Mark Scheme (Results)

Summer 2019

Pearson International Advanced Level
In Chemistry (WCH05) Paper 01General
Principles of Chemistry II - 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.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

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

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

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

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

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

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

Section A (multiple choice)

Question Number	Answer	Mark
1	**The only correct answer is C** ***A*** *is not correct because Al has an oxidation number of +3* ***B*** *is not correct because Cr has an oxidation number of +3* ***D*** *is not correct because V has an oxidation number of +4*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is C** ***A*** *is not correct because this is the number of moles of iodate(V) ions needed to react with 1 mol of hydrogensulfite ions* ***B*** *is not correct because the reaction is not 1:1* ***D*** *is not correct because this is the number of moles of hydrogensulfite ions needed to react with 2 mol of iodate(V) ions (giving an equation with integer coefficients).*	**(1)**

Question Number	Answer	Mark
3(a)	**The only correct answer is A** ***B*** *is not correct because manganese would react to form a cell system with* Mn^{2+} ***C*** *is not correct because* Mn^{2+} *is the reducing agent in the system* ***D*** *is not correct because* Mn^{2+} *is the reducing agent in the system and manganese would react to form a cell system with* Mn^{2+}	**(1)**

Question Number	Answer	Mark
3(b)	**The only correct answer is D** ***A*** *is not correct because all the substances in an electrode system must be present in a half-cell* ***B*** *is not correct because all the substances in an electrode system must be present in a half-cell* ***C*** *is not correct because all the substances in an electrode system must be present in a half-cell*	**(1)**

Question Number	Answer	Mark
4	**The only correct answer is D** ***A*** *is not correct because* $E_{cell}^{\ominus}$ *is proportional to neither* ΔS_{system} nor K ***B*** *is not correct because* $E_{cell}^{\ominus}$ *is proportional to* $\ln K$ *but not to* ΔS_{system} ***C*** *is not correct because* E_{cell}^{o} *is proportional to* ΔS_{total} *but not to* K	**(1)**

Question Number	Answer	Mark
5	**The only correct answer is A** ***B*** *is not correct because oxidation always occurs at the anode* ***C*** *is not correct because ethanol is oxidised in this cell* ***D*** *is not correct because ethanol is oxidised in this cell*	**(1)**

Question Number	Answer	Mark
6	**The only correct answer is A** ***B*** *is not correct because manganese in the +4 oxidation state will have partially filled d orbitals* ***C*** *is not correct because iron in the +4 oxidation state will have partially filled d orbitals* ***D*** *is not correct because copper in the +4 oxidation state will have partially filled d orbitals*	**(1)**

Question Number	Answer	Mark
7	**The only correct answer is B** ***A*** *is not correct because oxygen is not a reducing agent and sulfur dioxide is not an oxidising agent* ***C*** *is not correct because the highest stable oxidation number of vanadium is +5* ***D*** *is not correct because oxygen is not a reducing agent and sulfur dioxide is not an oxidising agent and because the highest stable oxidation number of vanadium is +5*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is B** ***A*** *is not correct because this shows benzene at a higher energy level than cyclohexa-1,3,5-triene and at a lower energy level than cyclohexane.* ***C*** *is not correct because this shows cyclohexane at the highest energy level instead of the lowest.* ***D*** *is not correct because this shows benzene at a higher energy level than cyclohexa-1,3,5-triene.*	**(1)**

Question Number	Answer	Mark
9	**The only correct answer is C** ***A*** *is not correct because this compound does not form an ionic compound with sodium hydroxide or react with ethanol* ***B*** *is not correct because this compound does not decolorise bromine water* ***D*** *is not correct because this compound does not react with ethanol*	**(1)**

Question Number	Answer	Mark
10	**The only correct answer is C** ***A*** *is not correct because ethanal cannot form the required electrophile* ***B*** *is not correct because ethanoic acid cannot form the required electrophile* ***D*** *is not correct because propanone cannot form the required electrophile*	**(1)**

Question Number	Answer	Mark
11	**The only correct answer is B** ***A*** *is not correct because alkenes form poly(alkenes) from single monomers* ***C*** *is not correct because* ***F*** *reacts with* ***G*** *to form a polyamide* ***D*** *is not correct because* ***F*** *reacts with* ***H*** *to form a polyester*	**(1)**

Question Number	Answer	Mark
12(a)	**The only correct answer is C** ***A*** *is not correct because the nitrogen atom furthest left in the structure is in an amine group* ***B*** *is not correct because the other two nitrogen atoms are part of amide groups* ***D*** *is not correct because the hydroxyl group attached directly to the benzene ring is phenolic*	**(1)**

Question Number	Answer	Mark
12(b)	**The only correct answer is A** ***B*** *is not correct because the phenolic OH group is very much less basic than the amine group* ***C*** *is not correct because the phenolic OH group will not lose a proton in acidic conditions* ***D*** *is not correct because the carboxylic acid group is very much less basic than the amine group*	**(1)**

Question Number	Answer	Mark
13(a)	**The only correct answer is C** **A** is not correct because covalent bonds are not broken when amino acids melt **B** is not correct because hydrogen bonds cannot form between zwitterions **D** is not correct because London forces are much weaker than ionic bonds	**(1)**

Question Number	Answer	Mark
13(b)	**The only correct answer is D** ***A*** *is not correct because only alanine has a chiral carbon and exists as optical isomers* ***B*** *is not correct because alanine has a chiral carbon and exists as optical isomers* ***C*** *is not correct because glycine does not have a chiral carbon and does not exist as optical isomers*	**(1)**

Question Number	Answer	Mark
13(c)	**The only correct answer is D** ***A*** *is not correct because neither structure has a peptide (CONH) link* ***B*** *is not correct because the right-hand structure does not have a peptide (CONH) link* ***C*** *is not correct because the left-hand structure does not have a peptide (CONH) link*	**(1)**

Question Number	Answer	Mark
14	**The only correct answer is B** ***A*** *is not correct because sulfuric acid is not involved in the hydrolysis so does not act as a catalyst* ***C*** *is not correct because the sodium hydroxide effects the hydrolysis* ***D*** *is not correct because this is not the function of the sulfuric acid*	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is A** ***B*** *is not correct because this is the number of protons in each environment, not the splitting pattern* ***C*** *is not correct because this considers the splitting of the C2 protons to be due only to the C1 protons* ***D*** *is not correct because this considers the splitting of the C2 protons to be due only to the C1 protons and additionally shows the hydroxy proton peak being split*	**(1)**

Question Number	Answer	Mark
16	**The only correct answer is D** ***A*** *is not correct because it will not form a white solid with dilute sulfuric acid.* ***B*** *is not correct because it will not form a pale yellow precipitate when warmed with iodine and sodium hydroxide* ***C*** *is not correct because it will not form a pale yellow precipitate when warmed with iodine and sodium hydroxide or a white solid with sulfuric acid.*	**(1)**

Total for Section A = 20 marks

Section B

Question Number	Acceptable Answer	Reject	Mark
17(a)(i)	$E^{\ominus}_{cell}$ = +0.40 − (−0.74) = (+)1.14 (V) **(1)** No TE on incorrect half equations $4Cr + 3O_2 + 6H_2O \rightleftharpoons 4Cr^{3+} + 12OH^-$ OR $4Cr + 3O_2 + 6H_2O \rightleftharpoons 4Cr(OH)_3$ ALLOW Multiples → in place of ⇌ Species and equation in correct direction **(1)** Balancing ALLOW TE on incorrect half equations from the table eg $4Cr^{2+} + O_2 + 2H_2O \rightleftharpoons 4Cr^{3+} + 4OH^-$ **(1)** IGNORE state symbols even if incorrect COMMENT Correct $E^{\ominus}_{cell}$ value may be credited in (a)(ii)	−1.14 (V) uncancelled electrons	**(3)**

Question Number	Acceptable Answer	Reject	Mark
17(a)(ii)	TE on any **positive** value in 17(a)(i) The positive $E^{\ominus}_{cell}$ value indicates that the corrosion of chromium is (thermodynamically) feasible ALLOW spontaneous for feasible E^{o}_{cell} value indicates chromium and oxygen should react / chromium corrodes **(1)** TE for M1 only on any **negative** value in 17(a)(i) So the corrosion is kinetically unfavourable / has a high activation energy / slow OR chromium forms a stable / unreactive **oxide** coating (that protects the metal from corrosion) ALLOW hydroxide for oxide **(1)**	Just 'needs high energy' Any reference to sacrificial protection	**(2)**

Question Number	Acceptable Answer	Reject	Mark
17(b)(i)	Correct equation with $E^{\ominus}_{cell}$ value scores (2) **Route 1** Zinc / Zn **(1)** IGNORE Acids / H^+ Ionic half-equation ($Zn(s) + 2Cr^{3+}(aq) \rightleftharpoons 2Cr^{2+}(aq) + Zn^{2+}(aq)$) $E^{\ominus}_{cell}$ [= −0.41− (−0.76)] = (+)0.35 (V) **(1)** **Route 2** Chromium / Cr **(1)** $E^{\ominus}_{cell}$ = −0.41− (−0.74) = (+)0.33 (V) **(1)**	Other additional reagents	**(2)**

Question Number	Acceptable Answer	Reject	Mark
17(b)(ii)	Standalone marks **Chromium(II)** (is readily oxidised back to chromium(III)) **(1)** **oxidised** by oxygen (in the air) ALLOW by air **(1)** IGNORE just 'reacts with oxygen (in the air)'	Oxidation to any other oxidation state	**(2)**

Question Number	Acceptable Answer	Reject	Mark
17(b)(iii)	From green to blue		**(1)**

	ALLOW violet to blue IGNORE modifiers (eg pale)		

Question Number	Acceptable Answer	Reject	Mark
17(b)(iv)	**M1** (energy gap) There is a **different** energy gap between the (3)d orbitals / in the (3)d subshell ALLOW **different** d-d splitting (3)d orbitals split **differently** **(1)** **M2** (explanation of energy gap) Because of the (different) charge / oxidation state / radius / size / charge density / electronic structure / numbers of (d)electrons of the ions **(1)** **M3** (effect of energy gap) So **different** frequencies / wavelengths of (visible) light / radiation / energy are absorbed / reflected / transmitted OR Photons of different energy are absorbed / reflected / transmitted **(1)** IGNORE Colour for (visible) light / radiation / energy General explanations of the colour of transition metal complexes even if incorrect	(3)d orbital Just different ions/ligands emitted emitted	**(3)**

Question Number	Acceptable Answer	Reject	Mark
17(c)(i)	In 17(c)(i) and (ii) two correct formulae scores (1) in (c)(i)		**(1)**

	Ignore omission of square brackets $[CrCl_4]^-$ **and** tetrahedral		

Question Number	Acceptable Answer	Reject	Mark
17(c)(ii)	$[Cr(NH_3)_6]^{3+}$ / $[Cr(NH_3)_4(H_2O)_2]^{3+}$ **and** octahedral	$[Cr(NH_3)_4]^{3+}$ square planar	**(1)**

Question Number	Acceptable Answer	Reject	Mark
17(d)(i)	$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ OR ⇌ in place of → ALLOW Multiples Formulae of both chromium species (in any equation) **(1)** Correct balanced equation **(1)** IGNORE State symbols even if incorrect No TE on incorrect chromium species	Additional chromium species	**(2)**

Question Number	Acceptable Answer	Reject	Mark

17(d)(ii)	**Cr^{6+}/chromium(VI) ion** (small and) highly charged OR **Cr^{6+}/chromium(VI) ion** has (very) high charge density **(1)** **Route 1** (So Cr^{6+} is very) polarising **(1)** H−O / OH bonds broken / water (ligands) deprotonated **(1)** IGNORE H−O bonds weakened / polarised **Route 2** Ionising six / so many electrons requires a large amount of energy **(1)** Not recovered from hydration energy / enthalpy ALLOW lattice energy for hydration energy **(1)** If no other mark is scored Cr^{6+} is is too small to coordinate six (water) ligands scores (1)		**(3)**

Question Number	Acceptable Answer	Reject	Mark
17(d)(iii)	Colourless **and** Cr^{6+} has no (3)d electrons ALLOW Colourless **and** (3)d subshell /orbitals empty /$(3)d^0$ IGNORE No d-d transitions No d-d splitting	White (3)d orbital is empty no (3)d orbitals / no (3)d subshell	**(1)**

Question Number	Acceptable Answer	Reject	Mark
17(e)(i)	Marks are standalone Starch (solution) **(1)** Blue-black / blue / black **and** to colourless / green **(1)** IGNORE clear	yellow	**(2)**

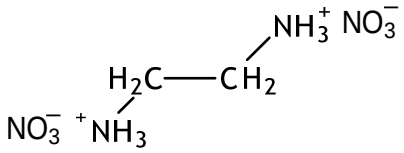
Question Number	Acceptable Answer	Reject	Mark
17(e)(ii)	**M1** mol $Cr_2O_7^{2-}$ = 10 x 0.0495 x 10^{-3} = 4.95 x 10^{-4} /0.000495 **(1)** **M2** mol I_2 = 3 x mol $Cr_2O_7^{2-}$ = 3 x 4.95 x 10^{-4} = 1.485 x 10^{-3} / 0.001485 **(1)** **M3** mol $S_2O_3^{2-}$ = 2 x mol I_2 = 2 x 1.485 x 10^{-3} = 2.97 x 10^{-3} /0.00297 **(1)** **M4** concentration of $S_2O_3^{2-}$ = 1000 x 2.97 x 10^{-3} / 19.50 = 0.1523 mol dm^{-3} **(1)** Ignore SF except 1 SF ALLOW TE at each stage Do not penalise correct intermediate rounding to 2 SF Correct answer with some / no working scores (4)	incorrect or missing units	**(4)**

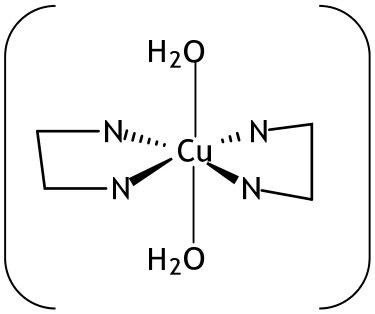
(Total for Question 17 = 27 marks)

Some Common Incorrect Answers

Error	Final Answer	Mark /4
mol $S_2O_3^{2-}$ = mol I_2 /2	0.03808 / 3.808 x 10^{-2}	3
mol $S_2O_3^{2-}$ = mol I_2	0.07615 / 7.615 x 10^{-2}	3
mol $S_2O_3^{2-}$ = mol I_2 x 2/3	0.05077 / 5.077 x 10^{-2}	3
mol $S_2O_3^{2-}$ = mol $Cr_2O_7^{2-}$ x 2	0.05077 / 5.077 x 10^{-2}	3

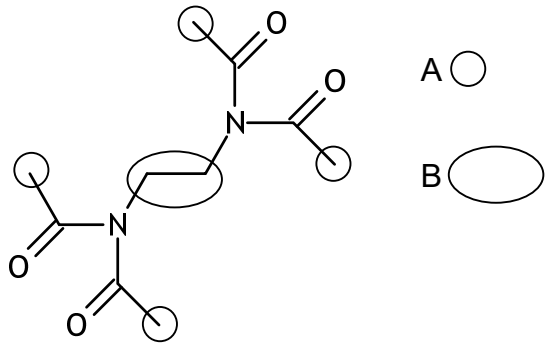
Question Number	Acceptable Answer	Reject	Mark
18(a)	**Step 1** Add bromine ALLOW Chlorine **(1)** Intermediate is 1,2-dibromoethane OR CH_2BrCH_2Br / displayed / skeletal formula OR 1,2-dichloroethane OR CH_2ClCH_2Cl / displayed / skeletal formula **(1)** IGNORE $C_2H_4Br_2$ / $C_2H_4Cl_2$ ALLOW feasible alternatives for **Step1** eg acidic/alkaline $KMnO_4$ **and** forms CH_2OHCH_2OH **and** using P / I_2 **(1)** 1,2-diiodoethane **(1)** **Step 2** TE on any halogenoalkane from Step 1 Ammonia ((gas)) ALLOW **Conc** $NH_3(aq)$ **(1)** Dissolved in ethanol / alcohol (and heat) OR heat in a sealed tube / heat under pressure (add alkali / NaOH / KOH) **(1)** If $NH_3(aq)$ used M4 may be scored	$Br_2(aq)$ / Br UV light Additional reagents Reflux	**(4)**

Question Number	Acceptable Answer	Reject	Mark
18(b)	**M1** (type of reaction) Neutralisation / acid-base reaction **(1)** **M2** (explanation of basic character) Ethane-1,2-diamine is basic because of the lone pairs (of electrons) on the nitrogen atoms ALLOW Ethane-1,2-diamine is basic because of (the basicity of) the amine group(s) OR amine group is basic OR amine group / nitrogen is protonated **(1)** **M3** (formula)  ALLOW Any formula showing the salt including just one NH_2 protonated Omission of charges **(1)**	(forming salt and) water Covalent bond to nitrate	**(3)**

Question Number	Acceptable Answer	Reject	Mark
18(c)(i)	 2+ OR displayed / structural formulae ALLOW Two or three 'en' molecules attached without showing octahedral shape provided nitrogens correctly bonded to copper IGNORE Omission of water Omission of square brackets Omission of charge / incorrect charge		**(1)**

Question Number	Acceptable Answer	Reject	Mark
18(c)(ii)	The number of particles / molecules / moles increases **(1)** Do not penalise the use of specific numbers showing an increase, even if incorrect IGNORE Just 'more product' ΔS_{system} is positive / increases (with no / negligible change in $\Delta S_{surroundings}$ so the reaction is favoured) ALLOW ΔS_{total} / entropy increases **(1)** IGNORE Disorder increases References to stability constants	Ammonia is released as a gas	**(2)**

Question Number	Acceptable Answer	Reject	Mark
18(d)(i)	Ethanoyl chloride / CH_3COCl OR Ethanoic anhydride / $(CH_3CO)_2O$ OR Displayed / skeletal formula ALLOW Acetic anhydride Acetic acid anhydride	CH_3ClCO Ethanoic acid / CH_3COOH Additional reagents	**(1)**

Question Number	Acceptable Answer	Reject	Mark
18(d)(ii)	The (four) protons on the central carbon chain are equivalent **(1)** The (twelve) protons on the four methyl groups are equivalent **(1)** Two peaks (because there are two proton environments) **and** The relative peak areas are 4 : 12 / 1 : 3 **(1)** Clearly labelled diagram scores M1 and M2 eg  No TE on incorrect numbers of equivalent protons IGNORE Splitting patterns, even if incorrect		**(3)**

(Total for Question 18 = 14 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Reject</th><th>Mark</th></tr>
<tr><td>19(a)</td><td>
Route 1
<table>
<tr><td></td><td>Carbon</td><td>Hydrogen</td><td>Oxygen</td><td></td></tr>
<tr><td>%</td><td>72.97</td><td>5.41</td><td>21.62</td><td></td></tr>
<tr><td>mol</td><td>72.97/12
= 6.081</td><td>5.41/1
= 5.41</td><td>21.62/16
= 1.35</td><td>(1)</td></tr>
<tr><td>÷1.35</td><td>4.50</td><td>4.01</td><td>1</td><td>(1)</td></tr>
<tr><td>Ratio</td><td>9</td><td>8</td><td>2</td><td></td></tr>
</table>
(Empirical formula) = $C_9H_8O_2$
(1)

(m/e of molecular ion = M_r)
M_r = 148 (= empirical formula mass)
and
molecular formula / M = $C_9H_8O_2$ (1)

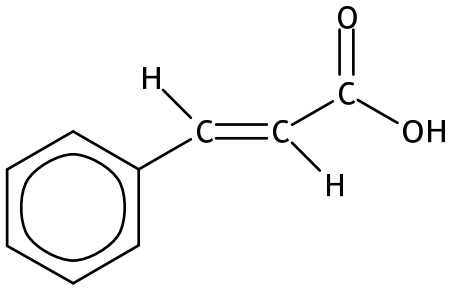
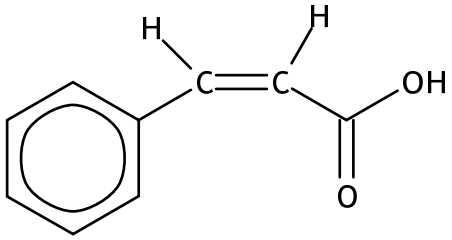
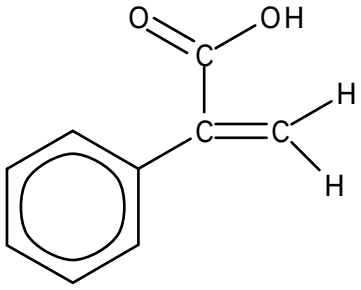
Route2
(m/e of molecular ion =) M_r = 148 (1)

<table>
<tr><td></td><td>Carbon</td><td>Hydrogen</td><td>Oxygen</td><td></td></tr>
<tr><td>%</td><td>72.97</td><td>5.41</td><td>21.62</td><td></td></tr>
<tr><td>mass /g</td><td>0.7297 x 148
= 108.0</td><td>0.0541 x 148
= 8.007</td><td>0.2162 x 148
= 32.00</td><td>(1)</td></tr>
<tr><td>mol</td><td>108/12
9</td><td>8.007/1
= 8</td><td>32/16
= 2</td><td>(1)</td></tr>
</table>
molecular formula / M = $C_9H_8O_2$ (1)

Correct empirical / molecular formula with no working scores (3)

If units for empirical / molecular formula are given they must be g mol^{-1}
</td><td></td><td>(4)</td></tr>
</table>

Question Number	Acceptable Answer	Reject	Mark
19(b)(i)	*m* / *e* = 77 (is $C_6H_5^+$) so phenyl group/C_6H_5 present ALLOW **M** is an arene / aromatic / contains benzene (ring) **(1)** Effervescence / reaction with $NaHCO_3$ is typical of an acid so carboxylic acid/COOH present **(1)** Decolourisation of reaction with $KMnO_4$ / H^+ indicates a carbon-carbon double bond / C=C / alkene **(1)** Three groups correctly identified with no explanation scores (1)	phenol C_6H_6	**(3)**

Question Number	Acceptable Answer	Reject	Mark
19(b)(ii)	 **(1)**  **(1)**  **(1)** No TE on incorrect deductions from mass spectrum or reactions Three di-substituted benzene rings scores (2) Two di-substituted benzene rings scores (1) ALLOW Structural, displayed, skeletal formulae or any correct combination of these		**(3)**

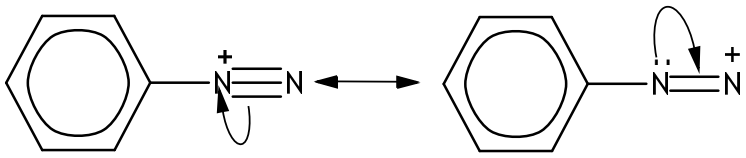
(Total for Question 19 = 10 marks)
Total for Section B = 51 marks

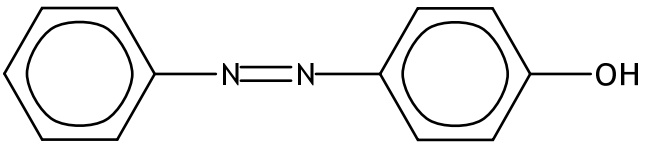
Section C

Question Number	Acceptable Answer	Reject	Mark
20(a)	In (a) and (b) award marks for correct intermediates even if prepared incorrectly and correct reagents used with correct functional groups even if the molecule is wrong. Penalise omission of conditions once only in (a) **Step 1** KCN / NaCN in ethanol / alcohol (reflux/heat) **(1)** To form butanenitrile / C_3H_7CN **(1)** **Step 2** Reflux with sulfuric acid / H_2SO_4 OR Reflux with NaOH **and** followed by addition of sulfuric acid / H_2SO_4 ALLOW Any strong acid / HCl for H_2SO_4 Heat / boil for reflux **(1)** IGNORE Concentration of acid To form butanoic acid / C_3H_7COOH **(1)** **Step 3** Lithium tetrahydridoaluminate(III) / lithium aluminium hydride / $LiAlH_4$ in (dry) ether / ethoxyethane (under reflux) (followed by dilute strong acid) ALLOW Lithal in (dry) ether **(1)** IGNORE Name or formula of butan-1-ol, even if incorrect	HCN	**(5)**

Question Number	Acceptable Answer	Reject	Mark
20(b)	**Step 1** KOH/ NaOH in ethanol / alcohol / alcoholic (reflux) **(1)** To form but-1-ene /$CH_3CH_2CHCH_2$ / skeletal / displayed formula IGNORE butene If name and formula are given, both must be correct **(1)** **Step 2** (depends on an alkene as the organic reactant) Add hydrogen bromide / HBr / hydrobromic acid / NaBr & H_2SO_4 **(1)**	Aqueous ethanol but-2-ene	**(3)**

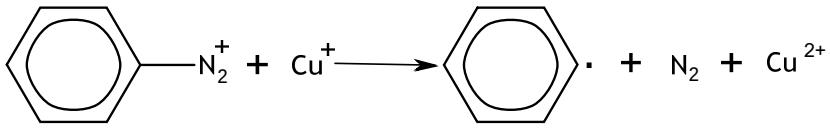
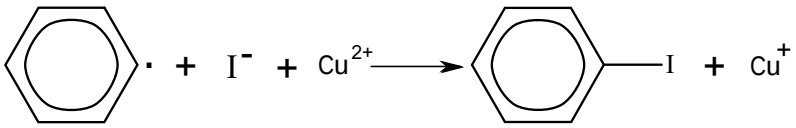
Question Number	Acceptable Answer	Reject	Mark
20(c)(i)	These marks are standalone Sodium nitrite /sodium nitrate(III) / $NaNO_2$ and hydrochloric acid / HCl((aq)) OR Potassium nitrite / KNO_2 and HCl((aq)) OR Sulfuric acid (for hydrochloric acid) ALLOW Nitrous acid / HNO_2 / HONO **(1)** IGNORE Concentration of acid hydrochloric acid / sulfuric acid with nitrous acid 0—10°C / ice(-water) bath ALLOW <10°C / <5°C **(1)**	sodium nitrate	**(2)**

Question Number	Acceptable Answer	Reject	Mark
20(c)(ii)	 Left-hand curly arrow ALLOW Left-hand curly arrow going to the positive charge **(1)** Right-hand curly arrow **and** lone pair **(1)** ALLOW any type of connecting arrow or none Penalise half-arrows once only IGNORE any additional lone pairs COMMENT Penalise additional curly arrows once only		**(2)**

Question Number	Acceptable Answer	Reject	Mark
20(c)(iii)	 OR 1,2 / 1,3 structures **(1)** Electrophilic substitution ALLOW Electrophilic coupling **(1)**		**(2)**

Question Number	Acceptable Answer	Reject	Mark
20(d)(i)	(nucleophilic substitution of groups attached directly to a benzene ring is normally very difficult because) High electron density of the ring repels nucleophiles OR benzene ring sterically hinders the approach of nucleophiles ALLOW pi / delocalised electrons repel nucleophiles OR Nucleophilic attack is difficult because of the high electron density of the ring **(1)** (benzenediazonium ions readily undergo nucleophilic substitution because) Nitrogen is a very good leaving group ALLOW Nitrogen is a gas so the entropy change (of the system) is (very) positive OR nitrogen gas is very stable OR $N_2^{(+)}$ (group) is electron withdrawing **and** decreases the electron density on the benzene ring **(1)** IGNORE References just to the positive charge on the nitrogen		**(2)**

Question Number	Acceptable Answer	Reject	Mark
20(d)(ii)	The (main) oxidation states of copper are readily interchanged ALLOW (Copper(I) ions) are (easily) changed into copper(II) ions **and** copper OR (Copper(I) ions) are (easily) oxidised **and** reduced OR Copper has variable oxidation states / variable valency IGNORE Copper is a transition element / metal References to partially filled 3(d) orbitals / subshell References to surface catalysis COMMENT ALLOW Copper(I) / Cu^{+}/ It / they have variable oxidation states		**(1)**

Question Number	Acceptable Answer	Reject	Mark
20(d)(iii)	Mark independently  **(1)**  ALLOW Balanced equations with (e.g) $2I^{-}$ on LHS and CuI on RHS **(1)** IGNORE Curly arrows even if incorrect.		**(2)**

(Total for Question 20 = 19 marks)
(Total for Section C = 19 marks)
Total for PAPER = 90 Marks

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