



Mark Scheme (Results)

October 2023

Pearson Edexcel International Advanced Level
In Chemistry (WCH15)
Paper 01 Unit 5: 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.

Question number	Answer	Mark
1	The only correct answer is D (zinc) <i>A is incorrect because cobalt forms a stable Co^{2+} ion with incompletely-filled d-orbitals</i> <i>B is incorrect because copper forms a stable Cu^{2+} ion with incompletely-filled d-orbitals</i> <i>C is incorrect because nickel forms a stable Ni^{2+} ion with incompletely-filled d-orbitals</i>	(1)

Question number	Answer	Mark
2	The only correct answer is D (VO_3^- and VO_2^+) <i>A is incorrect because chromium has oxidation numbers +6 and +3 respectively</i> <i>B is incorrect because copper has oxidation numbers +1 and +2 respectively</i> <i>C is incorrect because manganese has oxidation numbers +3 and +4 respectively</i>	(1)

Question number	Answer	Mark
3	The only correct answer is D (6) <i>A is incorrect because although there are two different ligands, there are 6 atoms bonded to the central ion</i> <i>B is incorrect because the charge on Cr is 3+ but there are 6 atoms bonded to the central ion</i> <i>C is incorrect because although there are 4 ligands, there are 6 atoms bonded to the central ion</i>	(1)

Question number	Answer	Mark
4	The only correct answer is C (Ni^{2+}) <i>A is incorrect because Cu^{2+} gives a blue precipitate with aqueous sodium hydroxide and with aqueous ammonia</i> <i>B is incorrect because the precipitate formed with Fe^{2+} and aqueous ammonia is insoluble in excess ammonia</i> <i>D is incorrect because V^{2+} is a purple solution</i>	(1)

Question number	Answer	Mark
5	The only correct answer is B ($[\text{Zn}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Zn}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{NH}_4^+$) <i>A is incorrect because the precipitate should not have a positive charge and the charges do not balance</i> <i>C is incorrect because $[\text{Zn}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ is formed when the precipitate dissolves in excess aqueous ammonia</i> <i>D is incorrect because $\text{Zn}(\text{NH}_3)_4(\text{H}_2\text{O})_2$ should have a 2+ charge and the equation is not balanced</i>	(1)

Question number	Answer	Mark
6	The only correct answer is B (Mn^{2+} acts as a catalyst; concentration of reactants decreases) <i>A is incorrect because the kinetic energies of the particles do not change</i> <i>C is incorrect because MnO_4^- is not a catalyst and the kinetic energies of the particles do not change</i> <i>D is incorrect because MnO_4^- is not a catalyst</i>	(1)

Question number	Answer	Mark
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7	The only correct answer is C (ΔS_{total} and $\ln K$) <i>A is incorrect because $E^\ominus_{\text{cell}}$ is not directly proportional to $\Delta_r H$</i> <i>B is incorrect because $E^\ominus_{\text{cell}}$ is not directly proportional to $\Delta_r H$ or to $\ln RT$</i> <i>D is incorrect because $E^\ominus_{\text{cell}}$ is not directly proportional to $\ln RT$</i>	(1)
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Question number	Answer	Mark
8	The only correct answer is A (standard reduction potential; most negative to most positive) <i>B is incorrect because the electrochemical series has the most negative standard electrode potential first</i> <i>C is incorrect because standard cell potentials are determined from two standard electrode potentials</i> <i>D is incorrect because standard cell potentials are determined from two standard electrode potentials and the electrochemical series has the most negative standard electrode potential first</i>	(1)

Question number	Answer	Mark
9	The only correct answer is A ($\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$) <i>B is incorrect because H^+ ions cannot be produced in an alkaline solution</i> <i>C is incorrect because H^+ ions cannot be produced in an alkaline solution</i> <i>D is incorrect because H^+ ions cannot be produced in an alkaline solution</i>	(1)

Question number	Answer	Mark
10	The only correct answer is B (negative; positive) <i>A is incorrect because $E_{\text{cell}}^\ominus = E_{\text{rhs}} - E_{\text{lhs}}$ so $0.17 - (-0.40) = +0.57 \text{ V}$ or $0.40 - (-0.17) = +0.57 \text{ V}$</i> <i>C is incorrect because $E_{\text{cell}}^\ominus = E_{\text{rhs}} - E_{\text{lhs}}$ so $0.17 - (-0.40) = +0.57 \text{ V}$ or $0.40 - (-0.17) = +0.57 \text{ V}$</i> <i>D is incorrect because $E_{\text{cell}}^\ominus = E_{\text{rhs}} - E_{\text{lhs}}$ so $0.17 - (-0.40) = +0.57 \text{ V}$ or $0.40 - (-0.17) = +0.57 \text{ V}$</i>	(1)

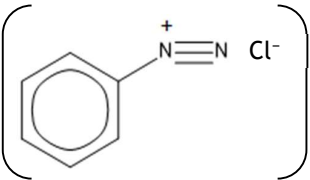
Question number	Answer	Mark
11	The only correct answer is C (magnesium) <i>A is incorrect because $1.635 \div 65.4 = 0.025 \text{ mol}$ of zinc produced which gives a relative atomic mass of 24.3 for G</i> <i>B is incorrect because $1.635 \div 65.4 = 0.025 \text{ mol}$ of zinc produced which gives a relative atomic mass of 24.3 for G</i> <i>D is incorrect because $1.635 \div 65.4 = 0.025 \text{ mol}$ of zinc produced which gives a relative atomic mass of 24.3 for G</i>	(1)

Question number	Answer	Mark
12	The only correct answer is D (phenylamine) <i>A is incorrect because the lone pair of electrons on N in ammonia is not delocalised so can be donated more easily</i> <i>B is incorrect because the lone pair of electrons on N in butylamine is not delocalised so can be donated more easily</i> <i>C is incorrect because the lone pair of electrons on N in ethylamine is not delocalised so can be donated more easily</i>	(1)

Question number	Answer	Mark
13	The only correct answer is B ($\text{H}_2\text{NCH}(\text{CH}_3)\text{COO}^-$) <i>A is incorrect because this is the structure of the uncharged molecule</i> <i>C is incorrect because this structure would exist at pH less than 6.0</i> <i>D is incorrect because this is the structure of the zwitterion</i>	(1)

Question number	Answer	Mark
14	The only correct answer is A ($\text{CH}_2=\text{CHCOOH}$) <i>B is incorrect because phenol does not react with ethanol</i> <i>C is incorrect because 2-propen-1-ol does not react with sodium hydroxide or ethanol</i> <i>D is incorrect because ethanoic acid does not react with hydrogen in the presence of a nickel catalyst</i>	(1)

Question number	Answer	Mark
15(a)	The only correct answer is A (further substitution by a nitro group occurs) <i>B is incorrect because nitrobenzene does not decompose at 80°C</i> <i>C is incorrect because fuming sulfuric acid is needed for the substitution of SO₃H</i> <i>D is incorrect because nitric acid does not decompose at 80°C</i>	(1)
15(b)	The only correct answer is C (Sn and concentrated HCl(aq) are added first, then NaOH(aq) is added at the end) <i>A is incorrect because the acid and alkali would react to form a salt if they are added together</i> <i>B is incorrect because the acid and alkali would react to form a salt if they are added together</i> <i>D is incorrect because dilute hydrochloric acid would not react quickly enough with the tin</i>	(1)

Question number	Answer	Mark
15(c)	The only correct answer is B  <i>A is incorrect because the chlorine is not bonded covalently to the nitrogen</i> <i>C is incorrect because the chlorine is not bonded covalently to the nitrogen</i> <i>D is incorrect because the charge should be on the nitrogen on the right not the nitrogen on the left</i>	(1)

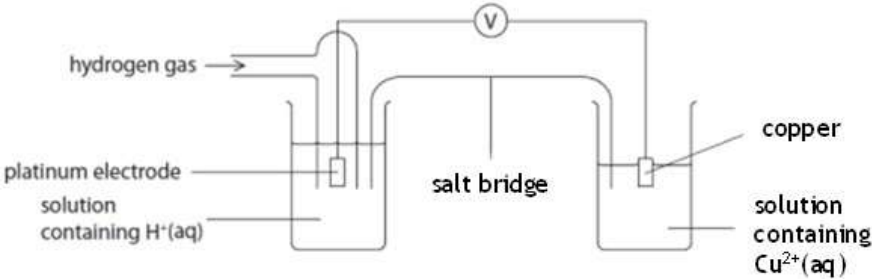
Question number	Answer	Mark
15(d)	The only correct answer is B (alkaline) <i>A is incorrect because a phenoxide ion is needed for the reaction and that is produced in alkaline solution</i> <i>C is incorrect because a phenoxide ion is needed for the reaction and that is produced in alkaline solution</i> <i>D is incorrect because a phenoxide ion is needed for the reaction and that is produced in alkaline solution</i>	(1)

Question number	Answer	Mark
16	The only correct answer is D (8 (cm³)) <i>A is incorrect because 2 cm³ of methane reacts with 4 cm³ of oxygen</i> <i>B is incorrect because 4 cm³ of methane would react with 4 cm³ of oxygen if they reacted in a 1:1 mole ratio</i> <i>C is incorrect because 6 cm³ would be the volume of argon if methane reacted with oxygen in a 1:1 mole ratio</i>	(1)

Question number	Answer	Mark
17	The only correct answer is A (x is 30 and y is 40) <i>B is incorrect because water is a liquid at room temperature</i> <i>C is incorrect because 10 cm³ of but-1-ene reacts with 60 cm³ of oxygen to form 40 cm³ of carbon dioxide so there is an initial decrease of 30 cm³</i> <i>D is incorrect because 10 cm³ of but-1-ene reacts with 60 cm³ of oxygen to form 40 cm³ of carbon dioxide so there is an initial decrease of 30 cm³ and water is a liquid at room temperature</i>	(1)

(Total for Section A = 20 marks)

Section B

Question Number	Answer	Additional Guidance	Mark
18(a)	COMMENT Ignore any electron flow unless shown on the salt bridge Hydrogen half-cell: • (M1) 1 mol dm⁻³ H⁺(aq) and platinum (black) electrode (1) • (M2) hydrogen gas in suitable apparatus at 100 kPa / 1 × 10⁵ Pa (at 298 K) (1) Copper half-cell: • (M3) copper (electrode) dipping into solution (1) • (M4) 1 mol dm⁻³ Cu²⁺ (solution) (1) Connections: • (M5) salt bridge (dipping into /touching both solutions) and voltmeter and complete circuit (1)	Example of diagram:  Allow hydrogen half-cell drawn on the right Concentration only needed once in M1 and M4 if both are 1 mol dm⁻³ Allow 1 mol dm⁻³ hydrochloric acid / HCl / nitric acid / HNO₃ Allow 0.5 mol dm⁻³ sulfuric acid / H₂SO₄ Do not award just 1 mol but only penalise once in M1 and M4 Accept 101 kPa / 1.01 × 10⁵ Pa / 1 atmosphere pressure Allow 1 bar pressure Do not award other temperatures Ignore references to anode/cathode Allow any soluble named copper(II) salt e.g. copper(II) sulfate / CuSO₄ / copper(II) nitrate / Cu(NO₃)₂ / copper(II) chloride / CuCl₂ Allow salt bridge drawn and labelled just with the electrolyte e.g. potassium, sodium or ammonium nitrate, chloride or sulfate Do not award M5 if the circuit is incorrect e.g. a cell or ammeter instead of voltmeter or incorrect compounds such as KOH/HNO₃ in salt bridge	(5)
Question Number	Answer	Additional Guidance	Mark
18(b)(i)	An explanation that makes reference to the following points:	Ignore any references to E_a /energy	(3)

	(concentrated hydrochloric acid) - increases the concentration of H^+ ions in the first equilibrium (and displaces it to the right) so increases the value of $E / E > 1.33 \text{ (V)}$ (1) (concentrated hydrochloric acid) - increases the concentration of chloride ions in the second equilibrium (and displaces it to the left) so decreases the value of $E / E < 1.36 \text{ (V)}$ (1) - the difference between 1.33 and 1.36 is (very) small and so using concentrated hydrochloric acid, E_{cell} will be positive (so the reaction occurs) (1)	Allow just 'when $[\text{H}^+]$ increases the first equilibrium shifts to the right' Allow because the coefficient for H^+ is 14, the position of equilibrium is very sensitive to the concentration of H^+ Allow just 'when $[\text{Cl}^-]$ increases the second equilibrium shifts to the left' There must be some indication of the equilibrium referred to but can simply be $\text{Cl}_2:2 \text{ Cl}^-$ Allow answer in terms of first $E^\ominus$ increasing (above 1.36 (V)) or second $E^\ominus$ decreasing (below 1.33(V)) so E_{cell} will be positive for M3 Allow chlorine escapes and displaces second equilibrium to the left and decreases $E^\ominus$ decreasing below 1.33 (V) so E_{cell} will be positive Ignore references to anode/cathode COMMENT If neither H^+ nor Cl^- are referred to but equilibrium shifts both stated correctly then award (1) for M1 and M2. If an overall equation is written and correct comments made then all marking points possible	
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Question Number	Answer	Additional Guidance	Mark
18(b)(ii)		Example of cell diagram:	(2)

	(1) Pt(s) 2Cl⁻(aq) Cl₂(g) [Cr₂O₇²⁻(aq) + 14H⁺(aq)], [2Cr³⁺(aq)+7H₂O(l)] Pt(s) • left hand side of cell diagram Allow comma between Cl⁻ and Cl₂ Do not award missing molar ratio but penalise once only COMMENT Allow use of Cl⁻(aq) ½Cl₂(g) and 6Cl⁻(aq) 3Cl₂(g) • central vertical lines and right hand side of cell diagram (1) Allow dotted / dashed vertical lines in the cell junction of the cell diagram Allow comma between dichromate ion and proton Allow vertical line between protons and chromium(III) ions Ignore missing / incorrect state symbols Ignore omission of water Ignore missing brackets/use of rounded brackets Penalise inclusion of electrons once only If no other mark is awarded, allow (1) for whole cell diagram written in reverse If no other mark is awarded, allow (1) for electrodes on correct sides but 2Cl⁻ and Cl₂ in reverse order and / or 2Cr³⁺ and Cr₂O₇²⁻ + 14H⁺ in reverse order Award (1) if Pt(s) missing both sides but all otherwise correct	
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Question Number	Answer	Additional Guidance	Mark
18(c)	- calculation of mol MnO_4^- and X_2O_5 (1) - deduction of mol ratio (1) - final oxidation number of X (1)	Example of calculation: $\text{mol MnO}_4^- = \frac{50.0 \times 0.02}{1000} = 0.001 / 1.00 \times 10^{-3}$ and $\text{mol X}_2\text{O}_5 = \frac{25.0 \times 0.1}{1000} = 0.0025 / 2.5 \times 10^{-3}$ or $\text{mol X} = \frac{25.0 \times 0.1 \times 2}{1000} = 0.0050 / 5 \times 10^{-3}$ COMMENT Accept use of fractions $\frac{1}{1000}$ and $\frac{1}{400}$ Allow M1 for these two values even if incorrectly labelled mol ratio X : MnO_4^- is 5 : 1 Allow calculation of moles of electrons per Mn and per X giving $5 \times 10^{-3} : 5 \times 10^{-3}$ (there are 5 electrons in the MnO_4^- half-equation so X's oxidation number decreased by 1 to (+) 4 Allow X^{+4} Allow TE of oxidation number (+) 3 from 5 : 2 ratio or from $5 \times 10^{-3} \div 2.5 \times 10^{-3} = 2$ so $+5 - 2 = (+)3$ Award (3) for oxidation number (+) 4 provided some working such as number of moles for M1	(3)

(Total for Question 18 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
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19(a)	- calculation of mol of K, Fe and O - deduction of mol ratio and empirical formula Alternative method - calculation of M_r value - deduction of elemental values and empirical formula	Example of calculation: <table border="1"> <tr> <td></td><td>K</td><td>Fe</td><td>O</td></tr> <tr> <td>mol</td><td>$\frac{39.5}{39.1} = 1.01$</td><td>$\frac{28.2}{55.8} = 0.505$</td><td>$\frac{32.3}{16} = 2.02$</td></tr> <tr> <td>ratio</td><td>2</td><td>1</td><td>4</td></tr> </table> (1) Empirical formula is K_2FeO_4 Accept symbols in any order Allow use of 39 as A_r of K, 56 as A_r of Fe and 0.504 as mol of Fe Allow TE for M2 from candidates own moles Correct empirical formula with no working scores (2) COMMENT Use of atomic numbers gives the correct empirical formula and so please check the working before awarding (2) if the answer is correct. If atomic numbers have been used then award (1) If one or two atomic numbers are used then allow TE as appropriate for (1) (1) $M_r = (\text{Atomic mass} \div \text{element percentage}) \times 100$ e.g. $M_r = (55.8 \div 28.2) \times 100 = 197.87 / 197.9 / 198$ K = $(39.5 \div 100) \times 198 = 78.2$ so 2K Fe = $(28.2 \div 100) \times 198 = 55.8$ so 1Fe O = $(32.3 \div 100) \times 198 = 64$ so 4O (1) Empirical formula is K_2FeO_4		K	Fe	O	mol	$\frac{39.5}{39.1} = 1.01$	$\frac{28.2}{55.8} = 0.505$	$\frac{32.3}{16} = 2.02$	ratio	2	1	4	(2)
	K	Fe	O												
mol	$\frac{39.5}{39.1} = 1.01$	$\frac{28.2}{55.8} = 0.505$	$\frac{32.3}{16} = 2.02$												
ratio	2	1	4												

Question Number	Answer	Additional Guidance	Mark
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19(b)(i)	An answer that makes reference to the following point: reaction between two negative ions is slow due to repulsion	Allow negative species for negative ions Allow just 'the negative ions repel' Ignore references to unlikelihood of three negative ions colliding Do not award negative molecules	(1)
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Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	- ionic equation involving iron(II) (1) - ionic equation involving iron(III) (1)	<u>Examples of ionic equations</u> $2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$ $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$ Award (1) for balanced equations given in reverse order Allow (1) for two unbalanced equations with all species paired correctly Ignore state symbols even if incorrect	(2)

Question	Answer	Additional Guidance	Mark
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Number			
19(c)(i)	An explanation that makes reference to the following points: - because it forms one dative (covalent) / co-ordinate bond (to Fe^{2+}) (1) - using a lone pair (of electrons) on oxygen (1)	Allow 'a dative/co-ordinate bond' Allow oxygen donates a pair of electrons Ignore water uses a lone pair of electrons COMMENT Allow M2 for a diagram showing the oxygen lone pair forming the co-ordinate bond but annotation needed to score M1	(2)

Question Number	Answer	Additional Guidance	Mark
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19(c)(ii)	An explanation that makes reference to the following points: - octahedral because there are six pairs of electrons (1) - which are as far apart as possible to minimise repulsion (1)	Allow this shown on a diagram Allow octahedral because there are 6 coordinate bonds/coordination number is 6 Ignore just octahedral because there are 6 ligands Do not award if bond angle other than 90° / 90° and 180° stated Allow repel/arrange/shape to maximum separation Do not allow repulsion between atoms or water molecules or ligands	(2)
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Question Number	Answer	Additional Guidance	Mark
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19(d)	An explanation that makes reference to the following points: - carbon monoxide replaces / takes the place of the oxygen molecule / ligand (and it may be toxic) because it binds strongly to the Fe^{2+} ion	(1) Accept ligand substitution / exchange reaction between oxygen and carbon monoxide COMMENT The question refers to oxygen being carried around and so there needs to be explicit reference and not just implied that to it being replaced/substituted or its place being taken (1) Allow carbon monoxide forms a stronger bond to Fe^{2+} (than oxygen) Allow carbon monoxide binds (almost) irreversible / permanently to Fe^{2+} Allow carbon monoxide forms a more stable complex ion with Fe^{2+} / the complex formed has a larger equilibrium constant Allow prevents / reduces the amount of oxygen being carried to the cells / organs / around the body / blood – scores M2 not M1 Allow just carbon monoxide binds more strongly to haemoglobin/globin	(2)
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Question Number	Answer	Additional Guidance	Mark
19(e)	An explanation that makes reference to the following points: - there are more particles / moles on the right (of the equation) or there is an increase from 3 particles / moles / species on the left of the equation to 5 on the right - so ΔS_{system} increases / is positive (and the reaction is thermodynamically feasible)	Allow species for particles Do not award reference to molecules / atoms / compounds (1) Do not award incorrect numbers (1) Allow ΔS_{total} is positive / increasing (and the reaction is thermodynamically feasible) Allow there is an increase in entropy (and the reaction is thermodynamically feasible) Ignore references to increases in disorder COMMENT Entropy is the subject of the question and so answers which refer to “it increases” can score M2 But Ignore just ‘entropy is positive’ since it is always positive	(2)

Question Number	Answer	Additional Guidance	Mark
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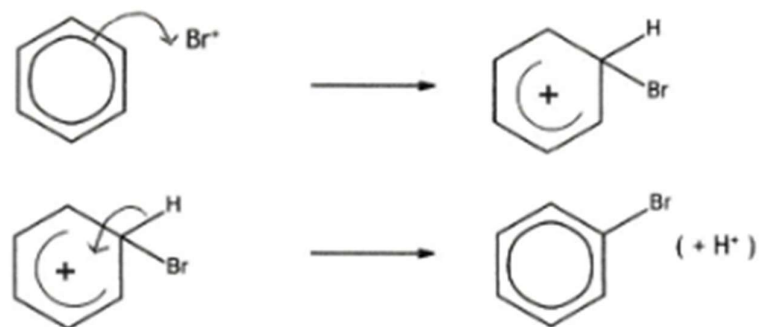
19(f)	• (M1) calculation of concentration of $\text{Cr}_2\text{O}_7^{2-}$ in mol dm^{-3} Process (division by 216) (1) • (M2) calculation of mol $\text{Cr}_2\text{O}_7^{2-}$ in 22.55 cm^3 Process (multiplying by 0.02255) (1) • (M3) calculation of mol Fe^{2+} in 25.0 cm^3 Process (molar ratio x6) (1) • (M4) calculation of mass of Fe^{2+} in 1 dm^3 Process (x55.8 and scaling up x40) (1) • (M5) calculation of percentage of Fe^{3+} Process (subtraction to get Fe^{3+} mass and then % calculation) (1) Alternative method • (M1) mass of $\text{Cr}_2\text{O}_7^{2-}$ in 22.55 cm^3 (1)	Example of calculation $\text{Conc } \text{Cr}_2\text{O}_7^{2-} = \frac{2.56}{216} = 0.011852 / 1.1852 \times 10^{-2} (\text{mol dm}^{-3})$ $\text{Mol } \text{Cr}_2\text{O}_7^{2-} = \frac{0.011852 \times 22.55}{1000} = 0.00026726 / 2.6726 \times 10^{-4} (\text{mol})$ $\text{Mol } \text{Fe}^{2+} = 0.00026726 \times 6 = 0.0016036 / 1.6036 \times 10^{-3} (\text{mol})$ $\text{Mass } \text{Fe}^{2+} = \frac{0.0016036 \times 1000 \times 55.8}{25.0} = 3.5791 (\text{g})$ Allow 3.5921 (g) using 56 as A_r for Fe $\text{Mass } \text{Fe}^{3+} = 6.28 - 3.5791 = 2.7009 (\text{g})$ and $\% \text{ of } \text{Fe}^{3+} = \frac{2.7009}{6.28} \times 100 = 43.007 / 43.0 (\%)$ Allow 42.8% using 56 as A_r for Fe Allow TE at each stage Ignore SF except 1 SF Do not award M5 if %>100 Correct answer with some working scores (5) COMMENT 56.8% / 57% scores (4) as missing subtraction in M5 98.6% scores (4) as missing scaling up in M4 90.5% scores (4) as missing molar ratio in M3 See second page for alternative method Example of calculation $\text{Mass } (\text{Cr}_2\text{O}_7^{2-}) = 2.56 \times 22.55 = 0.057728 (\text{g})$	(5)
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	Process (multiplying by 0.02255)		1000	
	• (M2) calculation of mol $\text{Cr}_2\text{O}_7^{2-}$ in 22.55 cm^3 Process (division by 216)	(1)	$\text{Mol } (\text{Cr}_2\text{O}_7^{2-}) = \frac{0.057728}{216} = 0.00026726 / 2.6726 \times 10^{-4} \text{ (mol)}$	
	• (M3) calculation of mol Fe^{2+} in 25.0 cm^3 Process (molar ratio x6)	(1)	$\text{Mol } \text{Fe}^{2+} = 0.00026726 \times 6 = 0.0016036 / 1.6036 \times 10^{-3} \text{ (mol)}$	
	• (M4) calculation of mass of Fe^{2+} in 25.0 cm^3 and calculation of total mass of $(\text{Fe}^{2+} + \text{Fe}^{3+})$ Process (x55.8 and scaling to get total mass by x 0.025)	(1)	$\text{Mass } \text{Fe}^{2+} = 0.0016036 \times 55.8 = 0.089481 \text{ (g)}$ and $\text{Mass } (\text{Fe}^{2+} + \text{Fe}^{3+}) = \frac{6.28 \times 25.0}{1000} = 0.157 \text{ (g)}$	
	• (M5) calculation of percentage of Fe^{3+} Process (subtraction to get Fe^{3+} mass and then % calculation)	(1)	$\text{Mass } \text{Fe}^{3+} = 0.157 - 0.089481 = 0.067519 \text{ (g)}$ and $\% \text{ of } \text{Fe}^{3+} = \frac{0.067519 \times 100}{0.157} = 43.0 / 43 \text{ (\%)}$	
			COMMENT There are variations of this approach. If the final answer is correct then award (5). If not then count the errors and deduct one mark for each error. Do allow TE at each stage by looking at the processes employed by the candidate.	

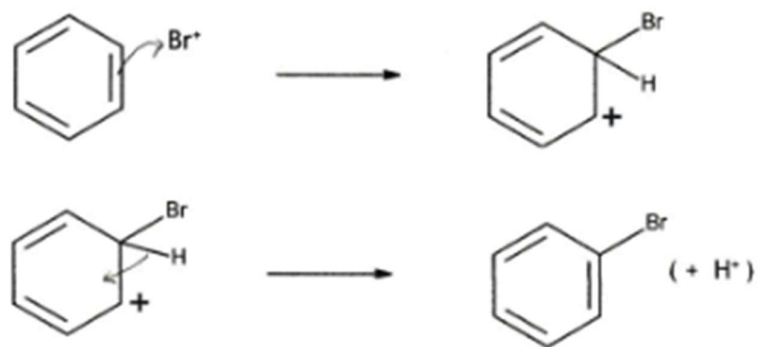
(Total for Question 19 = 18 marks)

Question Number	Answer	Additional Guidance	Mark
20(a)(i)	- equation for the formation of the electrophile - curly arrow within the circle/hexagon to anywhere towards or on Br^+ - intermediate structure including charge with horseshoe covering at least 3 carbon atoms and facing the tetrahedral carbon atom and some part of the positive charge must be within the horseshoe - curly arrow from C-H bond to anywhere in the hexagon, reforming the delocalised structure	See examples of mechanism on next page (1) $\text{FeBr}_3 + \text{Br}_2 \rightarrow \text{Br}^+ + \text{FeBr}_4^- /$ $\text{Br}-\text{Br} + \text{FeBr}_3 \rightarrow \text{Br}^{\delta+}-\text{Br}^{\delta-} \text{---FeBr}_3$ Allow this shown as part of the first step e.g.  Allow partial charges on $\text{Br}^{\delta+}-\text{Br}^{\delta-}$ COMMENT Allow the use of $\text{AlBr}_3/\text{AlCl}_3$ (1) Do not award curly arrow starting on or outside the hexagon Do not award missing $+/ \delta^+$ on electrophile Do not award curly arrow to a lone pair of electrons on Br^+ Do not award dotted bonds to H and Br unless they are part of a 3D structure (1) Ignore missing H^+ / involvement of FeBr_4^- in removal of H^+ Ignore reformation of the catalyst even if incorrect	(4)

Examples of mechanism

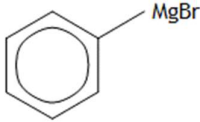
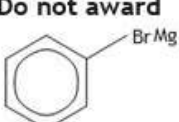
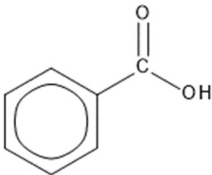
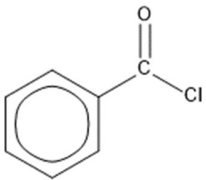


Or



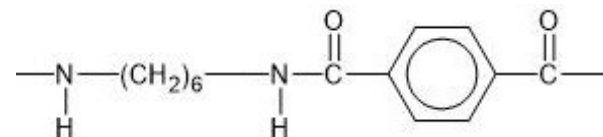
Question Number	Acceptable Answers	Additional Guidance	Mark																				
20(a)(ii)*	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some 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> Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning Indicative content IP1 – Similarity	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 line of reasoning	Answer shows a coherent and 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	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). 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. General points to note If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Accept structures for names throughout If name and formula given both must be correct Deduct a reasoning mark if there is no comparison given for IP1 to IP3 Do not penalise unbalanced / incomplete equations Deduct (mark) from reasoning if any products given are incorrect	(6)
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 line of reasoning																						
Answer shows a coherent and 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																						

	All are attacked by / react with electrophiles • IP2 – Types of reaction Cyclohexene undergoes addition reactions but benzene and/or phenol undergo substitution reactions • IP3 – Conditions Cyclohexene and/or phenol react with (aqueous) bromine / without a catalyst and benzene needs (a Friedel-Crafts catalyst / iron / iron(III) bromide) • IP4 – Benzene Benzene has delocalised electrons and is (kinetically) stable so the reaction has a high activation energy • IP5 – Cyclohexene Cyclohexene has localised electron density in one π bond (which increases the electron density and makes it more susceptible to electrophilic attack) • IP6 – Phenol Phenol has a lone pair of electrons on the oxygen which is delocalised (within the ring) and makes it more susceptible to electrophilic attack	All three need to be mentioned for this IP – evidence for phenol reacting with an electrophile may be seen in IP6 Accept benzene forms monobromo product / bromobenzene, cyclohexene forms dibromo product / 1,2-dibromocyclohexane and phenol forms tribromo product / 2, 4, 6-tribromophenol Allow HBr is produced with benzene and phenol but cyclohexene only forms one product Allow react under normal laboratory conditions / room temperature and pressure Allow reference to $\text{AlBr}_3/\text{AlCl}_3$ This IP can be awarded if benzene equation has catalyst and other equation(s) do not Ignore references to specific temperatures Allow delocalised (π) electron ring in benzene is (very) stable Allow delocalisation of electrons in π bonds which decreases the electron density (of the ring) and makes it less susceptible to electrophilic attack If neither IP4 or IP5 awarded then allow (1) for benzene has delocalised electrons but cyclohexene does not Allow the lone pair (of electrons) on the oxygen/OH in phenol and increases the electron density of the (benzene) ring/overlaps with the delocalised ring	
Question Number	Answer	Additional Guidance	Mark

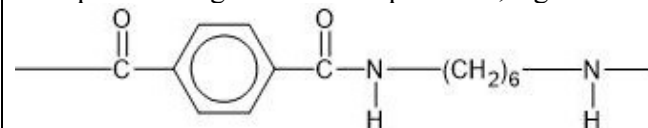
20(b)	An answer that makes reference to the following points: • (M1) reagent for step 1 - magnesium and (dry) ether (reacting with bromobenzene) (1) • (M2) first intermediate – phenyl magnesium bromide (1) • (M3) reagent for step 2 – phenyl magnesium bromide with carbon dioxide / CO₂ and (followed by hydrolysis with) dilute acid / H⁺ or methanal and dilute acid / H⁺ then oxidation (1) • (M4) second intermediate – benzoic acid (1) • (M5) reagent for step 3 – phosphorus(V) chloride / PCl₅ (1) • (M6) third intermediate – benzoyl chloride (1) • (M7) reagent for step 4 – ammonia / NH₃ added to an acyl chloride (1) COMMENT Allow the use of ammonia with benzoic acid if there is clear evidence of the ammonium salt being dehydrated. M5 to M7 can then be awarded, otherwise the do not award applies	Allow displayed / structural / skeletal formulae or any combination of these Ignore any references to heat/ incorrect inorganic products Examples of structures of intermediates:  MgBr Do not award  BrMg Allow (1) for M3 for the acid hydrolysis of benzonitrile  Allow thionyl chloride/SOCl₂  Do not award dilute ammonia or ammonia added to benzoic acid M4 to M7 from scheme above can be awarded from benzoic acid however produced	(7)
Question Number	Answer	Additional Guidance	Mark
20(c)(i)		Accept skeletal/displayed/structural formulae or combination thereof provided it is correct	(1)

- repeat unit

Example of repeat unit:



Accept switching of monomer positions, e.g.



Allow amide link to be drawn as CONH/ -NH - CO -
Allow 'cis' orientation of amide link

Ignore bond lengths and bond angles

Ignore brackets around repeat unit and n

Ignore byproducts such as HCl

Do not award additional incomplete repeat units

Do not award hydrogen drawn with two single bonds,
e.g. -N - H - CO

Do not award missing continuation/extension bonds

COMMENT

Allow two repeat units provided both are correct

Question Number	Answer	Additional Guidance	Mark
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20(c)(ii)	An answer that makes reference to the following point: • because there is hydrogen bonding (and London forces between the chains) in a polyamide (1) • (and this is) stronger than the London forces between the chains in polyalkenes (so more energy is needed to separate the polyamide molecules) or - the London forces between the chains in polyalkenes are weaker (than hydrogen bonding so more energy is needed to separate the polyamide molecules) (1)	Reference to breaking of covalent bonds scores (0) Ignore references to (permanent) dipole forces Allow 'it' for the polyamide since it is the subject of the question, so "it has hydrogen bonding" scores M1 Do not award if hydrogen bonding to water stated Do not award if hydrogen bonding shown by CH₂ Do not award if ionic bonding or ions referred to Accept dispersion forces / attractions between temporary and induced dipoles for London forces Allow van der Waals' forces for London forces Allow London forces in polyalkenes are easier to overcome (than hydrogen bonding) Note that M2 is awarded for a comparison of the weakness of London forces to the strength of hydrogen bonding. Hence M2 is dependent on M1 or near-miss COMMENT Reference to polyalkenes "only having London forces" compared to polyamides having hydrogen bonding is not enough for M2 unless the hydrogen bonding is stated to be strong Allow reference to molecules rather than chains	(2)
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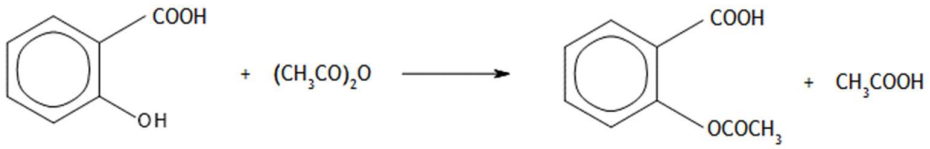
(Total for Question 20 = 20 marks)

(Total for Section B = 51 marks)

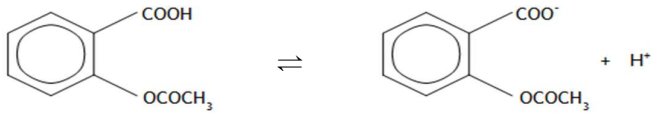
Section C

Question Number	Answer	Additional Guidance	Mark
21(a)	2-hydroxybenzoic acid	Accept 2-hydroxybenzenecarboxylic acid Allow minor misspellings such as 2-hydroxylbenzenoic acid Ignore missing hyphen or comma instead of hyphen COMMENT Allow 2-hydroxybenzonic acid	(1)

Question Number	Answer	Additional Guidance	Mark
21(b)(i)	carboxylic acid and ester and benzene / arene	Accept names given in any order Allow just 'carboxyl' for carboxylic acid Allow just 'carboxylic' Allow phenyl for benzene/arene Allow aromatic ring for benzene/arene Ignore formulae of groups Do not award phenol Do not award carbonyl	(1)

Question Number	Answer	Additional Guidance	Mark
21(b)(ii)	correct equation	Example of equation:  Accept displayed / skeletal formulae COMMENT Allow use of C₆H₄ for the benzene ring Do not award molecular formulae	(1)

Question Number	Answer	Additional Guidance	Mark
21(b)(iii)	- calculation of amount of salicylic acid (1) - calculation of theoretical mass of acetyl salicylic acid (1) - calculation of actual mass of acetyl salicylic acid (1)	Example of calculation: mol salicylic acid used = $\frac{2.00}{138} = 0.014493$ (mol) theoretical mass of acetyl salicylic acid = $0.014493 \times 180 = 2.6087$ (g) TE on M1 actual mass of acetyl salicylic acid = $\frac{2.6087 \times 74.8}{100} = 1.9513$ (g) TE on M2 provided answer ≤ 5.00 (g) OR mass salicylic acid converted = $2.00 \times 0.748 = 1.496$ (g) (1) mol salicylic acid converted = $\frac{1.496}{138} = 0.01084$ (mol) (1) mass acetyl salicylic acid formed = $0.01084 \times 180 = 1.9513$ (g) Ignore SF except 1 SF Correct answer scores (3) COMMENT If M_r values are reversed 1.1469 g scores (2) Allow fractions e.g. salicylic acid moles = $\frac{1}{69}$	(3)

Question Number	Answer	Additional Guidance	Mark
21(c)(i)	completed equation	Example of equation:  Accept equation with H_2O and H_3O^+ Allow H_3O^+ for H^+ on right hand side	(1)

Question Number	Answer	Additional Guidance	Mark
21(c)(ii)	An explanation that makes reference to the following points: - acetylsalicylic acid will dissociate less in acidic solution or acetylsalicylic acid dissociate more in alkaline solution (1) - because the additional H^+ / H_3O^+ ions in the acid will shift the equilibrium position to the left (1) - and OH^- / hydroxide ions in the alkali will <u>react</u> with the H^+ ions and shift the equilibrium position to the right (1)	Penalise reference to change in K_a once only Allow reference to the stomach for 'acidic solution' Allow reference to small intestine for 'alkaline' If both stated then both must be correct Allow the backward reaction is favoured by the additional/higher H^+ / H_3O^+ ions in the acid Accept $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ and this shifts the equilibrium position to the right Allow $-\text{COOH} + \text{OH}^- \rightarrow -\text{COO}^- + \text{H}_2\text{O}$ Or carboxylic acid group reacts with /neutralises the OH^- and this shifts the equilibrium position to the right/ favours the forward reaction	(3)
Question Number	Answer	Additional Guidance	Mark

21(d)	methanol / CH₃OH	Allow displayed formula / combination of structural and displayed formula If name and formula are given then both must be correct Allow methyl alcohol Ignore reference to acid catalyst/ H₂SO₄/ HCl/ heat Do not award methanal Do not award CH₄O	(1)
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Question Number	Answer	Additional Guidance	Mark															
21(e)	- chemical shift ranges for OH and CH₃ in acetylsalicylic acid - chemical shift ranges for OH and CH₃ in methyl salicylate (1) (1)	Example of table: <table><tr><td></td><td colspan="2">Acetylsalicylic acid</td><td colspan="2">Methyl salicylate</td></tr><tr><td>Type of proton</td><td>OH</td><td>CH₃</td><td>OH</td><td>CH₃</td></tr><tr><td>Chemical shift / ppm</td><td>10.0 – 12.0</td><td>1.6 – 2.8</td><td>3.8 – 7.6</td><td>2.8 – 4.3</td></tr></table> Allow ranges in reverse order e.g. 12.0 – 10.0 Allow any range within these ranges 11.8 – 10.2 COMMENT If no other mark is awarded, allow (1) for any two correct ranges If no other mark awarded, allow (1) for any three single values within the correct ranges or two single values with one acceptable range		Acetylsalicylic acid		Methyl salicylate		Type of proton	OH	CH ₃	OH	CH ₃	Chemical shift / ppm	10.0 – 12.0	1.6 – 2.8	3.8 – 7.6	2.8 – 4.3	(2)
	Acetylsalicylic acid		Methyl salicylate															
Type of proton	OH	CH ₃	OH	CH ₃														
Chemical shift / ppm	10.0 – 12.0	1.6 – 2.8	3.8 – 7.6	2.8 – 4.3														

Question Number	Answer	Additional Guidance	Mark
21(f)	(M1) calculation of mol NaOH added at start (1) (M2) calculation of mol HCl used in titration (1) (M3) calculation of mol NaOH remaining in 250 cm³ Process (scaling up of remaining NaOH x10) (1) (M4) calculation of mol acetylsalicylic acid reacted Process (subtraction and then ÷ by2) (1) (M5) calculation of acetylsalicylic acid mass Process (x180) (1) (M6) calculation of percentage of acetylsalicylic acid and deduction of Brand of tablet Process (% calc and brand identity) (1) COMMENT An answer of 95% and brand B does not automatically score (6) because 95% can be obtained incorrectly. Check that 0.76 is the denominator for the percentage calculation	Example of calculation: mol NaOH = $\frac{25.0 \times 1.00}{1000} = 0.025 / 2.5 \times 10^{-2}$ (mol) mol HCl = $\frac{16.95 \times 0.100}{1000} = 0.001695 / 1.695 \times 10^{-3}$ (mol) (mol NaOH remaining in 25.0 cm³ = 0.001695 / 1.695 × 10⁻³ (mol)) mol NaOH remaining in 250 cm³ = 0.01695 / 1.695 × 10⁻² (mol) mol NaOH = 0.025 – 0.01695 = 0.00805 / 8.05 × 10⁻³ (mol) mol acetylsalicylic acid = $\frac{0.00805}{2} = 0.004025$ mass acetylsalicylic acid = 0.004025 × 180 = 0.7245 (g) percentage of acetylsalicylic acid = $\frac{0.7245 \times 100}{0.760} = 95.329$ (%) and Brand B Allow TE at each stage Brand / percentage with no working scores (0) Ignore SF except 1 SF in the final mass calculated Ignore incorrect intermediate units Do not credit a division of moles by 2 if carried out before the subtraction	(6)

(Total for Question 21 = 19 marks)

(Total for Section C = 19 marks)

(Total for Paper = 90 marks)

