



Mark Scheme (Results)

January 2021

Pearson Edexcel International Advanced Level
In Chemistry (WCH15)
Paper 1: 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.

Section A (Multiple Choice)

Question number	Answer	Mark
1	<p>The only correct answer is B (gains electrons, decreases)</p> <p><i>A is incorrect because the oxidation number of manganese decreases</i></p> <p><i>C is incorrect because manganese gains electrons and its oxidation number decreases</i></p> <p><i>D is incorrect because manganese gains electrons</i></p>	(1)

Question number	Answer	Mark
2	<p>The only correct answer is A (To increase the rate of the equilibrium between the hydrogen gas and the hydrogen ions)</p> <p><i>B is incorrect because platinum black is chemically identical to shiny platinum</i></p> <p><i>C is incorrect because platinum black has the same electrical conductivity as shiny platinum</i></p> <p><i>D is incorrect because platinum black does not affect the conditions of the system</i></p>	(1)

Question number	Answer	Mark
3(a)	<p>The only correct answer is C ($\text{Fe(s)} \mid \text{Fe}^{2+}(\text{aq}) \parallel \text{Sn}^{2+}(\text{aq}) \mid \text{Sn(s)}$)</p> <p><i>A is incorrect because the oxidised part of $\text{Sn(s)} \mid \text{Sn}^{2+}(\text{aq})$ should be next to the cell junction</i></p> <p><i>B is incorrect because the oxidised part of $\text{Fe(s)} \mid \text{Fe}^{2+}(\text{aq})$ should be next to the cell junction</i></p> <p><i>D is incorrect because the oxidised part of both half-cells should be next to the cell junction</i></p>	(1)

Question number	Answer	Mark
3(b)	<p>The only correct answer is B (−0.14 V)</p> <p>A is incorrect because the $E^{\ominus}_{\text{cell}}$ value has been subtracted from the electrode potential of the Fe/Fe²⁺ electrode system rather than added.</p> <p>C is incorrect because the sign has been reversed.</p> <p>D is incorrect because the $E^{\ominus}_{\text{cell}}$ value has been subtracted from the electrode potential of the Fe/Fe²⁺ electrode system rather than added and the sign has been reversed.</p>	(1)

Question number	Answer	Mark
4	<p>The only correct answer is D ($\text{H}_2(\text{g}) + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^-$)</p> <p>A is incorrect because this is the cathode reaction</p> <p>B is incorrect because this is the reverse of the cathode reaction</p> <p>C is incorrect because hydrogen is the fuel and must be oxidised</p>	(1)

Question number	Answer	Mark
5	<p>The only correct answer is A (chromium)</p> <p>B is incorrect because an atom of iron has four unpaired electrons</p> <p>C is incorrect because an atom of manganese has five unpaired electrons</p> <p>D is incorrect because an atom of vanadium has three unpaired electrons</p>	(1)

Question number	Answer	Mark
6	<p>The only correct answer is C ((nickel) forms stable ions with partially filled d orbitals)</p> <p><i>A is incorrect because elements can be in the d block but not be transition metals</i></p> <p><i>B is incorrect because elements can have partially filled d orbitals but not be transition metals</i></p> <p><i>D is incorrect because elements can form stable compounds with different oxidation states but not be transition metals</i></p>	(1)

Question number	Answer	Mark
7(a)	<p>The only correct answer is D ($\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ is square planar and CrCl_4^- is tetrahedral)</p> <p><i>A is incorrect because CrCl_4^- is tetrahedral</i></p> <p><i>B is incorrect because $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ is square planar</i></p> <p><i>D is incorrect because $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ is square planar and CrCl_4^- is tetrahedral</i></p>	(1)

Question number	Answer	Mark
7(b)	<p>The only correct answer is B (the bonding in both complexes is dative covalent)</p> <p><i>A is incorrect because the bonding is ionic in neither complex</i></p> <p><i>C is incorrect because the bonding in CrCl_4^- is dative covalent</i></p> <p><i>D is incorrect because the bonding in $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ is dative covalent</i></p>	(1)

Question number	Answer	Mark
8	<p>The only correct answer is A (anhydrous cobalt(II) chloride is blue and hydrated cobalt(II) chloride is pink)</p> <p><i>B is incorrect because the colours are the wrong way round</i></p> <p><i>C is incorrect because the test does not involve a change of oxidation state</i></p> <p><i>D is incorrect because the test does not involve a change of oxidation state</i></p>	(1)

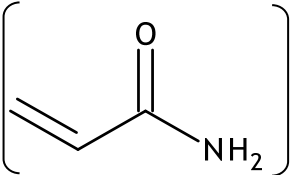
Question number	Answer	Mark
9	<p>The only correct answer is D (Fe^{2+} is readily oxidised to Fe^{3+} which is then reduced to Fe^{2+})</p> <p><i>A is incorrect because Fe^{2+} does not react with iodide ions</i></p> <p><i>B is incorrect because the number of outer electrons is not a factor in homogeneous catalysis</i></p> <p><i>C is incorrect because the number of active sites is a factor in heterogeneous catalysis not in homogeneous catalysis</i></p>	(1)

Question number	Answer	Mark
10	<p>The only correct answer is D ((the overlap of) p orbitals to form π bonds)</p> <p><i>A is incorrect because the σ bonds are not delocalised</i></p> <p><i>B is incorrect because s orbitals do not form π bonds</i></p> <p><i>C is incorrect because the σ bonds are not delocalised</i></p>	(1)

Question number	Answer	Mark
11	<p>The only correct answer is B (result in a kinetic barrier to intermediate formation)</p> <p><i>A is incorrect because the delocalised electrons attract electrophiles</i></p> <p><i>C is incorrect because both ethene and benzene have endothermic enthalpies of formation and this is not a factor in their reactivity</i></p> <p><i>D is incorrect because catalysts have no effect on the thermodynamics of a reaction</i></p>	(1)

Question number	Answer	Mark
12	<p>The only correct answer is C (2-methylbutanamide)</p> <p><i>A is incorrect because the amide carbon is part of the main carbon chain</i></p> <p><i>B is incorrect because the amide carbon is part of the main carbon chain</i></p> <p><i>D is incorrect because the carbon chain is numbered from the amide end</i></p>	(1)

Question number	Answer	Mark
13	<p>The only correct answer is C (phenylamine, ammonia, butylamine)</p> <p><i>A is incorrect because butylamine has the highest pH and phenylamine the lowest</i></p> <p><i>B is incorrect because phenylamine has the lowest pH</i></p> <p><i>D is incorrect because phenylamine has a lower pH than ammonia</i></p>	(1)

Question number	Answer	Mark
14	<p data-bbox="360 311 779 343">The only correct answer is A</p> <div data-bbox="891 260 1182 435" style="text-align: center;">  </div> <p data-bbox="360 531 1906 603">B is incorrect because this monomer has four carbon atoms not three and would give a polymer with a methyl group on a different carbon to the amide group</p> <p data-bbox="360 627 1906 699">C is incorrect because this monomer has four carbon atoms not three and would give a polymer with a methyl group branched chain</p> <p data-bbox="360 722 1839 794">D is incorrect because this monomer has five carbon atoms not three and would give a polymer with two methyl group branched chains</p>	(1)

Question number	Answer	Mark
15	<p data-bbox="360 949 1272 981">The only correct answer is D (a polyamide but not a polypeptide)</p> <p data-bbox="360 1005 1243 1037">A is incorrect because polypeptides are formed from amino acids</p> <p data-bbox="360 1061 907 1093">B is incorrect because it is a polyamide</p> <p data-bbox="360 1117 1030 1149">C is incorrect because it cannot be a polypeptide</p>	(1)

Question number	Answer	Mark
16	<p>The only correct answer is B (five)</p> <p><i>A is incorrect because the carbon with the two methyl groups attached has been omitted</i></p> <p><i>C is incorrect because the carbon with the two methyl groups attached has been omitted and the symmetry of the structure has been ignored</i></p> <p><i>D is incorrect because the symmetry of the structure has been ignored</i></p>	(1)

Question number	Answer	Mark
17	<p>The only correct answer is C (C₄H₆)</p> <p><i>A is incorrect because C₂H₃ cannot be a molecular formula</i></p> <p><i>B is incorrect because this formula is obtained without doubling the moles of water to give the moles of hydrogen</i></p> <p><i>D is incorrect because the moles of water has been halved instead of doubled</i></p>	(1)

Question number	Answer	Mark
18	<p>The only correct answer is C (19.51 g)</p> <p><i>A is incorrect because this is the mass of benzenecarboxylic acid that would be formed from 8.24 g of benzene in this sequence</i></p> <p><i>B is incorrect because this is the mass of benzene if both reactions have 100% yield</i></p> <p><i>D is incorrect because this value is calculated without using the M_r values</i></p>	(1)

TOTAL FOR SECTION A = 20 MARKS

Section B

Question number	Answer	Additional guidance	Mark
19(a)	<ul style="list-style-type: none"> • P = copper / Cu (1) • Q = hexaaquacopper(II) / $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ (1) • R = copper(II) hydroxide / $\text{Cu}(\text{OH})_2$ / $\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4$ (1) • S = copper(II) oxide / CuO (1) • T = tetraamminecopper(II) / $[\text{Cu}(\text{NH}_3)_4]^{2+}$ / $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ (1) • V = diamminecopper(I) / $[\text{Cu}(\text{NH}_3)_2]^+$ (1) • W = hexaaquacopper(II) / $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ (1) 	<p>Ignore omission of brackets in complexes If name and formula are given, both must be correct Penalise omission of oxidation states twice Ignore state symbols even if incorrect Ignore charge vertically above the Cu</p> <p>Allow $\text{Cu}^{2+}(\text{aq})$ / Cu^{2+} / copper(II) sulfate / CuSO_4</p> <p>Ignore copper oxide</p> <p>Do not award $[\text{Cu}(\text{NH}_3)_6]^{2+}$</p> <p>Allow 3 or 4 ammonia ligands Ignore water ligands</p> <p>Allow $\text{Cu}^{2+}(\text{aq})$ / Cu^{2+} / copper(II) nitrate / $\text{Cu}(\text{NO}_3)_2$</p>	(7)

Question number	Answer	Additional guidance	Mark
19(b)(i)	<ul style="list-style-type: none"> complex(es) 	Allow complex ions Allow ammine complexes Allow transition metal complexes Allow ligand complexes	(1)

Question number	Answer	Additional guidance	Mark
19(b)(ii)	<p>An explanation that makes reference to the following</p> <ul style="list-style-type: none"> (the colour is due to) transition /promotion of electrons between (split) (3)d subshell / orbitals (1) in Cu(II) the d orbitals are partially filled (so electron transitions are possible) (1) in Cu(I) the d orbitals are full and so no (electron) transitions are possible (1) 	<p>Allow use of T and V d (subshell /orbitals) must be mentioned at least once penalise use of 'orbital' /shell rather than orbitals/ subshell once only Ignore detailed explanations of colour in transition metal compounds even if incorrect</p> <p>Allow d-d electron transitions Ignore just 'from lower to higher energy level'</p> <p>If M2 and M3 not scored, correct d subshell electronic configurations of Cu(I) and Cu(II) without explanation score (1)</p> <p>Allow no incompletely filled (3)d subshell / orbitals</p> <p>Do not award subshell not split light frequency outside visible region no electrons in d orbitals</p>	(3)

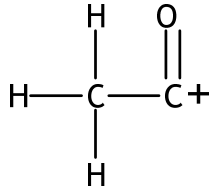
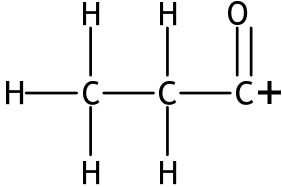
Question number	Answer	Additional guidance	Mark
19(b)(iii)	<p>An explanation that makes reference to the following</p> <ul style="list-style-type: none"> Cu(I) is oxidised to Cu(II) (1) by oxygen in the air (1) 	<p>Allow Cu(I) is oxidised Allow Cu(I) forms Cu(II) Allow V is oxidised to T</p> <p>Allow just 'by oxygen' or 'by air'</p>	(2)

Question number	Answer	Additional guidance	Mark
19(c)(i)	<ul style="list-style-type: none"> a balanced ionic equation 	<p><u>Example of equation</u></p> $2\text{CuI} \rightarrow \text{Cu} + \text{Cu}^{2+} + 2\text{I}^-$ <p>Allow</p> $2\text{Cu}^+ \rightarrow \text{Cu} + \text{Cu}^{2+}$ <p>Do not award additional / spectator ions</p> <p>Ignore state symbols even if incorrect.</p>	(1)

Question number	Answer	Additional guidance	Mark
19(c)(ii)	<p>An answer that makes reference to the following points</p> <ul style="list-style-type: none"> identification of the appropriate half-equations and E^\ominus values (1) calculation of E^\ominus_{cell} for the reaction and states (positive) so is feasible (1) 	<p> $\text{Cu}^{2+} + \text{e}^- \rightleftharpoons \text{Cu}^+ \quad E^\ominus = +0.15 \text{ V}$ and $\text{Cu}^+ + \text{e}^- \rightleftharpoons \text{Cu} \quad E^\ominus = +0.52 \text{ V}$ </p> <p>Allow just $E^\ominus_{\text{cell}} = 0.52 - 0.15$</p> <p>M2 dependent on M1</p> <p>$E^\ominus_{\text{cell}} (= 0.52 - 0.15) = (+)0.37 \text{ (V)}$ and therefore reaction is (thermodynamically) feasible</p> <p>No TE on incorrect half-equations / E^\ominus_{cell} values</p>	(2)

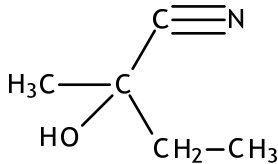
Question number	Answer	Additional guidance	Mark
19(d)	<ul style="list-style-type: none"> • calculation of moles of thiosulfate in mean titre (1) • determines ratio of Cu^{2+} to $\text{S}_2\text{O}_3^{2-}$ and gives moles of Cu^{2+} in 25 cm^3 (1) • calculation of moles of Cu^{2+} in 250 cm^3 (1) • calculation of M_r of mitscherlichite (1) • calculation of M_r of K_2CuCl_4 (1) • calculation of moles of water (1) <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Alternative M4 and M6 mass of K_2CuCl_4 in sample = $1.3325 \times 10^{-2} \times 283.7 = 3.7803 \text{ g}$ mass of water in sample = $4.26 - 3.7803 = 0.47970$ (1)</p> <p>mol water in sample = $0.47970 \div 18 = 0.026650$ and ratio $\text{H}_2\text{O} : \text{K}_2\text{CuCl}_4 = 0.026650 \div 0.013325 = 1:2$ (1)</p> </div>	<p><u>example of calculation</u></p> $\text{mol S}_2\text{O}_3^{2-} = \frac{26.65 \times 0.0500}{1000} = 1.3325 \times 10^{-3} / 0.0013325$ $\text{Cu}^{2+} \text{ in } 25 \text{ cm}^3 = \text{S}_2\text{O}_3^{2-} = 1.3325 \times 10^{-3}$ $= 10 \times 1.3325 \times 10^{-3} = 1.3325 \times 10^{-2}$ $= 4.26 / 1.3325 \times 10^{-2} = 319.70$ $= 2 \times 39.1 + 63.5 + 4 \times 35.5 = 283.7$ <p>mass of water = $319.7 - 283.7 = 36$ moles of water = $36 / 18 = 2$ (= n)</p> <p>correct answer with some working scores (6) TE at each stage but Do not award M4 or M6 if calculated value for M_r of (mitscherlichite) $< M_r$ (K_2CuCl_4)</p> <p>Factor of 10 may be used at any point M1 to M3</p> <p>Ignore SF in final answer</p>	(6)

(Total for Question 19 = 22 marks)

Question number	Answer	Additional guidance	Mark
20(a)(i)	<p data-bbox="409 703 427 722">•</p> <div style="text-align: center; margin-left: 100px;">  </div> <p data-bbox="409 938 427 957">•</p> <div style="text-align: center; margin-left: 100px;">  </div>	<p data-bbox="1227 245 1872 400">Penalise omission of the positive charge or use of negative charges once only in 20(a)(i) and (ii) Penalise use of just molecular formulae once only in 20(a)(i) and (ii)</p> <p data-bbox="1227 448 1778 560">Allow the positive charge anywhere on a structure or outside brackets covering a structure</p> <p data-bbox="1227 647 1742 683">Allow structural formulae e.g. CH₃CO⁺</p> <p data-bbox="1149 683 1189 718">(1)</p> <p data-bbox="1149 914 1189 949">(1)</p> <p data-bbox="1227 930 1464 1002">Allow C₂H₅CO⁺ Allow CH₃COCH₂⁺</p> <p data-bbox="1227 1050 1700 1085">Ignore <i>m/z</i> values even if incorrect</p>	<p data-bbox="1966 245 2007 280">(2)</p>

Question number	Answer	Additional guidance	Mark
20(a)(ii)	<ul style="list-style-type: none"> reasonable species 	Allow only CH_3^+ , CH_3CH_2^+ , C_2H_5^+ , $\text{CH}_3\text{COCH}_2\text{CH}_3^+$ Ignore m/z values even if incorrect Do not award species with $m/z = 43$ or 57	(1)

Question number	Answer	Additional guidance	Mark
20(b)	An answer that makes reference to the following points: <ul style="list-style-type: none"> reaction of butanone with iodine in sodium hydroxide / NaOH (1) to form sodium propanoate (1) add dilute sulfuric acid / H_2SO_4 and to form propanoic acid / $\text{CH}_3\text{CH}_2\text{COOH}$ (and distil off) (1) (reflux propanoic acid with) lithium tetrahydridoaluminate(III) / LiAlH_4/ lithium aluminium hydride in dry ether (to give propan-1-ol) (1) 	Score correct compounds / reagents even if preceding chemistry is incorrect) Allow unbalanced equations and reaction schemes Accept potassium hydroxide Allow alkali / alkaline / OH^- Accept $\text{CH}_3\text{CH}_2\text{COO}^-\text{Na}^+$ / $\text{CH}_3\text{CH}_2\text{COONa}$ Allow propanoate (ion) Accept any identified strong acid. Ignore H^+ Allow 'lithal' Allow the use of LiAlH_4 in dry ether on propanoic acid or propanal (however these are obtained) to give propan-1-ol	(4)

Question number	Answer	Additional guidance	Mark
20(c)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • identification of a suitable halogenoalkane (1) • reaction with magnesium (powder) in dry ether (1) • to form the Grignard reagent CH₃MgBr / methyl magnesium bromide (1) • formation of 2-methylbutan-2-ol by reacting the Grignard reagent with butanone (1) <div style="text-align: center;">  </div> <ul style="list-style-type: none"> • reaction with concentrated phosphoric acid or concentrated sulfuric acid (to give 2-methylbut-2-ene (and some 2-methylbut-1-ene)) (1) 	<p>Allow names or formulae for reagents and intermediates. Score correct compounds and reagents even if preceding chemistry is incorrect) Equations need not balance</p> <p>CH₃Br Allow Cl or I, Ignore X for halogen</p> <p>Allow the use of dry ether with or without Mg in this reaction</p> <p>or halogen given for M1</p> <p>Ignore just 2-methylbutan-2-ol</p> <p>If Grignard reagent not used (i.e. M1, M2, M3 & M4 not scored, reaction of butanone with HCN / KCN / CN⁻ to form 2-hydroxy-2-methylbutanenitrile scores (1) [ignore reaction conditions]</p> <p>Allow pass alcohol (vapour) over heated alumina / Al₂O₃</p> <p>Allow correct reaction to form halogenoalkane and dehydrohalogenation with OH⁻ in ethanol</p> <p>Allow 1 mark for the dehydration of any alcohol by any of these reactions</p>	(5)

(Total for Question 20 = 12 marks)



Question number	Answer	Additional guidance	Mark
21(a)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> equation relating E°_{cell} to half-cell values and determination of E° for the right-hand electrode (1) identification of F and G (1) 	<p>These are standalone marks</p> $E^\circ_{\text{cell}} = E^\circ_{\text{R}} - E^\circ_{\text{L}}$ $1.94 = E^\circ_{\text{R}} - (-0.61)$ $E^\circ_{\text{R}} = 1.94 - 0.61 = (+)1.33 \text{ (V)}$ <p>Allow (+)1.33 (V) with some working which relates 1.33 to 1.94 and -0.61</p> <p>Allow (+)1.33 (V) with the $\text{Cr}_2\text{O}_7^{2-} / \text{Cr}^{3+}$ half-equation</p> <p>F = $\text{Cr}_2\text{O}_7^{2-}$ and G = Cr^{3+} Species must be clearly identified</p>	(2)

Question number	Answer	Additional guidance	Mark
21(b)	<ul style="list-style-type: none"> correct species on both sides of the equation and no electrons (1) equation balanced (1) 	<p><u>Example of equation</u></p> $3\text{C}_2\text{H}_5\text{OH} + \text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ \rightleftharpoons 2\text{Cr}^{3+} + 3\text{CH}_3\text{CHO} + 7\text{H}_2\text{O}$ <p>Allow multiples uncancelled H⁺ ions → or ⇌ Ignore state symbols even if incorrect</p> <p>Correct balanced equation with uncancelled electrons scores (1)</p>	(2)

Question number	Answer	Additional guidance	Mark
21(c)	<ul style="list-style-type: none"> correct equation 	<p><u>Example of equation</u></p> $2\text{CrO}_4^{2-} + 2\text{H}^+ \rightleftharpoons \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$ <p>Allow multiples → or ⇌</p> <p>Ignore state symbols even if incorrect Do not award uncancelled electrons</p>	(1)

(Total for Question 21 = 5 marks)

Question number	Answer	Additional guidance	Mark
22(a)	<ul style="list-style-type: none"> <li data-bbox="365 491 1279 603">• identification of correct algebraic equation for x and solves equation to obtain x (1) <li data-bbox="365 651 1279 730">• identification of correct algebraic equation for x and y (1) <li data-bbox="365 810 1279 890">• solves equation to obtain y and gives formula of the hydrocarbon (1) 	<p data-bbox="1317 247 1912 443"><u>Example of calculation</u> {from the equation 1 mol of C_xH_y gives x mol of CO₂ so 25 mol will give 25x mol CO₂ and 25 cm³ will give 25x cm³CO₂ . Hence}</p> <p data-bbox="1317 491 1585 523">25x = 100 and x = 4</p> <p data-bbox="1317 571 1749 603">(1) Allow just x = 4 with no working</p> <p data-bbox="1317 651 1666 730">{change in volume is} (25 + 25(x+y/4) – 25x = 75</p> <p data-bbox="1317 778 1666 810">25y/4 = 50 therefore y = 8</p> <p data-bbox="1317 810 1384 890">and C₄H₈</p> <p data-bbox="1317 938 1899 970">correct formula with no working scores (1)</p>	(3)

Question number	Answer	Additional guidance	Mark
22(b)	<ul style="list-style-type: none"> • structure of cyclobutane (1) • structure of methylcyclopropane(1) 	<p>Examples of structures</p> <div style="border: 1px solid black; padding: 5px; display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"></div> <div style="text-align: center;"></div> </div> <p>or displayed / semi-displayed structures</p> <p>Ignore names even if incorrect</p> <p>TE on 22(a) for cycloalkanes only</p> <p>If (a) is an alkane with C>3 2 correct isomers scores 1 mark</p>	(2)

(Total for Question 22 = 5 marks)

Question number	Answer	Additional guidance	Mark																				
*23	<p>This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1" data-bbox="365 555 1200 799"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <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> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning</p> <table border="1" data-bbox="365 970 1227 1382"> <thead> <tr> <th></th> <th>Number of marks awarded for structure of answer and sustained lines of reasoning</th> </tr> </thead> <tbody> <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> </tbody> </table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	<p>Guidance on how the mark scheme should be applied.</p> <p>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).</p> <p>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).</p> <p>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 0 reasoning marks.</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</p> <p>Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning</p>	
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
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Question number	Answer	Additional guidance	Mark
*23 (cont)	<p>Indicative content</p> <p>IP1 both platinum and V₂O₅ are heterogeneous catalysts</p> <p>IP2 there is adsorption of reactants on the (catalyst) surface (this applies to both reactions)</p> <p>IP3 (in the catalytic converter) adsorbed reactant bonds are weakened / broken allowing reaction to occur more easily. (this applies only to the catalytic converter)</p> <p>IP4 (in the catalytic converter there is) desorption of products from the surface (this applies to both reactions)</p> <p>IP5 (in the Contact Process the) V₂O₅ is reduced (to V(III) / V(IV)) and by sulfur dioxide / SO₂</p> <p>IP6 Vanadium species V(III) / V(IV) is oxidised to V(V) and by oxygen</p>	<p>Allow (for IP1) both catalysts (provide an alternative path with) lower activation energy Do not award IP1 if V₂O₅ is homogeneous</p> <p>or chemisorption / bond strongly</p> <p>Allow IP2, IP3 and IP4 for general description of heterogeneous catalysis</p> <p>penalise absorption once only Ignore IP3 for the Contact Process</p> <p>Allow any indication of the products leaving the surface of the catalyst</p> <p>Equations showing reduction of V₂O₅ by SO₂ and the subsequent oxidation do not need to balance</p> <p>If neither IP5 nor IP6 scored Allow IP6 for Either V₂O₅ first reduced then (V compound) oxidised or 2SO₂ + O₂ ⇌ 2SO₃ and 2CO + 2NO → 2CO₂ + N₂</p>	(6)

(Total for Question 23 = 6 marks)
TOTAL FOR SECTION B = 60 MARKS

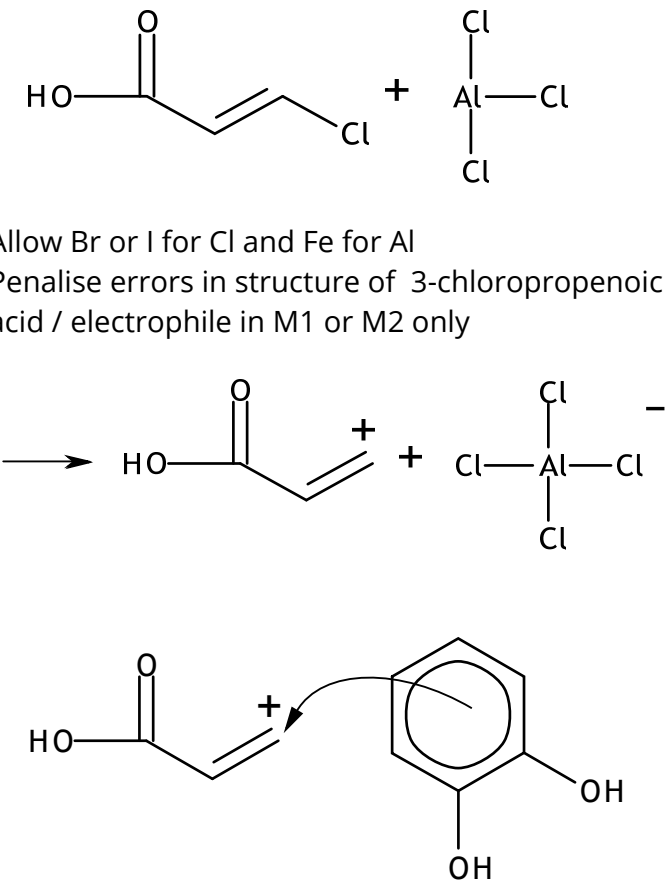
Section C

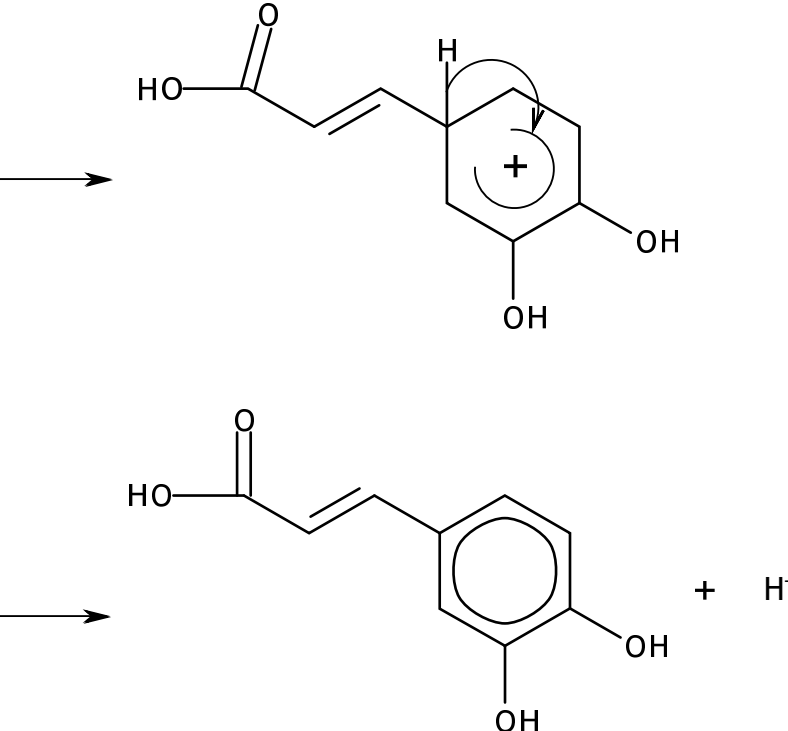
Question number	Answer	Additional guidance	Mark
24(a)(i)	<p>An explanation that makes reference to the following points</p> <ul style="list-style-type: none"> • (π) electron system (in the right-hand ring) is delocalised (1) <p>M2 and M3 scored from any two of</p> <ul style="list-style-type: none"> • the delocalisation involves the lone-pair(s) in the nitrogen (atom(s)) and the π electrons of the double bonds (1) • (the right-hand ring) will undergo substitution reactions rather than addition reactions (1) • caffeine has stabilisation / delocalisation energy(1) • all the C—N bonds (in the 5-membered ring) will be the same (length)(1) 	<p>Allow aromatic ring Ignore just 'form a π bond' Do not award just it is a benzene ring</p> <p>Allow just 'the delocalisation involves the lone-pair(s) in the nitrogen (atom(s))</p> <p>Allow electrophilic substitution (rather than addition) Ignore electrophilic reaction</p> <p>Allow caffeine / (delocalised) ring is more stable</p> <p>Allow all the bonds will be the same length Ignore C=C bonds will be the same length</p>	(3)

Question number	Answer	Additional guidance	Mark
24(a)(ii)	<p>An explanation that makes reference to the following points</p> <ul style="list-style-type: none"> • Description of basicity (1) • Effect of delocalisation(1) 	<p>Either lone pair donation Or proton acceptor</p> <p>Nitrogen lone pair incorporated in delocalised system / overlaps with the π (electron) ring and reduces electron density / lone pair availability</p> <p>Do not award overlap with the benzene ring</p> <p>Ignore references to the amide even if incorrect.</p> <p>If no other mark is scored the positive inductive effect of alkyl groups increases availability of the lone pair in a primary amine scores (1)</p>	(2)

Question number	Answer	Additional guidance	Mark
24(b)(i)	<ul style="list-style-type: none"> • determination of M_r(from molecular formula)(1) • calculation of amount of caffeine(1) • calculation of concentration of caffeine (1) • final answer to 1 or 2 SF (1) 	<p><u>Example of calculation</u></p> <p>$(C_8H_{10}N_4O_2) M_r = 194$</p> $\frac{85}{1000 \times 194} (= 4.3814 \times 10^{-4} / 0.00043814) \text{ (mol)}$ $= \frac{1000 \times 85}{200 \times 1000 \times 194} / \frac{1000 \times 0.00043814}{200}$ $= 2.1907 \times 10^{-3} / 0.0021907 \text{ (mol dm}^{-3}\text{)}$ $= 2 \times 10^{-3} / 2.2 \times 10^{-3} / 0.002 / 0.0022 \text{ (mol dm}^{-3}\text{)}$ <p>Do not award > 2 SF</p> <p>TE at each stage</p> <p>correct answer with no working scores (1)</p>	(4)

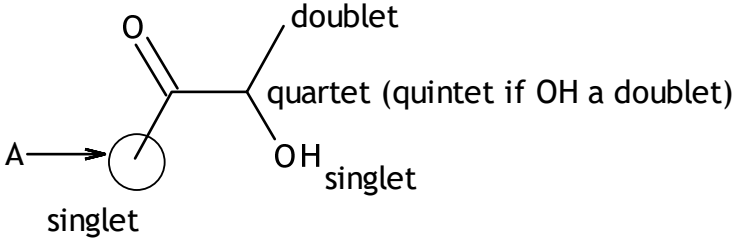
Question number	Answer	Additional guidance	Mark
24(b)(ii)	<ul style="list-style-type: none"> <li data-bbox="365 327 976 359">• calculation of number of half-lives (1) <li data-bbox="365 528 976 560">• applies half-lives to three hours (1) 	<p data-bbox="1249 247 1559 279"><u>Example of calculation</u></p> $\frac{20}{160} = \frac{1}{8} = \left(\frac{1}{2}\right)^n \quad n = 3$ <p data-bbox="1249 443 1760 475">or 160 → 80 → 40 → 20 (3 half lives)</p> <p data-bbox="1249 523 1547 555">time = 3 × 3 = 9 hours</p> <p data-bbox="1249 603 1753 635">TE on number of half lives calculated</p> <p data-bbox="1249 683 1861 715">correct answer with some working scores (2)</p>	(2)

Question number	Answer	Additional guidance	Mark
24(c)(i)	<p>A mechanism showing the following</p> <ul style="list-style-type: none"> structure of 3-chloropropenoic acid (1) structure of the electrophile and balanced equation involving AlCl_3 and AlCl_4^- (1) curly arrow from on or within the circle to the positively charged carbon (1) <p>Allow any electrophile for M3, M4 and M5</p>	<p>M1 and M2 are for the electrophile formation M3, M4 and M5 are for the electrophilic substitution Example of mechanism</p>  <p>Allow Br or I for Cl and Fe for Al Penalise errors in structure of 3-chloropropenoic acid / electrophile in M1 or M2 only</p> <p>Allow curly arrow from anywhere in the hexagon Allow dotted horseshoe</p>	(5)

Question number	Answer	Additional guidance	Mark
24(c)(i) cont	<ul style="list-style-type: none"> 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 with phenol groups in the 3 and 4 positions(1) 	 <p>penalise incorrect position / omission of the phenol groups at final marking point. Ignore omission of H⁺ in final step</p> <p>correct Kekulé structures score full marks</p> <p>Ignore structure of substituents apart from the position of the OH groups in final structure</p>	

Question number	Answer	Additional guidance	Mark
24(c)(ii)	<p>•</p>	<p>or displayed structure Allow COOH and CO₂H</p> <p>Ignore all connectivity errors to 'OH' Only penalise O-H-C</p>	(1)

Question number	Answer	Additional guidance	Mark
24(d)(i)	<p>•</p>	<p>Allow any labelling sequence</p> <p>Do not award any other labelling</p>	(1)

Question number	Answer	Additional guidance	Mark										
24(d)(ii)	<table border="1" data-bbox="367 301 1077 726"> <thead> <tr> <th data-bbox="367 301 736 432">Proton environment (labelled as in (i))</th> <th data-bbox="736 301 1077 432">Splitting pattern</th> </tr> </thead> <tbody> <tr> <td data-bbox="367 432 736 505">A</td> <td data-bbox="736 432 1077 505">singlet</td> </tr> <tr> <td data-bbox="367 505 736 579">B</td> <td data-bbox="736 505 1077 579">quartet</td> </tr> <tr> <td data-bbox="367 579 736 652">C</td> <td data-bbox="736 579 1077 652">doublet</td> </tr> <tr> <td data-bbox="367 652 736 726">D</td> <td data-bbox="736 652 1077 726">singlet</td> </tr> </tbody> </table> <p data-bbox="367 772 412 804">OR</p> 	Proton environment (labelled as in (i))	Splitting pattern	A	singlet	B	quartet	C	doublet	D	singlet	<p data-bbox="1173 328 1420 360">all four correct (2)</p> <p data-bbox="1173 408 1397 440">three correct (1)</p> <p data-bbox="1173 488 1917 560">Allow non-standard terms such as 'two splits' or just '2' for doublet</p> <p data-bbox="1173 608 1850 679">If D (OH proton) is given as a doublet, allow B as a quartet or as a quintet</p> <p data-bbox="1173 727 1771 799">Ignore carbonyl carbon labelled as a proton environment</p>	(2)
Proton environment (labelled as in (i))	Splitting pattern												
A	singlet												
B	quartet												
C	doublet												
D	singlet												

(Total for Question 24 = 20 marks)
TOTAL FOR SECTION C = 20 MARKS

