Mark Scheme (Results)

October 2022

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.

Section A (Multiple Choice)

Question number	Answer	Mark
1	**The only correct answer is A** (decreases; gains electrons) ***B*** *is incorrect because nitrogen gains electrons* ***C*** *is incorrect because the oxidation number of nitrogen decreases* ***D*** *is incorrect because the oxidation number of nitrogen decreasesand it gains electrons*	**(1)**

Question number	Answer	Mark
2	**The only correct answer is D** (100000 Pa) ***A*** *is incorrect because the standard pressure is 1 atm not 1 Pa* ***B*** *is incorrect because the standard pressure is 100 kPa not 100 Pa* ***C*** *is incorrect because the standard pressure is* 100000 *Pa not 1000 Pa*	**(1)**

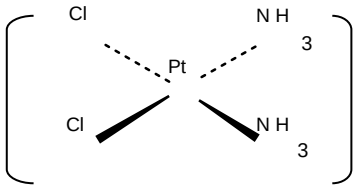
Question number	Answer	Mark
3(a)	**The only correct answer is D** (platinum and platinum) ***A*** *is incorrect because neither chromium metal nor titanium metal are involved in the cell* ***B*** *is incorrect because chromium metalis not involved in the cell* ***C*** *is incorrect because titanium metalis not involved in the cell*	**(1)**

Question number	Answer	Mark
3(b)	**The only correct answer is C**(+0.19 V) ***A*** *is incorrect because the* $E^{\ominus}_{cell}$ value *has been added to the electrode potential of the* $Cr_2O_7^{2-}$, Cr^{3+} *electrode system rather than subtractedand the sign has been reversed.* ***B*** *is incorrect because the sign has been reversed.* ***D*** *is incorrect because the* $E^{\ominus}_{cell}$ value *has been added to the electrode potential of the* $Cr_2O_7^{2-}$, Cr^{3+} *electrode system rather than subtracted*	**(1)**

Question number	Answer	Mark
4	**The only correct answer is D**(more positive; unchanged) ***A*** *is incorrect because the* E_{cell} *values must be increasing and* E_a *values are not affected by concentrations.* ***B*** *is incorrect because the* E_{cell} *values must be increasing* ***C*** *is incorrect because* E_a *values are not affected by concentrations.*	**(1)**

Question number	Answer	Mark
5	**The only correct answer is C**(the only stable zinc ion has the electronic configuration [Ar] $3d^{10}$) ***A*** *is incorrect because the electronic configuration of the atom does not determine the classification* ***B*** *is incorrect because while the formation of more than one type of ion is a characteristic of transition metals it does not determine the classification* ***D*** *is incorrect because while catalytic properties are a characteristic of transition metals, they do not determine the classification*	**(1)**

Question number	Answer	Mark
6	**The only correct answer is B** [Ar] ↑↓ | ↑ | ↑ | ↑ | ↑ | | ***A*** *is incorrect because both 4s electrons are removed when the Fe2+ ion is formed from the Fe atom* ***C*** *is incorrect because both 4s electrons are removed when the Fe2+ ion is formed from the Fe atom* ***D*** *is incorrect because electrons occupy a subshell with the maximum possible number of unpaired electrons*	**(1)**

Question number	Answer	Mark
7	**The only correct answer is A**(structure X only)  ***B*** *is incorrect because only the cis isomer is used* ***C*** *is incorrect because* $Pt(NH_3)_2Cl_2$ *is square planar* ***D*** *is incorrect because only the cis isomer is used*	**(1)**

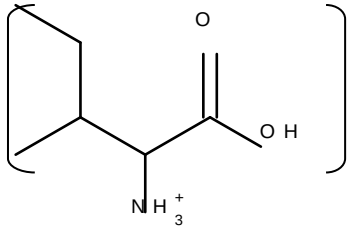
Question number	Answer	Mark
8	**The only correct answer is A**(bonds reversibly to an iron(II) ion) ***B*** *is incorrect because the reaction is reversible* ***C*** *is incorrect because the iron(II) ion is not replaced* ***D*** *is incorrect because the iron(II) ion is not replaced and the reaction is reversible*	**(1)**

Question number	Answer	Mark
9	**The only correct answer is C**(the oxidation of Ti^+ is catalysed by Ag^+ ions) ***A*** *is incorrect because* Ag^+ *is unchanged at the end of the sequence while the* Ce^{4+} *ions are reduced* ***B*** *is incorrect because* Ag^+ *is unchanged at the end of the sequence while the* Ti^{2+} *ions are formed from* Ti^+ *then further oxidised to* Ti^{3+} ***D*** *is incorrect because* Ag^{2+} *ions are formed and removed in the reaction*	**(1)**

Question number	Answer	Mark
10	**The only correct answer is C**(12 (σ bonds) 3 (π bonds)) ***A*** *is incorrect because this does not include the C−H bonds* ***B*** *is incorrect because this does not include the C−H bonds and counts all the C−C bonds asboth σ bonds and πbonds* ***D*** *is incorrect because this counts all the C−C bonds as both σ bonds and π bonds*	**(1)**

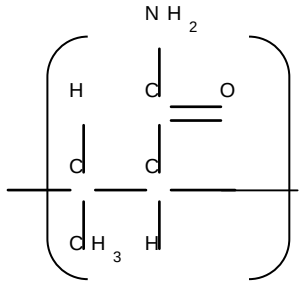
Question number	Answer	Mark
11	**The only correct answer is D**(concentrated sulfuric acid containing dissolved sulfur trioxide) ***A*** *is incorrect because fuming sulfuric acid contains dissolved* sulfur trioxide ***B*** *is incorrect because fuming sulfuric acid contains dissolved* sulfur trioxide ***C*** *is incorrect because fuming sulfuric acid contains dissolved* sulfur trioxide	**(1)**

Question number	Answer	Mark
12(a)	**The only correct answer is B**(2-amino-3-methylpentanoic acid) ***A*** *is incorrect because the longest carbon chain has five atoms* ***C*** *is incorrect because the longest carbon chain has five atoms and the carbon chain is numbered from the acid group* ***D*** *is incorrect because the carbon chain is numbered from the acid group*	**(1)**

Question number	Answer	Mark
12(b)	**The only correct answer is B**  ***A*** *is incorrect because this structure will occur at alkaline pH* ***C*** *is incorrect because the amine group will protonate in preference to the carboxylic acid group at this pH.* ***D*** *is incorrect because this zwitterion will occur at neutral pH*	**(1)**

Question number	Answer	Mark
13	**The only correct answer is B**($CH_3CH_2CH_2CH_2NH_3Cl$) *A* *is incorrect because substitution does not occur in these conditions* ***C*** *is incorrect because an amide does not form in this way* ***D*** *is incorrect because a carboxylic acid does not form in these conditions*	**(1)**

Question number	Answer	Mark
14	**The only correct answer is C**(butanenitrile; lithium tetrahydridoaluminate(III)) ***A*** *is incorrect because propanenitrile would give propylamine* ***B*** *is incorrect because propanenitrile would give propylamineand tin with HCl does not reduce nitriles* ***D*** *is incorrect because tin with HCl does not reduce nitriles*	**(1)**

Question number	Answer	Mark
15	**The only correct answer is A**  ***B*** *is incorrect because the methyl group cannot form part of the polymer chain* ***C*** *is incorrect because the peptide link cannot form from an amide group* ***D*** *is incorrect because the methyl group cannot form part of the polymer chain and the peptide link cannot form from an amide group*	**(1)**

Question number	Answer	Mark
16	**The only correct answer is A**(four) ***B*** *is incorrect because onlythe ring carbon atomshave been considered and symmetry has been ignored* ***C*** *is incorrect because the ring symmetry has been ignored* ***D*** *is incorrect because this is just the total number of carbon atoms*	**(1)**

Question number	Answer	Mark
17	**The only correct answer is C**(cocaine less soluble;cocaine higher pH) ***A*** *is incorrect because carboxylic acids are more soluble than esters* ***B*** *is incorrect because carboxylic acids are more soluble and more acidic than esters* ***D*** *is incorrect because carboxylic acids are more acidic than esters*	**(1)**

Question number	Answer	Mark
18	**The only correct answer is B**(soluble (at high temperature); insoluble (at low temperature) ***A****is incorrect because the hot filtration removes the insoluble impurities* ***C*** *is incorrect because the hot filtration removes the insoluble impurities and the cold filtration separates the soluble impurities* ***D*** *is incorrect because the hot filtration removes the insoluble impurities*	**(1)**

Total for Section A = 20 marks

Section B

Do not penalise case errors e.g. CO for Co and Pv = NRT

Question number	Answer	Additional guidance	Mark
19(a)	An explanation that makes reference to the following • +5 (1) • vanadium has 3 (unpaired) electrons in the (3)d subshell and 2 electrons in the 4s (orbital / subshell) (1) • the total number of 3d and 4s electrons gives the highest (stable) oxidation state (1)	Allow 5+ / 5 / +V / V / V^{5+} Accept electronic configuration of V is [Ar]$3d^3$ $4s^2$ / [Ar]$4s^2$ $3d^3$ / 'electrons in boxes' Ignore errors in [Ar] configuration Do not award incorrect electronic configurations of 3d and 4s Allow electronic configuration of V^{5+} shown if electronic configuration of V given for M2 Allow vanadium has 5 electrons in its valence shell Allow vanadium has 5 outer electrons Allow loss of 5 electrons from electronic configuration [Ar] $3d^5$ Do not award 'orbit' for orbital / shell / subshell No TE on other incorrect electronic configurations Ignore reference to stability of V^{5+} Ignore just 'loses 5 electrons'	**3**

Question number	Answer	Additional guidance	Mark
19(b)(i)	A justification that makes reference to the following • equation for reaction of thiosulfate ions and VO^{2+} (1) • equation for reaction of thiosulfate ions and V^{3+} (1) • calculation of first E_{cell} value (using correct half – equations) **and** (positive E_{cell} value indicates) reduction to V^{3+} feasible (1) • calculation of second E_{cell} value **and** (negative E_{cell} value indicates) further reduction (to V^{2+}) not feasible (1)	$2VO^{2+} + 4H^{+} + 2S_2O_3^{2-} \rightleftharpoons 2V^{3+} + S_4O_6^{2-} + 2H_2O$ $2V^{3+} + 2S_2O_3^{2-} \rightleftharpoons 2V^{2+} + S_4O_6^{2-}$ Penalise incorrect balancing once only. Penalise uncancelled species (including e^{-}) once only Four correct half-equations scores (1) Do not award use of $S_2O_3^{2-}$ / S half-equation $E_{cell} = 0.34 - 0.09 = (+)0.25(V)$ $E_{cell} = -0.26 - 0.09 = -0.35(V)$ Allow 1 mark for **both** E_{cell} values calculated without explanation Ignore state symbols even if not correct No TE on incorrect ionic half-equations	**4**

Question number	Answer	Additional guidance	Mark
19(b)(ii)	An explanation that makes reference to the following • Electrode potential for $Ni|Ni^{2+}$ is very close to $V^{2+}|V^{3+}$ (1) • Some reduction of V^{3+} will occur **and** although E_{cell} is negative (1)	Accept $E_{cell} = -0.26-(-0.25) = -0.01$(V) Allow E_{cell} close to zero /(only) 0.01 V difference Allow Some reduction of V^{3+} will occur **and** $Ni + 2V^{3+} \rightleftharpoons Ni^{2+} + 2V^{2+}$ / equilibrium formed Allow Some reduction of V^{3+} will occur **and** if conditions are not standard /conditions are changed Ignore just 'V^{3+} reduced' Ignore just 'nickel is a strong(er) reducing agent'	**2**

Question number	Answer	Additional guidance	Mark
19(c)(i)	An answer that makes reference to the following • pale pink	Allow just 'pink' Do not award purple / red Ignore reference to the colour before the end-point	**1**

Question number	Answer	Additional guidance	Mark
19(c)(ii)	An answer that makes reference to the following • Because MnO_4^- ions have more positive standard electrode potential than VO^{2+}, VO^{2+} should be oxidised using up MnO_4^- (1) • so reaction rate must be slow or activation energy is high (1)	Accept E_{cell}= 1.51− 1.00 = +0.51(V) Allow conditions not standard Allow MnO_4^- can oxidise VO^{2+} to VO_3^- (reaction ratio 1:5) (1) Then VO_3^- will oxidise Fe^{2+} to Fe^{3+} **and** Overall this is equivalent to MnO_4^- oxidising Fe^{2+} to Fe^{3+} (1) Ignore reference to catalysis	**2**

uestion number	Answer	Additional guidance	Mark
19(c)(iii)	• calculation of moles of manganate(VII) in mean titre (1) • calculation of moles of Fe^{2+} in 25 cm^3 after reaction (1) • calculation of moles of Fe^{2+} in 25 cm^3 at start (1) • calculation of mol Fe^{2+} that reacted in 25 cm^3 (1) • mol Fe^{2+} = mol VO_3^- ions (stated or implied) **and** scales VO_3^- ions to 250 cm^3 (1) • calculation of mass of vanadium (1) • calculation of percentage vanadium in ferrovanadium (1) If formula mass of VO_3^- (98.9) is used instead of A_r of vanadium, mass = 98.9 × 4.0562 x 10^{-2} = 4.0116 (g) percentage = 100 × 4.0116 ÷ 4.87 = 82.373(%) scores (6) If M3 and M4 omitted % = 100 x 0.021938 x 50.9 ÷ 4.87 = 22.939(%) scores (5)	Example of calculation mol MnO_4^-= $\frac{22.50 \times 0.0195}{1000}$ = 4.3875 x 10^{-4} / 0.00043875 mol Fe^{2+} in 25 cm^3 = 5 x mol MnO_4^- = 2.1938 x 10^{-3} / 0.0021938 mol Fe^{2+} in 25 cm^3= $\frac{25.00 \times 0.250}{1000}$ = 6.25 x 10^{-3} / 0.00625 6.25x 10^{-3} − 2.1938 x 10^{-3} = 4.0562 x 10^{-3} mol VO_3^- in 250 cm^3 = 10 x 4.0562 x 10^{-3} = 4.0562 x 10^{-2} mass of V = 50.9 x 4.0562 x 10^{-2} = 2.06463(g) [using unrounded values] % vanadium = $\frac{100 \times 2.06463}{4.87}$ = 42.395% [using unrounded values] = 42.4 % TE provided some attempt to use titration data to calculate mass and % < 100 Ignore SF except 1 SF Correct answer with some working scores (7) Do not penalise **correct** rounding of intermediate values	**7**

Question number	Answer	Additional guidance	Mark
19(d)	An answer that makes reference to the following • balanced equation showing the reduction of vanadium(V) oxide by sulfur dioxide (1) • balanced equation showing the oxidation of vanadium species formed by reduction back to vanadium(V) oxide (1)	Examples of equations $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ $V_2O_4 + ½O_2 \rightarrow V_2O_5$ Ignore uncancelled SO_3 Allow for 2 marks any balanced equations showing formation of a lower oxidation state oxide by reaction with SO_2 then a higher oxidation state by reaction with O_2 Penalise error in formula of intermediate (e.g. $V_2O_4^-$) once only Two balanced equations showing oxidation by O_2 followed by reduction by SO_2 scores (1) Allow multiples Ignore state symbols even if incorrect	**2**

Total for Question 19 = 21marks

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>*20</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, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

If there is 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>

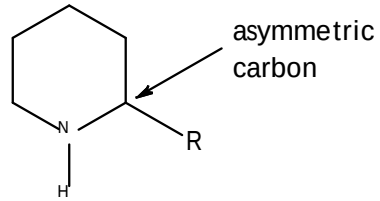
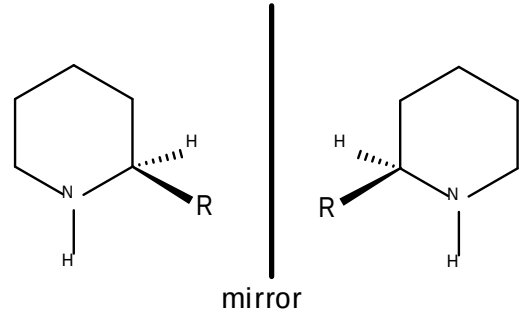
Question number	Answer	Additional guidance	Mark
20 continued	**Indicative content** **IP1** (the π electrons of) both benzene and cyclohexene attract / react with electrophiles (similarity) **IP2** delocalised (π) **electron** ring in benzene is (very)stable **IP3** so benzene undergoes (electrophilic) substitution whereas cyclohexene undergoes (electrophilic) addition **IP4** both benzene and phenol undergo (electrophilic) substitution (similarity) **IP5** the lone pair of electrons on the oxygen in phenol interacts with / overlaps the delocalised (π)electron system of the benzene ring **IP6** phenol reacts (with electrophiles) much faster / under much milder conditions / does not require a catalyst / has a lower activation energy / E_a	Accept structures for names throughout Do not penalise unbalanced / incomplete / incorrect equations If name and formula given both must be correct Allow both benzene and cyclohexene form carbocation (intermediates) Do not award nucleophilic reactions Allow delocalised (π) **electrons** make benzene stable If neither IP1 or IP2 given, allow an IP for benzene has delocalised **electrons** but cyclohexene does not. Allow benzene forms bromobenzene **and** cyclohexene forms 1,2-dibromocyclohexane. Do not award nucleophilic reactions Allow benzene forms bromobenzene **and** phenol forms 2,4,6-tribromophenol Allow the lone pair of electrons on the oxygen in phenol increases the electron density of the (benzene) ring Accept benzene requires a halogen carrier / catalyst Allow $AlBr_3$ / $AlCl_3$ / $FeBr_3$ / Fe & Br_2 Ignore just 'bromine reacts more easily with phenol than with benzene' / 'phenol is more susceptible to electrophilic attack'	**6**

Question number	Answer	Additional guidance	Mark
21(a)(i)	• rearrangement of the ideal gas equation (IGE) (1) • conversion of temperature to Kelvin (1) • conversion of volume of vapour to m^3 (1) • solve IGE for *M* (1) Alternative method • rearrangement of the ideal gas equation (IGE) (1) • conversion of temperature to Kelvin (1) • conversion of volume of vapour to m^3 (1) • solve IGE for *M* (1)	Example of calculation $pV = nRT = \frac{m \text{ x } R \text{ x } T}{M}$ $M = \frac{m \text{ x } R \text{ x } T}{p \text{ x } V}$ T = 185 + 273 (= 458 K) V = 67.1 ÷ 1 x 10^6 = 6.71 x 10^{-5} (m^3) $M = \frac{0.235 \text{ x } 8.31 \text{ x } 458}{105000 \text{ x } 6.71 \text{ x } 10^{-5}}$ = 126.95 / 127 (g mol^{-1}) TE on incorrect conversions for M4 $pV = nRT$ $n = \frac{pV}{RT}$ T = 185 + 273 (= 458 K) V = 67.1 ÷ 1 x 10^6 = 6.71 x 10^{-5} $n = \frac{105000 \text{ x } 6.71 \text{ x } 10^{-5}}{8.31 \text{ x } 458}$ = 1.8512 x 10^{-3} M = $\frac{0.235}{1.8512 \text{ x } 10^{-3}}$ = 126.947 / 126.9 / 127 (g mol^{-1}) Use of 1.85 gives 127.03 Allow units of g or no units Allow conversion of pressure to kPa **&** volume to dm^3 Correct answer with no working scores zero	**4**

Question number	Answer	Additional guidance	Mark
21(a)(ii)	An answer that makes reference to the following points: • calculation of the molar mass of the ring structure of coniine (1) • calculation of the molar mass of R **and** deduction of the molecular formula of R (1)	the molar mass of ring = 5 x 12 + 14 + 10 x 1 = 84 g mol^{-1} the molar mass of R = 127 – 84 = 43 (g mol^{-1}) R is C_3H_7 (only possible alkyl group formula for molar mass = 43 (g mol^{-1})) Allow structural formulae e.g. $–CH_2CH_2CH_3$ Allow this mark if the formula is given in (b)(i) TE on incorrect molar mass of ring provided R contains C and H only	2

Question number	Answer	Additional guidance	Mark
21(b)(i)	An answer that makes reference to the following points: • identification of the two possible R structures (1) • $-CH_2CH_2CH_3$ has three proton environments (as all three are different) (1) • $–CH(CH_3)_2$ has two proton environments (because the methyl groups are equivalent) (1)	$-CH_2CH_2CH_3$ and $–CH(CH_3)_2$ Do not award if additional structures are given Accept the peak areas show that the environments have 2, 2 and 3 protons as in $-CH_2CH_2CH_3$ Accept $–CH(CH_3)_2$ would have peak areas 1 and 6 If no other mark is scored identifying R as $-CH_2CH_2CH_3$ with any valid reason based on the NMR data, scores (1) No TE if R not given as an alkyl group e.g. CH_3CO	3

Question number	Answer	Additional guidance	Mark
21(b)(ii)	An answer that makes reference to the following points: • proton environment 1 (has 3 protons and) will be a triplet (1) • proton environment 3 (has 2 protons and) will be a quartet (1) **Either** • proton environment 1(is a triplet because it) is adjacent to a CH_2 in the chain **or** • as proton environment 3(is a quartet because it) is adjacent to a CH in the ring and to a CH_2 in the chain (1)	May be shown on a diagram Allow there are 2 adjacent protons Allow there are 3 adjacent protons M3 dependent on correct splitting pattern(s)	**3**

Question number	Answer	Additional guidance	Mark
21(c)	An explanation that makes reference to the following points: EITHER • identification of the asymmetric carbon atom in coniine (1) • the molecule is non-superimposable on its mirror image **and** hence coniine shows optical isomerism (1) OR • There is not free rotation around the N─C(─R) bond (because of the ring) (1) • Coniine shows cis-trans / *E*-*Z* / geometrical isomerism **and** because the lone pair on N leads to the H having two possible orientations (1)	 Ignore incorrect alkyl groups Allow carbon atom is attached to four different groups **and** hence coniine shows optical isomerism OR Allow carbon atom is chiral **and** coniine shows optical isomerism Do not award four different 'molecules' Diagram showing the two enantiomers and a mirror plane scores M1 and M2 (dots and wedge **not** required)  This diagram including the mirror plane but without H shown (and chiral carbon unlabelled) scores (1)	**2**

Total for Question 21 = 14 marks

Question number	Answer	Additional guidance	Mark
22(a)	• equating of % water with mass in 1 mol of viridian (1) • calculation of molar mass of viridian (1) • calculation of molar mass of metal oxide (1) • calculation of molar mass of metal **and** deduction of its identity (1)	Example of calculation 19.15% of 1 mol of viridian weighs 36 g 1 mol of viridian weighs 100 x 36 ÷ 19.15 (g) **and** molar mass = (100 x 36 ÷ 19.15) = 188 (g mol^{-1}) molar mass = 188 – 36 = 152 (g mol^{-1}) molar mass of metal = ½(152 – 3 x 16) = 52 (g mol^{-1}) **and** element is chromium / Cr TE at each stage Correct answer with some working scores (4) Correct answer with no working (0)	**4**

Question number	Answer	Additional guidance	Mark
22(b)(i)	An answer that makes reference to • ligand exchange / ligand replacement / ligand substitution		**1**

Question number	Answer	Additional guidance	Mark
22(b)(ii)	An answer that makes reference to • Full formula of one complex (1) • completion of full balanced **ionic** equation (1)	Allow omission of square brackets Ignore extra brackets e.g. $[Co(Cl)_4]^{2-}$ $[Co(H_2O)_6]^{2+}$ or $[CoCl_4]^{2-}$ $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$ Ignore state symbols even if incorrect	**2**

Question number	Answer	Additional guidance	Mark
22(b)(iii)	An explanation that makes reference to the following points • (the aqua complex is octahedral and) chloro complex of cobalt / tetrachlorocobaltate(II) / $CoCl_4^{2-}$ is tetrahedral (1) • because chloride ions / Cl^- are too large for six ions to coordinate around the cobalt(II) ion / Co^{2+} (1)	Allow octahedral (complex) changes to tetrahedral (complex) Allow the complex formed is tetrahedral Do not award Cl / chlorine atoms / molecules If no other mark is scored, chloride ions / Cl^- are larger than H_2O scores (1) [Both species needed] If no other mark is scored, coordination number changes from 6 to 4 scores (1) Ignore just 'chloride ions / Cl^- are larger'	**2**

Total for Question 22 = 9 marks
Total for Section B = 50 marks

Section C

<table>
<tr><th>Question number</th><th>Answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>23(a)</td><td>

working out molecular formula (1)
calculation of molar mass (1)
calculation of percentage by mass of one element (1)
calculation of percentage by mass of other elements (1)

Some common incorrect answers (score (3))
<table>
<tr><th>Formula</th><th>M_r</th><th>%C</th><th>%H</th><th>%O</th></tr>
<tr><td>$C_{13}H_{10}O_7$</td><td>278</td><td>56.12</td><td>3.60</td><td>40.29</td></tr>
<tr><td>$C_{13}H_{11}O_7$</td><td>279</td><td>55.91</td><td>3.94</td><td>40.14</td></tr>
<tr><td>$C_{13}H_{13}O_7$</td><td>281</td><td>55.52</td><td>4.63</td><td>39.86</td></tr>
<tr><td>$C_{13}H_{17}O_7$</td><td>285</td><td>54.74</td><td>5.96</td><td>39.30</td></tr>
<tr><td>$C_{13}H_{20}O_7$</td><td>288</td><td>54.17</td><td>6.94</td><td>38.89</td></tr>
<tr><td>$C_{13}H_{23}O_7$</td><td>291</td><td>53.61</td><td>7.90</td><td>38.49</td></tr>
<tr><td>$C_{13}H_{24}O_7$</td><td>292</td><td>53.42</td><td>8.22</td><td>38.36</td></tr>
</table>
</td><td>Example of calculation

$C_{13}H_{18}O_7$ (Accept numbers of C, H and O indicated in calculation)

286

% by mass of carbon = 100 x 13 x 12 ÷ 286
= 54.545

% by mass of hydrogen = 100 x 18 x 1 ÷ 286
= 6.294
and

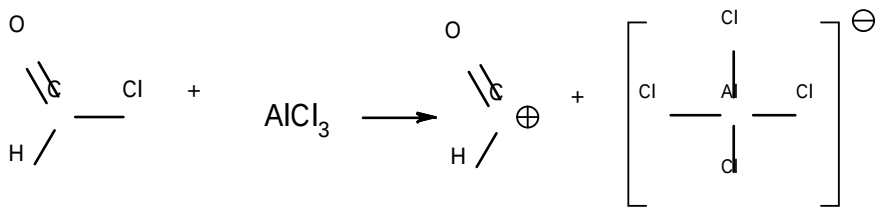
% by mass of oxygen = 100 x 7 x 16 ÷ 286
or
% by mass of oxygen = 100 − (54.545 + 6.2937)
= 39.161

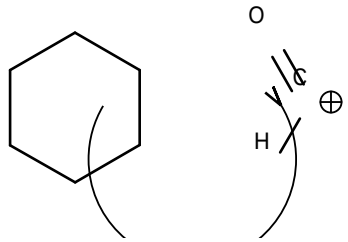
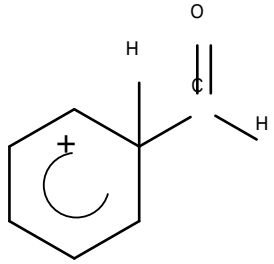
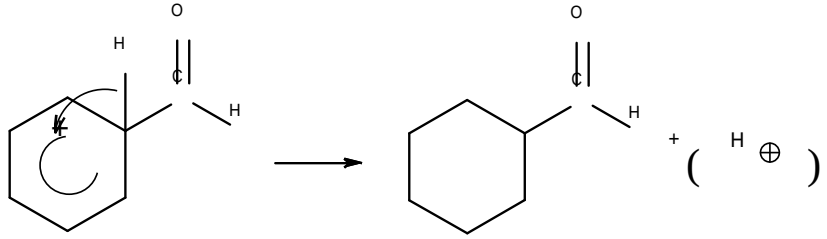
TE at each stage

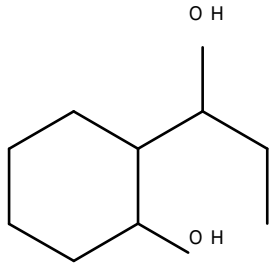
Ignore SF except 1 SF</td><td>4</td></tr>
</table>

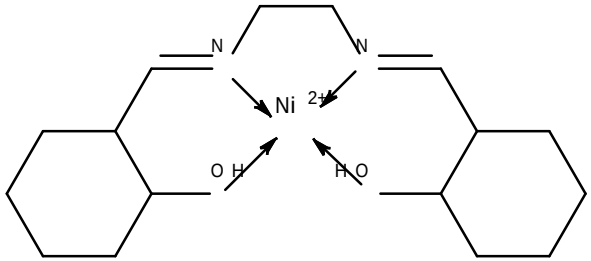
Question number	Answer	Additional guidance	Mark
23(b)(i)	An answer that makes reference to the following • a suitable oxidising agent (1) • sulfuric acid / H_2SO_4 **and** (heat under) reflux (1)	Standalone marks sodium dichromate(VI) / $Na_2Cr_2O_7$ / potassium dichromate(VI) / $K_2Cr_2O_7$ Allow dichromate(VI) / $Cr_2O_7^{2-}$ Ignore omission of oxidation state but, if given, oxidation state must be correct Allow acid / acidified / H^+ / H_3O^+ Ignore concentration of the acid Do not award other acids Do not award other solvents / reagents If name and formula are given both must be correct.	**2**

Question number	Answer	Additional guidance	Mark
23(b)(ii)	An answer that makes reference to the following • salicylaldehyde needs to be distilled / separated (from the reaction mixture to prevent its further oxidation) (1) EITHER • (because) at high temperatures salicylaldehyde will be oxidised (to salicylic acid / carboxylic acid) (1) OR • (because) its high boiling temperature means that salicylaldehyde cannot be easily be separated as the other components of the mixture have lower / similar boiling temperatures (1)	Allow salicylaldehyde is more easily oxidised than salicyl alcohol Allow oxidation of salicylaldehyde is fast Allow salicylaldehyde is hard to separate from the mixture If no other mark is scored, salicylaldehyde / salicyl alcohol will be oxidised to salicylic acid / carboxylic acid scores (1)	**2**

Question number	Answer	Additional guidance	Mark
23(c)(i)	• equation showing formation of electrophile	Example of equation  Allow Structural formulae Allow $CO + HCl + AlCl_3 \rightarrow HCO^+ + AlCl_4^-$ Allow $CO + HCl \xrightarrow{AlCl_3} HCO^+ + Cl^-$ Ignore $CO + HCl \longrightarrow HCO^+ + Cl^-$	1

Question number	Answer	Additional guidance	Mark
23(c)(ii)	A mechanism showing the following • curly arrow from on or within the circle to the positively charged carbon (1) • intermediate structure including charge with horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon **and** with some part of the positive charge within the horseshoe (1) • curly arrow from C—H bond to anywhere in the benzene ring reforming delocalised structure and giving benzaldehyde (1) Ignore use of $AlCl_4^-$ in mechanism	Example of mechanism  Allow curly arrow from anywhere in the hexagon Allow arrow to positive charge provided the charge is on the C atom TE on **any** correct electrophile formed in (c)(i)   Allow TE on any electrophile from (c)(i) Correct Kekule mechanism scores (3) Ignore connectivity of undisplayed CHO in M2 and M3	**3**

Question number	Answer	Additional guidance	Mark
23(d)	An answer that makes reference to the following points: • reagent and conditions for the formation of the Grignard reagent (1) • identification of Grignard reagent (1) • addition product of reaction between salicylaldehyde and Grignard reagent (1) • identification of a suitable dehydrating reagent (1)	Penalise use of Cl or I in Grignard once only Reaction of bromoethane with magnesium (powder) in (dry) ether (under reflux) Ignore heat CH_3CH_2MgBr / ethyl magnesium bromide  Ignore reference to hydrolysis of the Grignard intermediate (conc) phosphoric((V)) acid / H_3PO_4 / (conc) sulfuric acid / H_2SO_4 Do not award dilute acids Allow conversion of OH to halogen using a suitable reagent (e.g. PCl_5) **and** Dehydrohalogenation using alcoholic KOH / NaOH	**4**

Question number	Answer	Additional guidance	Mark
23(e)(i)	A diagram showing • nickel(II) ion coordinated to the two oxygen and two nitrogen atoms of the salen ligand (1) • at least one **dative** covalent bond from an oxygen or a nitrogen to the nickel (II) ion in any structure involving one salen ligand (1)	Example of diagram  Accept charge shown over whole structure Ignore omission of C=N double bond Allow 'dative /coordinate (covalent) bond' stated provided complex structure is involves a salen ligand and at least one O─Ni^{2+} or N─Ni^{2+} bond is shown Penalise incorrect connectivity of OH with Ni^{2+} only in M2. If two OH groups are shown, both must be correctly connected to the Ni^{2+}	**2**

Question number	Answer	Additional guidance	Mark
23(e)(ii)	An answer that makes reference to the following points: • converting the aqua complex to the salen ligand complex results in an increase in the number of particles (in solution) (1) • (thus) the entropy of the system increases / ΔS_{system} is positive (1)	Standalone marks Allow 'molecules' for 'particles' Accept ΔS_{system} increases Ignore just 'entropy increases' If no other mark is scored balanced equation (1)	**2**

(Total for Question 24 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS

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