PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 13: ENERGETICS II

SCORE	PERCENTAGE
/279	%

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(3)

(Total for question = 3 marks)

Q54.

For the reaction

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

at 450 K the total entropy change, ΔS_{total}, is negative. Hence the equilibrium constant, K_p, for this reaction at 450 K is

☒ **A** zero.

☒ **B** positive and greater than 1.

☒ **C** positive and less than 1.

☒ **D** negative.

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	B		1

Q2.

Question Number	Correct Answer	Reject	Mark
(a)(i)			**2**

	$CH_2CHCHCH_2$	CO	H_2O	$HOOC(CH_2)_4COOH$
ΔH_f / kJ mol^{-1}	+109.9	**−110.5**	**−285.8**	−994.3
S / J mol^{-1} K^{-1}	278.7	**197.6**	**69.9**	250.0

4 values correct **(2)** marks

3 / 2 values correct **(1)** mark

0 / 1 values correct **(0)** marks

Question Number	Correct Answer	Reject	Mark
(a)(ii)	−994.3 − [+109.9 + (2 x −110.5) + (2 x −285.8)] **(1)** = − 311.6 (kJ mol^{-1}) **(1)** Allow TE from (a) **NOTE** If both −110.5 and −285.8 are not doubled, answer CQ = −707.9 (kJ mol^{-1}) for **1** mark Ignore SF except 1 SF		**2**

Question Number	Correct Answer	Reject	Mark
(a)(iii)	250(.0) − [278.7 + (2 x 197.6) + (2 x 69.9)] **(1)** = −563.7 (J mol^{-1} K^{-1}) **(1)** Allow TE from (a) **NOTE** If both 197.6 and 69.9 are not doubled, answer CQ = −296.2 (J mol^{-1} K^{-1}) for **1** mark Ignore SF except 1 SF		**2**

Question Number	Correct Answer	Reject	Mark
(a) (iv)	ΔS_{surr} at 298 K = $-\Delta H/T$ **(1)** = − (−311.6 x 1000) / 298 = (+) **1045.6** (J mol^{-1} K^{-1}) Allow TE from (a)(ii) e.g. ΔS_{surr} = (+)2375.5(0) (J mol^{-1} K^{-1}) scores (2) if no doubling in (a)(ii) **(1)** $\Delta S_{tot} = \Delta S_{surr} + \Delta S_{sys}$ / ΔS_{tot} = 1045.6 −563.7 / ΔS_{tot} = (+) **481.9** (J mol^{-1} K^{-1}) Allow TE from (a)(ii) and (a)(iii) **(1)** Allow correct answers given in **kJ mol^{-1} K^{-1}** e.g. 0.4819 **kJ mol^{-1} K^{-1}** Ignore SF except 1 SF If candidates forget to convert ΔH into J mol^{-1}, then ΔS_{tot} = −562.7 (J mol^{-1} K^{-1}) would score (2) if correct working is included		**3**

Question Number	Correct Answer	Reject	Mark
(a)(v)	(Decrease in T) **1st mark: consideration of ΔS_{system}** ΔS_{system} is not (significantly) changed / is unchanged / remains (approximately) constant **(1)** **2nd mark: consideration of ΔS_{surr}** ΔS_{surr} or $-\Delta H/T$ is more positive / larger / greater COMMENT ALLOW 'less negative' **(1)** **3rd mark: consideration of ΔS_{total}** (So) increases ΔS_{tot} / makes ΔS_{tot} more positive / makes ΔS_{tot} greater **(1)** **NOTE** IF no reference / an incorrect reference made to ΔS_{system}, then only the 2nd and 3rd marks can be awarded **NOTE** If candidate states that ΔS_{surr} becomes **less +ve**, no M2 But if **then** states CQ that ΔS_{tot} decreases award M3 as a TE		**3**

Question Number	Correct Answer	Reject	Mark
(b)	**DIMINISHING:** (Peak between) **1669 – 1645** (cm^{-1}) (due to C=C) **OR** (Peak between) **3095 – 3010** (cm^{-1}) (due to alkene C-H) **(1)** **INCREASING:** (Peak between) **1725 – 1700** (cm^{-1}) (due to C=O in carboxylic acid) **OR** (Peaks due to alkane C–H bonds at) EITHER **2962 – 2853** (cm^{-1}) OR **1485 – 1365** (cm^{-1}) **ALLOW** (Peak between) **3300 – 2500** (cm^{-1}) (due to O–H in carboxylic acid) **(1)**	**1740 – 1720** **3750 – 3200**	**2**

Question Number	Correct Answer	Reject	Mark
(c)	(Makes it taste) sour / sharp / tart IGNORE 'acidic' / 'bitter' NOTE Contradictory answers (e.g. 'sharp and sweeter') score **(0)**	fruity sweet(er) none	**1**

Q3.

Question number	Acceptable Answer	Additional Guidance	Marks
(a)(i)	• ΔH_1 – enthalpy change of formation (of strontium chloride) (1) • ΔH_2 – enthalpy change of atomisation of strontium (1)		**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(a)(ii)	• $\Delta H_7 = \Delta H_1 - (\Delta H_2 + \Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6)$ (1) • $\Delta H_7 = -828 - 164 - 548 - 1060 - 242 - (-728)$ $= -2114$ (kJ mol^{-1}) (1)	Allow correct answer with no working scores 2	**2**

Question number	Answer	Additional Guidance	Marks
(b)	**B** (the inter-ionic distance is smaller in magnesium chloride)		**1**

Q4.

Question Number	Answer	Mark
	The only correct answer is B ***A*** *is incorrect because (−1031) + (79 + 520 + 159) is incorrect* ***C*** *is incorrect because (−1031) + (79 + 520) is incorrect* ***D*** *is incorrect because (−1031) + 79 +520 +159 – 616 is incorrect*	**(1)**

Q5.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • identification and correction of the first error **(1)** • identification and correction of the second error **(1)**	Allow corrections to be made on the diagram Error 1 – arrow for enthalpy change of formation should go down/be reversed Error 2 – the word 'half ' should be deleted from the enthalpy change of atomisation of hydrogen	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of first electron affinity of hydrogen	Example of calculation 1st EA= –(218+496+107)–56 +804 = –73 (kJ mol^{-1}) Allow a TE 1st EA = +39(kJ mol^{-1}) if the first arrow reversed direction is not identified	**(1)**

Q6.

Question Number	Answer	Mark
	The only correct answer is D (-216.6) **A** *is not correct because the values for magnesium and magnesium oxide have not been doubled and the entropy for the products has been incorrectly subtracted from the reactants entropy* **B** *is not correct because the values for magnesium and magnesium oxide have not been doubled* **C** *is not correct because the entropy for the products has been incorrectly subtracted from the entropy of the reactants*	(1)

Q7.

Question Number	Answer	Additional Guidance	Mark
	• application of Hess's law (1) • evaluation of lattice energy (1)	Example of calculation LE = (−1577 + (2 × −336) − (−73)) = = −2176 kJ mol^{-1} Final answer without working scores (2) (+) 2176 kJ mol^{-1} scores (1) for TE on incorrect application of Hess's law −1840 kJ mol^{-1} scores (1) for use of single −336 instead of double	(2)

Q8.

Question number	Answer	Additional guidance	Marks
	• construction of balanced cycle (1) • substitution and evaluation of 2nd IE (1)	Example calculation −2258 = −590 − 2nd IE + 2 (349) − 178 − 2 (122) − 796 hence 2nd IE = (+) 1148 (kJ mol^{-1}) correct answer, no working scores 2 marks	2

Q9.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	+89.6 – [+32.7 + 165] **(1)** = −108.1 J mol^{-1} K^{-1}/ J K^{-1} mol^{-1} Value, sign and **units** **(1)** Ignore SF except one Internal TE for recognisable numbers allowed, for example: ΔH°_{at} magnesium chloride (147.7→ -223.1) Halving S° [Cl_2] (82.5 → -25.6) Correct answer with no working **(2)** +/no sign 108.1 J mol^{-1} K^{-1}/ J K^{-1} mol^{-1} **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	(The sign is negative because) Any two from: • (A solid and) a gas reacting to form a solid. OR (Entropy decreases because) a gas reacting to form a solid. • There are fewer ways of arranging particles in a solid than a gas or vice-versa. OR Decrease in disorder as solid more ordered than gas or vice versa • Two mol(es) of reactant forming one mole of product. (Ignore two molecules form one molecule) OR Number of mol(es)/molecules decreases OR Fewer/less mol(es) of products than reactants	Energy... '(Positive) Answer is as expected...' **(0)**	**2**

Question Number	Correct Answer	Reject	Mark
(b)	$\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{surroundings} + \Delta S^{\ominus}_{system}$ OR $= +2152 + (-108.1)$ $= (+)2043.9$ Value 2043.9 / 2044 **(1)** $= (+)2040$ (J mol^{-1} K^{-1}) 3SF This mark conditional on correct value or correct TE value from (a)(i) **(1)** Accept TE from (a)(i), for example, -223.1 → +1928.9 → +1930 -25.6 → +2126.4 → +2130 Correct answer (2040, etc) with or without working scores 2		**2**

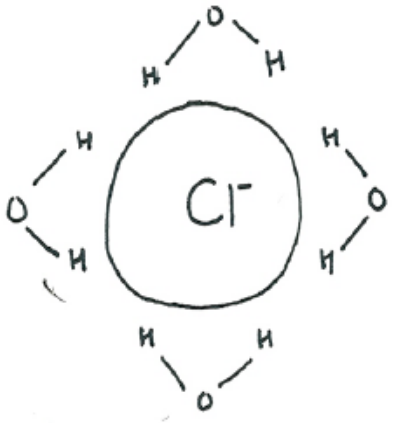
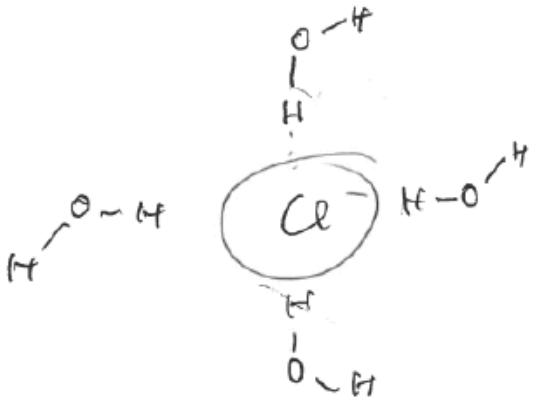
Question Number	Correct Answer1	Reject	Mark
(c)	$\Delta S^{\ominus}_{surroundings} = -\frac{\Delta H^{\ominus}}{298}$ $\Delta H^{\ominus} = -\Delta S^{\ominus}_{surroundings} \times 298$ OR $\Delta H^{\ominus} = -2152 \times 298$ **(1)** $= -641.296$ $= -641.3$ (kJ mol^{-1}) **(1)** ALLOW $= -641.3 \times 10^3$ **J mol^{-1}** Note 1. -640.1338 = -640.1 (if 2040/answer to part (b) used to recalculate entropy change of surroundings first.) **(2)** 2. $\Delta H^{\ominus} = +641.3$ (kJ mol^{-1}) **(1)** 3. $\Delta H^{\ominus} = -\frac{\Delta S^{\ominus}_{surroundings}}{298}$ **(0)** Ignore SF except one		**2**

Question Number	Correct Answer	Reject	Mark
(d)(i)	50 x 4.2 x 22.5 = 4725 (J) Ignore sign ALLOW 4.725 **kJ** Ignore SF except one		**1**

Question Number	Correct Answer	Reject	Mark
(d)(ii)	There are two legitimate answers to this part. If **both** methods have been used, you **must** send the item to review under mark scheme (−)4725 ÷ 0.0300 = −157.5 (kJ mol^{-1}) /−157500 **J mol^{-1}** OR (−)4725 ÷ 0.0500 = /−94.5 (kJ mol^{-1}) /−94500 **J mol^{-1}** ALLOW TE answer (d)(i) ÷ 0.0300/0.0500 Ignore SF except one Value **(1)** Sign **(1)** The mark for the negative sign is awarded for their calculation even if value is wrong, providing any **energy divided by moles or energy multiplied by 1/number of moles** calculation has been done.		**2**

Question Number	Correct Answer	Reject	Mark
(d)(iii)	There are two correct answers: Using 0.03 gives the answer of -381.75 kJ mol^{-1} Using 0.05 gives the answer of -350.25 kJ mol^{-1} Both these answers score full marks with or without correct working. **First mark** Appreciation of Hess's Law either in words, numbers, symbols or on the diagram For example, $\Delta H_{solution}$ + Lattice energy $= \Delta H_{hydration}\, Mg^{2+} + (2)\Delta H_{hydration}\, Cl^{-}$ **(1)** **Second mark** $2\ \Delta H_{hydration}\, Cl^{-} = -2526 - 157.5 - (-1920) = -763.5$ OR $2\ \Delta H_{hydration}\, Cl^{-} = -2526 - 94.5 - (-1920) = -700.5$		**3**

	ALLOW Any number or group of numbers minus (-1920) **(1)** **Third mark** $\Delta H_{hydration}\ Cl^-$ = − 381.75 (kJ mol^{-1}) OR $\Delta H_{hydration}\ Cl^-$ = − 350.25 (kJ mol^{-1}) Any number, wherever it has come from, divided by two can score this mark, provided that the sign is consistent. **(1)** Ignore SF except one Use of lattice energy − 2326 gives −281.75/−250.25 scores **(2)** ALLOW TE from (d)(ii)		

Question Number	Correct Answer	Reject	Mark
(d)(iv)	 OR  	**$Cl^-.H_2O$**	**1**

	• One/several water molecule(s) all correctly orientated. • $H^{\delta+}$/ hydrogen (one or two hydrogens from each water molecule) towards chloride ion • with negative charge either on chlorine or on the whole hydrated ion. ALLOW • A minus sign with a ring around it for the Cl^- • Bonds shown by lines/broken lines/dotted lines/wedges	$H^{\delta-}$ / H^+ / H^- $Cl^{\delta-}$ / Cl (with no charge)	

Q10.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	+104.6 – [+41.4 +165] **(1)** = -101.8 J mol^{-1} K^{-1} Value, sign and unit **(1)** Ignore SF except one Internal TE allowed for recognisable numbers, for example: ΔH°_{at} calcium instead of S° (178.2 → -238.6) OR Halving S° [Cl_2] (82.5 → -19.3) Correct answer with no working **(2)** +/no sign 101.8 J mol^{-1} K^{-1} **(1)**		2

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	(The sign is negative because) Any two from: • (A solid and) a gas reacting to form a solid. OR (Entropy decreases because) a gas reacting to form a solid. • There are fewer ways of arranging particles in a solid than a gas or vice-versa. OR Decrease in disorder as solid more ordered than gas or vice versa • Two mol(es) of reactant forming one mole of product. (Ignore two molecules form one molecule) OR Number of mol(es)/molecules decreases OR Fewer/less mol(es) of products than reactants	 Energy…	2
	COMMENT If answer to (a)(i) is positive then answer should start 'Answer is not as expected because…' Then score as above (which can score full marks).	'(Positive) Answer is as expected…'	

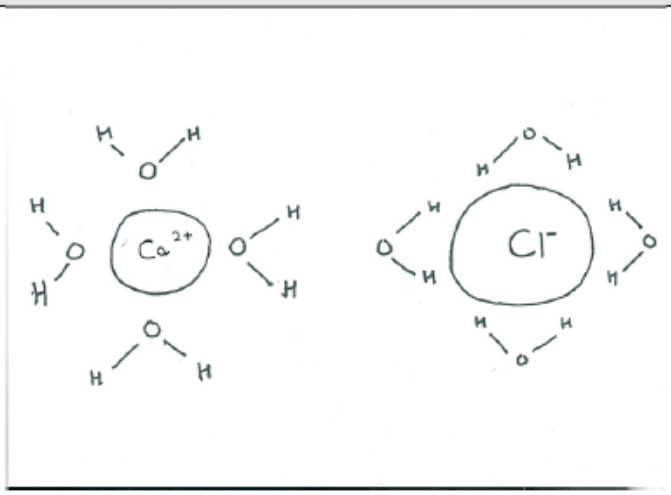
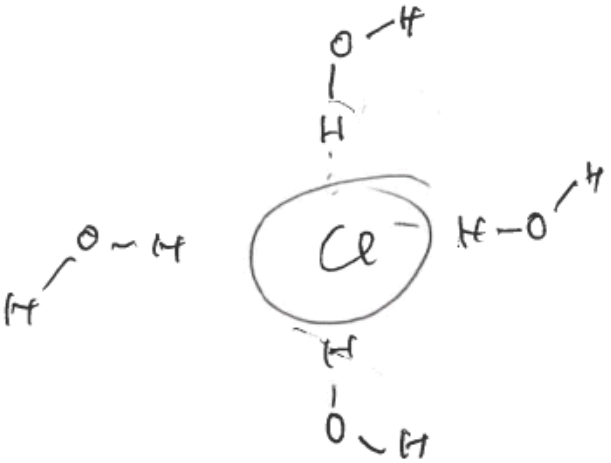
Question Number	Correct Answer	Reject	Mark
(b)	$\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{surroundings} + \Delta S^{\ominus}_{system}$ OR = +2670 + (-101.8) = (+)2568.2 Value 2568.2/2568 **(1)** = (+)2570 (J mol^{-1} K^{-1}) 3SF This mark is conditional on correct value or correct TE value from (a)(i) **(1)** Accept TE from (a)(i) -238.6 → +2431.4 → +2430 -19.3 → 2650.7 → +2650 Correct answer (2570, etc) with or without working scores (2)		2

Question Number	Correct Answer1	Reject	Mark
(c)	$\Delta S^{\ominus}_{surroundings} = -\frac{\Delta H^{\ominus}}{298}$ $\Delta H^{\ominus} = -\Delta S^{\ominus}_{surroundings} \times 298$ OR $= -2670 \times 298$ **(1)** $= -795.660$ $= -795.7$ (kJ mol^{-1}) **(1)** ALLOW $= -795.7 \times 10^3$ **J mol^{-1}** Note 1. -796 = -796.1964 (if 2570 used to calculate entropy change of surroundings first.) 2. $\Delta H^{\ominus}$ (= + $\Delta S^{\ominus}_{surroundings}$ x 298) = +795.7 (kJ mol^{-1}) **(1)** But $\Delta H^{\ominus} = -\frac{\Delta S^{\ominus}_{surroundings}}{298}$ **(0)** Ignore SF except one		2

Question Number	Correct Answer	Reject	Mark
(d)(i)	50 x 4.2 x 15.0 = 3150 (J) Ignore sign ALLOW 3.15 **kJ** Ignore SF except one		1

Question Number	Correct Answer	Reject	Mark
(d)(ii)	3150/0.05 or 20 x 3150 = -63 (kJ mol^{-1}) /-63000 **J mol^{-1}** Allow TE answer (d)(i) / 0.05 Ignore SF except one Value **(1)** Sign **(1)** The mark for the negative sign is awarded for the calculation even if the value is wrong, providing any **energy divided by moles or energy multiplied by 1/number of moles** calculation has been done.		2

Question Number	Correct Answer	Reject	Mark
***(d)(iii)**	The correct answer: -380.5/-381 kJ mol^{-1} Full marks with or without correct working. **First mark** Appreciation of Hess's Law either in words, numbers, symbols or on the diagram For example, $\Delta H_{solution}$ + Lattice energy $= \Delta H_{hydration}\ Ca^{2+} + (2)\Delta H_{hydration}\ Cl^{-}$ **(1)** **Second mark** $2\ \Delta H_{hydration}\ Cl^{-} = -2258 - 63 -$ $(-1560) = -761$ ALLOW Any number or group of numbers minus (-1560) **(1)** **Third mark** $\Delta H_{hydration}\ Cl^{-} = -380.5/-381$ (kJ mol^{-1}) Any number, wherever it has come from, divided by two can score this mark, provided that the sign is consistent. **(1)**		3
	Ignore SF except one Use of lattice energy – 2223 gives −363 scores **(2)** ALLOW TE from (d)(ii)		

Question Number	Correct Answer	Reject	Mark
(d)(iv)	 OR 	**$Cl^-.H_2O$**	2
	• One/several water molecule(s) all correctly orientated. • $H^{\delta+}$/ hydrogen (one or two hydrogens from each water molecule) towards chloride ion and O□□□/ oxygen (one oxygen from each water molecule) towards calcium ion • With negative charge either on chlorine or on the whole hydrated ion and with double positive charge either on calcium or on the whole hydrated ion. ALLOW • A minus sign with a ring around it for the Cl^- and a 2+ sign with a ring around it for the Ca^{2+} • Bonds shown by lines/broken lines/dotted lines/wedges	$H^{\delta-}$ / H^+ / H^- $Cl^{\delta-}$ / Cl (with no charge)	

Question Number	Correct Answer	Reject	Mark
(d)(v)	Both marks may be awarded in either part. **First mark** (Temperature increases) because the reaction/process/dissolving/hydration of ions is **exothermic**. OR Strong(er) forces between the δ+ H and Cl^- OR Strong(er) forces between the δ− O and Mg^{2+} OR Strong(er) ion-dipole forces OR Formation of bonds releases energy OR Strong(er) bonds formed OR Enthalpy of hydration is greater than lattice energy **(1)**	The breaking of the lattice is exothermic.	2
	Second mark (Volume decreases so) shorter bonds between ion and water molecules ALLOW Water molecules more tightly arranged/pack better/occupy less space OR Water molecules more ordered/ clustered (around the ions). **(1)**	Ions more tightly arranged Ions more ordered	

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• +5		**1**

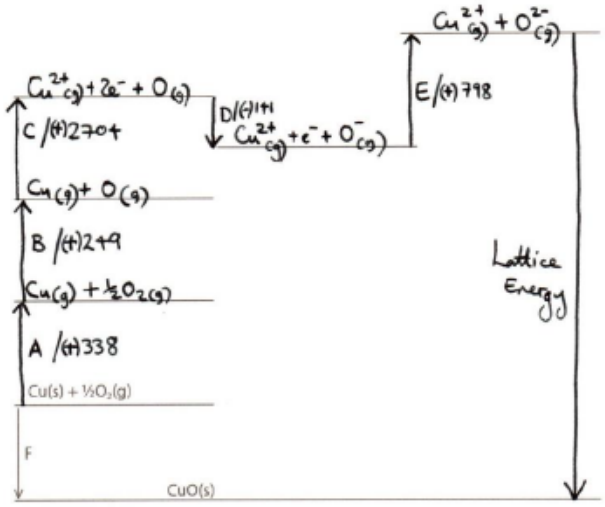
Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (i)	• choice of suitable reducing agent	From Data Booklet of the standard electrode potentials, the right hand substance in numbers 16-24	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (ii)	An answer that makes reference to the following point: • may be kinetically hindered **or** activation energy may be too high	Allow reaction may be too slow	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (iii)	An explanation that makes reference to the following points: • (yellow to) green then blue (1) • when the blue colour initially forms, it mixes with the yellow unreacted VO_2^+ (to turn green) (1)	Ignore colours caused by contamination with reducing agent chosen	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b) (iv)	An explanation that makes reference to the following point: • justification of choice (1) • correct equation for reaction (1)	$E^\ominus$ value is between +0.34 V and −0.26 V Allow by comparison of electrode potentials / calculation of E_{cell} / use of anti-clockwise rule $S_2O_3^{2-} + VO^{2+} + 2H^+ \rightarrow V^{3+} + H_2O + \frac{1}{2}S_4O_6^{2-}$ or multiples	**2**

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that includes • species on lines (1) • state symbols (1) • energy changes / values (1) • arrows indicating direction (1)	Example of Born-Haber cycle and calculation Allow omission of electrons but if included then must be correct A and B can be drawn in either order or A then C followed by B Exemplar cycle:  Each different species error can be penalised so four different species errors scores (0)	(4)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of lattice energy	LE= −4105 (kJ mol^{-1})	(1)

Q13.

Question Number	Correct Answer	Reject	Mark
	D		**1**

Q14.

Question Number	Answer	Additional Guidance	Mark
	• equation (1) • state symbols (1)	Example of equation $Cl(g) + e^- \rightarrow Cl^-(g)$ Allow just e for electron Stand alone mark for species on both sides of equation Ignore state symbol for electron	(2)

Q15.

Question number	Answer	Additional guidance	Marks
(a)	D		1
(b)	B		1
(c)	D		1

Q16.

Question Number	Correct Answer	Reject	Mark
(a)	D		1

Question Number	Correct Answer	Reject	Mark
(b)	A		1

Q17.

Question Number	Answer	Additional guidance	Mark
(i)	An explanation that makes reference to the following points • C=C bond is weaker than 2 x C-C bond (1) • as it consists of a pi and a sigma bond (rather than 2 sigma bonds) (1)	Ignore pi bond formed by sideways / less effective orbital overlap	(2)

Question number	Answer	Additional guidance	Mark
(ii)	• calculation of energy required to break reactant bonds **(1)** • calculation of energy release when product bonds form **(1)** • calculation of enthalpy change **(1)**	Example of calculation: 5(C-H) + (C=C)+(C- C)+(C-O)+(O-H)+4(O=O) 5(413) + (612) + (347) + (358) + (464) + (4x498) = 5838 (kJ mol^{-1}) 6(C=O) + 6(O-H) (6x805) + (6x464) = 7614 (kJ mol^{-1}) 5838 – 7614 = –1776 (kJ mol^{-1}) Ignore SF except 1 SF Allow TE from M1 and M2 Correct answer no working scores 3	**(3)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to one of the following points EITHER • ΔS_{total} is always positive (1) **(1)** • As both $\Delta S_{surroundings}$ and ΔS_{system} are positive **(1)** • OR • ΔG is always negative **(1)** • as ΔH is negative and $\Delta S_{(system)}$ is positive **(1)**	If no marking points awarded allow 1 mark for idea that ΔS_{system} / $\Delta S_{surroundings}$ / entropy increases with correct explanation	**(2)**

Q18.

Question Number	Correct Answer	Mark
	B	**1**

Q19.

Question number	Answer	Additional guidance	Marks
(b)	• rearrangement of equation (1) • Calculation of $\Delta H_{solution}$ (1)	Example of calculation $-2493 + \Delta H_{solution} = -1920 + (-2 \times 364)$ $\Delta H_{solution} = -155$ (kJ mol^{-1}) Correct sign must be given in final answer Correct answer and sign with no working scores 2 marks	**2**
(c)(i)	An explanation that makes reference to the following points: • breaking the lattice is endothermic and the hydration of ions is exothermic (1) • (therefore the dissolving of magnesium sulphate is exothermic) because the enthalpy of hydration (of the ions) is greater in magnitude than the lattice energy (of $MgSO_4$) (1)		**2**
(c)(ii)	• $\Delta G^{\ominus} = -87 - (298 \times -0.210)$ $= -24(.42)$ (kJ mol^{-1}) (1) • since ΔG is negative the process/reaction is spontaneous/feasible (1)		**2**

***(d)**	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5–4 / 3 3–2 / 2 1 / 1 0 / 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	**6**

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*** cont.**

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Indicative content

($\Delta G^{\ominus}_{solution} = \Delta H^{\ominus}_{solution} - T\Delta S^{\ominus}_{system}$)

- for $BaSO_4$: $\Delta H^{\ominus}_{solution}$ and $-T\Delta S^{\ominus}_{system}$ are both positive (1)
- for $CaSO_4$: $\Delta H^{\ominus}_{solution}$ is negative and $-T\Delta S^{\ominus}_{system}$ is positive (1)
- but the magnitude of $-T\Delta S^{\ominus}_{system}$ is greater than that of $\Delta H^{\ominus}_{solution}$ (1)
- therefore $\Delta G\ominus solution$ for both salts is positive (1)
- when $\Delta G^{\ominus}_{solution}$ is positive the salt is only slightly soluble (1)
- $BaSO_4$ is less soluble than $CaSO_4$ because $\Delta G^{\ominus}_{solution}$ is more positive (1)

Q20.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • there is an increase of number of moles **(1)** • change of state as gas / liquid / solution are produced from solids **(1)**	Allow particles for moles 3 to 13 moles Do not award 11 to 13 moles Do not award reference to 'more types' of products than reactants Ignore references to ΔH	**(2)**

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Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • the reaction is endothermic (1) • (and so) freezes the water (which attaches the wooden block to the flask) (1)	Allow description of endothermic	(2)

Q21.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q22.

Question Number	Acceptable Answers	Reject	Mark
(a)	Units are not required in (a) or (c) but if used should be correct. Penalise incorrect units in (a), (b) & (c) once only IGNORE case of J and K order of units **First mark:** 65.3/ 130.6 **and** 69.9 (J mol^{-1} K^{-1}) **(1)** **Second mark:** ΔS = 69.9 − (130.6 +102.5) **(1)** **Third mark:** ΔS = −163.2 = −163 (J mol^{-1} K^{-1}) **(1)** Correct answer with no working scores 3 Ignore SF except 1 SF TE at each stage If 65.3 used instead of 130.6 penalize once (answer is then ΔS = −97.9 (J mol^{-1} K^{-1})	+163 or any positive answer	**3**

Question Number	Acceptable Answers	Reject	Mark
(b)	$\Delta S_{surroundings}$ = − ΔH / T or just numbers **(1)** = +285800/298 = +959.06 = +959 J mol^{-1} K^{-1} / +0.959 kJ mol^{-1} K^{-1} Correct value to 3SF **(1)** Correct units and positive sign **(1)** Correct answer with no working scores 3	answer with no sign	**3**

Question Number	Acceptable Answers	Reject	Mark
(c)	$\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$ **(1)** Allow $\Delta S_{reaction}$ for ΔS_{system} ΔS_{total} = answer (a) + answer (b) = −163.2 + 959 = (+)795.8 = (+)796 (J mol^{-1} K^{-1}) If $\Delta S_{surroundings}$=+959.06 then ΔS_{total} = +795.9 **(1)** Correct answer with no working scores 2 Ignore SF except 1 SF TE on values in (a) & (b) no TE on incorrect equation If answer to (a) = -97.9 (J mol^{-1} K^{-1}) ΔS_{total} = (+)861.1 (J mol^{-1} K^{-1})		**2**

Question Number	Acceptable Answers	Reject	Mark
(d)	A mixture of hydrogen and oxygen is **thermodynamically** unstable **because** ΔS_{total} is positive OR Reaction between hydrogen and oxygen is **thermodynamically** feasible **because** ΔS_{total} is positive ALLOW ΔS for ΔS_{total} **(1)** No TE on negative ΔS_{total} from (c) The mixture is kinetically inert /stable or reaction is (very) slow **because** the activation energy is (very) high **(1)** Mixture / reaction is **kinetically** inert / stable but **thermodynamically** unstable / feasible scores 1 mark IGNORE References to spark / flame providing the (activation) energy for reaction	Reference to the stability of individual elements	**2**

Q23.

Question Number	Acceptable Answers	Reject	Mark
***(a)**	(A green solution) forms a yellow / orange / brown (solution) ALLOW reddish-brown **(1)** A grey / black precipitate ALLOW silver ppt ALLOW solid / crystals for precipitate **(1)**	Red 'Green(ish)' with any other colour Silver mirror silver compound	**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(i)	0.05(00) (mol dm^{-3})		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(ii)	Amount of silver ion in 10 cm^3 = amount of thiocyanate = $\frac{5.6 \times 0.0200}{1000} = 0.000112/1.12 \times 10^{-4}$ (mol) **(1)** So concentration of silver ion = $0.000112 \times \frac{1000}{10} = 0.0112/1.12 \times 10^{-2}$ (mol dm^{-3}) **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)(iii)	$0.0112/1.12 \times 10^{-2}$ (mol dm^{-3}) Accept TE = answer to (ii)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(iv)	$0.0500 - 0.0112 = 0.0388/3.88 \times 10^{-2}$ (mol dm^{-3}) Accept TE = 0.05 - answer to (iii) Accept answer to (i) – answer to (iii)		**1**

Question Number	Acceptable Answers	Reject	Mark
(b)(v)	$K_c = \frac{[Fe^{3+}(aq)]}{[Fe^{2+}(aq)]\,[Ag^{+}(aq)]}$ ALLOW $K_c = \frac{[Fe^{3+}]}{[Fe^{2+}]\,[Ag^{+}]}$ **(1)** $= \frac{0.0388}{0.0112^2}$ $= 309.311 = 309\ dm^3\ mol^{-1}$ Value **(1)** Unit (any order) **(1)** Three SF **(1)** Accept TE from (iii) and (iv): (use of 0.1 from (i) gives 708 $dm^3\ mol^{-1}$) If [Ag] is included in the numerator and taken as $=[Fe^{3+}(aq)]$, then allow unit and SF marks ONLY, but must either state 'no units' or show working	[Ag] in numerator	**4**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	$\Delta S^{\ominus}_{total} = 8.31 \times \ln 309$ $= +47.6(4) / +47.6(5) J\ mol^{-1}\ K^{-1}$ OR $= 8.31 \times \ln 309.311 = +47.6(5)\ J\ mol^{-1}\ K^{-1}$ Accept TE : 8.31 x ln(answer from b(v)) Value **(1)** Sign **and** Unit (any order) **(1)** IGNORE sf except 1		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	First Mark: One of the products is a solid OR Two moles going to two moles but one of them is a solid OR Two moles of solution react to form one mole of solution / liquid and one mole of solid **(1)** **Second Mark** (Hence) RHS more ordered / LHS less ordered **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(iii)	$\Delta S^{\ominus}_{surroundings} = \Delta S^{\ominus}_{total} - \Delta S^{\ominus}_{system}$ $= +47.6 - (-208.3) = (+)255.9$ (J mol^{-1} K^{-1}) Accept TE on c(i) IGNORE sf except 1		**1**

Question Number	Acceptable Answers	Reject	Mark
(c)(iv)	Because $\Delta S^{\ominus}_{surroundings} = \frac{-\Delta H^{\ominus}}{T}$ **(1)** $\Delta H = -298 \times 255.9 = -76258$ (J mol^{-1}) $= -76.258$ (kJ mol^{-1}) **(1)** Units if given must be correct Correct answer with or without working scores 2 marks IGNORE SF except 1 As T increases $\Delta S^{\ominus}_{surroundings}$ becomes less positive / decreases **therefore** ΔS_{total} becomes less positive / decreases ALLOW more negative for less positive **(1)**	$\Delta S^{\ominus}_{total} = \frac{-\Delta H^{\ominus}}{T}$	**3**

Question Number	Acceptable Answers	Reject	Mark
***(d)**	No change in the titre ALLOW No significant change Stand alone mark **(1)** (though silver solid was removed the equilibrium constant remains the same so) the equilibrium **concentration(s)** would remain the same **(1)** Second mark dependent on first IGNORE references to temperature		**2**

Q24.

Question Number	Correct Answer	Reject	Mark
	B		**1**

Q25.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	$(K_C =) \frac{[CH_3COOCH_2CH_3]\ [H_2O]}{[CH_3COOH]\ [CH_3CH_2OH]}$ ALLOW C_2H_5 for CH_3CH_2 State symbols are not required IGNORE any incorrect state symbols		**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)			**2**

Component	$CH_3COOH(l)$	$CH_3CH_2OH(l)$	$CH_3COOCH_2CH_3(l)$	$H_2O(l)$
Equilibrium amount / mol	(0.20)	**0.10**	**0.20**	**0.35**

BOTH 0.10 AND 0.20 (1) **0.35 (1)**

0.10 **and** 0.20 scores first mark
Allow 0.1 and 0.2
0.35 scores second mark

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	Units cancel **OR** same number of **moles**/same number of **molecules** on each side **OR** volume / V cancels Ignore statements such as 'concentrations cancel' 'products and reactants cancel' 'same number of products as reactants'	Concentrations are the same	**1**

Question Number	Acceptable Answers	Reject	Mark
(a)(iv)	$K_C = \frac{(0.20) / V \times (0.35) / V}{(0.20) / V \times (0.10) / V}$ $= 3.5 / 3.50$ Correct answer with or without working scores 1 Ignore omission of V TE from values in (ii) table	$K_C = 4$	**1**

Question Number	Acceptable Answers	Reject	Mark
(b)	• No effect on (position of) equilibrium **(1)** • Rate (of attainment of equilibrium) is faster / equilibrium reached sooner **(1)**		**2**

Question Number	Acceptable Answers	Reject	Mark
(c)(i)	**Bonds Broken** C—O **and** O—H **(1)** Ignore where these bonds are broken in the acid and alcohol molecules. **ALLOW** C—OH for C—O CO—H for O—H **Bonds Made** C—O **and** O—H **(1)** Ignore where these bonds are made in the ester and water molecules. **ALLOW** C—OC for C—O H—OH for O—H Marks can be awarded by annotating displayed or structural formulae. Comment: Max **1** if any other bonds mentioned	**Two** O—H bonds formed in H_2O molecule **ONLY** C—O bond broken and made scores **(0)** overall	**2**

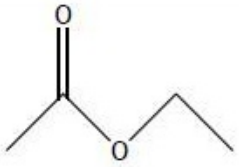
Question Number	Acceptable Answers	Reject	Mark
(c)(ii)	(C–O and O–H) bond enthalpies differ in: different environments /different molecules /different compounds OR Bond enthalpies/bond energies are average values **ALLOW** Bonds being broken and made are attached to different atoms	'Heat loss'	**1**

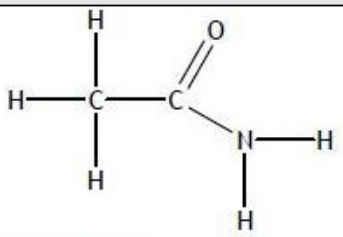
Question Number	Acceptable Answers	Reject	Mark
(d)(i)	$\Delta S_{total} = R \ln K$ Allow ΔS_{total} is proportional to **<u>ln</u>***K* ALLOW K_c or K_p instead of K	log instead of ln ΔS_{total} is proportional to K / ΔS_{total} increases as K increases	**1**

Question Number	Acceptable Answers	Reject	Mark
* **(d)(ii)**	**First mark:** (ΔH = 0 so) $\Delta S_{surroundings} = 0$ OR $-\frac{\Delta H}{T} = 0$ **(1)** IGNORE "$\Delta S_{surroundings}$ stays the same". **Second mark:** (so) ΔS_{total} does not change OR (so) $\Delta S_{total} = \Delta S_{system}$ **(1)** **Third mark:** (As $\Delta S_{total} = R \ln K$) ***K*** does not alter **(1)** **ALLOW** "it does not alter" to assume K does not alter. ALLOW use of K_c or K_p instead of K **Each point is stand alone** **IGNORE** justifications in terms of Le Chatelier's Principle **NOTE:** **Can award max (1) (i.e. the third scoring point) if the effect on *K* stated follows on CQ from a change to ΔS_{total}**	If only mentions 'no effect on position of equilibrium' rather than the equilibrium constant	**3**

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Question Number	Acceptable Answers	Reject	Mark
(e)(i)	$CH_3COCl + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + HCl$ Allow C_2H_5 for CH_3CH_2 Allow $CH_3CO_2CH_2CH_3$ for $CH_3COOCH_2CH_3$ IGNORE missing or incorrect state symbols	CH_3CClO/ CH_2CH_3OH	**1**

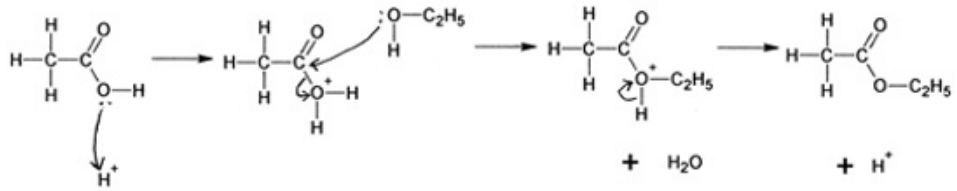
Question Number	Acceptable Answers	Reject	Mark
(e)(ii)	 **IGNORE** Bond angles and length of the lines.		**1**

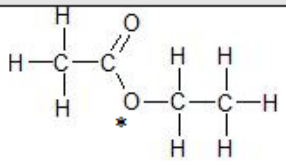
Question Number	Acceptable Answers	Reject	Mark
(e)(iii)	 **IGNORE** Other products of the reaction if the above structure has been correctly drawn.	NH_2 or CH_3	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(i)	$(CH_3COOCH_2CH_3 + NaOH \rightarrow)$ $CH_3COONa + CH_3CH_2OH$ /C_2H_5OH Allow ionic representations of the sodium salt $CH_3COO^-Na^+$ IGNORE missing or incorrect state symbols	CH_2CH_3OH for ethanol	**1**

Question Number	Acceptable Answers	Reject	Mark
(f)(ii)	(Reaction with sodium hydroxide is) **not** an equilibrium / **not** reversible / goes to completion OR Reverse argument for acid hydrolysis		**1**

Q26.

	Answer	Additional Guidance	Mark
(i)	• oxygen lone pair and curly arrow to the H^+ **(1)** • curly arrow from oxygen lone pair on the ethanol to the carbon of the C = O **(1)** • curly arrow from C-O bond to oxygen of water molecule **(1)** • curly arrow from O–H bond back to the O^+ oxygen **(1)** Example of reaction mechanism  Penalise additional curly arrows for each marking point Penalise missing lone pair on oxygen once only in M1 and M2		**(4)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct oxygen identified **(1)** • the single bond C–O in the carboxylic acid breaks rather than the one in ethanol **or** the oxygen in ethanol acts as the nucleophile (to attack the carbon of the carboxylic acid group and so ends up in the ester) **(1)**	 Allow 'loss of OH from the carboxylic acid'	**(2)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• (M1) calculation of ΔG **(1)** • (M2) correct equation **(1)** • (M3) rearrangement of equation **(1)** • (M4) calculation of ΔS_{system} **(1)** • (M5) rearrangement of equation so $S_{(ethyl\ ethanoate)}$ = **(1)** • (M6) calculation of $S_{(ethyl\ ethanoate)}$ with sign and units **(1)**	Example of calculation $\Delta G = -RT \ln K = -8.31 \times 298 \times \ln 4.0 = -3433$ (J mol^{-1}) $\Delta G = \Delta H - T\Delta S_{system}$ $\Delta S_{system} = (\Delta H - \Delta G) \div T$ $\Delta S_{system} = (-6.0 \times 10^3 - (-3433)) \div 298 = -8.614....$ (J mol^{-1} K^{-1}) ($\Delta S_{system} = \sum S_{(products)} - \sum S_{(reactants)}$) $S_{(ethyl\ ethanoate)} = \Delta S + \sum S_{(reactants)} - S(water)$ $S_{(ethyl\ ethanoate)} = (-8.614 + (159.8+160.7) - 69.9) = +242/240$ J mol^{-1} K^{-1} Ignore SF except 1SF Correct final answer without working scores (6) TE throughout	**(6)**

Q27.

Question Number	Answer	Mark
	The only correct answer is D ***A*** *is not correct because* $\Delta S_{surroundings}$ *is incorrect* ***B*** *is not correct because* $\Delta S_{surroundings}$ *is incorrect* ***C*** *is not correct because sign of* $\Delta H/T$ *is incorrect*	**(1)**

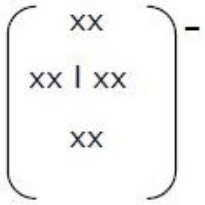
Q28.

Question Number	Answer	Additional guidance	Mark
(a)	• substitution into $\Delta S^{\ominus}$ equation (1) • evaluation of $\Delta S^{\ominus}$ (1) • substitution into $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$, using $\Delta S^{\ominus}$ in $kJK^{-1}mol^{-1}$ (1) • correct answer to 3.s.f (1) • since $\Delta G^{\ominus}$ is negative, the reaction is feasible (1)	Example of calculation $\Delta S^{\ominus} = (2 \times 193) - 192 - (3 \times 131)$ $= -199\,JK^{-1}mol^{-1}$ / $-0.199\,kJK^{-1}mol^{-1}$ $\Delta G^{\ominus} = -92.0 - (298 \times -0.199)$ $= -32.7\,kJmol^{-1}$ / $-32\,700\,Jmol^{-1}$ The first four marking points can be awarded for a correct answer to 3 s.f. with no working	5
(b)	An explanation that makes reference to the following points: • (as temperature increases) $T\Delta S$ becomes more negative (1) • (eventually) $\Delta H - T\Delta S$ becomes positive (1)		2

Q29.

Question Number	Answer	Additional Guidance	Mark
		Penalise incorrect units in M1 or M3 once only Working is not required for the calculations	**(3)**
	• calculation of ΔG **(1)**	Example of calculation $\Delta G = 178 - (298 \times \frac{165}{1000})$ $= (+)128.83 / 129$ (kJ mol^{-1}) **or** $\Delta G = 178000 - (298 \times 165)$ $= (+)128830 / 129000$ (J mol^{-1})	
	• ΔG is positive / >0 so reaction is not feasible **(1)**	Stand alone mark Allow ΔG must be negative for a reaction to be feasible Ignore 'so reaction is not feasible' without a reason No TE on a calculated negative value	
	• calculation of T **(1)**	Example of calculation $\Delta G = 0$, so $\Delta H = T\Delta S_{(sys)}$ or $T = \Delta H/\Delta S_{(sys)}$ **or** $\Delta S_{total} = \Delta S_{sys} - \Delta H/T = 0$, so $T = \Delta H/\Delta S_{(sys)}$ $T = 178/0.165 = 1078.8 / 1079 / 1080$ (K) **or** $T = 178000/165 = 1078.8 / 1079 / 1080$ (K) **or** $T = 806$ (°C) Ignore SF except 1 SF	

Q30.

Question Number	Acceptable Answers	Reject	Mark
(a)	$[:Li]^+$ (1)  (1) Accept all or mixture of dots and crosses **Check inner electrons present on lithium** If no element symbols but fully correct with Li first give **1 max** If no / incorrect charge(s) if the electrons are correct **1 max** If arrow drawn from third / outer shell electron on lithium to join electrons in iodine / iodide with correct charges scores **1 max** Brackets are not essential		**2**

Question Number	Acceptable Answers	Reject	Mark
(b)	Li(s) **and** $Li^+(g)$ **and** $I^-(g)$ **(1)** $\frac{1}{2}I_2(s)$ **and** I(g) **(1)** (ΔH_{at}) **[**$\frac{1}{2}I_2(s)$**]** **(1)** Notice the square brackets are essential for this mark If wrong state for iodine element ie if $\frac{1}{2}I_2(g/l)$ and consistent (ΔH_{at})[$\frac{1}{2}I_2(g/l)$] allow third mark If I(s) given for element and (ΔH_{at}) [I(s)] allow third mark If wrong state with monatomic iodine both the last two marks lost If $Li^+(g)$ + e appears ignore electron		**3**

Question Number	Acceptable Answers	Reject	Mark
(c)	**First mark for one of:** −270 = + 159 + 107 + 520 + electron affinity − 759 Or Electron affinity = −270 − (159 + 520 + 107 − 759) **(1)** OR Electron affinity = −270 - 159 - 520 - 107 + 759 **(1)** **Second mark for:** (Electron affinity =) −297 (kJ mol^{-1}) **(1)** −297 (kJ mol^{-1}) alone scores **(2)** NB providing method is recognisable with one transcription error eg 795 for 759 and the final answer is consistent **1 max** NB (+) 297 (kJ mol^{-1}) **1 max**	Wrong unit e.g. J	**2**

Question Number	Acceptable Answers	Reject	Mark
(d)	(Experimental lattice energy is) more negative / exothermic **(1)** OR Theoretical lattice energy is less negative / exothermic **(1)** OR Recognition that more energy **released** **(1)** Irrespective of first answer then, any two from: Due to a degree of covalency **(1)** Deviation from pure ionic model (in experimental value) OR The theoretical model is pure ionic bonding **(1)** **Polarization / distortion** of the iod**ide** / negative ions (by the lithium ion). Can be shown by diagram **(1)** Iodine/ I / I_2 ion is not acceptable but iodine / I **anion** is allowed Note I_2 anion is not allowed	Greater / less Increase / decrease alone	**3**

Question Number	Acceptable Answers	Reject	Mark
(e)	Electron affinities become less negative / less exothermic / more positive (going down Group 7) **(1)** As (added) **electron** further from the nucleus OR **More** shielding / shielded (from the nucleus) **(1)** Second mark stands alone Ignore larger (ionic) radius / atom / ion / charge density	Greater / less / Increase / decrease alone Any indication of ionization/ removing an electron	**2**

Q31.

Question Number	Correct Answer	Mark
	D	**1**

Q32.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Indicator: starch **(1)** • Colour change: Starting colour: blue/black or blue or black Final colour: colourless **(1)**	M2 is conditional on starch or no indicator Ignore mention of precipitate Ignore other words to describe colour e.g. deep / dark Ignore clear	**(2)**

Q33.

Question number	Answer	Additional Guidance	Marks
(a)	**B** $\left(\frac{p_{SO_3}}{p_{SO_2} . p_{O_2}^{\frac{1}{2}}} \right)$		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(b)	An answer that makes reference to the following point: • the amount of SO_3 is much greater than the amounts of SO_2 and O_2 **or** • as K_p greater than 1 x 10^{10} the equilibrium lies completely to the right / reaction goes to completion		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
(c)	An explanation that makes reference to the following points: • the yield of sulfur trioxide decreases because the forward reaction is exothermic (1) • because as the temperature increases K_p decreases (1)		**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(d)	• calculating $\Delta_r G^\ominus$ (1) • since $\Delta_r G^\ominus$ is negative this confirms the reaction is thermodynamically feasible (1)	$\Delta_r G^\ominus$ = − 8.31 x 298 x ln 2.00 x 10^{12} = − 70 100 J mol^{-1} accept any number of significant figures e.g. 70 141	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(e)	• the rate of the reaction is increased (even though the yield is less)		**1**

Q34.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that includes • barium iodide has (almost) 100% ionic (bonds)	 Allow small amount of/zero covalency Ignore just it is 'ionic'	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that includes • the magnesium ion is small and highly charged (1) • the iodide ion has a large ionic radius (1) • the iodide ion is **polarised** by the magnesium ion (1) • (so) the bonding in magnesium iodide has (partial) covalent character (which is why the lattice energy values are different) (1)	 Allow magnesium ion has a high charge density Allow iodide ion has a much larger radius Ignore reference to atomic radius ALLOW description of polarisation such as distortion of the iodide electron cloud by the magnesium ion Do not award magnesium iodide is covalent Do not award 'MgI' Penalise once only reference to magnesium/iodine/iodide without 'ion' in marking points 1 to 3	(4)

Q35.

Question Number	Answer	Mark
	The only correct answer is B (-804, -711, -2718) ***A*** *is not correct because the lattice energy of magnesium hydride is not exothermic enough* ***C*** *is not correct because the lattice energy of potassium hydride should be less exothermic than sodium hydride and also that the lattice energy of magnesium hydride is not exothermic enough* ***D*** *is not correct because the lattice energy of potassium hydride should be less exothermic than sodium hydride*	**(1)**

Q36.

Question Number	Correct Answer	Reject	Mark
	C		**1**

Q37.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following point: • the concentration of a solid / $Mg(OH)_2$ is constant / unchanged / changes very little	Allow magnesium hydroxide is in a different phase / state (from the aqueous ions) Ignore solids do not appear in K_c expressions / just 'it is solid' Ignore solid does not affect the concentration of the solution Ignore it is a heterogeneous equilibrium Ignore it is difficult to measure the concentration of a solid Do not award the solid does not have a concentration	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
6(b)(ii)	• $mol^3\ dm^{-9}$	Allow $dm^{-9}\ mol^3$ mol^3/dm^9 Ignore any working before the answer	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• use of $\Delta_{sol}H = \Delta_{hyd}H[Mg^{2+}(aq)] + 2\Delta_{hyd}H[OH^-(aq)] - \Delta_{latt}H[Mg(OH)_2(s)]$ **(1)** • calculation of $\Delta_{sol}H$ **(1)**	Example of calculation $\Delta_{sol}H = -1920 + 2(-460) - (-2842)$ Allow this shown on a Hess cycle $\Delta_{sol}H = (+)2$ (kJ mol^{-1}) Allow 2000 J mol^{-1} Correct answer with no working scores 2	**(2)**

Question Number	Answer	Mark
(iv)	**The only correct answer is D** ***A*** *is not correct because it should not be linear and should level off* ***B*** *is not correct because it should not increase in that way and should level off* ***C*** *is not correct because it should not be horizontal*	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(v)	An answer that makes reference to the following points: Addition of magnesium sulfate solution: • equilibrium position shifts to the left / in the backwards direction **(1)** • because increased concentration / amount of magnesium ions / $Mg^{2+}((aq))$ **(1)** Addition of dilute hydrochloric acid: • equilibrium shifts to the right / in the forwards direction **(1)** • because the hydrogen ions / $H^+((aq))$ react with / neutralise / removes the hydroxide ions / $OH^-((aq))$ **(1)**	Mark independently Allow more magnesium hydroxide precipitates / forms Allow more Mg^{2+} ions present Allow more magnesium hydroxide dissolves / dissociates Allow $H^+((aq)) + OH^-((aq)) \rightarrow H_2O((l))$ Allow magnesium hydroxide reacts with / is neutralised by acid / equation to show this Allow acid / HCl reacts with / neutralises / removes hydroxide ions Penalise reference to K_c changing once only	**(4)**

Q38.

Question number	Acceptable Answer	Additional Guidance	Marks
(a)	• use of 1:8 ratio in kg, grams or moles (1) • calculating mass of lithium (1) • answer to two or three sf (1)	Example of calculation: 146.1 kg of SF_6 react with (8 x 6.90) 55.2 kg of Li ∴ 398 kg of SF_6 react with $\frac{55.2}{146.1} \times 398$ kg = 150(.3737.....) kg of Li 150 (kg) Final answer must be to two/three significant figures Correct final answer to two/three significant figures with no working scores (3)	**3**

Question number	Acceptable Answer	Additional Guidance	Marks
(b)	• calculating $\Delta S^{\ominus}_{system}$ (1) • calculating $\Delta S^{\ominus}_{surroundings}$ (1) • conversion of units to be the same (1) • calculating $\Delta S^{\ominus}_{total}$ with units (1)	Example of calculation: $\Delta S^{\ominus}_{system}$ = 63.0 + (6 x 35.6) – 292 – (8 x 29.1) = –248.2 (J K^{-1} mol^{-1}) $\Delta S^{\ominus}_{surroundings} = -\frac{-2\,934\,000}{298}$ = +9845.638 (J K^{-1} mol^{-1}) Accept 9850 (J K^{-1} mol^{-1}) Accept 9.846 kJ K^{-1} mol^{-1} $\Delta S^{\ominus}_{total}$ = +9597 J K^{-1} mol^{-1} Accept any number of significant figures up to and including the calculator value of 9597.437584 Correct answer with units and no working scores 4	**4**

Question number	Acceptable Answer	Additional Guidance	Marks
(c)	An answer that makes reference to the following points: • $\Delta S^{\ominus}_{total}$ is positive, so the reaction is (thermodynamically) feasible (1) • therefore (if it needs a fuse), it must have a high activation energy (1)		**2**

Q39.

Question Number	Answer	Mark
	The only correct answer is A ***B*** *is not correct because all increase in entropy as disorder increases when gases are formed* ***C*** *is not correct because all increase in entropy as disorder increases when gases are formed* ***D*** *is not correct because all increase in entropy as disorder increases when gases are formed*	**(1)**

Q40.

Question number	Answer	Additional guidance	Marks
	• order: GZ > DX > EY (1) Justification: • the ions in GZ have higher charges (than those in both EY and DX) (1) • the ions in DX are smaller than those in EY (1)		**3**

Q41.

Question Number	Correct Answer	Mark
	B	**1**

Q42.

Question Number	Correct Answer	Reject	Mark
(a)	C		**1**
(b)	A		**1**

Q43.

Question Number	Answer	Additional Guidance	Mark
Penalise incorrect or missing units in (b)(i) and (b)(ii) once only			
(i)	• calculation of ΔG **(1)** • ΔG is negative/ <0 and so reaction is feasible **(1)**	Example of calculation $\Delta G = -56 - \left(298 \times \frac{-76.5}{1000}\right)$ $= -33.203$ (kJ mol^{-1}) or $\Delta G = -56000 - (298 \times -76.5)$ $= -33203$ (J mol^{-1}) Ignore SF except 1 Allow ≤0 and so reaction is feasible Standalone mark Allow TE on own ΔG calculated value	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of T	Example of calculation $\Delta G = 0$, so $\Delta H = T\Delta S_{(system)}$ or $T = \Delta H/\Delta S_{(system)}$ T = 56/0.0765 = 732 K **or** T = 56000/76.5 = 732 K **or** T = 459°C Ignore SF except 1 SF Do not award −732K TE on incorrect values penalised already in (b)(i)	**(1)**

Q44.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• correct equation	Examples of equations $Cu + 4HNO_3 \rightarrow Cu^{2+} + 2NO_3 + 2NO_2 + 2H_2O$– **or** $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$ Allow multiples Allow ⇌ provided equation is written in the direction shown Ignore state symbols, even if incorrect Ignore cancelled electrons Ignore Ag or Au on both sides Do not award uncancelled electrons	**(1)**

Q45.

Question Number	Answer	Additional Guidance	Mark
	• expression for ΔS_{system} **(1)** • calculation of ΔS_{system} **(1)** • expression for $\Delta S_{surroundings}$ **(1)** • calculation of $\Delta S_{surroundings}$ **(1)** • calculation of ΔS_{total}, correct units and comment on feasibility **(1)**	Example of calculation $\Delta S_{system} = [(6x205)+(219.5)+(160.7)] - [(4x213.6)+(5x69.9)]$ $= 1610.2 - 1203.9 = (+) 406.3$ ($J\,K^{-1}\,mol^{-1}$) $\Delta S_{surroundings} = -\Delta H/T = -2778 \times 10^3 \div 298$ $= -9322.14765$ ($J\,K^{-1}\,mol^{-1}$) $\Delta S_{total} = 406.3 - 9322.14765$ $= -8915.85\ J\,K^{-1}\,mol^{-1}$, (negative) so not feasible Ignore SF except 1 SF. Allow TE and KJ throughout	**(5)**

Q46.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• all 3 correct **(2)** • any 2 correct **(1)**	Example of table Reaction: $CO_2(s) \rightarrow CO_2(g)$ — Sign of ΔS_{system}: positive / + / +ve / plus Reaction: $NaCl(s) + aq \rightarrow NaCl(aq)$ — Sign of ΔS_{system}: positive / + / +ve / plus Reaction: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ — Sign of ΔS_{system}: negative / – / –ve / minus	**(2)**

Q47.

Question Number	Answer	Mark
	The only correct answer is B (–157) ***A*** *is incorrect because this is the value if the cycle is used in the opposite direction* ***C*** *is incorrect because this is the value if the hydration enthalpy for the chloride ion is not multiplied by 2* ***D*** *is incorrect because this is the value if the cycle is used in the opposite direction and the hydration enthalpy for the chloride ion is not multiplied by 2*	**(1)**

Q48.

Question Number	Correct Answer	Mark
	D	**1**

Q49.

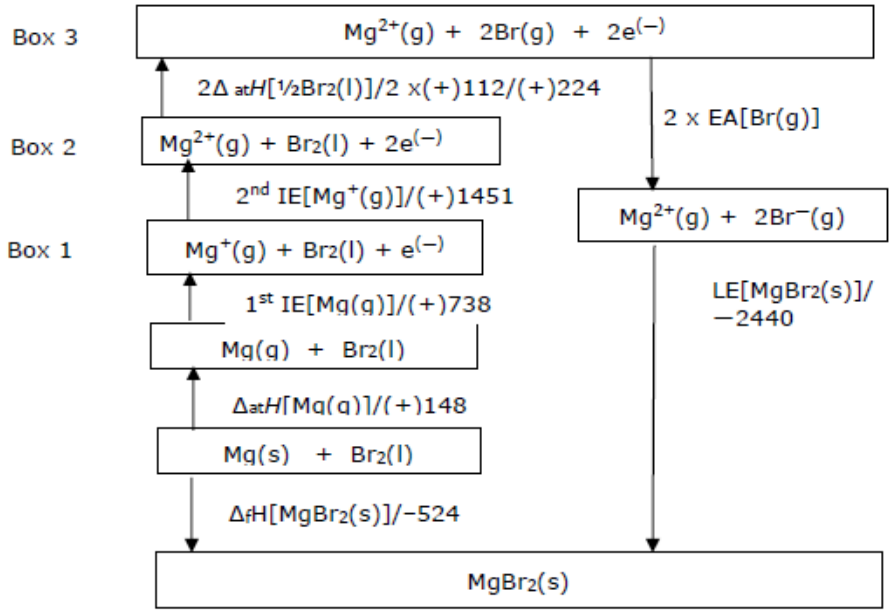
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• correct working **(1)** • correct answer **and** sign **(1)**	Example of calculation (2 x 95.6) – ((2 x 248.1) + 205.0) / (2 x 95.6) – (2 x 248.1) – 205.0 -510(.0) (J K^{-1} mol^{-1}) **or** -0.510 (kJ K^{-1} mol^{-1}) TE on working Ignore SF except 1SF Correct answer with sign and working scores both marks	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• use of $\Delta G = \Delta H - T\Delta S_{system}$ **(1)** • calculation of ΔG **and** sign **and** units **(1)** • ΔG is negative / less than 0 / <0 **and** so the reaction is feasible **(1)**	Example of calculation The equation may be stated or numbers substituted directly e.g.−288.4 – (298 x −0.510) / −288400 – (298 x −510) −136(.42) kJ mol^{-1} / −136420 J mol^{-1} TE on ΔS_{system} in (i) Ignore SF except 1SF Correct answer with sign and units without working scores both marks Conditional on a stated number TE on sign of ΔG: ΔG is positive / greater than 0 / >0 so the reaction is not feasible	**(3)**

Question Number	Acceptable Answer		Additional Guidance	Mark
(iii)	• use of $\Delta G = -RT\ln K$	**(1)**	Example of calculation $-60000 = -$ 8.31×700 $\ln K$	(3)
	• rearrangement of equation **and** substitution of correct values	**(1)**	$(\ln K = -\Delta G/RT)$ $\ln K = \frac{-(-60000)}{(8.31 \times 700)}$ Allow $\ln K = \frac{60000}{8.31 \times 700}$ Allow $\ln K = 10.3146$ / 10.315 / 10.32 / 10.3 / 10	
		(1)	TE on equation, provided equation involves all of ΔG, K, R and T and no others e.g. S	
	• calculation of K		$K = e^{10.315} = 3.016975 \times 10^4$ / 30169.75 TE on $\ln K$ expression / value Allow answers based on earlier correct rounding Ignore SF **including** 1SF Ignore units Correct answer without working scores 3 marks	

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to any **two** of the following points: • **Yield** - even though the (percentage) yield / amount of SO_3 is higher at 298 K / lower temperature **(1)** • **Rate** - the rate of reaction is slower at 298 K / lower temperature **(1)** • **Compromise** - so 700 K is a compromise between a (high) yield and (high) rate **(1)**	Allow reverse argument for M1 and M2 Ignore reference to changing the pressure Allow the unused reactants can be recycled to increase the yield / products are removed to increase the yield Allow the reaction does not reach equilibrium in industry so there is no effect on the yield Ignore just a reference to 'equilibrium shifting' Ignore references to activation energy Allow at 700K the amount of product per unit time is larger Ignore just '700 K is more economically viable' **Note** If three points are made related to yield, rate and compromise and one of these is incorrect, maximum mark is (1) for 1 correct point	**(2)**

Q50.

Question Number	Answer and Additional Guidance	Mark
(i)	 • Correct arrows with 1st **and** 2nd IE of Mg labelled **and** correct Mg symbols with state symbols in boxes 1 and 2 or 2 and 3 **(1)** • 2 x $\Delta_{at}H^{\ominus}[\frac{1}{2}Br_2(l)]$ / 2 x(+)112 / (+)224 **and** 2Br(g) in box 3 or 1 **and** 2 x EA[Br(g)] labelled **and** $2Br^-(g)$ in box 4 **and** correct arrows **(1)** • LE$[MgBr_2(s)]$ / −2440 labelled **and** arrow in correct direction **(1)** Allow any unambiguous labels for the arrows with words and/or numbers – state symbols not required Accept enthalpy change of atomisation of bromine before IEs of magnesium Ignore missing electrons / $2e^{(-)}$ in boxes 1, 2 and 3 Allow 1 state symbol missing but penalise 2 missing, or an incorrect state symbol in boxes once only	(3)

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct expression for 2 x EA(Br) in numbers or symbols **(1)** • calculation of EA(Br) **(1)**	Example of calculation 2 x EA(Br) = − (2 x +112) − (+1451) − (+738) − (+148) + (−524) − (−2440) EA(Br) = $-\frac{645}{2}$ = −322.5 /−323 (kJ mol^{-1}) Correct answer with no working scores (2) Allow for 1 mark: (+)322.5 / (+)323 (wrong sign) −266.5 /−267 (2 missing from $\Delta_{at}H$ (Br)) −645 (2 missing from EA) −533 (both 2s missing for Br) Ignore units No TE on incorrect arrows in (b)(i)	(2)

Q51.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td>
<td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured
with some linkages and lines of reasoning
scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td>(6)</td>
</tr>
<tr>
<td></td>
<td>
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr>
</table>
</td>
<td>General points to note
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). e.g.
penalise any reference to 'molecule' once only
or
penalise 'ion' not mentioned in word or formula at least once in answer, once only

Allow reverse arguments for IP3 to IP6 Ignore mention of stoichiometry Ignore references to electronegativity</td>
<td></td>
</tr>
</table>

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	Indicative content • **IP1 - Ionic** lithium chloride / LiCl (has very similar theoretical and experimental lattice energy values so) is (almost 100%) ionic	Allow **very** small amount of / no covalent character in LiCl Allow assumption that ions act as point charges / are spherical is true for LiCl	
	• **IP2 - Covalency** magnesium iodide / MgI_2 (has different theoretical and experimental lattice energy values so) has (some) covalent character	Allow MgI_2 more covalent character than LiCl	
	• **IP3 - Charge on cations** magnesium is Mg^{2+} and lithium is Li^+	Allow magnesium has 2+ charge and lithium has 1+ charge / magnesium ion has a larger charge than a lithium ion	
	• **IP4 - Polarising** – what does the polarising magnesium ion/Mg^{2+} is (more) polarising / has a large(r) polarising power (than lithium ion)	Allow charge density for charge	
	• **IP5 - Size of anion** iodide ion / I^- is larger (than chloride ion / Cl^-)	Allow iodine ion / I^- is a large atom / has a large atomic radius Ignore size of cation Do not award iodide has a larger charge density	
	• **IP6 – Polarisable** – what is polarised iodide ion / I^- is (more easily) polarised / distorted	Allow this shown in a diagram Ignore just 'greater attraction to cation'	

Q52.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
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The following table shows how the marks should be awarded for structure and lines of reasoning
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</table>
</td>
<td>
Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

Accept any six indicative content points

More than one indicative marking point may be made within the same comment or explanation
</td>
<td>(6)</td>
</tr>
</table>

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	Indicative content • ΔG needs to be negative for a reaction to be feasible • if ΔS_{system} and ΔH are both negative then a reaction is feasible if the magnitude of $\Delta H >$ (magnitude of) $T\Delta S_{system}$ • if ΔS_{system} and ΔH are both positive then a reaction is feasible if the magnitude of $T\Delta S_{system} >$ (magnitude of) ΔH • if ΔS_{system} is positive and ΔH is negative then the reaction is (always) feasible • if ΔS_{system} is negative and ΔH is positive then the reaction is never feasible • even if it is feasible the reaction may not occur because of kinetic factors	High activation energy/energy barrier/physical barrier e.g. oxide layer Ignore just reference to slow rate of reaction Ignore reference to non-standard conditions	

Q53.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $\Delta S_{surroundings} = -\Delta H/T$ **(1)** • calculation of $\Delta S_{surroundings}$ **(1)** • calculation of ΔS_{total} **and** sign **and** units **(1)**	Example of calculation $-(178000 \div 298) / -(178 \div 298)$ $-597(.315)$ (J K^{-1} mol^{-1}) **or** $-0.597(315)$ (kJ K^{-1} mol^{-1}) TE on equation with minus sign missing $\frac{160}{1000} + (-0.597315) = -0.437(315)$ kJ K^{-1} mol^{-1} **or** $160 + (-0.597315 \times 1000)$ $= -437.(315)$ J K^{-1} mol^{-1} TE on $\Delta S_{surroundings}$ Allow correct units shown once in answer for ΔS_{total} or $\Delta S_{surroundings}$ Ignore SF except 1SF Correct answer with sign and units without working scores 3 marks	**(3)**

Q54.

Question Number	Correct Answer	Reject	Mark
	C		**1**