{ kJ mol}^{-1}$ ✓	3	1.2 2.2 x 2	State symbols required For other answers, check for a single transcription error or calculation error which could merit 1 mark DO NOT ALLOW any answer which involves two errors ALLOW ECF from incorrect answer to d(ii)
			Total	18		

[illegible]

Question	Answer	Marks	AO element	Guidance
9	A	1	AO1.2	

Question			Answer	Marks	AO element	Guidance
10	(a)	(i)	(enthalpy change for) 1 mole of a compound/substance/solid/solute dissolving ✓	1	AO1.1	IGNORE 'energy released' OR 'energy required' For dissolving, ALLOW forms aqueous/hydrated ions IGNORE ionic OR covalent DO NOT ALLOW dissolving elements DO NOT ALLOW response that implies formation of 1 mole of aqueous ions
	(a)	(ii)	$\underline{\text{Mg}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{g})} \quad \checkmark$ $\underline{\text{Mg}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})} \quad \checkmark$	2	AO2.2 ×2	ALLOW $\text{Mg}^{2+}(\text{g}) + 2\text{F}^{-}(\text{aq})$ ALLOW $\text{MgF}_2(\text{aq})$
	(a)	(iii)	$-6 \text{ (kJ mol}^{-1}\text{)}$ ✓ $\Delta_{\text{sol}}H (\text{MgF}_2) = -(-2926) + (2 \times -506) + (-1920)$	1	AO2.2	1 mark ONLY
	(a)	(iv)	Ionic radius Halide ion gets larger down the group ✓ Lattice enthalpy Lattice enthalpy is less exothermic down group OR halide ion has less attraction for Mg^{2+} ✓ Hydration enthalpy Hydration enthalpy is less exothermic down group OR halide ion has less attraction for H_2O ✓ Enthalpy of solution Difficult to predict whether lattice enthalpy or hydration enthalpy has bigger effect ✓	4	AO1.2 ×3 AO3.2	ALLOW ORA throughout ALLOW ions closer together in MgF_2 OR further apart in MgI_2 DO NOT ALLOW atomic radius ALLOW MgI_2 is less exothermic than MgF_2 for LE and hydration enthalpy -as trend 'down the group'. ALLOW less negative/more positive BUT IGNORE is smaller/less
			Total	14		

Question			Answer	Marks	AO element	Guidance
11	(a)		rate of forwards reaction = rate of backwards reaction OR concentrations/pressure/temperature are constant /do not change ✓	1	AO1.1	DO NOT ALLOW “are the same”
	(b)	(i)	$\Delta G = \Delta H - T\Delta S = -114 - (298 \times -0.147) \checkmark$ $= -70.194 \text{ (kJ mol}^{-1}\text{)}$ AND statement of $\Delta G < 0$ OR ΔG is -ve OR $\Delta H < T\Delta S \checkmark$	2	AO2.2 ×2	ALLOW $-114000 - (298 \times -147)$ ALLOW -70 up to calculator value of -70.194 correctly rounded, i.e. -70 OR -70.2 OR -70.19 ALLOW -70000 up to -70194 (J mol ⁻¹) ALLOW ECF for an incorrectly calculated negative value of ΔG linked to feasibility statement IGNORE rounding after 3 SF ORA for comment about – sign required for feasibility
	(b)	(ii)	776 (K) ✓ i.e. Maximum temperature = $\frac{\Delta H}{\Delta S} = \frac{-114}{-0.147} = 776 \text{ (K)}$ 3 SF required (appropriate from supplied data)	1	AO2.2	

Question	Answer	Marks	AO	Guidance
12	A	1	2.1	

Question			Answer	Marks	AO element	Guidance
13	(a)	(i)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF $T = 52.4\text{ }^{\circ}\text{C}$ OR $52.5\text{ }^{\circ}\text{C}$ award 4 marks IF $T = 32.4\text{ }(^{\circ}\text{C})$ award 3 marks Correctly calculates $n(\text{AgNO}_3)$ $= 0.400 \times \frac{100.0}{1000}$ OR $0.04(00)$ (mol) ✓ Energy released per mole of AgNO_3 in J OR kJ $= \frac{678 \times 0.0400}{2}$ OR 13.56 (kJ) OR 13560 (J) ✓ Correctly calculates ΔT $\Delta T = \frac{13560}{100 \times 4.18}$ OR 32.4 ($^{\circ}\text{C}$) ✓ Maximum temperature reached $= 32.4... + 20.0 = 52.4\text{ }^{\circ}\text{C}$ ✓ 3 SF required	4		FULL ANNOTATIONS MUST BE USED ALLOW ECF throughout AO1.2 AO2.4 ALLOW 13.6 kJ OR 13600 J (to 3SF) DO NOT ALLOW < 3 SF IGNORE any sign and units <i>i.e. ALLOW correctly calculated value in J OR kJ</i> AO2.8 AO2.8 ALLOW ECF ONLY from calculated $\Delta T + 20\text{ }^{\circ}\text{C}$ Common errors 3 marks $84.9\text{ }^{\circ}\text{C}$ (not divided $\frac{\Delta H}{2}$)

	(a)	(ii)	Maximum temperature is the same AND Half the energy/ moles AND half the mass/volume	1	AO3.4	ALLOW response that links the same proportionality/ratio of volume/mass and energy/moles ALLOW if seen by a calculation
	(b)	(i)	(Enthalpy change) when 1 mole of a compound is formed from its elements ✓	1	AO1.1 ×1	ALLOW energy required OR energy released ALLOW one mole of product/substance DO NOT ALLOW 1 mole of element DO NOT ALLOW is formed from its gaseous elements when 1 mole of a solid compound when 1 mole of a gaseous compound
		(ii)	FIRST, CHECK THE ANSWER ON ANSWER LINE If answer = (+)90 award 2 marks ----- $4(\Delta_f H^\ominus \text{.NO}) = -1172 - 6(-286) + 4(-46)$ $= -1172 + 1716 - 184$ $= (+)360 \text{ (kJ mol}^{-1}\text{)} \checkmark$ $\Delta_f H^\ominus \text{.NO} = \frac{360}{4} = (+)90 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	AO2.2 ×2	ALLOW ECF providing all values are used ALLOW one transcription error in the values used for M2 Common error 1 mark -90 (wrong sign)

	(c)	(i)	a measure of the dispersal of energy (in a system) ✓	1	AO1.1	ALLOW a measure/degree of the disorder (of a system) ORA
		(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = $-2587 \text{ (kJ mol}^{-1}\text{)}$ award 3 marks ΔS° $\Delta S^\circ = 256 + 4(214) + 8(192) - 4(151) - 8(220)$ $= (+)284 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ OR $(+)0.284 \text{ (kJ K}^{-1} \text{ mol}^{-1}\text{)}$ ✓ <i>Use of</i> $T = 298 \text{ (K)}$ AND $\Delta S = 0.284 \text{ (kJ K}^{-1} \text{ mol}^{-1}\text{)}$ ✓ $\Delta H = (\Delta G + T\Delta S)$ $= -2587 \text{ (kJ mol}^{-1}\text{)}$ ✓	3	AO2.2 ×3	ALLOW ECF throughout M2 is for unit conversions seen anywhere. ALLOW 3SF up to the calculator value $-2587.368 \text{ (kJ mol}^{-1}\text{)}$ ALLOW ECF from incorrect unit conversions or incorrect ΔS.

13	(c)	(iii)	ΔS is positive/ + AND ΔH is negative/ – ✓ ΔG is negative (– at all temperatures) OR ΔG is (always) negative/ – ✓	2	AO3.1 AO3.2	ALLOW ΔH is exothermic ALLOW ‘ $-T\Delta S$ ’ is negative’ ΔG comment is dependent on on the signs assigned to ΔS AND ΔH (either in answer or from 17 cii). ALLOW ECF from incorrect signs for ΔS and/or ΔH from c(ii) i.e. ΔS is positive/ + AND ΔH is positive/ + Reaction is feasible only at high temperatures ΔS is negative/ - AND ΔH is negative/ - Reaction is feasible only at low temperatures IGNORE ΔS is negative/ - AND ΔH is positive/ + (- ΔG given in 17 cii) Alternative Approach ALLOW use of $\Delta G=0$ for 2 marks i.e. calculates $T = -9109\text{K}$ ✓ It is always feasible above -9109K / calculated -ve value and all temperatures are above this ✓
			Total	14		

Question	Answer	Marks	AO element	Guidance
14	B	1	AO2.2	

Question	Answer	Marks	AO element	Guidance
15	B	1	AO2.1	

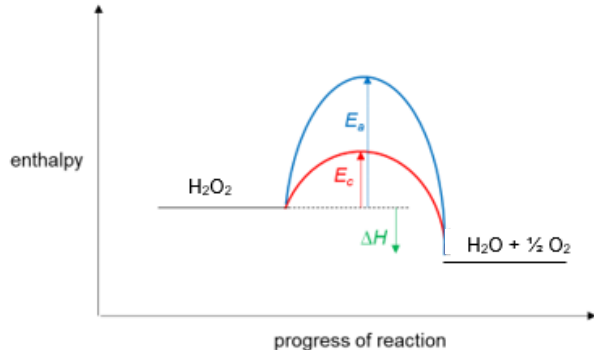
Question			Answer	Marks	AO element	Guidance
16	(a)	(i)	$\text{Ba}^{2+}(\text{g}) + 2\text{I}(\text{g}) + 2\text{e}^-$ $\text{Ba}^+(\text{g}) + 2\text{I}(\text{g}) + \text{e}^-$ ✓ $\text{Ba}(\text{g}) + 2\text{I}(\text{g})$ ✓ $\text{Ba}^{2+}(\text{g}) + 2\text{I}^-(\text{g})$ ✓ $\text{Ba}(\text{s}) + 2\text{I}(\text{g})$ $\text{Ba}(\text{s}) + \text{I}_2(\text{s})$ ✓ $\text{BaI}_2(\text{s})$	4	AO1.2 ×4	

Question			Answer	Marks	AO element	Guidance
16	(a)	(ii)	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = –1872 award 2 marks ----- ΔH lattice = $2(+296) - 965 - 503 - 180 + 2(-107) - 602 \checkmark$ ΔH lattice = $-1872 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	AO2.2 ×2	ALLOW for 1 mark +1872 (wrong sign on answer) Common errors for 1 mark –3056 (–296 × 2 instead of 296 × 2) –2168 (296 × 1 instead of 296 × 2) –1765 (–107 × 1 instead of –107 × 2) –1512 (180 instead of –180) –1444 (107 × 2 instead of –107 × 2) –866 (503 instead of –503) –668 (602 instead of –602) +58 (965 instead of –965) For other answers, check for a single transcription error or calculation error which could merit 1 mark if all values have been used. DO NOT ALLOW any answer which involves two errors

Question			Answer	Marks	AO element	Guidance
17	(a)		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = –4950 award 3 marks ----- $q = mc\Delta T$ $= 150 \times 4.18 \times 10.5$ $= 6583.5 \text{ (J) OR } 6.5835 \text{ (kJ) } \checkmark$ $n(\text{C}_7\text{H}_{16})$ $= \frac{0.133}{100} = 1.33 \times 10^{-3} \checkmark$ $\Delta_c H = q \div n$ $= \frac{6.5835}{1.33 \times 10^{-3}}$ $= -4950 \text{ kJ mol}^{-1}$ – sign required $\checkmark$	3	AO2.4 $\times 1$ AO2.8 $\times 2$	ALLOW 3 SF up to the calculated value Ignore RE after 3SF IGNORE sign ALLOW ECF from incorrect q and/or n Common errors for 2 marks +4950 kJ mol⁻¹ (wrong sign) -5077 (use of 0.0013 and 6.6 2SF) -5064 (use of 0.0013 2SF) -4962 (use of 6.6kJ use of 2SF)
	(b)		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = –3535 award 2 marks ----- $186 = \Delta_c H(\text{C}_9\text{H}_{20}) - \Delta_c H(\text{C}_5\text{H}_{12}) - 2 \Delta_c H(\text{C}_2\text{H}_4)$ OR From Hess cycle with all numerical values used and correct multiples used/labelled $\begin{array}{c} +186 \\ \text{C}_9\text{H}_{20}(\text{g}) \rightarrow \text{C}_5\text{H}_{12}(\text{g}) + 2\text{C}_2\text{H}_4(\text{g}) \\ \downarrow -6171 \quad \downarrow \Delta_c H(\text{C}_5\text{H}_{12}) \quad \downarrow 2 \times -1411 \\ \text{common combustion products} \end{array}$ $\checkmark$ $\Delta_c H(\text{C}_5\text{H}_{12}) = (-6171) - 2(-1411) - 186$ $= -3535 \text{ kJ mol}^{-1} \checkmark$	2	AO2.2 $\times 2$	IGNORE any incorrect combustion products on bottom line. Common errors for 1 mark +3535 (wrong sign for final answer) +8807 (use of +6171) -9179 (use of +1411) -4946 (use of 1 x -1411) -3163 (use of +186) For other answers, check for a single transcription error or calculation error using all values which could merit 1 mark

[illegible]

Question			Answer	Marks	Guidance
18	(a)	(i)	FIRST CHECK ANSWER ON ANSWER LINE If answer = -117 kJ mol^{-1}, award 4 marks. $\Delta H = -286 - (-188)$ $= -98 \text{ kJ mol}^{-1} \checkmark$ $\Delta S = 70 + \frac{1}{2}(205) - 110 = 62.5 \text{ (J K}^{-1} \text{ mol}^{-1})$ or $0.0625 \text{ (kJ K}^{-1} \text{ mol}^{-1}) \checkmark$ $\Delta G = \Delta H - T\Delta S$ $= -98 - (298 \times 0.0625) \checkmark$ $\Delta G = -117 \text{ kJ mol}^{-1} \text{ (3SF)} \checkmark$	4	ALLOW ECF throughout ALLOW $-98000 - (298 \times 62.5)$ Common Errors for ΔG 3 marks -18700 (ΔS not converted to kJ) -493 ($\Delta H = -286 + (-188) = -474$) -147 ($\Delta S = 165$: not halving 205) -99.6 (T not converted to K) -18.7 (ΔH not converted J but $\Delta S \text{ J K}^{-1} \text{ mol}^{-1}$) $(+)79.4$ ($-188 - (-286) = +98$) 2 marks $(+) 117$ (incorrect signs for ΔH and ΔS) Final Answer MUST BE 3 SF

Question			Answer	Marks	Guidance
18	(a)	(ii)	(Rate of reaction) slow OR Activation energy high ✓	1	ALLOW ΔG takes no account of rate of reaction ALLOW molecules do not have sufficient energy to equal or exceed the activation energy. IGNORE molecules do not have sufficient energy to react. DO NOT ALLOW there is not enough activation energy
	(b)	(i)	 H₂O₂ on LHS AND H₂O + ½ O₂ on RHS AND ΔH labelled with product line below reactant line AND Arrow downwards ✓	3	Care enthalpy profile must match ΔH sign in 16 a) i) – check calculation ALLOW endothermic profile as ECF from + ΔH calculated in 16 a) i) for all three marks State symbols not required ΔH DO NOT ALLOW –ΔH DO NOT ALLOW double headed arrow on ΔH ALLOW ΔH arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line.

Question			Answer	Marks	Guidance
			E_a correctly labelled ✓ E_c <u>correctly</u> <u>labelled</u> with $E_c < E_a$ ✓		E_a and E_c ALLOW no arrowhead or arrowheads at both end of E_a or E_c lines E_a or E_c lines must reach maximum (or near to maximum) on curve ALLOW overlapping lines OR lines on side reaching maximum For E_a, ALLOW AE OR A_E OR Eact OR suitable alternatives ALLOW ECF marks for E_a and E_c for correctly labelled endothermic diagram from a $-\Delta H$ value (from 16 a) i))
18	(b)	(ii)	(MnO₂) is in different phase/state (to the reactant / H₂O₂) OR catalyst is a <u>solid</u> AND reactant is <u>liquid</u> ✓	1	ASSUME 'it' is MnO₂ ALLOW 'species in the reaction' IGNORE references to products
		(iii)	Mn is +2 AND +3 OR Mn is +1 AND +6 ✓	1	+ required ALLOW 2+ and 3+ DO NOT ALLOW Mn²⁺ Mn³⁺ DO NOT ALLOW + 4 (this is the oxidation state in MnO₂)

Question			Answer	Marks	Guidance
18	(c)	(i)	(Enthalpy / heat energy change / released when) 1 mol of (ionic lattice) ✓ Is formed from its gaseous ions ✓	2	ALLOW 1 mol of (ionic) compound/product/substance IGNORE energy released/required ALLOW $M^+(g) + X^-(g) \rightarrow MX(s)$ DO NOT ALLOW <u>one mole</u> of gaseous ions
		(ii)		3	Care: State symbols are required

Question			Answer	Marks	Guidance
18	(c)	(iii)	FIRST CHECK ANSWER ON ANSWER LINE If answer = -3798 award 2 marks ----- $\Delta H_{\text{lattice}}$ $= -281 - 249 - 717 - 1509 - (-141) - 798 + (-385) \checkmark$ $\Delta H_{\text{lattice}} = -3798 \text{ (kJ mol}^{-1}\text{)} \checkmark$	2	Common errors for 1 mark -4080 (use of -141) -3674 (use of +249/2 and correctly rounded) -3673.5 (use of +249/2) -3236 (use of +281) -3300 (use of +249) -3028 (use of -385) -2364 (use of +717) -2202 (use of +798) -780 (use of +1509) +3798 (wrong sign on answer) For other answers , check for a single transcription error or calculation error which could merit 1 mark

Question	Answer	Marks	Guidance
19	B	1	

Question			Answer	Mark	Guidance
20	(a)	(i)	Iron is an <u>element</u> (in its standard state) ✓	1	Takes no energy to make an <u>element</u> from an <u>element</u> (under standard conditions)
		(ii)	$(\Delta H =) 3(-394) + 0 - (-824) - 3(-111)$ ✓ $(\Delta H =) -25 \text{ kJ mol}^{-1}$ ✓	2	ALLOW ECF for one transcriptional error Common Errors 1 mark (+) 763 (no 3 x -394) (+) 25 (incorrect sign) -247 (no 3 x -111) -2339 (+ for - (-824 + 3 x -111))
		(iii)	Fe_2O_3 is a solid and CO_2 is a gas ✓ So CO_2 / gas more disordered OR greater number of ways a system can be arranged / energy can be dispersed in CO_2 / gas ✓	2	ALLOW ORA
		(iv)	$15 = 3(214) + 2x - 87 - 3(198)$ OR 54✓ $(2x = 54 \text{ so}) S = 27 \text{ (J K}^{-1} \text{ mol}^{-1} \text{)}$ ✓	2	ALLOW ECF for a calculated value using all numerical values Common Errors 1 mark 241 (No 3 x 214) 12 (Subtraction backwards) -171 (No 3 x 198)

Question	Answer	Mark	Guidance
20 (b)	ΔG at 100°C $(\Delta G = \Delta H - T\Delta S =$ $491 - (373 \times 0.543) / 491000 - (373 \times 543))$ $= (+) 288 \text{ (kJ mol}^{-1}\text{) OR } (+) 288461 \text{ (J mol}^{-1}\text{) } \checkmark$ Feasibility statement Not feasible when $\Delta G > 0 \checkmark$ Minimum Temperature whole number required $(T = \frac{\Delta H}{\Delta S} = \frac{491000}{543})$ $= 904 \text{ OR } 905 \text{ K } \checkmark$	3	ALLOW 3 SF up to calculator value IGNORE units ALLOW ECF for any <u>positive value</u> determined in M1 Alternative approach for first two marks ΔH and $T\Delta S$ at 100°C $T\Delta S = 373 \times 0.543$ $= 202.539$ Feasibility statement $(\Delta H > T\Delta S)$ $491 > 202.539 \text{ OR } 491000 > 202539$ so not feasible