Mark Scheme (Results)

January 2024

Pearson Edexcel International Advanced Level
In Chemistry (WCH15)
Paper 01 Transition Metals and Organic Nitrogen Chemistry

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities. Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A

Question Number	Answer	Mark
1(a)	**The only correct answer is D** (zinc platinum) ***A*** *is incorrect because zinc is part of the reaction equation so the electrode must be zinc* ***B*** *is incorrect because zinc is needed in electrode 1 and chromium metal is not inert in electrode 2 so cannot be used* ***C*** *is incorrect because chromium metal is not inert in electrode 2*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is C** (358 g) ***A*** *is incorrect because this is the mass of chromium ions required for a 1 mol* dm^{-3} *solution* ***B*** *is incorrect because this is the mass of the anhydrous solid required* ***D*** *is incorrect because this mass of the hydrate gives a 2 mol* dm^{-3} *solution of* Cr^{3+}	**(1)**

Question Number	Answer	Mark
1(c)	**The only correct answer is A** (ΔS_{total} and ln K are positive) ***B*** *is incorrect because both are directly proportional to* E^o_{cell} ***C*** *is incorrect because both are directly proportional to* E^o_{cell} ***D*** *is incorrect because both are directly proportional to* E^o_{cell}	**(1)**

Question Number	Answer	Mark
2(a)	**The only correct answer is C** ($H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$) ***A*** *is incorrect because water is the product, not a reactant* ***B*** *is incorrect because oxygen is a reactant, not a product* ***D*** *is incorrect because this is the reverse equation*	**(1)**

Question Number	Answer	Mark
2(b)	**The only correct answer is D** (+1.23V) ***A*** *is incorrect because the sign is incorrect* ***B*** *is incorrect because this is the sum of the two electrode potentials and the first value must be positive not negative* ***C*** *is incorrect because this is the changing of both signs for the electrode potentials and then subtracting*	**(1)**

Question Number	Answer	Mark
3	**The only correct answer is B** (759 1561 2958 5290 7236) ***A*** *is incorrect because there is a large difference between ionisation 3 and 4 so this element is in Group 3* ***C*** *is incorrect because there is a large difference between ionisation 4 and 5 so this element is in Group 4* ***D*** *is incorrect because there is a large difference between ionisation 3 and 4 so this element is in Group 3*	**(1)**

Question Number	Answer	Mark
4	**The only correct answer is D** ($Fe^{2+} < V^{2+} < Cr^{2+}$) ***A*** *is incorrect because* V^{2+} ($V^{3+} + e^- \rightleftharpoons V^{2+} = -0.26V$) *has a greater reducing strength than* Fe^{2+} ($Fe^{3+} + e^- \rightleftharpoons Fe^{2+} = +0.77V$) ***B*** *is incorrect because* Cr^{2+} ($Cr^{3+} + e^- \rightleftharpoons Cr^{2+} = -0.41V$) *has the greatest reducing strength* ***C*** *is incorrect because this is the reverse order to the correct one*	**(1)**

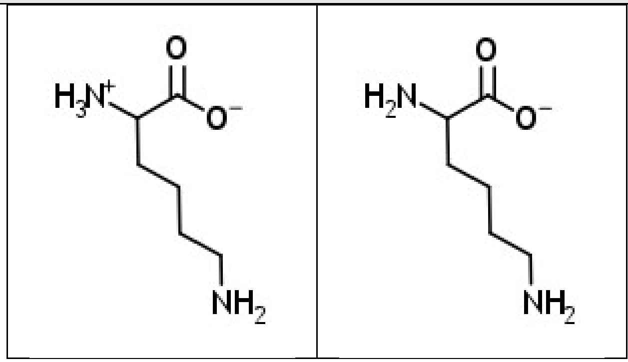
Question Number	Answer	Mark
5(a)	**The only correct answer is D** ([Ar] $3d^{10}$ $4s^1$ [Ar] $3d^{10}$ [Ar] $3d^9$) ***A*** *is incorrect because the copper atom has the structure [Ar]$3d^{10}4s^1$ and Cu^+ is [Ar]$3d^{10}$* ***B*** *is incorrect because the copper atom has the structure [Ar]$3d^{10}4s^1$ and Cu^+ is [Ar]$3d^{10}$ and Cu^{2+} is [Ar]$3d^9$* ***C*** *is incorrect because Cu^+ has the structure [Ar]$3d^{10}$ and Cu^{2+} is [Ar]$3d^9$*	**(1)**

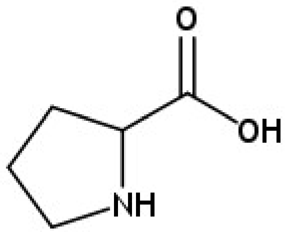
Question Number	Answer	Mark
5(b)	**The only correct answer is C** (T S P) ***A*** *is incorrect because T is the only Cu(0) present in the scheme* ***B*** *is incorrect because T is the only Cu(0) present in the scheme* ***D*** *is incorrect because S is the only Cu(I) in the scheme other than Cu(I) in copper(I) iodide*	**(1)**

Question Number	Answer	Mark
5(c)	**The only correct answer is D** (NH_3) ***A*** *is incorrect because aqueous ammonia is needed to convert $Cu(OH)_2$ to $[Cu(NH_3)_4(H_2O)_2]^{2+}$* ***B*** *is incorrect because aqueous ammonia is needed to convert $Cu(OH)_2$ to $[Cu(NH_3)_4(H_2O)_2]^{2+}$* ***C*** *is incorrect because aqueous ammonia is needed to convert $Cu(OH)_2$ to $[Cu(NH_3)_4(H_2O)_2]^{2+}$*	**(1)**

Question Number	Answer	Mark
6	**The only correct answer is D** (ketone) ***A*** *is incorrect because there are two methyl groups attached to two of the nitrogen atoms* ***B*** *is incorrect because there are two amide groups in the six-membered ring* ***C*** *is incorrect because there are two amine groups in the five-membered ring*	**(1)**

Question Number	Answer	Mark
7	**The only correct answer is B** (5) ***A*** *is incorrect because glycine, glutamic acid, 4 aspartic acid, tryptophan and phenylalanine are linked* ***C*** *is incorrect because glycine, glutamic acid, 4 aspartic acid, tryptophan and phenylalanine are linked* ***D*** *is incorrect because this is the total number of amino acids, but 4 are aspartic acid so 5 different types*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is B** () ***A*** *is incorrect because lysine is a zwitterion as a solid* ***C*** *is incorrect because lysine is a zwitterion as a solid and the structure in solution is for low pH* ***D*** *is incorrect because the structure in solution is for low pH*	**(1)**

Question Number	Answer	Mark
9	**The only correct answer is C** () ***A*** *is incorrect because there is no sulfur in the molecular formula* ***B*** *is incorrect because this has 2 more hydrogen atoms than the correct number* ***D*** *is incorrect because this has one more carbon atom and four more hydrogen atoms than the correct number*	**(1)**

Question Number	Answer	Mark
10(a)	**The only correct answer is C** (**R** and **S** only) ***A*** *is incorrect because P has six peaks* ***B*** *is incorrect because Q has six peaks* ***C*** *is incorrect because Q has six peaks*	**(1)**

Question Number	Answer	Mark
10(b)	**The only correct answer is A** (**P**) ***B*** *is incorrect because* ***Q*** *has a methyl group adjacent to a carbon with only one hydrogen so giving a doublet* ***C*** *is incorrect because* ***R*** *has a methyl group adjacent to a carbon with only one hydrogen so giving a doublet* ***D*** *is incorrect because* ***S*** *has a methyl group adjacent to a carbon with only one hydrogen so giving a doublet*	**(1)**

Question Number	Answer	Mark
10(c)	**The only correct answer is A** (**Q** only) ***B*** *is incorrect because* ***R*** *does not have a chiral carbon* ***C*** *is incorrect because* ***R*** *and* ***S*** *do not have a chiral carbon* ***D*** *is incorrect because* ***R*** *and* ***S*** *do not have a chiral carbon*	**(1)**

Question Number	Answer	Mark
11	**The only correct answer is B** (**X** and **Y**) ***A*** *is incorrect because* ***Z*** *is a condensation polymer* ***C*** *is incorrect because* ***Z*** *is a condensation polymer* ***D*** *is incorrect because* ***Z*** *is a condensation polymer*	**(1)**

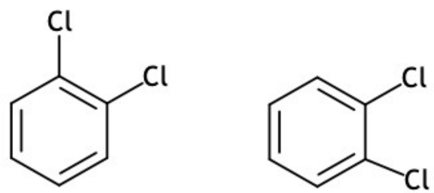
Question Number	Answer	Mark
12a	**The only correct answer is A** (± 0.0025 g) ***B*** *is incorrect because a balance must be used twice to measure a mass* ***C*** *is incorrect because this answer is obtained by doubling the percentage uncertainty rather than halving it* ***D*** *is incorrect because a balance must be used twice to measure a mass and also the value has been multiplied by 10*	**(1)**

Question Number	Answer	Mark
12b	**The only correct answer is C** (colourless) ***A*** *is incorrect because this is the colour of the solution after starch is added just before the end-point* ***B*** *is incorrect because this is the colour of a solution of iodine* ***D*** *is incorrect because this is the colour of the solution just before the end-point before starch indicator is added*	**(1)**

TOTAL FOR SECTION A = 20 MARKS

Section B

Question Number	Answer	Additional Guidance	Mark
13(a)	An explanation that makes reference to the following points: • (the x-ray diffraction shows) the bonds are the same length **(1)** Either • (therefore) electrons are evenly distributed (around the benzene ring) **(1)** Or • Kekule structure would have shorter double bonds / longer single bonds **(1)**	Ignore references to bond angles Allow it is a **regular** hexagon Ignore just it is a hexagon Ignore bond energy is the same Ignore electrons are delocalised / there is a ring of electrons Ignore shorter π bonds / longer σ bonds Ignore double bonds and single bonds are of different length	**(2)**

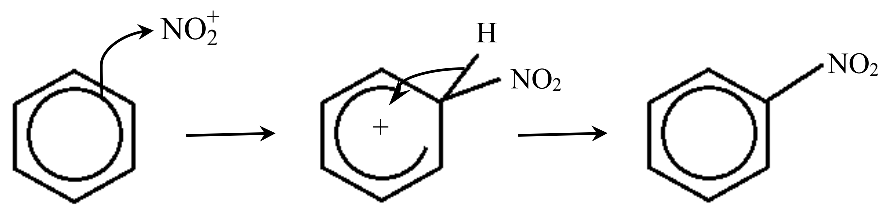
Question Number	Answer	Additional Guidance	Mark
13(b)	An explanation that makes reference to the following points: • because a Kekulé structure would have two isomers / two different structures **(1)** • one with the chlorines attached to carbons with a single bond between them and one with a double bond between them **(1)**	Allow shown as diagrams  Two diagrams showing the two possible structures would score (2)	**(2)**

Question Number	Answer	Additional Guidance	Mark
13(c)	An answer that makes reference to the following points: • the Kekulé structure would be expected to have an enthalpy change of hydrogenation of 3 x -118 kJ mol^{-1} / -354 kJ mol^{-1} (which is significantly different from the actual value of -205 kJ mol^{-1})	Allow 3 times enthalpy change of cyclohexene Award the actual value is 149 kJ mol^{-1} less exothermic than expected Award the actual value is 149 kJ mol^{-1} more stable than expected	**(1)**

Question Number	Answer	Additional Guidance	Mark
13(d)	A description that makes reference to the following points • there are six sigma bonds between carbon atoms / sigma bonds between pairs of carbon atoms **(1)** • six p_z orbitals (not involved in sigma bonding) **(1)** • which overlap (continuously) above and below the carbon ring / which overlap to form a (large) pi-system **(1)**	All three marks are available from labelled diagrams Allow there are twelve sigma bonds 6 of which are between carbon atoms Ignore reference to C-H sigma bonds Allow six p-orbitals Allow six electrons in (3) pi bonds Allow six electrons from the carbon (atoms) Allow six electrons from p-orbitals Allow around the benzene ring Ignore reference to numbers of electrons above and below the ring	**(3)**

(Total for Question 13 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
14(a)(i)	An explanation that makes reference to the following points: • concentrated / conc sulfuric acid concentrated / conc H_2SO_4 **(1)** • nitronium ion / NO_2^+ **(1)**	If name and formula are given both must be correct Do not award (dilute) sulfuric acid Allow balanced or unbalanced equation to form / NO_2^+ Do not award NO_2 without charge If no electrophile is given in (a)(i) allow the mark if NO_2^+ is used in the mechanism in (a)(ii) Allow answers in any order	**(2)**

Question Number	Answer	Additional Guidance	Mark
14(a)(ii)	• arrow from on or within the circle to N of NO_2^+ **(1)** • structure of intermediate ion **(1)** • curly arrow from C–H bond to within ring and correct organic product **(1)**	Example of mechanism  $(+\ H^+)$ Allow arrow from within hexagon Allow to anywhere on NO_2 including positive charge Allow TE on incorrect electrophile from (a)(i) 'Horseshoe' facing tetrahedral carbon and covering at least three carbons. Some part of the positive sign within the horseshoe. Do not award dotted/dashed C–H/C–N bonds unless clearly a 3D structure	**(3)**

Question Number	Answer	Additional Guidance	Mark
14(b)(i)	An answer that makes reference to the following points: • tin / Sn **and** (concentrated / conc) hydrochloric acid / HCl(aq)	If name and formula are given both must be correct Allow HCl Do not award other acids Ignore concentration even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
14(b)(ii)	An answer that makes reference to the following point: • reduction	Accept redox Ignore hydrogenation	**(1)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*14(c)</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.
<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 lines of reasoning</th></tr>
<tr><td>Answer shows a coherent 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>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 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 were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

In general it would be expected that
5 or 6 indicative points would get 2 reasoning marks
3 or 4 indicative points would get 1 reasoning mark
0, 1 or 2 indicative points would get zero reasoning marks

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning</td><td>(6)</td></tr>
</table>

	Indicative content **IP1** hazard advantage HCl produced by ethanoyl chloride is toxic (but ethanoic acid is not) / ethanoic acid is not toxic / poisonous (but HCl is) **IP2** hazard disadvantage ethanoic acid (produced by ethanoic anhydride) is flammable (but hydrogen chloride is not) **IP3** hazard disadvantage ethanoic anhydride is toxic / poisonous (but ethanoyl chloride is not) **IP4** reactivity (advantage) ethanoyl chloride might cause further reactions / side reactions / is harder to control or (advantage) ethanoic anhydride is slower so easier to control or (disadvantage) ethanoic anhydride would be slower / be too slow / have a lower rate	Allow reverse arguments For IPs 1-5. award IPs if not attributed to an advantage or disadvantage to a maximum of 5 IPs For IPs 1-5, award IPs if attributed incorrectly to advantage or disadvantage, but deduct one reasoning mark Allow hydrogen chloride may be produced as a corrosive mist (and is hard to handle / control) Allow hydrogen chloride means the reaction must be used in a fume cupboard Allow this is neutral because both ethanoyl chloride (and ethanoic anhydride are) also flammable Ignore comments about other hazards unless incorrect, then penalise in logic mark Ignore just ethanoyl chloride is more dangerous Accept ethanoyl chloride is too reactive / unsafe	

	IP5 atom economy calculation either calculation of atom economy for ethanoic anhydride and ethanoyl chloride or calculation of the molecular mass of HCl and ethanoic acid and a link to the lower mass giving the higher atom economy	Ignore sale of the other product ethanoic anhydride = 69.231 / 69.2 % and ethanoyl chloride = 78.717 / 78.7 % Or Mr ethanoic acid = 60 and HCl = 36.5 so ethanoyl chloride gives higher atom economy	
	IP6 atom economy statement identification that the starting material with the lower atom economy (ethanoic anhydride) is at a disadvantage / that the higher atom economy is an advantage	Ignore sale of the other product Allow TE relative to calculations in IP5 Allow a statement that one has a higher atom economy and that this is an advantage if IP5 has not been scored	

Question Number	Answer	Additional Guidance	Mark
14(d)	• One correct mathematical process even if the answer is incorrect **(1)** • Two further correct mathematical process even if the answer is incorrect **(1)** • Two further correct mathematical processes even if the answers are incorrect **(1)** • Final process and correct answer **(1)**	This calculation involves six mathematical processes 1) Calculation of molecular mass of *N*-phenylethanamide 2) Calculation of molecular mass of benzene 3) Divide by 135 (molecular mass of *N*-phenylethanamide) 4 Multiply by 78 (molecular mass of benzene) 5 Divide by 0.879 (density of benzene) 6) Divide by 35.2 × 100 (percentage yield) It is possible to carry out these processes in any order. Look first for the answer. Correct answer with some working scores (4). Next look for the processes and mark as shown in the Answer column. <u>Two examples of calculation</u> Route 1 M_r of *N*-phenylethanamide = (12 x 8) + 9 + 14 + 16 = 135 (g mol^{-1}) M_r of benzene = (12 × 6) + 6 = 78 (g mol^{-1}) moles of *N*-phenylethanamide = (10 ÷ 135) = 0.074074 (mol) mass of benzene for 100% yield = 0.074074 × 78 = 5.7778 / 5.78 (g) volume of for 100% yield = 5.7778 ÷ 0.879 = 6.573 (cm^3) minimum volume = 6.573 ÷ 35.2 × 100 = 18.674 / 18.7 / 19 (cm^3) Route 2 M_r of *N*-phenylethanamide = (12 x 8) + 9 + 14 + 16 = 135 (g mol^{-1}) M_r of benzene = (12 × 6) + 6 = 78 (g mol^{-1}) mass of *N*-phenylethanamide giving actual yield = 10 ÷ 35.2 × 100 = 28.409 (g) moles of *N*-phenylethanamide = 28.409 ÷ 135 = 0.21044 (mol) mass of benzene required = 0.21044 × 78 = 16.414 (g) volume of benzene required = 16.414 ÷ 0.879 = 18.674 / 18.7 / 19 (cm^3) If no other mark is awarded allow (1) for 10 ÷ 135 = 0.074074 (mol) Allow TE throughout Ignore SF except 1SF	**(4)**

Question Number	Answer	Additional Guidance	Mark
14(e)	An explanation that makes reference to the following points: • **lone pair of electrons on the oxygen** (may be shown on a diagram **(1)** • overlaps with pi / π cloud **and** activating the ring / increasing the electron density of the ring / making electrophilic attack easier **(1)**	Allow lone pair of electrons on the -OH group Accept donates / feeds into / interacts with delocalised electrons in the benzene / phenol ring Accept are delocalised into the benzene ring Ignore just makes the phenol more reactive. Ignore milder conditions are used to prevent further substitution	**(2)**

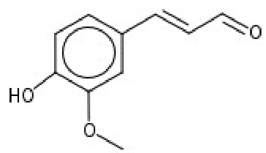
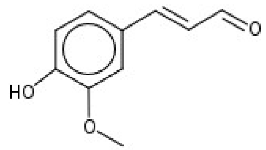
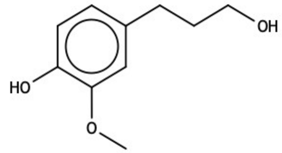
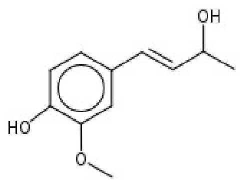
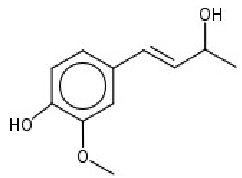
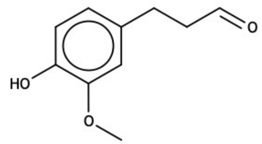
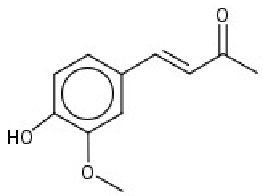
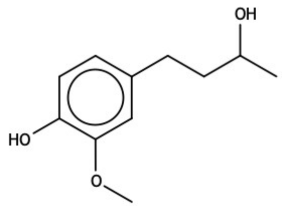
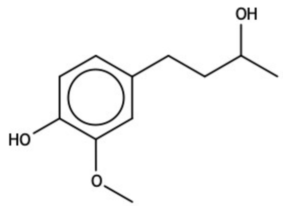
(Total for Question 14 = 19 marks)

Question Number	Answer	Additional Guidance	Mark
15(a)(i)	An answer that makes reference to the following points: • $C_{17}H_{26}O_4$		**(1)**

Question Number	Answer	Additional Guidance	Mark
15(a)(ii)	An answer that makes reference to the following points: • the OH is attached to a chiral carbon / gingerol exists as optical isomers **(1)** • The wedge shows the stereochemical arrangement / shows the shape of the molecule at the carbon (it is attached to) **(1)**	Ignore arguments about repulsion of the electrons Allow it shows the 3d arrangement of the C-OH bond Allow because the molecule is tetrahedral at the carbon Ignore just the molecule/shape is tetrahedral Ignore the molecule is not planar at the carbon Do not award the molecule is trigonal planar at the carbon Award (a wedged shaped bond) indicates the bond / OH group is in front of the plane of the paper / in the foreground Allow the wedge shaped bond shows the -OH group is in a different plane (to the carbon chain) Do not award a wedge shaped bond indicates the bond is behind the plane of the paper / in the background	**(2)**

Question Number	Answer	Additional Guidance	Mark
15(b)	An answer that makes reference to the following points:	Look for any of the given reagents and conditions and intermediates, but use only one Route (the one scoring the most marks). Allow the intermediates even if they would not be formed from the reagents and conditions stated.	**(7)**

- Reagents and conditions for Step 1 **(1)**
- structure of intermediate 1 **(1)**
- reagents and conditions for Step 2 **(1)**
- structure of intermediate 2 **(1)**
- reagents and conditions for Step 3 **(1)**
- structure of intermediate 3 **(1)**
- reagents and conditions for Step 4 **(1)**

Route 1	Route 2	Route 3
Oxidation A	Oxidation A	Reduction
		
Grignard Reagent	Grignard Reagent	Oxidation A
		
Oxidation B	Reduction	Grignard Reagent
		
Reduction	Oxidation B	Oxidation B

Allow any type of structural diagram / skeletal diagram

Penalise lack of sulfuric acid / H^+ and/or use of HCl in oxidation steps

		once only Oxidation A $K_2Cr_2O_7$ and H_2SO_4 / H^+ (with distillation) Or acidified $K_2Cr_2O_7$ Allow acidified $KMnO_4$ / $KMnO_4$ and H_2SO_4 Do not award reflux Oxidation B $K_2Cr_2O_7$ and H_2SO_4 / H^+ Or acidified $K_2Cr_2O_7$ Allow acidified $KMnO_4$ / $KMnO_4$ and H_2SO_4 (and reflux) Allow distillation Grignard Reagent CH_3MgBr or CH_3Br + Mg **and** (in) dry ether (followed by aqueous acid / water / acid) Allow equivalent chloride or iodide compounds Reduction H_2 and Ni / Pt (catalyst). Do not award $LiAlH_4$ in dry ether	

(Total for Question 15 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
16(a)(i)	An answer that makes reference to the following point: • oxygen is -2 / total for oxygen is -8 **and** hydrogen is +1 / total for hydrogen is +3 **and** a compound must be 0 overall (so Mn is +5)	Values may be seen in a calculation Values may be seen as labels on equation in the question Allow just the totals or the values for each atom for oxygen and hydrogen This can be scored by a statement or by a mathematical justification through a suitable calculation which assumes overall is 0.	**(1)**

Question Number	Answer	Additional Guidance	Mark
16(a)(ii)	An answer that makes reference to the following point: • correct formula for all three manganese compounds **(1)** • balanced equation **(1)**	$2H_3MnO_4 \rightarrow HMnO_4^- + MnO_2 + 2H_2O + H^+$ Accept $2MnO_4^{3-} + 4H^+ \rightarrow MnO_4^{2-} + MnO_2 + 2H_2O$ Dependent on M1 Do not award uncancelled electrons Allow multiples Ignore state symbols even if incorrect	**(2)**

Question Number	Answer	Additional Guidance	Mark
16(a)(iii)	An answer that makes reference to the following points: • selection of correct values for equation **(1)** • calculation of $E^{\ominus}$ and statement regarding thermodynamic feasibility **(1)**	<u>Example of calculation</u> $E^{\ominus}$ = 2.90 - 1.28 Allow (+)1.62(V) with no indication of electrode values $E^{\ominus}$ = (+)1.62(V) Value is positive so (thermodynamically) feasible Allow TE on calculation Allow > 0 for positive If no calculation is attempted allow a positive value of $E^{\ominus}$ is feasible Or A negative value for $E^{\ominus}$ is unfeasible	**(2)**

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	An answer that makes reference to the following points: • (pale) pink to colourless	Do not award purple Do not award colourless to pink	**(1)**

Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	• use of two mathematical process **(1)** • use of two further mathematical process **(1)** • use of two further mathematical processes **(1)** • use of two further mathematical processes **(1)**	To mark this item look first for the final answer. Correct answer with some working scores (4). Next look for the processes. Mark according to the number of processes as shown in the Answer column. This calculation involves eight mathematical processes 1) Calculation of Mr of sodium ethanedioate 2) Divide by calculated Mr (molecular mass of sodium ethanedioate) 3) $\times 10^{-3}$ or $\div$ 1000 an odd number of times 4) Divide by 250 (volume of sodium ethanedioate solution) 5) Multiply by 22.95 (mean titre volume) 6) multiply by 2/5 (mole ratio of manganate(VII) to ethanedioate) 7) divide by 25 (volume of manganate(VII) solution) 8) final answer to **2 or 3 SF** These processes can be done in any order except process 8. Volumes can be in cm^3 rather than dm^3 (as two of the powers will cancel) so do not penalise. This is covered in process 3. <u>Example of calculation</u> One common route is shown: $1.915 \div 134 = 0.014291$ / 0.0143 / 1.4291×10^{-2} / 1.43×10^{-2} (mol) $0.014291 \div 250 = 5.7164 \times 10^{-5}$ (mol cm^{-3}) (or = 0.057164 (mol dm^{-3})) $5.7164 \times 10^{-5} \times 22.95 = 0.0013119$ (mol) $2/5 \times 0.0013119 = 5.2477 \times 10^{-4}$ (mol) $5.2477 \times 10^{-4} \div 25 \times 10^{-3} = 0.0020991$ (mol dm^{-3}) = 0.0210 / 0.021 / 2.10×10^{-2} / 2.1×10^{-2} Ignore SF except for final mark Allow TE throughout	**(4)**

Question Number	Answer	Additional Guidance	Mark
16(b)(iii)	An answer that makes reference to the following points: • (brown suspension is) MnO_2 **(1)** • because only three electrons are required in forming MnO_2 (while five are required on forming Mn^{2+}) or because only three electrons are required to convert Mn(VII) to Mn(IV) (while five are required to convert Mn(VII) to Mn(II)) **(1)** • this results in a smaller titration volume / less ethanedioate required **(1)**	Allow any identification of MnO_2 including in an equation. May be shown in an ionic half-equation Allow formation of MnO_2 / Mn(IV) / requires less electrons Allow the ratio of manganese species:ethanedioate is 2:3 for Mn(IV) (but 2:5 for Mn(II)) Dependent on one of the previous two marks	**(3)**

(Total for Question 16 = 13 marks)

TOTAL FOR SECTION B = 50 MARKS

Section C

Question Number	Answer		Additional Guidance	Mark
17(a)(i)	An answer that makes reference to the following points: • the presence of chloride ligands / change in ligands / different ligands results in a different energy gap between (lower and higher energy) d-orbitals / result in a different splitting in the d-subshell	**(1)**	Penalise incorrect use of orbital rather than orbitals once only Allow different numbers of chloride ligands results in a different energy gap between the lower and higher energy d-orbitals Allow different ligands result in different splitting of the d-orbitals Allow different ligands give different d-d splitting Do not award the number of ligands is different Do not award the charge on the chromium ion is different Do not award they have different shapes	**(3)**
	• (colour results from the absorption of light by electrons) as they are promoted between d-orbitals / move from lower energy to higher energy (d-orbitals) / move to a higher energy level (d-orbital)	**(1)**	Allow d-d transitions as long as the splitting of the d-orbitals has been stated Do not award d-orbital Do not award d-block electrons	
	• so different wavelengths / frequencies (of light) are absorbed / transmitted / reflected (resulting in different colours)	**(1)**	Allow different energies of light Allow colour absorbed? Do not award emitted	

Question Number	Answer	Additional Guidance	Mark
17(a)(ii)	An explanation that makes reference to the following points: Reagent • use silver nitrate solution (which reacts with free chloride ions) to give a precipitate **(1)** Practical technique • use equal volumes of each solution of the three isomers (because they are equimolar solutions) **(1)** • add an excess of silver nitrate solution **(1)** • collect the precipitate / silver chloride by filtration / centrifuge **and** dry the precipitate **(1)** • weigh the silver chloride **and** calculate the number of moles (of silver chloride / chloride ions / silver ions and so find the ratio) or weigh the silver chloride for each isomer **and** find the ratio **(1)**	May be shown with an equation Ignore presence / absence of dilute nitric acid Do not award if other reagents are added but allow other marks to be scored Allow an appropriate titrimetric method Allow the same amount of solution Allow prepare solutions using the same mass of isomer Allow add until no more precipitate is produced Do not award decant Allow centrifuge (MP4) followed by measure the height of the precipitate (in the tube) **and** calculate ratio heights (MP5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
17(b)(i)	An answer that makes reference to the following point: • correct equation	$[Pt(NH_3)_2Cl_2] + H_2O \rightarrow [Pt(NH_3)_2(H_2O)Cl]^+ + Cl^-$ Allow ligands in any order Allow displayed formula but ignore incorrect shapes Ignore state symbols even if incorrect Ignore omission of square brackets Do not award products without charges	**(1)**

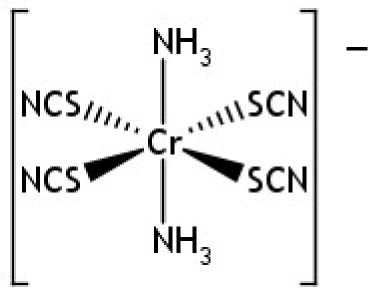
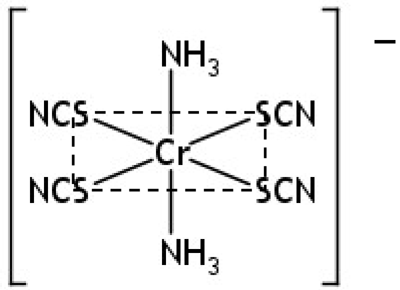
Question Number	Answer	Additional Guidance	Mark
17(b)(ii)	An answer that makes reference to the following point: • a **lone pair / pair of electrons** on nitrogen is donated to / forms a coordinate bond / forms a dative (covalent) bond (with platinum ion)	Allow a lone pair is attached (to the platinum ion) Allow oxygen Do not award long pair Ignore just guanine/adenine/it has a lone pair Ignore ligand exchange	**(1)**

Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	An answer that makes reference to the following points: • the second chloride is too far from / on the opposite side to the DNA strand **(1)** • to bind with a second guanine / adenine is too difficult / not possible **(1)**	Ignore just the chloride is on the opposite side Ignore the chloride is on the opposite side of the trans-platin Allow so trans-platin can only form one bond with DNA (while cis-platin can form two)	**(2)**

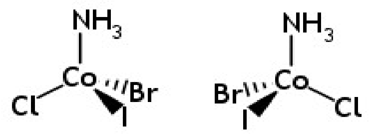
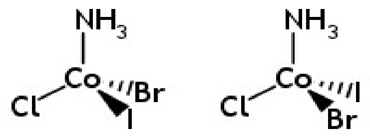
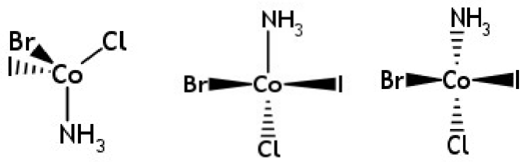
<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>17(c)(i)</td>
<td>

calculation of the moles of Cr, S, O and N (1)
calculation of the ratio of moles (1)
calculation of x, y and z (1)

</td>
<td>
<u>Example of calculation:</u>
<table>
<tr><th></th><th>Cr</th><th>S</th><th>O</th><th>N</th></tr>
<tr><td>$\div A_r$</td><td>14.67 ÷ 52.0
= 0.28212</td><td>36.23 ÷ 32.1
= 1.1287</td><td>4.51 ÷ 16
= 0.28188</td><td>27.65 ÷ 14
= 1.975</td></tr>
<tr><td>÷
0.28188</td><td>1</td><td>4</td><td>1</td><td>7</td></tr>
<tr><td>so</td><td></td><td>x = 4</td><td>z = 1</td><td>y = 7 – 5 = 2</td></tr>
</table>
Award correct formula for Reinecke’s salt given
Ignore any attempts to calculate C or H
Correct values with some working scores (3)
If no other mark is awarded 3 correct ratio of moles (and one incorrect) scores 1
</td>
<td>(3)</td>
</tr>
</table>

Question Number	Answer	Additional Guidance	Mark
17(c)(ii)	An answer that makes reference to the following points: • ammine ligands trans (180°) to each other in an octahedral complex **(1)** • the rest of the ion correct including charge and at least one dot bond and one wedge bond **(1)** or the rest of the ion correct including four ligands joined to show them in plane	Examples of diagram   Allow charge anywhere Allow structure lines with no bracket Ignore connectivity of ligands A cis- structure scores 1 for the octahedral shape and charge on the ion	**(2)**

Question Number	Answer	Additional Guidance	Mark
17(d)(i)	An answer that makes reference to the following points: • cobalt / central metal ion has four different groups / ligands attached to it **(1)** • giving (two) non-superimposable mirror images **(1)**	Allow cobalt is a chiral centre Allow Co is bonded to four different atoms / four different ligands Ignore rotation of plane polarised light	**(2)**

Question Number	Answer	Additional Guidance	Mark
17(d)(ii)	An answer that makes reference to the following points: • two structures drawn as mirror images or two structures drawn with two ligands swapped	Examples of diagram Correct answers must contain at least one dotted line and one wedged line   Accept second molecule in any correct orientation e.g. (compared to the molecule on the left in the examples above)  would all score the mark Ignore connectivity of the ammonia molecule on the vertical bond. Do not award connectivity of ammonia on the three bonds which are not vertical if via the H	**(1)**

(Total for Question 17 = 20 marks)
TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 90 MARKS