Question Number	Acceptable Answer	Additional Guidance	Mark
1(a)	• **A** = $CaO(s)$ (1) • **B** = $CO_2(g)$ (1) • **C** = $Ca(OH)_2$ (aq)/(s) (1) • **D** = $CaCl_2(aq)$ (1) • **E** = $CaCO_3(s)$ (1) correct formulae with incorrect / missing symbol scores (4) correct formulae with 2 or more incorrect / missing symbols scores (3)	Allow $Ca(HCO_3)_2(aq)$	**5**

Question Number	Acceptable Answer	Additional Guidance	Mark
1(b)	An explanation that makes reference to the following points: • magnesium decomposes at lower temperature / more readily (1) • because it is a smaller ion with the same charge (1) • so polarises the anion (more) (1) • and weakens the carbon–oxygen bond (1)	Allow for four marks reverse argument for Ca^{2+} ions magnesium ion has a larger charge density distorts the electron cloud	**4**

(Total for Question 1 = 9 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)(i)	• 203.3 (g mol^{-1})	Allow 203 if Mg = 24	**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)(ii)	An answer that makes reference to the following point: • white precipitate / white solid		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)(iii)	$Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$ equation and state symbols		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to the following points: • AgCl dissolves in dilute aqueous ammonia (and in concentrated aqueous ammonia (1) • AgBr is insoluble / only partially soluble in dilute aqueous ammonia, but is soluble in concentrated aqueous ammonia (1) • AgI is insoluble in both dilute and concentrated aqueous ammonia (1)		**3**

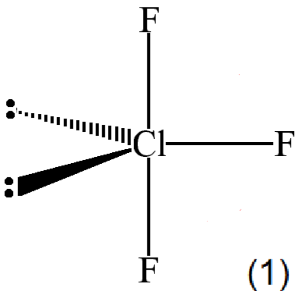
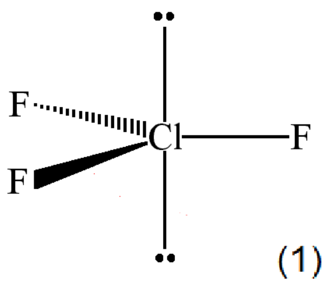
(Total for Question 2 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	**C** (iodine)		**1**

Question Number	Answer	Additional Guidance	Mark
3(b)	**C** (P_4O_{10})		**1**

Question Number	Answer	Additional Guidance	Mark
3(c)	**D** (ice has a lower density than water at 0ºC)		**1**

Question number	Answer	Additional Guidance	Marks
3(d)(i)	**A** ($AlCl_3$ and BCl_3)		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
3(d)(ii)	 (1) Shape 1  (1) Shape 2	Allow other indications of 3D shapes Allow shapes in either order	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
3(d)(iii)	An explanation that makes reference to the following points: Shape 2 because • lone pair-lone pair repulsion is greater (than both lone pair-bond pair repulsion and bond pair-bond pair repulsion) (1) • hence having the lone pairs as far apart as possible (will result in less repulsion between them) **OR** • Lone pair-lone pair bond angle is 180º rather than 120º (1)		**2**

(Total for Question 3 = 8 marks)

Question number	Acceptable Answer	Additional Guidance	Marks
4(a)	An answer that makes reference to the following points:		

	• a species that gains electrons **OR** a species that removes (one or more) electrons from another species		**1**

Question Number	Acceptable Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to one of the following pairs: **either** • oxidation number of Cl changes from +5 to +4 (1) • therefore ClO_3^- is the oxidising agent (because Cl (in ClO_3^-) has been reduced) (1) **or** • oxidation number of S changes from +4 to +6 (and oxidation number of H does not change) (1) • (therefore S (in SO_2) has been oxidised) therefore ClO_3^- is the oxidising agent (1)	Allow oxidation number of Cl goes down by 1 Allow oxidation number of S goes up by 2 (and oxidation number of H does not change)	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
4(c)(i)	$2ClO_2 + 2OH^- \rightarrow ClO_2^- + ClO_3^- + H_2O$ • species (1) • balanced (1)	Ignore state symbols	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
4(c)(ii)	An answer that makes reference to the following point: • because chlorine (in ClO_2) is both oxidised and reduced	Allow chlorine has gone from +4 to +3 and +5 (maybe shown underneath the equation in ci)	**1**

(Total for Question 4 = 6 marks)

Question number	Acceptable Answer	Additional Guidance	Marks
5(a)(i)	An explanation that makes reference to the following points: • the outermost electron of the magnesium atom is in a quantum shell of lower energy (than that of the strontium atom) \ the outermost electron is in the 3s rather than the 5s (orbital) (1) • the outermost electron of the magnesium atom is closer to the nucleus so is more strongly attracted **OR** the outermost electron(s) of the magnesium atom experiences less shielding (that that of the strontium atom) so is more strongly attracted (1)	Ignore any mention of (effective) nuclear charge	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
5(a)(ii)	An explanation that makes reference to the following points: **<u>EITHER</u>** • greater proton to electron ratio so greater attraction **/**electron is being removed from a positively charged particle (1) • remaining electron is closer to the nucleus (1) **<u>OR</u>** • after the first electron is removed the remaining electron experiences less repulsion (1) • therefore it has a lower energy (than before) (1)		**2**

Question number	**Acceptable Answer**	**Additional Guidance**	**Marks**
5(a)(iii)	An explanation that makes reference to the following points: • the third electron is removed from a different (quantum) shell / removed from the second (quantum) shell as opposed to the third (1) • of lower energy / closer to the nucleus **OR** • less shielding of the 2p electron (1)		**2**

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

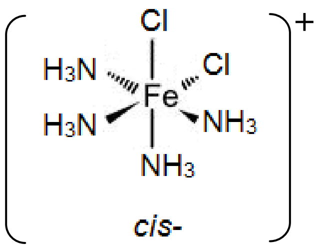
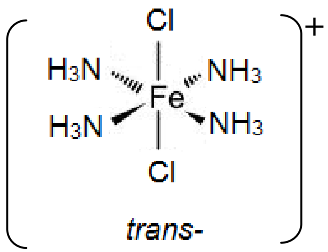
(Total for Question 5 = 11 marks)

Question number	Answer	Additional Guidance	Marks
6(a)	**C** ([Ar] $3d^6 4s^0$)		**1**

Question number	Answer	Additional Guidance	Marks
6(b)(i)	**D** (+6)		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
6(b)(ii)	• $E^\ominus$ for the reaction is +0.97 V (1) • because $E^\ominus$ is positive FeO_4^{2-} will react and so is unstable (in acidic conditions) (1) • $4FeO_4^{2-} + 20\ H^+ \rightarrow 4Fe^{3+} + 10\ H_2O + 3O_2$ – correct species (1) – balancing (1)	Accept correct use of 'anti-clockwise rule' Award 1 mark for: $4FeO_4^{2-} + 32H^+ + 6H_2O$ $\rightarrow 4Fe^{3+} + 16H_2O + 3O_2 + 12H^+$ Ignore state symbols	**4**

Question number	Acceptable Answer	Additional Guidance	Marks
6(c)(i)	$[Fe(NH_3)_4Cl_2]^+$ / $[FeCl_2(NH_3)_4]^+$	Square brackets not essential	**1**

Question number	Acceptable Answer	Additional Guidance	Marks
6(c)(ii)	  • both isomers (1) • *cis* and *trans* correctly labelled (1)	Ignore absence of square brackets and charge Allow one isomer with correct label for 1 mark	**2**

Question number	Answer	Additional Guidance	Marks
6(d)	**B** (Cl_2(g))		**1**

(Total for Question 6 = 10 marks)

Question number	Acceptable Answer	Additional Guidance	Marks
7(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
7(b)	• calculating $\Delta S^{\ominus}_{\text{system}}$ (1) • calculating $\Delta S^{\ominus}_{\text{surroundings}}$ (1) • conversion of units to be the same (1) • calculating $\Delta S^{\ominus}_{\text{total}}$ with units (1)	<u>Example of calculation:</u> $\Delta S^{\ominus}_{\text{system}} = 63.0 + (6 \times 35.6) - 292 - (8 \times 29.1)$ $= -248.2$ (J K^{-1} mol^{-1}) $\Delta S^{\ominus}_{\text{surroundings}} = -\frac{-2\,934\,000}{298}$ $= +9845.638$ (J K^{-1} mol^{-1}) Accept 9850 (J K^{-1} mol^{-1}) Accept 9.846 kJ K^{-1} mol^{-1} $\Delta S^{\ominus}_{\text{total}} = +9597$ 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
7(c)	An answer that makes reference to the following points: • $\Delta S^{\ominus}_{\text{total}}$ is positive, so the reaction is (thermodynamically) feasible (1) • therefore (if it needs a fuse), it must have a high activation energy (1)		**2**

(Total for Question 7 = 9 marks)

Question number	Answer	Additional Guidance	Marks
8(a)	**B** (the extent of dissociation into ions of the acid)		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
8(b)(i)	$HClO_2(aq) + HCOOH(aq) \rightleftharpoons ClO_2^-(aq) + HCOOH_2^+(aq)$ acid 1 base 2 . base 1 acid 2 **or** acid 2 base 1 . base 2 acid 1		**1**

Question number	Acceptable Answer	Additional Guidance	Marks
8(b)(ii)	An explanation that makes reference to the following points: • $HCOOH + C_6H_5OH \rightleftharpoons HCOO^- + C_6H_5OH_2^+$ (1) • because methanoic acid has a larger K_a value / methanoic acid is the stronger acid (1)	Ignore state symbols second mark is conditional on correct equation	2

Question number	Acceptable Answer	Additional Guidance	Marks
8(c)(i)	• pH = − log[H^+(aq)]	Allow lg / log_{10} / lg_{10} Ignore state symbol	**1**

Question number	Acceptable Answer	Additional Guidance	Marks
8(c)(ii)	<u>HCl(aq)</u>: • calculation of pH (1) <u>HCOOH(aq)</u>: • rearrangment of K_a equation to find $[H^+(aq)]$ (1) • calculation of $[H^+(aq)]$ (1) • calculation of pH (1)	<u>HCl(aq)</u>: pH = − log 0.0540 = 1.27 <u>HCOOH(aq)</u>: $[H^+(aq)] = \sqrt{K_a \times [HCOOH(aq)]}$ / $= \sqrt{1.60 \times 10^{-4} \times 0.0540}$ $[H^+(aq)] = 2.94 \times 10^{-3}$ (mol dm^{-3}) pH = (− log 2.94×10^{-3}) = 2.53 penalise lack of 2 dp in first and fourth marks once only	**4**

<table>
<tr><th>Question number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Marks</th></tr>
<tr>
<td>*8(c)(iii)</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>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<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</td><td>1</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></td>
</tr>
</table>

linkages and lines of reasoning.	
Answer has no linkages between points and is unstructured.	0

Indicative content

Similarity

• reaction is between Mg and H^+ / $Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$	both acids produce one H^+ / are monobasic / are monoprotic	
• 100 cm^3 of HCl and 100 cm^3 HCOOH contain the same initial number of moles of the acid	the same volume <u>and</u> concentration of both acids is used	
• therefore same total volume of gas evolved	a calculation to show the same volume	

Difference

• HCl is fully dissociated/ionised but HCOOH only partially dissociated/ionised	dissociation/ionisation of HCOOH requires energy	
• $[H^+]$ is greater in HCl / $[H^+]$ is smaller in HCOOH	therefore larger activation energy with HCOOH	**6**
• therefore rate is greater with HCl / lower with HCOOH		

(Total for Question 8 = 15 marks)

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

Question number	Acceptable Answer	Additional Guidance	Marks
9(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
9(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
9(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
9(e)	• the rate of the reaction is increased (even though the yield is less)		**1**

(Total for Question 9 = 7 marks)

Question number	Acceptable Answer	Additional Guidance	Marks
10(a)	• starch (1) • blue-black to colourless (1)	accept blue or black	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
10(b)	$(2S_2O_3^{2-} + I_2) \rightarrow S_4O_6^{2-} + 2I^-$	Ignore state symbols	**1**

Question number	Acceptable Answer	Additional Guidance	Marks
10(c)	• calculation of moles of $S_2O_3^{2-}$ (1) • calculation of moles of I_2 in excess (1) • calculation of moles of initial I_2 and reacted I_2 (1) • calculation of concentration of SO_2 in mol dm^{-3} (1) • calculation of concentration of SO_2 in mg dm^{-3} (1) • conclusion (1)	$n(S_2O_3^{2-}) = \frac{38.70 \times 0.00100}{1000}$ / 3.870×10^{-5} (mol) $n(I_2)$ in excess = ½ x $n(S_2O_3^{2-})$ / 1.935×10^{-5} (mol) $n(I_2)$ initial = $\frac{10.0 \times 0.00500}{1000}$ / 5.00×10^{-5} (mol) $n(I_2)$ reacted (= $n(SO_2)$) = $n(I_2)$ initial − $n(I_2)$ in excess / 3.065×10^{-5} (mol) $[SO_2] = \frac{3.065 \times 10^{-5}}{10} \times 1000 = 3.065 \times 10^{-3}$ (mol dm^{-3}) $[SO_2] = 3.065 \times 10^{-3} \times 64.1 \times 1000$ mg dm^{-3} = 196.47 mg dm^{-3} (196 < 400) so the wine can be sold	**6**

(Total for Question 10 = 9 marks)

TOTAL FOR PAPER = 90 MARKS