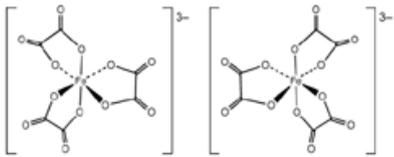
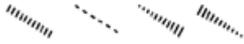
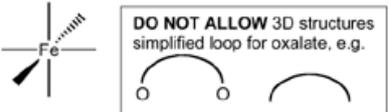
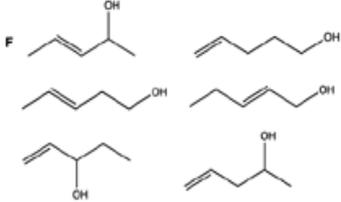
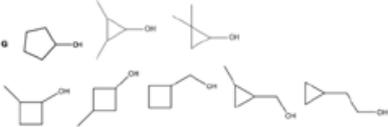
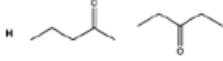


Mark scheme

Question	Answer/Indicative content	Marks	Guidance
1	<p>i</p> <p>species with two lone pairs (of electrons) ✓</p> <p>forming dative (covalent)/co-ordinate bond(s)</p> <p>OR</p> <p>donates electrons to a (central) metal atom/ion ✓</p>	2	<p>ALLOW species with lone pairs that form two dative/coordinate bonds ✓✓</p> <p>ALLOW non-bonding pair for lone pair</p> <p>IGNORE LP for lone pair</p> <p>IGNORE donates two pairs of electrons alone</p> <p><u>Examiner's Comments</u></p> <p>The term 'bidentate ligand' was well-known with most candidates gaining some credit.</p> <p>A mark was sometimes not given if 'lone pairs' had been omitted. A significant number of candidates just wrote 'a pair of electrons', which could have been a bonded pair.</p>
	<p>ii</p> <p>Charge</p> <p>Overall 3- charge shown (outside brackets) on at least ONE optical isomer ✓</p> <p><i>3- must apply to the overall charge of structures</i></p> <p>-----</p> <p>3D structures</p>  <p>1 mark for each isomer ✓✓</p>	3	<p>IGNORE charges or dipoles on atoms within diagrams (even if wrong)</p> <p>Square brackets NOT required</p> <p>ALLOW unambiguous structures</p> <p>-----</p> <p>ALLOW -3 for 3-</p> <p>-----</p> <p>3D: Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper</p> <p>OR 4 lines, 1 'out wedge' and 1 'in wedge':</p> <p>For bond into paper, ALLOW:</p> 

		<ul style="list-style-type: none"> Bonds MUST go to O⁻ of (COO⁻)₂ ligands <p>DO NOT ALLOW impossible 3D diagrams, e.g.</p> 		<p>ALLOW following geometry throughout:</p>  <p>For incorrect element in centre, e.g. Cu, AWARD 2 marks max</p> <p><u>Examiner's Comments</u></p> <p>The diagrams and 3- charge were usually correct. The standard of 3D diagrams has improved over the years with most candidates using the wedges requirements outlined in the mark scheme.</p> <p>Some candidates often did not use wedges and their diagrams were not given marks.</p> <p>It should be noted that 'impossible' 3D diagrams showing wedges in unrealistic positions were also not given marks. Examples are shown in the published mark scheme.</p>
		Total	5	
2	i	<p>Green solution Cr³⁺ OR [Cr(H₂O)₆]³⁺ ✓</p> <p>Orange solution Cr₂O₇²⁻ ✓</p> <p>Formulae AND charges must be correct</p>	2	<p>Green solution</p> <p>IGNORE H⁺ ALLOW Cr₂(SO₄)₃ OR CrCl₃ OR Cr⁺³</p> <p>Orange solution</p> <p>IGNORE H⁺ ALLOW K₂Cr₂O₇ OR Na₂Cr₂O₇ DO NOT ALLOW Cr⁶⁺</p> <p>ALLOW 1 mark for correct formulae but wrong way round</p> <p><u>Examiner's Comments</u></p>

				<p>Although high attaining candidates responded with the formulae of chromium-containing species, it was common to see organic compounds being suggested. Consequently, a large proportion of candidates did not score either of the 2 marks. Many candidates seem to expect to only give organic species in their responses on this paper and would benefit from understanding that inorganic species may also need to be provided.</p>
	ii	<p>Level 3 (5-6 marks) Reaches a comprehensive conclusion to determine possible correct structures for ALL of F, G, H and I AND ALL functional groups of F, G, H and I</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured.</i> <i>The information presented is relevant and substantiated.</i></p> <p>Level 2 (3-4 marks) Reaches a conclusion to determine possible correct structures for two of F, G, H and I AND most functional groups of F, G, H and I</p> <p><i>There is a line of reasoning presented with some structure.</i> <i>The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1-2 marks) Reaches a simple conclusion to determine a possible correct structure for one of F, G, H and I OR some functional groups of F, G, H and I</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks No response or no response worthy of credit.</p>	6	<p>Indicative scientific points may include: <u>Identity of F, G, H and I showing CORRECT structures</u></p>  <p>ALLOW enols for F, e.g.</p>  <p>For G, DO NOT ALLOW tertiary -OH. e.g.</p>  <p>For G, DO NOT ALLOW tertiary -OH. e.g.</p>  



IGNORE names, even if incorrect

For communication, a typical 'logical structure' would link functional groups to **SOME** of the test results, e.g.

2,4-DNP

H and **I** have carbonyl group/aldehyde or ketone

H⁺/Cr₂O₇²⁻

F, G and **I** are primary or secondary alcohols or aldehydes

Bromine

F is unsaturated/has C=C

Tollens

I is aldehyde

Correct functional groups may be shown in correct structures

Examiner's Comments

This Level of Response question was answered well with many candidates identifying compounds **F-I** correctly to reach Level 3. Structures were usually shown skeletally and this practice is to be recommended. Not only is it far quicker and clearer, it eliminates writing every atom in a displayed or structural formula. Some candidates were not given marks for missing hydrogen atoms or for 'sticks' being shown. In these structures, the chemical meaning of a stick is a terminal CH₃ group.

Candidates were also asked to show how the results of the chemical tests helped the identification of the unknown compounds and this formed the basis of the communication strand of the LOR mark. Candidates answered this part of the analysis extremely well and most were given marks for their good communication skills.

This question differentiated very well between well-prepared and less confident candidates. The latter often

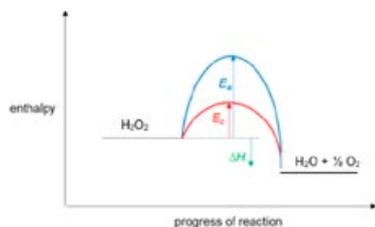
					The response is clearly at Level 3 for the four correct structures and the good communication ensures that the communication strand can be given. This response received all 6 marks.
			Total	8	
3	a		<p>s orbital p orbital</p>  <p>✓Fe = $(1s^2)2s^22p^63s^23p^64s^23d^6$ AND $Fe^{2+} = (1s^2)2s^22p^63s^23p^63d^6$ ✓</p>	2	<p>IGNORE shading</p> <p>IGNORE axes directions x, y, z</p> <p>DO NOT ALLOW multiple p orbitals</p> <p>For electron configuration, ALLOW $4s^2$ after $3d^6$</p> <p>i.e. $1s^22s^22p^63s^23p^63d^64s^2$</p> <p>ALLOW upper case D, etc and subscripts, e.g.$4S_23D_1$</p> <p>ALLOW $4s^0$</p> <p>IGNORE $[Ar]3d^6 4s^2$</p> <p><u>Examiner's Comments</u></p> <p>Many candidates were successful in drawing the orbital shapes. Occasionally candidates linked the question to the formation of a π bond or drew two arrows in a box to represent the electrons. Many candidates did not realise that when transition metal ions are formed, the first electrons removed from atoms are the 4s electrons and so wrote $2s^2 2p^6 3s^2 3p^6 3d^4 4s^2$.</p>
	b	i	<p>(A =) $[Co(H_2O)_6]^{2+}$ ✓</p> <p>(B =) $Co(OH)_2$ ✓</p> <p>(C =) $[CoCl_4]^{2-}$ OR $CoCl_4^{2-}$ ✓</p>	3	<p>IGNORE state symbols even if incorrect</p> <p>[] essential</p> <p>ALLOW $[Co(OH)_2(H_2O)_4]$ OR $Co(OH)_2(H_2O)_4$</p> <p>ALLOW -2 for 2- i.e. $[CoCl_4]^{-2}$</p> <p><u>Examiner's Comments</u></p> <p>Most candidates scored three marks. Some used other transition metal ions such as Cu^{2+} or Mn^{2+} and candidates</p>

					should be mindful of the information given in the question. Charges were sometimes incorrect, and some responses lacked the square brackets to show the complex.
		ii	<p>Complex : $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]$ ✓</p> <p>Charge +1 / + / 1+ ✓</p>	2	<p>IGNORE Any charges for 1st mark</p> <p>ALLOW $[\text{CoCl}_2(\text{NH}_3)_4]$</p> <p>ALLOW $[\text{Co}(\text{Cl})_2(\text{NH}_3)_4]$</p> <p>DO NOT ALLOW $[\text{Co}(\text{Cl}_2)(\text{NH}_3)_4]$</p> <p>DO NOT ALLOW if charges shown in formula within brackets for 2nd mark</p> <p><u>Examiner's Comments</u></p> <p>Most candidates identified the formula and the charge as 1+. A few candidates stated no charge or 3+. Candidates should consider the use of brackets in the formula, e.g. square brackets to show the complex and curly brackets to show the number of ligands attached. A few candidates used NH_4 rather than NH_3 for the ammonia ligand.</p>
	c		<p>Oxygen (O lone pair) forms a <u>coordinate/dative</u> bond to <u>Fe(II)/Fe/Iron/Fe²⁺</u> ✓</p> <p>replaced by H_2O or CO_2</p> <p>OR</p> <p>O_2 bonds <u>reversibly</u> (with metal ion) ✓</p> <p>FIRST CHECK ANSWER ON ANSWER LINE</p> <p>If 7.3(0) AND not healthy / below 7.35 award three calculation marks</p> <p>-----</p> <p>-----</p> <p>$[\text{H}^+] = K_a \times \frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]}$</p> <p>OR</p> <p>$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]}$ ✓</p> <p>$[\text{H}^+] = 5.02 \times 10^{-8}$ ✓</p> <p>$\text{pH} = -\log(5.02 \times 10^{-8}) = 7.3(0)$</p> <p>AND not healthy / below 7.35 ✓</p> <p><u>Alternative method 1:</u></p>	5	<p>ALLOW word equations using \rightarrow and \rightleftharpoons</p> <p>IGNORE number of coordinate bonds</p> <p>ALLOW ORA</p> <p>Check for alternative methods on mark scheme.</p> <p>ALLOW ECF throughout</p> <p>ALLOW $[\text{A}^-]$ for $[\text{HCO}_3^-]$ AND/OR $[\text{HA}]$ for $[\text{H}_2\text{CO}_3]$ (asked for in 19 a ii))</p> <p>ALLOW $[\text{H}^+] = K_a \times \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$</p> <p>ALLOW $\frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]} = \frac{[\text{H}^+]}{K_a}$</p> <p>$[\text{H}^+]$ value subsumes MP3</p> <p>ALLOW $[\text{H}^+] = 5.02 \times 10^{-8}$ up to the calculator value ($5.023529412 \times 10^{-8}$)</p> <p>DO NOT ALLOW a weak acid approach for marking points 3 and 5. i.e. $[\text{H}^+]$ can be awarded.</p>

		<p>pH of healthy blood is between 7.35 and 7.45</p> <table border="1"> <tbody> <tr> <td>pH 7.35</td> <td></td> <td>pH 7.45</td> <td></td> </tr> <tr> <td>$[H^+] = 4.47 \times 10^{-8}$</td> <td>OR</td> <td>$[H^+] = 3.55 \times 10^{-8}$</td> <td>✓</td> </tr> <tr> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$</td> <td></td> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$</td> <td>✓</td> </tr> <tr> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$</td> <td></td> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$</td> <td></td> </tr> <tr> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = 9.55:1$</td> <td></td> <td>$\frac{[HCO_3^-]}{[H_2CO_3]} = 12.03:1$</td> <td></td> </tr> </tbody> </table> <p>8.5:1 does not lie in the range of 9.55:1 to 12.03:1 AND unhealthy ✓</p> <p>Alternative method 2:</p> $pH = pK_a + \log \frac{[HCO_3^-]}{[H_2CO_3]} \quad \checkmark$ $pK_a = 6.37 \quad \checkmark$ $6.37 + \log \frac{(8.5)}{(1)}$ <p>7.3(0) AND not healthy / below 7.35 ✓</p>	pH 7.35		pH 7.45		$[H^+] = 4.47 \times 10^{-8}$	OR	$[H^+] = 3.55 \times 10^{-8}$	✓	$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$	✓	$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = 9.55:1$		$\frac{[HCO_3^-]}{[H_2CO_3]} = 12.03:1$		<p>ALLOW 7.3 up to calculator value (pH =7.298991951)</p> <p>ALLOW $[H^+] = 3.98 \times 10^{-8}$ from average pH 7.40 used. 3</p> <p>Examiner's Comments</p> <p>The key chemistry that candidates needed to discuss in their response was as follows:</p> <ul style="list-style-type: none"> • O₂ molecules forming coordinate bonds with and Fe²⁺ ions in haemoglobin. Often candidates omitted the Fe²⁺ and just stated it was to haemoglobin • O₂ molecules being replaced by another ligand (e.g. H₂O or CO₂) <p>The calculation using the $[HCO_3^-] : [H_2CO_3]$ ratio of 8.5 : 1 was well described, although sometimes the final expression of the ratio left ambiguity as it was hard to tell whether the ratio given referred to the $[HCO_3^-] : [H_2CO_3]$ ratio or the $[H_2CO_3] : [HCO_3^-]$ ratio. ECF was given for the $[H^+]$ and then the pH linked to whether the blood was healthy.</p> <p>A smaller number of candidates approached the question by calculating the ratio of $[HCO_3^-] : [H_2CO_3]$ for both pH 7.35 <u>and</u> pH 7.45 and then compared <u>both</u> ratios to the ratio of 8.5 : 1 for healthy blood. A few candidates attempted the calculation by the weak acid approach using $[H^+]^2$. In this case only the $[H^+]$ was given.</p>
pH 7.35		pH 7.45																					
$[H^+] = 4.47 \times 10^{-8}$	OR	$[H^+] = 3.55 \times 10^{-8}$	✓																				
$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]}$	✓																				
$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$		$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$																					
$\frac{[HCO_3^-]}{[H_2CO_3]} = 9.55:1$		$\frac{[HCO_3^-]}{[H_2CO_3]} = 12.03:1$																					
		Total	12																				
4		D	1																				
			Examiner's Comments																				

					The correct answer was D. Many candidates were able to identify the green precipitate as $\text{Fe}(\text{OH})_2$ and the white precipitate as BaSO_4 . A few candidates suggested C, identifying BaCl_2 as the white precipitate, or B, identifying $\text{Cu}(\text{OH})_2$ as the green precipitate.
			Total	1	
5			D	1	<p><u>Examiner's Comments</u></p> <p>The correct answer was D. Most candidates were able to select this response, but the common error was the selection of A. It is important that candidates can distinguish the difference between oxidation states and charge on the ions. Oxidation state is the measure of the number of electrons that an atom uses to bond with atoms of another element.</p>
			Total	1	
6			C	1	<p><u>Examiner's Comments</u></p> <p>The correct answer was C. Most candidates chose the correct answer but a few selected A. The position of the element is based on its atomic number.</p>
			Total	1	
7	a	i	<p>FIRST CHECK ANSWER ON ANSWER LINE If answer = -117 kJ mol^{-1}, award 4 marks.</p> <p>----- -----</p> <p>$\Delta H = -286 - (-188)$ $= -98 \text{ kJ mol}^{-1} \checkmark$</p> <p>$\Delta S = 70 + \frac{1}{2}(205) - 110 = 62.5 \text{ (J K}^{-1} \text{ mol}^{-1})$ or $0.0625 \text{ (kJ K}^{-1} \text{ mol}^{-1}) \checkmark$</p>	4	<p>ALLOW ECF throughout</p> <p>ALLOW $-98000 - (298 \times 62.5)$</p> <p>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 $\Delta S \text{ J K}^{-1} \text{ mol}^{-1}$) $(+79.4$ ($-188 - (-286) = +98$)</p>

			$\Delta G = \Delta H - T\Delta S$ $= -98 - (298 \times 0.0625) \checkmark$ $\Delta G = -117 \text{ kJ mol}^{-1} \text{ (3SF)} \checkmark$		<p>2 marks (+) 117 (incorrect signs for ΔH and ΔS)</p> <p>Final Answer MUST BE 3 SF</p> <p>Examiner's Comments</p> <p>Almost all candidates had a good attempt at this calculation, with many gaining full marks. Most were able to calculate the entropy change. Almost all could reproduce the equation for free energy. Of those who did not get the correct final answer, the most common error was not converting the entropy value into kJ and / or the temperature to K. There were a few candidates who did not manipulate the equation correctly. A few candidates incorrectly calculated ΔS, obtaining the value of $165 \text{ J K}^{-1} \text{ mol}^{-1}$ or ΔH, obtaining -474 kJ mol^{-1}. Candidates were given ECF in these cases.</p>
		ii	(Rate of reaction) slow OR Activation energy high \checkmark	1	<p>ALLOW ΔG takes no account of rate of reaction</p> <p>ALLOW molecules do not have sufficient energy to equal or exceed the activation energy.</p> <p>IGNORE molecules do not have sufficient energy to react.</p> <p>DO NOT ALLOW there is not enough activation energy</p> <p>Examiner's Comments</p> <p>Lots of good answers from candidates were seen for this question. A few candidates attempted the explanation via a $\Delta G / \Delta S$ argument and misinterpreted the comment within the question.</p>
	b	i		3	<p>Care enthalpy profile must match ΔH sign in 16 a) i) – check calculation</p> <p>ALLOW endothermic profile as ECF from + ΔH calculated in 16 a) i) for all three marks</p>



H_2O_2 on LHS **AND** $\text{H}_2\text{O} + \frac{1}{2} \text{O}_2$ on RHS
AND
 ΔH labelled with product line below reactant line

AND
 Arrow downwards ✓

E_a correctly labelled ✓

E_c correctly labelled with $E_c < E_a$ ✓

State symbols not required

ΔH DO NOT ALLOW $-\Delta H$

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.

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

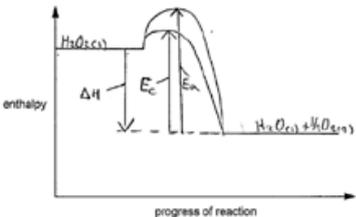
For E_a , **ALLOW** AE **OR** A_E **OR** E_{act} **OR** suitable alternatives

ALLOW ECF marks for **E_a and E_c** for correctly labelled endothermic diagram from a $-\Delta H$ value (from 16 a i))

Examiner's Comments

This question proved more difficult for candidates with lots of inaccuracies. The profile was dependent on the calculation for ΔH in Question 16 (a) (i). The arrowhead for ΔH needs to be pointing from the reactants to the products. The activation energies, again, need to start at the reactant line and go to the maximum level of the curve. Those that needed to draw an endothermic profile were far more likely to make an error with the E_a and E_c arrows, often starting from the product line or even from the base line of the graph. A significant number of candidates did not add arrows and instead labelled the curves E_a and E_c . Some candidates drew a Boltzmann distribution curve scoring 0 marks.

Exemplar 1

					 <p>The candidate has the correct exothermic profile but has the incorrect starting point for the activation energy going from the product line.</p>
		ii	<p>(MnO₂) is in different phase/state (to the reactant / H₂O₂)</p> <p>OR</p> <p>catalyst is a <u>solid</u> AND reactant is <u>liquid</u> ✓</p>	1	<p>ASSUME 'it' is MnO₂</p> <p>ALLOW 'species in the reaction'</p> <p>IGNORE references to products</p> <p>Examiner's Comments</p> <p>This was a well answered question. A few candidates, incorrectly, suggested that it was heterogeneous due to the reactants and products being in different states, and did not mention the catalyst.</p>
		iii	<p>Mn is +2 AND +3</p> <p>OR</p> <p>Mn is +1 AND +6 ✓</p>	1	<p>+ required</p> <p>ALLOW 2+ and 3+</p> <p>DO NOT ALLOW Mn²⁺ Mn³⁺</p> <p>DO NOT ALLOW + 4 (this is the oxidation state in MnO₂)</p> <p>Examiner's Comments</p> <p>This question proved more challenging for candidates. Candidates stating +4 was the most common error; this is the oxidation state in MnO₂. Some candidates stated fractions, negative values and gave the state symbol instead i.e. solid and liquid.</p>
			Total	10	
8	a		<p>Any correct formula for X₂Y(ZO₄)₂ • 6H₂O ✓</p> <p>with suitable elements for X, Y and Z using information in stem:</p>	1 (AO 3.2)	<p>Suitable transition elements: Ti, V, Cr, Mn, Fe, Co, Ni</p>

			<ul style="list-style-type: none"> • X can be K, Rb, Cs, Fr ONLY • Y can be Mg or a transition element in period 4: Ti → Ni • Z must be Cr <p>Example: $K_2Mg(CrO_4)_2 \cdot 6H_2O$</p>		<ul style="list-style-type: none"> • <i>Cu</i> in in the <i>Tutton's salt</i> in Q4 • <i>Sc</i> and <i>Zn</i> and not classified as <i>transition elements</i> <p><u>Examiner's Comments</u></p> <p>Question 4 assesses candidates' ability to apply their chemical knowledge and understanding from different parts of the specification in a novel context. Information is supplied throughout the question, and clues are sometimes presented to candidates.</p> <p>In part (a), candidates are introduced to Tutton's salts and are given an example of a Tutton's salt that forms the context of the whole question. A candidate needs to apply the information in the bullet points to predict the formula of a different Tutton's salt.</p> <p>This question discriminated extremely well across different abilities and highlighted that some candidates struggled to use supplied information. This was repeated in other parts of Question 4.</p> <p>Just over half the candidates gave a correct formula from the information. Some candidates did not choose one of the acceptable ions shown in the first and second bullet points, and many chose S rather than Cr, despite S being in the supplied Tutton's salt; a significant number omitted the $\cdot 6H_2O$.</p>
	b	i	<p>$[Cu(NH_3)_4(H_2O)_2]^{2+}$ ✓</p> <p>TAKE CARE with correct brackets, numbers and 2+ charge</p>	1 (AO 2.4)	<p>ALLOW +2 for charge</p> <p>IGNORE $[Cu(NH_3)_4]^{2+}$</p> <p>H_2O and NH_3 can be in either order, i.e. $[Cu(H_2O)_2(NH_3)_4]^{2+}$</p> <p><u>Examiner's Comments</u></p> <p>This reaction of copper(II) ions with</p>

				<p>aqueous ammonia and the formula of the complex ion formed are part of the specification. Within this novel context, the molar mass had been provided as a clue.</p> <p>Less than half the candidates correctly gave the correct formula and it was noticeable how well this part discriminated across abilities. This was another example of many candidates being unable to apply their knowledge and understanding to a novel context.</p>
	ii	<p>Formula of precipitate Cu(OH)₂ ✓ IGNORE name: copper(II) hydroxide</p> <hr/> <p>Formula of gas ;NH₃ ✓ IGNORE name: ammonia</p> <hr/> <p>Test for ammonia Available only from a reasonable attempt for identifying the gas as NH₃, e.g. NH₄, NH₄⁺, NH₂, ammonia, ammonium</p> <p>(Moist/damp) indicator/litmus (paper) turns blue ✓</p> <p>Moist/damp NOT required. Initial colour of litmus NOT required but <i>blue</i> is CON</p>	<p>3 (AO 2.3 ×3)</p>	<p>ALLOW Cu(OH)₂(H₂O)₄</p> <p>ALLOW charges on Cu AND OH e.g. Cu²⁺(OH⁻)₂ ✓ DO NOT ALLOW unbalanced charges. e.g. Cu(OH⁻)₂ ✗</p> <hr/> <p>DO NOT ALLOW correct test for NH₃ based on incorrect ID of the gas</p> <p>NO ECF for a test on the wrong gas (has to be test for NH₃)</p> <p>DO NOT ALLOW bleaches indicator CON</p> <p><u>Examiner's Comments</u></p> <p>Addition of NaOH(aq) to the Tutton's salt results in two reactions: precipitation of copper(II) hydroxide and a reaction of an ammonium ion, used to show its presence as a qualitative test. As with Question 4 (c) (i), this part discriminated very well with many candidates able to be rewarded with some of the marks.</p> <p>The formula of copper(II) hydroxide, as Cu(OH)₂ or Cu(OH)₂(H₂O)₂ were both acceptable. This was correct more often than the responses related to the ammonium ion.</p> <p>The formula of the gas formed in the reaction of NaOH(aq) with the ammonium ion caused problems, with NH₃ and its subsequent test with</p>

					<p>moist indicator turning blue seen much less than the reaction of $\text{Cu}^{2+}(\text{aq})$ ions. Hydrogen (the 'squeaky pop test) and oxygen (relighting a glowing split) were common incorrect responses.</p> <p>This was another question in which referring back to the formula of the Tutton's salt would have revealed important clues.</p>
		iii	<p>Reagent</p> <p>BaCl_2 / barium chloride (solution) OR $\text{Ba}(\text{NO}_3)_2$ / barium nitrate (solution) OR Ba^{2+} (solution/aq) / barium ions ✓</p> <p>Observation</p> <p>white precipitate/ppt ✓ Only available from soluble Ba^{2+} reagent</p> <p>ALLOW minor slips in formula of Ba^{2+} reagent, e.g. BaCl, BaNO_3</p>	<p>2 (AO 2.3 ×2)</p>	<p>ALLOW $\text{Ba}(\text{OH})_2$ or other soluble Ba^{2+} compounds</p> <p>-----</p> <p>IGNORE test for other anions provided they do NOT interfere with SO_4^{2-} test e.g.</p> <p>IGNORE addition of $\text{HCl}/\text{HNO}_3/\text{H}^+$ BUT DO NOT ALLOW H_2SO_4 <i>Interferes with SO_4^{2-} test</i></p> <p>IGNORE $\text{Ag}^+/\text{AgNO}_3$ after SO_4^{2-} test DO NOT ALLOW before SO_4^{2-} test</p> <p>IGNORE bubbling any gas through limewater</p> <p>IGNORE responses linked to CrO_4^{2-} <i>Not in Tutton's salt that student prepares</i></p> <p><u>Examiner's Comments</u></p> <p>Th final part of Question 4 required candidates to identify the anion in the Tutton's salt as sulfate, and to recall that Ba^{2+} ions is used for the sulfate test to form a white precipitate. Any soluble barium compound was credited with barium chloride and nitrate being the commonest seen.</p> <p>As with earlier parts, this part discriminated very well. Most candidates who knew that barium ions were needed also collected the mark for the white precipitate observation. Over half the candidates</p>

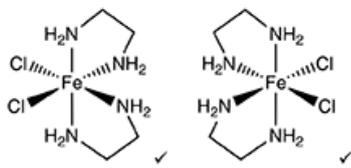
					did not score here, the most common errors being to repeat the test for the ammonium ion, or to use silver nitrate, clear confusion with the halide test.
			Total	7	
9			Cr ✓ Mn ✓	2 (AO 1.2)	IGNORE ions <u>Examiner's Comments</u> Most candidates chose at least one of the two elements Cr and Mn, with Mn being the most common. Incorrect elements were usually other d block elements.
			Total	2	
10	a		<p>Level 3 (5–6 marks) Explains the terms 'd-block element' AND 'transition element' AND Explains why not all d-block are transition elements AND At least THREE correct electron configurations (need to be one electron configuration of d block atom, transition element ion and zinc (or scandium) ion)</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks)</p> <p>Explains both the terms 'd-block element' and 'transition element' AND Explains why not all d-block are transition elements</p> <p>OR</p> <p>Explains both the terms 'd-block element' and 'transition element' AND Links terms to at least TWO correct electron configurations</p> <p>OR</p> <p>Explains the terms 'd-block element' OR 'transition element' AND</p>	6 (AO 1.1 × 4)	<p>Indicative scientific points may include:</p> <p><u>Terms</u></p> <p>d-block element: element with highest energy/ valence electron in d-orbital/sub-shell OR d subshell is being filled DO NOT ALLOW d block for d-subshells</p> <p>Transition element: element forming one or more ions (allow atom and ion - IUPAC definition) with incomplete/partially filled d-subshell/d-orbitals DO NOT ALLOW d shell</p> <p><u>d-block element:</u> ALLOW examples with an ion with an incomplete d-subshell, e.g. Fe²⁺ - [Ar]4s⁰3d⁶</p> <p>ALLOW examples with highest energy electrons in a d-subshell, e.g. Fe - [Ar]4s²3d⁶</p> <p><u>Not all d-block are transition elements:</u></p> <p>Sc and Zn form ions with complete or empty d-shells ORA</p>

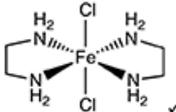
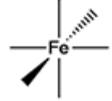
		<p>Explains why not all d-block are transition elements AND Links terms to at least ONE correct electron configuration</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks)</p> <p>Explains the term 'd-block element' OR 'transition element' AND Attempts to link terms with ONE correct electron configuration</p> <p>OR</p> <p>Explains the term 'd-block element' AND 'transition element'</p> <p>OR</p> <p>Explains the term 'd-block element' OR 'transition element' AND Explains why not all d-block are transition elements</p> <p>OR</p> <p>Any TWO out of THREE correct electron configurations (one element and one ion that is a transition element and one ion that is not a transition element)</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 mark No response or no response worthy of credit</p>	<p>For Sc^{3+}, ALLOW Sc^{3+} OR Sc forms a 3+ ion For Zn^{2+}, ALLOW Zn^{2+} OR Zn forms a 2+ ion</p> <p>$\text{Sc}^{3+} 1s^2 2s^2 2p^6 3s^2 3p^6$ Sc^{3+} AND d subshell empty / d orbital(s) empty $\text{Zn}^{2+} 1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ Zn^{2+} AND d subshell full / ALL d orbitals full</p> <p>ALLOW minor slips on inner shell electron configurations</p> <hr/> <p>NOTE: A clear and logically structured response would link definitions to electron configurations to support the explanations. If stated, for the level, there should be clear indication that the d subshell is full/empty or partially full</p> <p><u>Examiner's Comments</u></p> <p>Only the higher-attaining candidates scored full marks. Very few candidates were able to define d-block element correctly without the minor slip of saying outermost electron instead of highest energy or valence electron. Many candidates often did not mention ions for the transition metal definition. Many did not include any of the electron arrangements for d-block elements and transition elements. The majority of candidates who were able to recognise zinc and scandium as d-block elements, but not transition elements, gave their electronic configurations correctly. Common errors included the presence of the 4s electrons in the electron configurations of the ions and incorrect electron configurations of copper and chromium atoms. A few candidates thought chromium and copper were not transition elements due to the $4s^1$ electron configuration.</p>
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				<p>Exemplar 3</p> <p>transition element. Explain why some d-block elements are not transition elements. - d block }² - transition } Sc + Zn? Use electron configurations to support your explanations. <u>d-block elements are elements where their last, outer most electron lies in the d subshell.</u> <u>For example, Titanium is a d-block element because its last electron is in 3d. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$</u></p> <p><u>A transition element is an element when forming ions which have a partially filled d-subshell.</u> <u>An example would be Vanadium, it forms V^{2+} ions and has an incomplete d-subshell: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^4$</u></p> <p><u>Some d-block elements aren't considered transition elements because the extra ion do not form an incomplete d-subshell.</u> <u>For example, Sc is not a transition metal because as a Sc^{3+} it doesn't have an incomplete d-subshell.</u> <u>$Sc^{3+}: 1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^0$</u> <u>Another example is zinc, its Zn^{2+} ion forms a full d-subshell instead of incomplete, so although it is a d-block element it isn't a transition metal.</u> <u>$Zn^{2+}: 1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^{10}$</u></p> <p>This candidate has mentioned outer electrons rather than highest energy but was this is a minor slip and they were still given a Level 3 response as everything else is correct. A holistic approach for LoRs is used and not a point-based marking system.</p>
b	i	<p>Cu Precipitation with OH^-/NH_3 2 marks</p> <p>(Pale) Blue (precipitate) AND $Cu(OH)_2$ (can be seen in the equation)✓</p> <p>$Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2 \checkmark$</p> <p>OR Precipitation with I^- 2 marks</p> <p>White (precipitate) AND $CuI \checkmark$</p> <p>$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2 \checkmark$</p>	<p>2 (AO 1.1) (AO 1.2)</p>	<p>ALLOW any one precipitation reaction any one ligand substitution</p> <p>ALLOW other correct equations linked to correct colour change -check with TL</p> <p>IGNORE state symbols</p> <p>DO NOT ALLOW dark/royal blue (complex ion colour)</p> <p>ALLOW $Cu(H_2O)_4(OH)_2$</p> <p>ALLOW $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2(H_2O)_4 + 2H_2O$ OR $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$ OR $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2(H_2O)_4 + 2NH_4^+$</p> <hr/>

			<p>-----</p> <p>Cr Precipitation with OH⁻/NH₃ 2 marks</p> <p>(Dark) Grey-Green (precipitate) AND Cr(OH)₃ ✓</p> <p>Cr³⁺ + 3OH⁻ → Cr(OH)₃ ✓</p>		<p>ALLOW Green ALLOW Cr(H₂O)₃(OH)₃</p> <p>ALLOW [Cr(H₂O)₆]³⁺ + 3OH⁻ → Cr(OH)₃(H₂O)₃ + 3H₂O OR [Cr(H₂O)₆]³⁺ + 3NH₃ → Cr(OH)₃(H₂O)₃ + 3NH₄⁺ OR [Cr(H₂O)₆]³⁺ + 3OH⁻ → Cr(OH)₃ + 6H₂O</p> <p><u>Examiner's Comments</u></p> <p>Most candidates scored 1 mark. Most used Cu²⁺ as their example and recognised Cu(OH)₂ forms a blue precipitate. Some candidates either did not give the colour of the precipitate or were unable to write a balanced equation. Some candidates defined rather than described precipitation.</p>
	ii	<p>Cu Ligand substitution with NH₃/Cl⁻ 2 marks</p> <p>NH₃ Deep/dark/royal blue (solution) AND [Cu(NH₃)₄(H₂O)₂]²⁺ ✓</p> <p>[Cu(H₂O)₆]²⁺ + 4NH₃ → [Cu(NH₃)₄(H₂O)₂]²⁺ + 4H₂O ✓</p> <p>OR</p> <p>Cl⁻ yellow (solution) AND [CuCl₄]²⁻ ✓</p> <p>[Cu(H₂O)₆]²⁺ + 4Cl⁻ → [CuCl₄]²⁻ + 6H₂O ✓</p> <p>-----</p> <p>Cr Ligand substitution with NH₃ 2 marks</p> <p>NH₃ Purple (solution) AND [Cr(NH₃)₆]³⁺</p>	2 (AO 1.1) (AO 1.2)	<p>ALLOW other correct equations linked to correct colour change -check with TL</p> <p>ALLOW ECF on any incorrect charges of the complex ions when linked to colour via an equation.</p> <p><u>Examiner's Comments</u></p> <p>Only the highest-attaining candidates on the paper were able to give an example of a ligand substitution reaction with the colour of the new complex ion. Some candidates confused a precipitation reaction for a ligand substitution and some candidates were perhaps a little ambitious in giving 'unusual' complex ions for which they did not know the colour. Cu was often chosen over Cr, usually the formation of [CuCl₄]²⁻, but [Cu(NH₃)₄(H₂O)₂]²⁺ was also chosen. With both, there were issues with charges of the complex, and with the latter some were confused with how many NH₃ were coordinated. Some</p>	

		<p>✓</p> $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 6\text{H}_2\text{O} \checkmark$ <p>OR</p> <p>Dark Green (solution) AND</p> $[\text{Cr}(\text{OH})_6]^{3-} \checkmark$ $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{OH}^- \rightarrow [\text{Cr}(\text{OH})_6]^{3-} + 6\text{H}_2\text{O} \checkmark$		<p>candidates defined rather than described ligand substitution.</p>
	c	<p>Charge: -1 OR - OR 1- ✓</p> <p>Coordination number: 6 ✓</p>	<p>2 (AO1.2 × 2)</p>	<p>ALLOW $[\text{Co}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^-$</p> <p>DO NOT ALLOW Co^-</p> <p>IGNORE sign</p> <p>Examiner's Comments</p> <p>Most candidates identified the charge as -1 and a coordination number of 6. A few candidates identified the coordination number as 4 as they did not spot that ethanedioate is bidentate and charge of +3 stated.</p>
	d	$3\text{V}^{3+} + \text{Cr}_2\text{O}_7^{2-} + 2\text{H}^+ \rightarrow 3\text{VO}_2^+ + 2\text{Cr}^{3+} + \text{H}_2\text{O}$ <p>ALL reactant and product species correct ✓</p> <p>Correct balancing (of correct equation) AND cancelling of species ✓</p>	<p>2 (AO 2.5) (AO 2.6)</p>	<p>IGNORE Balancing and electrons for first mark</p> <p>DO NOT ALLOW electrons in final answer</p> <p>Examiner's Comments</p> <p>Very few candidates were able to produce the balanced overall equation; a few had the correct reactants and products but not balanced. Candidates are advised to look for the information contained within the question. The formulas were given, and it was stated that the solution was acidified, leaving only water to be identified. Some candidates approached this through two half equations whereas others used oxidation numbers to balance their equations.</p>
		Total	14	

11			D	1 (AO 1.2)	<p>Examiner's Comments</p> <p>The correct answer was D. Most candidates recognised that the complex represented cisplatin. Cisplatin has a bond angle of 90 degrees due to being square planar and shows cis/trans isomerism, but some candidates thought it showed optical isomerism too. Most could tell the oxidation number of platinum is not +4.</p>
			Total	1	
12	a	i	<p>(N) donates two electron pairs (to a metal ion/metal/Fe^{3+}) AND forms two coordinate / dative (covalent) bonds ✓</p>	1 (AO1.2)	<p>ALLOW lone pairs for electron pairs</p> <p>TWO is only needed once if bonds are plural e.g. donates 2 electron pairs to form coordinate bonds OR donates electron pairs to form 2 coordinate bonds.</p> <p>Examiner's Comments</p> <p>There were some good answers to this standard question, but candidates did not gain the mark due to missing one of the three key ideas of "donation, electron pairs and forming two coordinate bonds".</p>
		ii	<p>Empirical formula</p> <p>$\text{FeC}_4\text{H}_{16}\text{N}_4\text{Cl}_2$ (any order)</p> <p>AND charge = (1)+ ✓</p> <p>Structures</p> <p>i.e. Optical isomers (<i>cis</i>)</p> 	4 (AO1.2×1) (AO3.1×3)	<p>DO NOT ALLOW $\text{Fe}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{Cl}_2$ for empirical formula</p> <p>ALLOW any order</p> <p>----- ----</p> <p>TAKE CARE: structures may be in different orientations and in different order</p> <p>IGNORE charges (anywhere)</p> <p>IF connectivity between Fe AND N of NH_2 is incorrect then penalise first time ONLY</p>

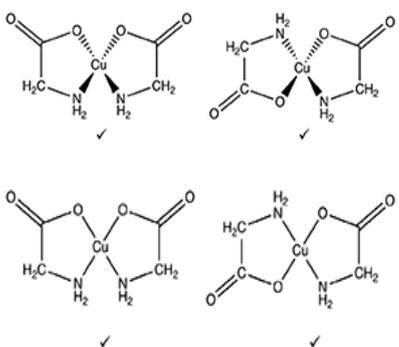
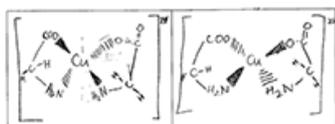
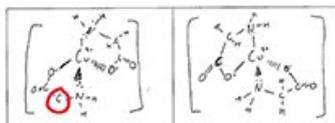
			<p><i>i.e. trans isomer</i></p>  <p>For NH₂CH₂CH₂NH₂, ALLOW skeletal, structural, displayed formula AND C-C without Hs and NH₂ NH₂ IF NH₂ shown with incorrect number of H, eg. N N, penalise first time ONLY</p> <p>IF ALL 3 isomers are 'correct', but 2 x Cl AND no Ns, e.g.</p> <p>AWARD 1 mark</p>		<p>Each structure to contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper OR 4 lines, 1 'out wedge' and 1 'in wedge':</p> <p>Bond into paper can be shown as:</p>  <p>ALLOW</p>  <p>Examiner's Comments</p> <p>Most candidates did not seem to understand how to apply their knowledge of what an empirical formula should look like to this situation. Many giving the formula of the complex ion instead. Those candidates who were successful often had the incorrect overall charge on the ion with 3+ as the common error, not considering the 2 Cl⁻ ligands. Conversely, most candidates did very well at representing the isomers of the complex. Most were able to use the wedge and broken line notation to suggest the geometry of what they were drawing. Although a small number drew the trans isomer in three different orientations, most correctly drew the trans and cis forms and managed to show the optical isomers – even when they did not make use of the top pair of answer boxes to assist them with their mirror images. Candidates are advised to focus on the mirror image and avoid subsequent rotations and inversions of the molecule. This can often lead to two of the same isomers being drawn. Candidates showed a good accuracy with their connectivity of the N atom.</p>
	b	i	$\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 \checkmark$	1(AO2.6)	<p>IGNORE state symbols, even if wrong</p> <p>ALLOW</p> $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{H}_2\text{O}$ <p>OR</p>

				$[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 + 6\text{H}_2\text{O}$ <p><u>Examiner's Comments</u></p> <p>Most students scored this mark, although several gave no response.</p>
	ii	<p>Explanation of the brown precipitate</p> <p>The brown ppt is $\text{Fe}(\text{OH})_3$</p> <p>OR</p> <p>$\text{Fe}(\text{OH})_2$ loses electrons/ $\text{Fe}(\text{OH})_2$ oxidised ✓</p> <p>Comparison of E values</p> <p>(E of) Fe/Redox system 1 is more negative/less positive (than E of O_2/redox system 2)</p> <p>OR</p> <p>(E of) O_2/Redox system 2 is more positive/less negative (than E of Fe/redox system 1) ✓</p> <p>Equilibrium shift</p> <p>More negative/less positive OR Fe system OR Redox system</p> <p>1 shifts left</p> <p>OR</p> <p>More Positive/less negative OR O_2 system OR Redox system</p> <p>2 shifts right ✓</p> <p>Equation</p>	4(AO3.1×4)	<p>ORA</p> <p>ALLOW Fe^{2+} is oxidised to Fe^{3+}</p> <p>ALLOW Fe ALLOW E_{cell} is (+) 0.96V IGNORE 'lower/higher'</p> <p>For equilibrium shift ALLOW E_{cell} is +ve therefore the reaction is feasible. OR Direction of half equation correctly written.</p> <p>ALLOW multiples ALLOW equilibrium IGNORE state symbols, even if wrong DO NOT ALLOW uncanceled species</p> <p><u>Examiner's Comments</u></p> <p>Although a spread of marks across the full available range was seen, a good proportion of candidates gained 3 or 4 marks. Most candidates were able to produce a balanced equation, but candidates should take care cancelling out any species present on both side of the equation, e.g. the hydroxide ions. A common error within the formula of iron (III) hydroxide was to place the number of hydroxide ions within the brackets,</p>

		$4\text{Fe}(\text{OH})_2(\text{s}) + \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{Fe}(\text{OH})_3(\text{s}) \checkmark$		<p>e.g. $\text{Fe}(\text{OH})_3$. Candidates are advised to read the instructions contained within the equation and to use or comment on all the data presented. When commenting on electrode potentials, candidates should avoid the use of higher/lower as these phrases are meaningless due to the negative signs involved.</p>														
c		<p>Level 3 (5–6 marks) Reaches a comprehensive conclusion to determine the correct formulae of almost all of B, C, D, E, F and G. AND most correct equations and identifies some changes in oxidation number AND Calculation of M_r of the gas</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Reaches a conclusion to determine the correct formulae of at least half of B, C, D, E, F and G. AND EITHER some correct equations OR Any one correct equation and a relevant change in oxidation number OR any one correct equation and a correct calculation of the M_r</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Reaches a simple conclusion to determine the correct formulae of some of B, C, D, E, F and G OR The correct formulae for 1 of B, C, D, E, F and G with correct equation or</p>	<p>6(AO3.1×3 AO3.2×3)</p>	<p>Indicative scientific points may include</p> <table border="1"> <thead> <tr> <th></th> <th>Formula</th> </tr> </thead> <tbody> <tr> <td>B</td> <td>CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$</td> </tr> <tr> <td>C</td> <td>$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4</td> </tr> <tr> <td>D</td> <td>SO_2</td> </tr> <tr> <td>E</td> <td>$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$</td> </tr> <tr> <td>F</td> <td>CuI</td> </tr> <tr> <td>G</td> <td>I_2</td> </tr> </tbody> </table> <p>Experiment 1</p> <p>Equation</p> $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$ $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O} + 4\text{H}^+$ <p>Experiment 2</p> <p>Evidence</p> $n(\text{D}) = \frac{45}{24000} = 1.875 \times 10^{-3}$ $\text{Molar mass (D)} = \frac{0.12}{1.875 \times 10^{-3}} = 64$ <p>Equation</p> $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$ <p>Oxidation numbers</p> $\text{Cu } 0 \rightarrow \text{Cu } +2; \text{ S } +6 \rightarrow \text{S } +4$ <p>Experiment 3</p>		Formula	B	CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$	C	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4	D	SO_2	E	$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	F	CuI	G	I_2
	Formula																	
B	CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$																	
C	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4																	
D	SO_2																	
E	$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$																	
F	CuI																	
G	I_2																	

		<p>calculation.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p> <p>0 marks <i>No response or no response worthy of credit.</i></p>		<p>Equation</p> $\text{CuO} + 2\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O}$ $2\text{Cu}^{2+} + 4\text{I}^- \rightarrow 2\text{CuI} + \text{I}_2$ <p>OR</p> $2\text{Cu}(\text{NO}_3)_2 + 4\text{KI} \rightarrow 2\text{CuI} + \text{I}_2 + 4\text{KNO}_3$ <p>Oxidation numbers</p> <p>$\text{Cu} +2 \rightarrow \text{Cu} +1; \text{I} -1 \text{ to } 0$</p> <p><u>Examiner's Comments</u></p> <p>Answers were distributed across all 3 levels of achievement. Most of the candidates managed to identify at least some of the substances. Of the equations, the reaction of copper (II) oxide with nitric acid was most regularly seen correct, although many students could also represent the ligand replacement in Experiment 1. Many candidates were able to calculate M_r for gas D but some of those suggesting SO_2 as a possible formula preferred to have an equation in experiment 2 producing hydrogen. A few candidates used the M_r to suggest that the gas was 2O_2 and as such candidates found the equation between copper and sulphuric acid challenging. A good number of candidates identified F and G, recognising what they had learned from their work on redox titrations, and some were able to reproduce the equation. Incorrect formula of copper (I) iodide (CuI_2) was a common error. Many candidates made no attempt at identifying changes in oxidation states. Candidates are advised to address all parts of the question in order to access the higher levels and to allow sufficient time to attempt the LoR questions.</p>
		Total	16	
13		B	1 (AO1.2)	<u>Examiner's Comments</u>

					<p>This was another challenging question, with fewer candidates choosing the correct answer of B. Successful candidates often had the electronic configuration written down and focused on the higher energy electrons as to whether they were paired or not. Missing the $4s^1$ in Cu was the main omission to identify the correct answer.</p>
			Total	1	
14		i	<p>Bond angles $\text{H}_2\text{NCH}_2\text{COONa}$, bond angle = 107° AND $\text{HOOCCH}_2\text{NH}_3\text{Cl}$, bond angle = 109.5° ✓ Number of electron pairs Mark independently of angles</p> <p>In $\text{NaOH}/107^\circ$, (NH_2 has) 3 bonded pairs / 3 bonds AND 1 lone pair ✓</p> <p>In $\text{HCl}/109.5^\circ$, (NH_3^+ has) 4 bonded pairs / 4 bonds ✓</p>	3 (3 × AO1.2)	<p>ALLOW 107 ± 0.5</p> <p>ALLOW 109 OR 110°</p> <p>ALLOW NH_2 has 4 pairs, one of which is a lone pair</p> <p>For bonded pairs/bonds ALLOW bonded groups, atoms, elements, regions Bonded essential</p> <p>IGNORE electron region OR electron density</p> <p>IGNORE NH_3 has no lone pairs</p> <p>IGNORE lone pairs repel more (than bonded pairs)</p> <p>IGNORE shapes, even if wrong</p> <p>ALLOW bp for bonded pair and lp for lone pair</p> <p><u>Examiner's Comments</u></p> <p>This question required candidates to apply their knowledge and understanding of bond angles and electron pair repulsion of NH_3 and NH_4^+ to amino acid salts. The best candidates rose to this challenge and secured all 3 marks for correct bond angles and explanations in terms of the numbers of bonded and lone pairs around the N atoms.</p> <p>Overall, candidates found this question quite difficult. Many different</p>

				<p>bond angles were predicted, with 120° being the commonest incorrect H-N-H bond angle in $\text{H}_2\text{NCH}_2\text{COONa}$. The explanation for 120° was in terms of three bonding pairs and no lone pairs. 104.5° was also seen, presumably relating H_2N to H_2O. The 109.5° bond angle was correct more often, as was its explanation in terms of 4 bonding pairs.</p> <p>Many successful responses showed working on diagrams in which bonded and lone pairs had been included. This strategy will have helped candidates in their conclusions.</p>
	ii	<p>Equation:</p> $2 \text{H}_2\text{NCH}_2\text{COOH} + \text{Cu}(\text{CH}_3\text{COO})_2 \rightarrow \text{Cu}(\text{H}_2\text{NCH}_2\text{COO})_2 + 2 \text{CH}_3\text{COOH} \checkmark$ <p>Structures</p>  <p>Ligands must be shown as bidentate rings</p> <p>IGNORE connectivity for NH_2 BUT connectivity must be to O of COO</p>	<p>3 (AO2.6) (2 × AO2.5)</p> <p>ALLOW molecular formulae or mixture, e.g. $2\text{C}_2\text{H}_5\text{NO}_2 + \text{CuC}_4\text{H}_6\text{O}_4 \rightarrow \text{CuC}_4\text{H}_8\text{N}_2\text{O}_4 + 2\text{C}_2\text{H}_4\text{O}_2$ IGNORE charges i.e. IGNORE wrong or missing charges in ionic compounds if formula is correct/ e.g. ALLOW $\text{Cu}(\text{CH}_3\text{COO}^-)_2$, $\text{Cu}^+(\text{CH}_3\text{COO}^-)_2$</p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>IGNORE charges</p> <p>ALLOW arc to represent $-\text{CH}_2-$ between: C of $\text{C}=\text{O}$ and NH_2</p> <p>ALLOW 1 mark for 2 'correct' structures shown as tetrahedral e.g.</p>  <p>IGNORE missing Hs on C, e.g.</p> 	

					<p><u>Examiner's Comments</u></p> <p>Candidates were asked to predict an unfamiliar equation from provided information and to draw structures of square planar complexes containing an amino acid. Candidates found the structures easier than the equation, with many drawing 3D structures with 2 out-wedges and 2 in-wedges and attaching the NH₂ and COO groups correctly. It was also common to see a 'criss-cross' orientation, looking down on the complex, which is easier to draw. Many candidates connected the NH₂ and COO groups next to, and across from, each other in the isomers. A common error was for candidates to rotate their first structure, to produce a second drawing of the first structure. Less successful responses often tried to attach NH₂ and COO groups but with no CH₂ between the groups to produce a cyclic attachment. A minority of candidates ignored 'square planar' and drew tetrahedral structures instead.</p> <p>The equation proved to be very difficult, the commonest error being omission of the '2' balancing numbers for H₂NCH₂COOH and CH₃COOH. The formulae for ethanol or propanoic acid were also often seen for ethanoic acid.</p> <p>Candidates are advised to check all formulae and then to check balancing, the golden rules for successfully constructing all equations.</p>
			Total	6	
15		i	<p>Cl⁻ /It/They react with AgNO₃ / Ag⁺ /silver ions</p> <p>OR</p> <p>AgCl formed</p> <p>OR</p> <p>Ag⁺ + Cl⁻ → AgCl ✓</p>	1 (AO3.2)	<p>IGNORE chlorine/Cl for chloride ion</p> <p>IGNORE AgCl₂</p> <p><u>Examiner's Comments</u></p> <p>Almost all candidates realised that Cl⁻ ions would react with the added AgNO₃ at time = t₁.</p>

			<p>$[\text{CoCl}_4^{2-}]$ decreases AND $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ increases ✓</p> <p>ii Cl^- increase is $4 \times$ change in $[\text{CoCl}_4^{2-}]$ $/ [\text{Co}(\text{H}_2\text{O})_6]^{2+}$ ✓</p> <p>Equilibrium shifts to right ✓</p>	<p>3 (2 ×AO3.1) (1 ×AO3.2)</p>	<p>IGNORE missing charges and small slips in formulae, e.g. CoCl_4 missing bracket, etc IGNORE Cl^- for changes in concentration ALLOW suitable alternatives for 'shifts to right', e.g. towards products OR in forward direction OR 'favours the right'</p> <p><u>Examiner's Comments</u></p> <p>In contrast with Question 4 (a), most candidates did interpret the graphical information provided and related this to the reduced concentration of CoCl_4^{2-} ions and the increased concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ ions. Most candidates also referred to Equilibrium 4.1 to conclude that the equilibrium shifts to the right. Only the very best candidates recognised that the increase in Cl^- concentration following the initial addition of AgNO_3 was 4 times greater than the increase in the concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$, arising from the 4 : 1 ratio in the stoichiometry in the equation.</p>
			Total	4	