Pearson Edexcel

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) ***A*** *is incorrect because cobalt forms a stable* Co^{2+} *ion with incompletely-filled d-orbitals* ***B*** *is incorrect because copper forms a stable* Cu^{2+} *ion with incompletely-filled d-orbitals* ***C*** *is incorrect because nickel forms a stable* Ni^{2+} *ion with incompletely-filled d-orbitals*	**(1)**

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

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

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

Question number	Answer	Mark
5	**The only correct answer is B (**$[Zn(H_2O)_6]^{2+} + 2NH_3 \rightarrow Zn(OH)_2(H_2O)_4 + 2NH_4^+$) ***A*** *is incorrect because the precipitate should not have a positive charge and the charges do not balance* ***C*** *is incorrect because $[Zn(NH_3)_4(H_2O)_2]^{2+}$ is formed when the precipitate dissolves in excess aqueous ammonia* ***D*** *is incorrect because $Zn(NH_3)_4(H_2O)_2$ should have a 2+ charge and the equation is not balanced*	**(1)**

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

Question number	Answer	Mark

7	**The only correct answer is C** (ΔS_{total} and ln K) ***A*** *is incorrect because* $E^{\ominus}_{cell}$ *is not directly proportional to* $\Delta_r H$ ***B*** *is incorrect because* $E^{\ominus}_{cell}$ *is not directly proportional to* $\Delta_r H$ *or to ln RT* ***D*** *is incorrect because* $E^{\ominus}_{cell}$ *is not directly proportional to ln RT*	**(1)**

Question number	Answer	Mark
8	**The only correct answer is A** (standard reduction potential; most negative to most positive) ***B*** *is incorrect because the electrochemical series has the most negative standard electrode potential first* ***C*** *is incorrect because standard cell potentials are determined from two standard electrode potentials* ***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*	**(1)**

Question number	Answer	Mark
9	**The only correct answer is A** (H_2 + $2OH^-$ → $2H_2O$ + $2e^-$) ***B*** *is incorrect because H^+ ions cannot be produced in an alkaline solution* ***C*** *is incorrect because H^+ ions cannot be produced in an alkaline solution* ***D*** *is incorrect because H^+ ions cannot be produced in an alkaline solution*	**(1)**

Question number	Answer	Mark
10	**The only correct answer is B** (negative; positive) ***A*** *is incorrect because $E^\ominus_{cell} = E_{rhs} - E_{lhs}$ so 0.17 –(−0.40) = +0.57 V or 0.40 –(−0.17) = +0.57 V* ***C*** *is incorrect because $E^\ominus_{cell} = E_{rhs} - E_{lhs}$ so 0.17 –(−0.40) = +0.57 V or 0.40 –(−0.17) = +0.57 V* ***D*** *is incorrect because $E^\ominus_{cell} = E_{rhs} - E_{lhs}$ so 0.17 –(−0.40) = +0.57 V or 0.40 –(−0.17) = +0.57 V*	**(1)**

Question number	Answer	Mark
11	**The only correct answer is C** (magnesium) ***A*** *is incorrect because 1.635 ÷ 65.4 = 0.025 mol of zinc produced which gives a relative atomic mass of 24.3 for G* ***B*** *is incorrect because 1.635 ÷ 65.4 = 0.025 mol of zinc produced which gives a relative atomic mass of 24.3 for G* ***D*** *is incorrect because 1.635 ÷ 65.4 = 0.025 mol of zinc produced which gives a relative atomic mass of 24.3 for G*	**(1)**

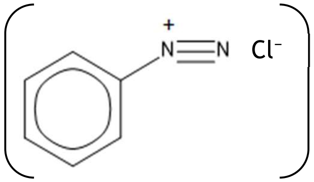
Question number	Answer	Mark
12	**The only correct answer is D** (phenylamine) ***A*** *is incorrect because the lone pair of electrons on N in ammonia is not delocalised so can be donated more easily* ***B*** *is incorrect because the lone pair of electrons on N in butylamine is not delocalised so can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

Question number	Answer	Mark
13	**The only correct answer is B** ($H_2NCH(CH_3)COO^-$) ***A*** *is incorrect because this is the structure of the uncharged molecule* ***C*** *is incorrect because this structure would exist at pH less than 6.0* ***D*** *is incorrect because this is the structure of the zwitterion*	**(1)**

Question number	Answer	Mark
14	**The only correct answer is A** (CH_2=CHCOOH) ***B*** *is incorrect because phenol does not react with ethanol* ***C*** *is incorrect because 2-propen-1-ol does not react with sodium hydroxide or ethanol* ***D*** *is incorrect because ethanoic acid does not react with hydrogen in the presence of a nickel catalyst*	**(1)**

Question number	Answer	Mark
15(a)	**The only correct answer is A** (further substitution by a nitro group occurs) ***B*** *is incorrect because nitrobenzene does not decompose at 80°C* ***C*** *is incorrect because fuming sulfuric acid is needed for the substitution of* SO_3H ***D*** *is incorrect because nitric acid does not decompose at 80°C*	**(1)**

Question number	Answer	Mark
15(b)	**The only correct answer is C** (Sn and concentrated HCl(aq) are added first, then NaOH(aq) is added at the end) ***A*** *is incorrect because the acid and alkali would react to form a salt if they are added together* ***B*** *is incorrect because the acid and alkali would react to form a salt if they are added together* ***D*** *is incorrect because dilute hydrochloric acid would not react quickly enough with the tin*	**(1)**

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

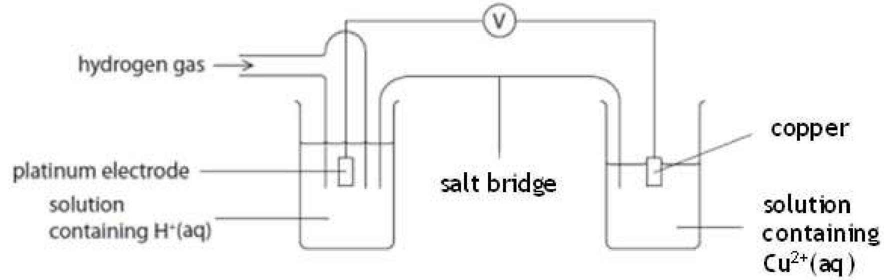
Question number	Answer	Mark
15(d)	**The only correct answer is B** (alkaline) ***A*** *is incorrect because a phenoxide ion is needed for the reaction and that is produced in alkaline solution* ***C*** *is incorrect because a phenoxide ion is needed for the reaction and that is produced in alkaline solution*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

Question number	Answer	Mark
16	**The only correct answer is D** (8 (cm^3)) ***A*** *is incorrect because 2 cm^3 of methane reacts with 4 cm^3 of oxygen* ***B*** *is incorrect because 4 cm^3 of methane would react with 4 cm^3 of oxygen if they reacted in a 1:1 mole ratio* ***C*** *is incorrect because 6 cm^3 would be the volume of argon if methane reacted with oxygen in a 1:1 mole ratio*	**(1)**

Question number	Answer	Mark
17	**The only correct answer is A** (x is 30 and y is 40) ***B*** *is incorrect because water is a liquid at room temperature* ***C*** *is incorrect because 10 cm^3 of but-1-ene reacts with 60 cm^3 of oxygen to form 40 cm^3 of carbon dioxide so there is an initial decrease of 30 cm^3* ***D*** *is incorrect because 10 cm^3 of but-1-ene reacts with 60 cm^3 of oxygen to form 40 cm^3 of carbon dioxide so there is an initial decrease of 30 cm^3 and water is a liquid at room temperature*	**(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 / 1×10^5 Pa (at 298 K) **(1)** **Copper half-cell:** • (**M3**) copper (electrode) dipping into solution **(1)** • (**M4**) 1 mol dm^{-3} Cu^{2+} (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 / HNO_3 Allow 0.5 mol dm^{-3} sulfuric acid / H_2SO_4 Do not award just 1 mol but only penalise once in M1 and M4 Accept 101 kPa / 1.01×10^5 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 / $CuSO_4$ / copper(II) nitrate / $Cu(NO_3)_2$ / copper(II) chloride / $CuCl_2$ 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/HNO_3 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 / $E > 1.33$ (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 / $E < 1.36$ (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 $[H^+]$ 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 $[Cl^-]$ increases the second equilibrium shifts to the left' There must be some indication of the equilibrium referred to but can simply be Cl_2:2 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	

Question Number	Answer	Additional Guidance	Mark
18(b)(ii)		Example of cell diagram:	**(2)**

	(1) • left hand side of cell diagram • central vertical lines and right hand side of cell diagram **(1)**	$Pt(s) \mid 2Cl^{-}(aq) \mid Cl_2(g) \parallel [Cr_2O_7^{2-}(aq) + 14H^{+}(aq)], [2Cr^{3+}(aq)+7H_2O(l)] \mid Pt(s)$ Allow comma between Cl^{-} and Cl_2 Do not award missing molar ratio but penalise once only COMMENT Allow use of $Cl^{-}(aq) \mid ½Cl_2(g)$ and $6Cl^{-}(aq) \mid 3Cl_2(g)$ 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 Cl_2 in reverse order and / or $2Cr^{3+}$ and $Cr_2O_7^{2-} + 14H^{+}$ in reverse order Award (1) if Pt(s) missing both sides but all otherwise correct	

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: mol $MnO_4^- = \frac{50.0 \times 0.02}{1000} = 0.001 / 1.00 \times 10^{-3}$ **and** mol $X_2O_5 = \frac{25.0 \times 0.1}{1000} = 0.0025 / 2.5 \times 10^{-3}$ or 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 5×10^{-3} : 5×10^{-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

<table>
<tr><td>19(a)</td><td>

- calculation of mol of K, Fe and O **(1)**

- deduction of mol ratio
and
empirical formula **(1)**

Alternative method

- calculation of M_r value **(1)**

- deduction of elemental values
and
empirical formula **(1)**

</td><td>

Example of calculation:

	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

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)

M_r = (Atomic mass ÷ element percentage) x 100
e.g. M_r = (55.8 ÷ 28.2) x 100 = 197.87 / 197.9 / 198

K = (39.5 ÷ 100) x 198 = 78.2 so 2K
Fe = (28.2 ÷ 100) x 198 = 55.8 so 1Fe
O = (32.3 ÷ 100) x 198 = 64 so 4O
Empirical formula is K_2FeO_4

</td><td>(2)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark

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)**

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> $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ 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

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

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^{o} / 90^{o} and 180^{o} stated Allow repel/arrange/shape to maximum separation Do not allow repulsion between atoms or water molecules or ligands	**(2)**

Question Number	Answer	Additional Guidance	Mark

19(d)	An explanation that makes reference to the following points: • carbon monoxide replaces / takes the place of the oxygen molecule / ligand **(1)** • (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 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)**

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 **(1)** • so ΔS_{system} increases / is positive (and the reaction is thermodynamically feasible) **(1)**	Allow species for particles Do not award reference to molecules / atoms /compounds Do not award incorrect numbers 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

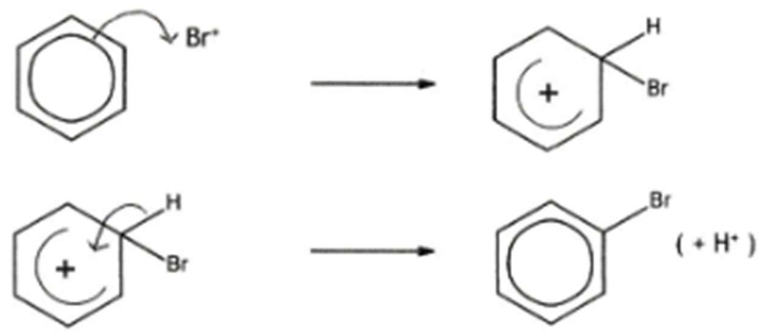
19(f)	• (**M1**) calculation of concentration of $Cr_2O_7^{2-}$ in mol dm^{-3} **(1)** Process (division by 216) • (**M2**) calculation of mol $Cr_2O_7^{2-}$ in 22.55 cm^3 **(1)** Process (multiplying by 0.02255) • (**M3**) calculation of mol Fe^{2+} in 25.0 cm^3 **(1)** Process (molar ratio x6) • (**M4**) calculation of mass of Fe^{2+} in 1 dm^3 **(1)** Process (x55.8 and scaling up x40) • (**M5**) calculation of percentage of Fe^{3+} **(1)** Process (subtraction to get Fe^{3+} mass and then % calculation) Alternative method • (**M1**) mass of $Cr_2O_7^{2-}$ in 22.55 cm^3 **(1)**	Example of calculation Conc $Cr_2O_7^{2-}$ = $\frac{2.56}{216}$ = 0.011852 / 1.1852 × 10^{-2} (mol dm^{-3}) Mol $Cr_2O_7^{2-}$ = $\frac{0.011852 \times 22.55}{1000}$ = 0.00026726 /2.6726 × 10^{-4} (mol) Mol Fe^{2+} = 0.00026726 × 6 = 0.0016036 / 1.6036 × 10^{-3} (mol) Mass Fe^{2+} = $\frac{0.0016036 \times 1000 \times 55.8}{25.0}$ = 3.5791 (g) Allow 3.5921 (g) using 56 as A_r for Fe Mass Fe^{3+} = 6.28 – 3.5791 = 2.7009 (g) **and** % of Fe^{3+} = $\frac{2.7009}{6.28}$ × 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 Mass ($Cr_2O_7^{2-}$) = $\underline{2.56 \times 22.55}$ = 0.057728 (g)	**(5)**

	Process (multiplying by 0.02255) • (**M2**) calculation of mol $Cr_2O_7^{2-}$ in 22.55 cm^3 Process (division by 216) **(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 25.0 cm^3 **and** calculation of total mass of (Fe^{2+} + Fe^{3+}) Process (x55.8 and scaling to get total mass by x 0.025) **(1)** • (**M5**) calculation of percentage of Fe^{3+} Process (subtraction to get Fe^{3+} mass and then % calculation) **(1)**	1000 Mol ($Cr_2O_7^{2-}$) = $\frac{0.057728}{216}$ = 0.00026726 /2.6726 × 10^{-4} (mol) Mol Fe^{2+} = 0.00026726 × 6 = 0.0016036 / 1.6036 × 10^{-3} (mol) Mass Fe^{2+} = 0.0016036 × 55.8 = 0.089481 (g) **and** Mass (Fe^{2+} + Fe^{3+}) = $\frac{6.28 \times 25.0}{1000}$ = 0.157 (g) Mass Fe^{3+} = 0.157 − 0.089481 = 0.067519 (g) **and** % of Fe^{3+} = $\frac{0.067519 \times 100}{0.157}$ = 43.0/ 43 (%) **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.	

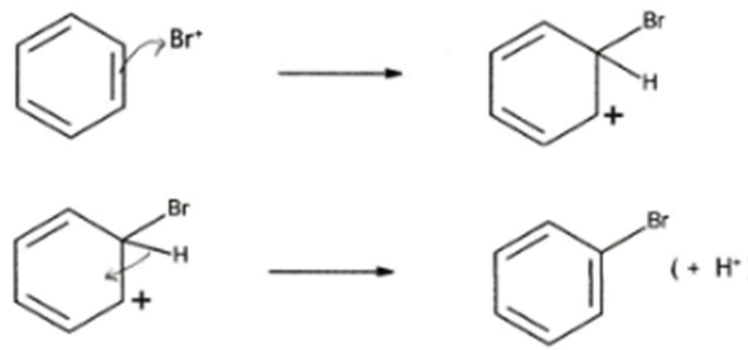
(Total for Question 19 = 18 marks)

Question Number	Answer		Additional Guidance	Mark
20(a)(i)			See examples of mechanism on next page	**(4)**
	• equation for the formation of the electrophile	**(1)**	$FeBr_3 + Br_2 \rightarrow Br^+ + FeBr_4^-$ / $Br{-}Br + FeBr_3 \rightarrow Br^{\delta+}{-}Br^{\delta-}$ ----$FeBr_3$ Allow this shown as part of the first step e.g.  Allow partial charges on $Br^{\delta+}{-}Br^{\delta-}$ **COMMENT** Allow the use of $AlBr_3$/$AlCl_3$	
	• curly arrow within the circle/hexagon to anywhere towards or on Br^+	**(1)**	Do not award curly arrow starting on or outside the hexagon Do not award missing +/δ^+ on electrophile Do not award curly arrow to a lone pair of electrons 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	**(1)**	Do not award dotted bonds to H and Br unless they are part of a 3D structure	
	• curly arrow from C−H bond to anywhere in the hexagon, reforming the delocalised structure	**(1)**	Ignore missing H^+ / involvement of $FeBr_4^-$ in removal of H^+ Ignore reformation of the catalyst even if incorrect	

Examples of mechanism



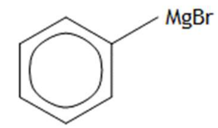
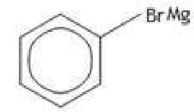
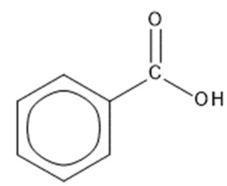
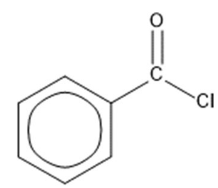
Or



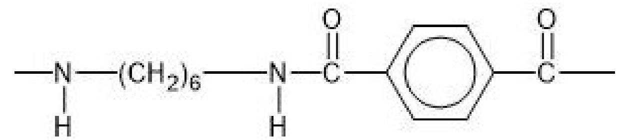
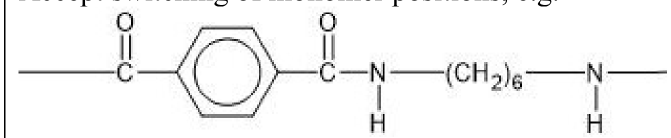
Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(ii)*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. 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 The following table shows how the marks should be awarded for structure and lines of reasoning. 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 **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**	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)**

	All are attacked by / react with electrophiles	All three need to be mentioned for this IP – evidence for phenol reacting with an electrophile may be seen in IP6	
	• **IP2 – Types of reaction** Cyclohexene undergoes addition reactions but benzene and/or phenol undergo substitution reactions	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	
	• **IP3 – Conditions** Cyclohexene and/or phenol react with (aqueous) bromine / without a catalyst **and** benzene needs (a Friedel-Crafts catalyst / iron / iron(III) bromide)	Allow react under normal laboratory conditions / room temperature and pressure Allow reference to $AlBr_3$/$AlCl_3$ This IP can be awarded if benzene equation has catalyst **and** other equation(s) do not Ignore references to specific temperatures	
	• **IP4 – Benzene** Benzene has delocalised electrons and is (kinetically) stable so the reaction has a high activation energy	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	
	• **IP5 – Cyclohexene** Cyclohexene has **localised** electron density in one π bond (which increases the electron density and makes it more susceptible to electrophilic attack)	If neither IP4 or IP5 awarded then allow (1) for benzene has delocalised **electrons** but cyclohexene does not	
	• **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	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 / CO_2 **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 / PCl_5 **(1)** • (**M6**) third intermediate – benzoyl chloride **(1)** •(**M7**) reagent for step 4 – ammonia / NH_3 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:  Do not award  Allow (**1**) for M3 for the acid hydrolysis of benzonitrile  Allow thionyl chloride/$SOCl_2$  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

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 CH_2 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)**

(Total for Question 20 = 20 marks)
(Total for Section B = 51 marks)

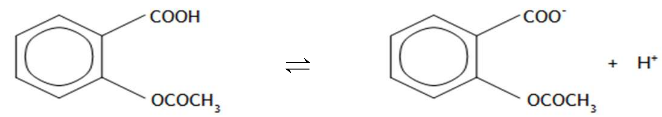
Section C

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 phen**y**l for benzene/arene Allow aromatic ring for benzene/arene Ignore formulae of groups Do not award phenol Do not award carbo**n**yl	**(1)**

Question Number	Answer	Additional Guidance	Mark
21(b)(ii)	• correct equation	Example of equation:  Accept displayed / skeletal formulae COMMENT Allow use of C_6H_4 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 × 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 × 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 × 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 react 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 $H^+ + OH^- \rightarrow H_2O$ **and** this shifts the equilibrium position to the right Allow $-COOH + OH^- \rightarrow -COO^- + H_2O$ 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 / CH_3OH	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/ H_2SO_4/ HCl/ heat Do not award methan**a**l Do not award CH_4O	**(1)**

Question Number	Answer	Additional Guidance	Mark
21(e)	• chemical shift ranges for OH and CH_3 in acetylsalicylic acid **(1)** • chemical shift ranges for OH and CH_3 in methyl salicylate **(1)**	Example of table: (see below) 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	**(2)**

Example of table:

	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 cm^3 **(1)** Process (scaling up of **remaining** NaOH x10) • (**M4**) calculation of mol acetylsalicylic acid reacted **(1)** Process (subtraction and then ÷ by2) • (**M5**) calculation of acetylsalicylic acid mass **(1)** Process (x180) • (**M6**) calculation of percentage of acetylsalicylic acid **and** deduction of Brand of tablet **(1)** Process (% calc and brand identity) **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 × 10^{-2} (mol) mol HCl = $\frac{16.95 \times 0.100}{1000}$ = 0.001695 / 1.695 × 10^{-3} (mol) (mol NaOH remaining in 25.0 cm^3 = 0.001695 / 1.695 × 10^{-3} (mol)) mol NaOH remaining in 250 cm^3 = 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)

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