Mark Scheme (Results)

January 2023

Pearson Edexcel International Advanced Level
in Chemistry (WCH15)
Paper 01 Transition Metals and Organic Nitrogen Chemistry

January 2023
Question Paper Log Number P71888A
Publications Code WCH15_01_2301_MS

General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

Using the Mark Scheme

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

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

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

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

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.

Question number	Answer	Mark
1	**The only correct answer is D** ($Ni(CO)_4$) ***A*** *is incorrect because copper has oxidation number +1 in* $[Cu(NH_3)_2]^+$ *and nickel has oxidation number 0 in* $Ni(CO)_4$ ***B*** *is incorrect because iron has oxidation number +3 in* $[Fe(CN)_6]^{3-}$ ***C*** *is incorrect because manganese has oxidation number + 2 in* $MnSO_4$	**(1)**

Question number	Answer	Mark
2(a)	**The only correct answer is D** (6) ***A*** *is incorrect because this is the number of types of ligand* ***B*** *is incorrect because this is the oxidation number of chromium* ***C*** *is incorrect because this is the number of ligands*	**(1)**

Question number	Answer	Mark
2(b)	**The only correct answer is B** (+1) ***A*** *is incorrect because there is a* Cr^{3+} *ion, two* Cl^- *ligands and the* $NH_2CH_2CH_2NH_2$ *ligands are neutral* ***C*** *is incorrect because there is a* Cr^{3+} *ion, two* Cl^- *ligands and the* $NH_2CH_2CH_2NH_2$ *ligands are neutral* ***D*** *is incorrect because there is a* Cr^{3+} *ion, two* Cl^- *ligands and the* $NH_2CH_2CH_2NH_2$ *ligands are neutral*	**(1)**

Question number	Answer	Mark
3	**The only correct answer is A** ($[Al(H_2O)_6]^{3+}$) ***B*** *is incorrect because* $[Cu(H_2O)_6]^{2+}$ *gives a blue solution* ***C*** *is incorrect because* $[Fe(H_2O)_6]^{3+}$ *gives an orange / brown solution* ***D*** *is incorrect because* $[Ni(H_2O)_6]^{2+}$ *gives a green solution*	**(1)**

Question number	Answer	Mark
4	**The only correct answer is D** ($Zn(OH)_2$) ***A*** *is incorrect because* $Cu(OH)_2$ *is only soluble in excess aqueous ammonia* ***B*** *is incorrect because* $Fe(OH)_2$ *is insoluble in both excess aqueous ammonia and excess aqueous sodium hydroxide* ***C*** *is incorrect because* $Ni(OH)_2$ *is only soluble in excess aqueous ammonia*	**(1)**

Question number	Answer	Mark
5	**The only correct answer is C** (24.4 %) ***A*** *is incorrect because 6.10 % is the value when only 1 mol of water is considered* ***B*** *is incorrect because 8.06 % is the value when only 1 mol of water is considered and no water has been included in the molar mass of the salt* ***D*** *is incorrect because 32.2 % is the value when no water has been included in the molar mass of the salt*	**(1)**

Question number	Answer	Mark
6	**The only correct answer is C** (diagram C with peak at (0.001, 8)) ***A*** *is incorrect because the complex ion with EDTA^{4-} has a more intense colour intensity than that with CN^{-} ions* ***B*** *is incorrect because EDTA^{4-} is a hexadentate ligand so the mol ratio Cr^{3+} ; EDTA^{4-} is 1 : 1 and the colour intensity should be higher* ***D*** *is incorrect because EDTA^{4-} is a hexadentate ligand so the mol ratio Cr^{3+} ; EDTA^{4-} is 1 : 1*	**(1)**

Question number	Answer	Mark
7	**The only correct answer is D** (activation energy is high) ***A*** *is incorrect because a positive value for $E^{\ominus}_{cell}$ indicates the reaction is thermodynamically feasible* ***B*** *is incorrect because a positive value for $\Delta_r H$ would not be affected by a catalyst* ***C*** *is incorrect because a positive value for ΔS_{total} indicates the reaction is thermodynamically feasible*	**(1)**

Question number	Answer	Mark
8	**The only correct answer is B** ($Fe^{2+}(aq) \rightleftharpoons Fe^{3+}(aq) + e^{-}$ and $Br_2(aq) + 2e^{-} \rightleftharpoons 2Br^{-}(aq)$) ***A*** *is incorrect because both half-equations cannot be oxidation* ***C*** *is incorrect because these half-equations would give $E^{\ominus}_{cell} = -0.32$ V* ***D*** *is incorrect because both half-equations cannot be reduction*	**(1)**

Question number	Answer	Mark
9	**The only correct answer is C** (525 (cm^3)) ***A*** *is incorrect because 225 cm^3 is the volume of oxygen needed to react with only 50 cm^3 propene* ***B*** *is incorrect because 300 cm^3 is the volume of oxygen needed to react with only 50 cm^3 but-1-ene* ***D*** *is incorrect because 700 cm^3 is the volume of oxygen needed to react with the whole mixture if the equations are balanced incorrectly by assuming that 1 mol of O_2 is needed to form 1 mol of H_2O*	**(1)**

Question number	Answer	Mark
10	**The only correct answer is C** (0.1 (cm^3)) ***A*** *is incorrect because the volume of carbon dioxide is 250 x 405/1 x 10^6 = 0.101 cm^3, which is approximately 0.1 cm^3* ***B*** *is incorrect because the volume of carbon dioxide is 250 x 405/1 x 10^6 = 0.101 cm^3, which is approximately 0.1 cm^3* ***D*** *is incorrect because the volume of carbon dioxide is 250 x 405/1 x 10^6 = 0.101 cm^3, which is approximately 0.1 cm^3*	**(1)**

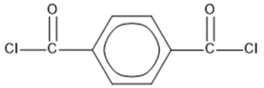
Question number	Answer	Mark
11(a)	**The only correct answer is B** (3095 – 3010 cm^{-1}) ***A*** *is incorrect because 3500 – 3300 cm^{-1} shows the presence of N-H in an amine which is present in valine* ***C*** *is incorrect because 2962 – 2853 cm^{-1} shows the presence of C-H in an alkane which is present in valine* ***D*** *is incorrect because 1725 – 1720 cm^{-1} shows the presence of C=O in an carboxylic acid which is present in valine*	**(1)**

Question number	Answer	Mark
11(b)	**The only correct answer is A** (doublet and octet) ***B*** *is incorrect because the peak corresponding to the H attached to C with 2* CH_3 *groups and CH will be an octet as there are 7 protons on the neighbouring carbons* ***C*** *is incorrect because the peak corresponding to the 2* CH_3 *groups will be a doublet as there is 1 proton on the neighbouring carbon* ***D*** *is incorrect because the peak corresponding to the 2* CH_3 *groups will be a doublet as there is 1 proton on the neighbouring carbon and the H attached to C with 2* CH_3 *groups and CH will be an octet as there are 7 protons on the neighbouring carbons*	**(1)**

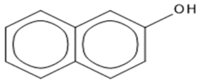
Question number	Answer	Mark
12(a)	**The only correct answer is D** (nucleophilic addition) ***A*** *is incorrect because electrophiles attack electron rich regions but the carbon atom attached to the magnesium is* $\delta-$ ***B*** *is incorrect because the Grignard reagent is not a source of free radicals* ***C*** *is incorrect because increasing the length of the carbon chain is not oxidation*	**(1)**

Question number	Answer	Mark
12(b)	**The only correct answer is B** ($CH_3CH_2CH(CH_3)MgBr$) ***A*** *is incorrect because this would form 1-phenylpentan-1-ol* ***C*** *is incorrect because this would form 1-phenyl-3-methylbutan-1-ol* ***D*** *is incorrect because this would form 1-phenyl-2,2-dimethylpropan-1-ol*	**(1)**

Question number	Answer	Mark
13	**The only correct answer is C** (0.6) ***A*** *is incorrect because the amino acid in the lower spot will have an* R_{f} *value of about 0.2* ***B*** *is incorrect because the distance moved by X is measured from the solvent front instead of from the baseline* ***D*** *is incorrect because the amino acid in the higher spot will have an* R_{f} *value of about 0.8*	**(1)**

Question number	Answer	Mark
14	**The only correct answer is D** ( and ) **A** *is incorrect because amines do not react with carboxylic acids* **B** *is incorrect because amides do react to form polyamides* **C** *is incorrect because this pair of monomers will not produce the required polyamide*	**(1)**

Question number	Answer	Mark
15(a)	**The only correct answer is A** ($NaNO_2$ and HCl at 5 °C) ***B*** *is incorrect because* $NaNO_3$ *does not react with HCl to form the nitrous acid needed for the formation of benzenediazonium ions* ***C*** *is incorrect because nitrous acid and benzenediazonium ions decompose at 50°C* ***D*** *is incorrect because* $NaNO_3$ *does not react with HCl to form the nitrous acid needed for the formation of benzenediazonium ions and nitrous acid and benzenediazonium ions decompose at 50°C*	**(1)**

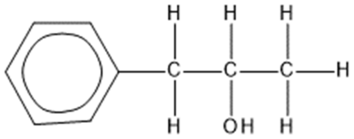
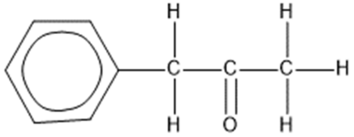
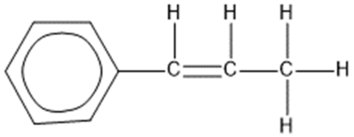
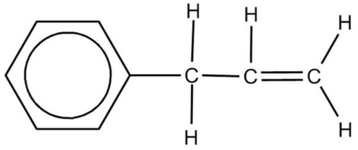
Question number	Answer	Mark
15(b)	**The only correct answer is B (**  in alkaline solution) ***A*** *is incorrect because alkaline conditions are needed to form an azo dye* ***C*** *is incorrect because the OH group is in the wrong position and alkaline conditions are needed to form an azo dye* ***D*** *is incorrect because the OH group is in the wrong position*	**(1)**

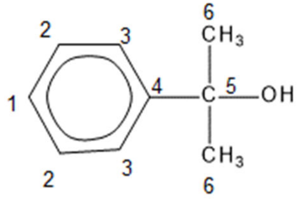
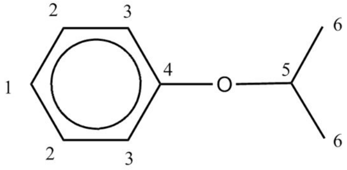
Question number	Answer	Mark
16	**The only correct answer is A (** ) ***B*** *is incorrect because the OH group will not be protonated in preference to the NH_2 group* ***C*** *is incorrect because the addition of an acid will cause protonation not loss of a proton* ***D*** *is incorrect because the addition of an acid will cause protonation not loss of protons*	**(1)**

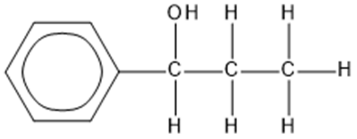
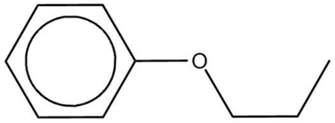
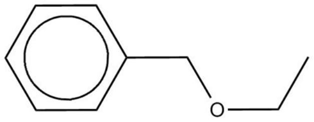
(Total for Section A = 20 marks)

Section B

Question Number	Answer	Additional Guidance	Mark
17(a)	• calculation of mol C / CO_2 **(1)** • calculation of mol H **(1)** • calculation of mol of O **(1)** • formula **(1)** **Comment** – alternative method via moles of A • M1 calculate moles of A : 5.26÷136 =0.0387 (mol) • M2 calculate moles of CO_2 and H_2O • M3 use combustion equation to show A forms 9CO_2 and 6H_2O, so C=9 and H=12 • M4 use of Mr to show mass due to O = 16, so number of O atoms = 1 If candidate does not score 4 marks, mark using method that gives best score	Example of calculation: mol CO_2 = 15.3/44 = 0.34773 = mol C or mass C = 15.3 x 12/44 = 4.1727 (g) **and** mol C = 4.1727/12 = 0.34773 mol H_2O = 4.18/18 = 0.23222 **and** mol H = 2 x 0.23222 = 0.46444 or mass H = 4.18 x 2/18 = 0.46444 (g) **and** mol H = 0.46444 mass O = 5.26 – 4.1727 – 0.46444 = 0.62286 (g) **and** mol O = 0.62286/16 = 0.038929 **or** moles of O = 5.26/136 = 0.03876 (mol) TE on mass C and H ratio mol $\frac{0.34773}{0.038929}$ C : $\frac{0.46444}{0.038929}$ H : $\frac{0.038929}{0.038929}$ O 9 12 1 So formula is $C_9H_{12}O$ (and this is the same as the molecular formula as M_r = (9 x 12) + (12 x 1) + 16 = 136) No TE on incorrect mol Ignore SF except 1 SF at each stage Comment : Ignore minor rounding errors e.g. 4.172 is acceptable for mass of C Allow masses of C, H and O to be determined and expressed as percentages e.g. C = 79.4%, H = 8.8%, so O = 11.8% Allow alternative methods	**(4)**

Question Number	Answer	Additional Guidance	Mark
17(b)	• structure of **A** **(1)**	Examples of structures  Ignore connectivity of OH	**(5)**
	• structure of **B** **(1)**		
	• structure of **C** **(1)**	CHI_3 (standalone mark)	
	• structure of **D** **(1)**	 Allow *E* or *Z* isomer or both isomers	
	• structure of **E** **(1)**	 Allow displayed / structural formulae or any combination of these / skeletal formulae Allow Kekule Structures Allow **D** TE on incorrect 2° alcohol **A** e.g. if A is C_6H_5 $CH(OH)C_2H_5$ Allow **E** as TE on incorrect 1° alcohol **A** e.g. if A is $C_6H_5CH_2CH_2CH_2OH$ If **D** and **E** are the wrong way around, allow (1) for M4 and M5	

Question Number	Answer	Additional Guidance	Mark
17(c)	An explanation that makes reference to the following points: • structure of **F** **(1)** • carbon atoms labelled **(1)**	Example of structure:  Allow displayed / structural formulae or any combination of these / skeletal formulae Allow alternative clear ways of identifying carbon atoms Allow  M2 dependent on M1, unless very near miss (e.g. accidental omitting H on OH group)	**(2)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
17(d)	An answer that makes reference to the following points: - structure of G **(1)** - m/z corresponds to $C_7H_7O^+$ / $C_6H_5CHOH^+$ / $C_6H_5OCH_2^+$ / $C_6H_5CH_2O^+$ / loss of C_2H_5 **(1)**	Example of structure  OR  OR  Allow any combination of structural and displayed formula / skeletal formula – if 2 structures are shown both must be incorrect Ignore missing + M1 and M2 are standalone marks No TE from incorrect structure	**(2)**

(Total for Question 17 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
18(a)	• +5 / 5+	Allow V / 5 / V^{5+}	**(1)**

Question Number	Answer	Additional Guidance	Mark
18(b)	An explanation that makes reference to the following points: • V^{5+} / the vanadium ion is (very) small / highly charged **(1)** • so it would polarise (two) water molecules / OH bonds **(1)** • causing them to lose hydrogen ions / H^+ ions / deprotonate **(1)**	Allow high charge density Allow 'so it weakens OH bonds' Allow 'distorts electron clouds in water' Allow the energy required to remove 5 electrons to form V^{5+} is too high (1) because the energy is not recovered by the hydration of the ion (1) If no marks given allow 1 mark for correct electronic configuration of V^{5+} e.g. [Ar]	**(3)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>18(c)</td>
<td>• calculation of mol of each element (1)

• deduction of mol ratio (and empirical formula) (1)

• overall formula (1)</td>
<td>Example of calculation:
<table>
<tr><th></th><th>K</th><th>V</th><th>S</th><th>H</th><th>O</th></tr>
<tr><td>moles</td><td>$\frac{7.9}{39.1}$
= 0.202</td><td>$\frac{10.2}{50.9}$
= 0.200</td><td>$\frac{12.9}{32.1}$
= 0.402</td><td>$\frac{4.8}{1}$
= 4.8</td><td>$\frac{64.2}{16}$
= 4.01</td></tr>
<tr><td>divide by smallest</td><td>$\frac{0.202}{0.200}$
= 1</td><td>$\frac{0.200}{0.200}$
= 1</td><td>$\frac{0.402}{0.200}$
= 2</td><td>$\frac{4.8}{0.200}$
= 24</td><td>$\frac{4.01}{0.200}$
= 20</td></tr>
<tr><td></td><td colspan="5">Empirical formula $KVS_2H_{24}O_{20}$</td></tr>
</table>
Ignore minor rounding errors in M1 and M2
TE on mol ratio from M1

Example of overall formula:
$KV(SO_4)_2 \cdot 12H_2O$
or
$K_2SO_4 \cdot V_2(SO_4)_3 \cdot 24H_2O$

Allow $KV(SO_4)_2(H_2O)_{12}$

Allow $K_2SO_4 \cdot V_2(SO_4)_3(H_2O)_{24}$

Ignore SF

Allow the ions in any order / correct charges shown by individual ions, even if charges are not shown on all ions / missing dot(s)
No TE from M2 to M3</td>
<td>(3)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
18(d)(i)	• calculation of mol of V^{3+} **(1)** • calculation of mol MnO_4^- **(1)** • calculation of ratio of MnO_4^- to V^{3+} **(1)**	Example of calculation: Mol V^{3+} $= \frac{10.0 \text{ x } 0.132}{1000} = 0.00132$ / $1.32 \text{ x } 10^{-3}$ (mol) Mol MnO_4^- $= \frac{26.40 \text{ x } 0.0200}{1000} = 0.000528$ / $5.28 \text{ x } 10^{-4}$(mol) Ratio $MnO_4^- : V^{3+} = 0.000528 : 0.00132$ $= 1 : 2.5$ or $2 : 5$ Allow TE on M1 and M2 Ignore SF except 1 SF in calculation of moles Allow 5 to 2 if it's clear it's $V^{3+} : MnO_4^-$	**(3)**

Question Number	Answer	Additional Guidance	Mark
18(d)(ii)	• correct species on each side of equation **(1)** • balancing **(1)** Comment – M2 dependent on M1	Example of equation: $2MnO_4^- + 5V^{3+} + 2H_2O \rightarrow 2Mn^{2+} + 5VO_2^+ + 4H^+$ Or $2MnO_4^- + 5V^{3+} + 22H_2O \rightarrow 2Mn^{2+} + 5[VO_2(H_2O)_4]^+ + 4H^+$ Allow multiples Allow (1) for $2MnO_4^- + 5V^{3+} + 16H^+ \rightarrow 2Mn^{2+} + 5V^{5+} + 8H_2O$ Ignore state symbols even if incorrect Allow oxidation to V(IV) if ratio 1 : 5 in (d)(i) $MnO_4^- + 5V^{3+} + H_2O \rightarrow Mn^{2+} + 5VO^{2+} + 2H^+$ species (1) balancing (1)	**(2)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>18(e)*</td><td>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.</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, 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).</td><td>(6)</td></tr>
</table>

	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

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.

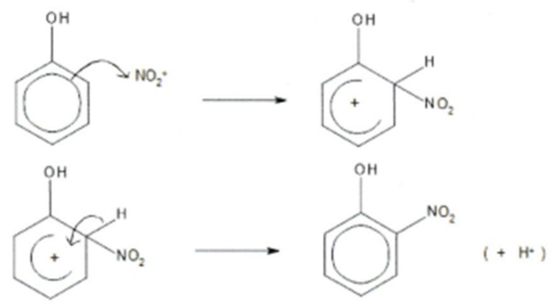
General points to note
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

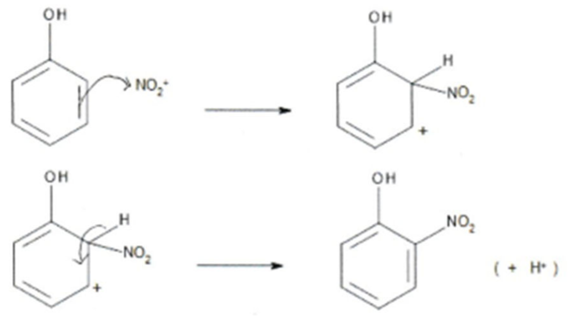
	Indicative content • **IP1 – vanadium(V) to vanadium(IV)** Both iron and tin will reduce / convert / change V(V) to V(IV) **and** $E^\ominus_{\text{cell}}$ for Fe = (+)1.44 V **and** $E^\ominus_{\text{cell}}$ for Sn = (+)1.14 V • **IP2 – equations** $2VO_2^+ + 4H^+ + Fe \rightarrow 2VO^{2+} + 2H_2O + Fe^{2+}$ **and** $2VO_2^+ + 4H^+ + Sn \rightarrow 2VO^{2+} + 2H_2O + Sn^{2+}$ • **IP3 – vanadium(IV) to vanadium(III)** Both iron and tin will reduce / convert / change V(IV) to V(III) **and** $E^\ominus_{\text{cell}}$ for Fe = (+)0.78 V **and** $E^\ominus_{\text{cell}}$ for Sn = (+)0.48 V • **IP4 – equations** $2VO^{2+} + 4H^+ + Fe \rightarrow 2V^{3+} + 2H_2O + Fe^{2+}$ **and** $2VO^{2+} + 4H^+ + Sn \rightarrow 2V^{3+} + 2H_2O + Sn^{2+}$ • **IP5 – vanadium(III) to vanadium(II)** iron will reduce / convert / change V(III) to V(II) **and** $E^\ominus_{\text{cell}}$ = (+)0.18 V **and** tin will not reduce / convert / change V(III) to V(II) **and** as $E^\ominus_{\text{cell}} = -0.12$ V • **IP6 – equation** $2V^{3+} + Fe \rightarrow 2V^{2+} + Fe^{2+}$	Ignore state symbols in all equations even if incorrect If IP1 and IP2 not awarded, allow 1 IP for either totally correct iron or totally correct tin If IP3 and IP4 not awarded, allow 1 IP for either totally correct iron or totally correct tin Comment penalise references to Fe or Sn as oxidising agents once only in IP1, IP3 and IP5 Ignore any references to colour of vanadium species If no other marks awarded, allow 1 IP for idea that Fe can reduce to V^{2+} but Sn (only) to V^{3+} If no other marks awarded allow 1 IP for three pairs of correct $E^\ominus_{\text{cell}}$ values	

(Total for Question 18 = 18 marks)

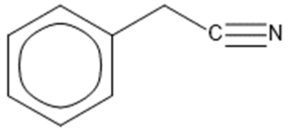
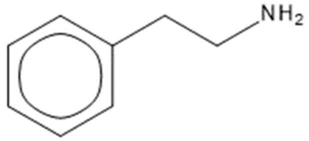
Question Number	Answer	Additional Guidance	Mark
19(a)(i)	• curly arrow from on or within the circle to anywhere towards or on NO_2^+ **(1)** • intermediate structure including charge with horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon atom **and** some part of the positive charge must be within the horseshoe **(1)** • curly arrow from **C−H bond** to anywhere in the hexagon, and final organic product shown **(1)**	Allow arrow that starts from anywhere within the hexagon Do not award curly arrow starting on or outside the hexagon Do not award missing + on electrophile Do not award missing OH in M1 only Do not award dotted bonds to H and NO_2 unless they are part of a 3D structure Do not award formation of 4-nitrophenol / 3-nitrophenol in M2 only Comment – some part of the 'horseshoe' opening must be opposite the tetrahedral carbon, so only penalise if the line of the circle extends level with or past the tetrahedral C Ignore missing H^+ Ignore additional equations to generate NO_2^+ and reform catalysts	**(3)**

Examples of mechanism:

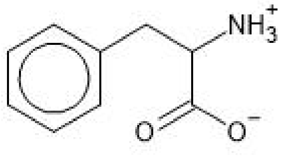


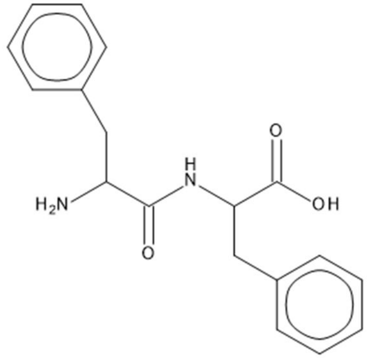


Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	An explanation that makes reference to the following points: Phenol is more reactive than benzene / requires milder conditions because: • the **lone pair** (of electrons) on oxygen overlaps with the pi cloud / delocalised electrons **/** ring **(1)** • so increases the electron density of the (benzene) ring **(1)**	Allow reverse argument for why benzene is less reactive / requires harsher conditions Allow lone pair on OH group Ignore just lone pair Allow spreads into the pi cloud / delocalised electrons / ring (of electrons) Allow interacts with the pi cloud / delocalised electrons / ring (of electrons) Allow donated to the pi cloud / delocalised electrons / ring (of electrons) Allow the (benzene) ring is more susceptible to electrophilic attack Allow makes the (benzene) ring more nucleophilic Do not award 'makes the ring more electronegative'	**(2)**

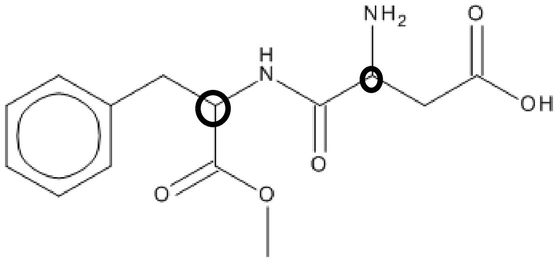
Question Number	**Answer**	**Additional Guidance**	**Mark**
19(b)	An answer that makes reference to the following points: • Reagent for step 1: potassium cyanide and (aqueous) ethanol **(1)** • First intermediate: 2-phenylethanenitrile **(1)** • Reagent for step 2: lithium tetrahydridoaluminate(III) / $LiAlH_4$ in (dry) ether (followed by (hydrolysis with) dilute acid / H^+) **(1)** • Second intermediate: 2-phenylethylamine **(1)** • Reagent for step 3: ethanoyl chloride / CH_3COCl / ethanoic anhydride / $(CH_3CO)_2O$ **(1)**	Allow displayed / structural formulae or any combination of these / skeletal formulae for intermediates Ignore any references to heat / reflux throughout Ignore HCN Allow NaCN Stand alone mark  Allow -CN (i.e.triple bond not displayed) Do not award H_2 and Ni / Pt / Pd Stand alone mark  Allow TE from M2, if extra C shown in nitrile Do not award ethanoic acid / CH_3COOH Ignore $AlCl_3$	**(5)**

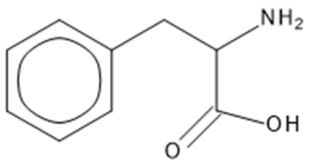
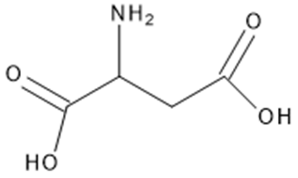
		Comment – allow (3) for use of Grignard reagent ; M1 –formation of Grignard, then reaction with HCHO to form $C_6H_5CH_2CH_2OH$, then reaction with KBr / H_2SO_4 to form $C_6H_5CH_2CH_2Br$, then reaction with NH_3 M2 structure of $C_6H_5CH_2CH_2NH_2$ M3 reaction of $C_6H_5CH_2CH_2NH_2$ with CH_3COCl	

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	- structure of zwitterion	Example of zwitterion:  Allow '+' anywhere on NH_3 group Allow carboxylate ion shown with charge delocalised across two oxygen atoms Allow displayed / structural / skeletal formulae or any combination of these Ignore bond lengths and bond angles	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	• structure of dipeptide	Example of dipeptide:  Allow displayed / structural / skeletal formulae or any combination of these Allow C_6H_5 for the phenyl groups Ignore bond lengths and bond angles Ignore connectivity of OH unless displayed as C-H-O (i.e. a bond shown from C to H then to O)	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(c)(iii)	• $C_{14}H_{18}N_2O_5$	Allow symbols in any order e.g. $C_{14}H_{18}O_5N_2$	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(c)(iv)	- two chiral carbon atoms circled	Example of circled chiral carbons:  Allow other ways of representing the two carbon atoms e.g. asterisk * If more than two carbons are circled then do not award	**(1)**

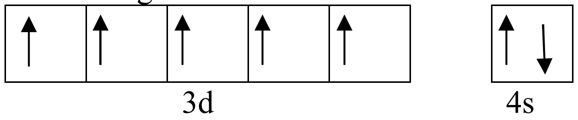
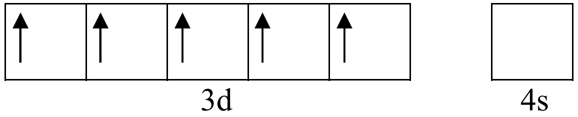
Question Number	Answer	Additional Guidance	Mark
19(c)(v)		Examples of structures:	**(3)**
	- structure of methanol **(1)**	CH_3OH / —OH	
	- structure of 2-amino-3-phenylpropanoic acid **(1)**	 	
	- structure of 2-aminobutanedioic acid **(1)**	 	
	Comment Ignore connectivity of OH unless displayed as C-H-O (i.e. a bond shown from C to H then to O)	Allow structures in any order Allow displayed / structural / skeletal formulae or any combination of these Accept NH_3^+ for NH_2 groups Allow C_6H_5 for the phenyl group Ignore bond lengths and bond angles Ignore names even if incorrect	

Question Number	Answer	Additional Guidance	Mark
19(c)(vi)	• calculation of mass of aspartame in 1 can **(1)** • calculation of mol of aspartame **(1)** • calculation of molecules of aspartame **and** answer to 1 / 2 / 3 SF **(1)** **or** • calculation of mol of aspartame in 100 cm^3 **(1)** • calculation of mol of aspartame in 1 can **(1)** • calculation of molecules of aspartame **and** answer to 1 / 2 / 3 SF **(1)**	Examples of calculation: Mass of aspartame = 53 x 330/100 = 174.9 mg / 0.1749 g Mol of aspartame = 0.1749/294 = 5.949×10^{-4} / 0.0005949 (mol) Molecules aspartame = $5.949 \times 10^{-4} \times 6.02 \times 10^{23}$ (= 3.5813×10^{20}) = 4×10^{20} / 3.6×10^{20} / 3.58×10^{20} **Or** Mol aspartame = $53 \times 10^{-3}/294$ = 1.8027×10^{-4} / 0.00018027(mol) Mol aspartame in can = $1.8027 \times 10^{-4} \times 330/100$ = 5.949×10^{-4} / 0.0005949 (mol) Molecules aspartame = $5.949 \times 10^{-4} \times 6.02 \times 10^{23}$ (= 3.5813×10^{20}) = 4×10^{20} / 3.6×10^{20} / 3.58×10^{20} Allow alternative methods Allow TE throughout Correct answer with no working scores (3) Ignore SF except 1 SF in first 2 steps of working	**(3)**

(Total for Question 19 = 20 marks)

(Total for Section B = 51 marks)

Section C

Question Number	Answer	Additional Guidance	Mark
20(a)(i)	• both electronic configurations correct	Examples of electronic configurations: Mn atom: [Ar]  Mn^{2+} ion: [Ar]  Allow half-arrows Allow all arrows pointing downwards in 3d subshell	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(a)(ii)	An explanation that makes reference to the following points: • there is stability associated with a half-full set of (3)d orbitals **(1)** • Mn^{2+} has five d electrons so is more stable than Mn^{3+} (and has a higher $E^{\ominus}$ value) **(1)** • Fe^{2+} has six d electrons so is less stable than Fe^{3+} (and has a lower $E^{\ominus}$ value) **(1)** If M2 and M3 not awarded then allow 1 rescue mark for two correct electronic configuration from Mn^{3+} = [Ar] $3d^4$ Fe^{2+} = [Ar] $3d^6$ Fe^{3+} = [Ar] $3d^5$ If more than two electronic configurations are given and one is incorrect then do not award the rescue mark	Allow reverse argument Allow 3d subshell with 5 electrons as alternative for half-filled Allow Mn^{2+} has five d electrons so eqm moves to RHS / Mn^{2+} has five d electrons so is energetically more favourable / more energy needed to remove an electron from Mn^{2+} as it has five d electrons Allow Fe^{3+} is more stable as it has a half-filled subshell so Fe^{2+} tends to lose electrons, (making $E^{\ominus}$ less positive) Allow Fe^{2+} has a pair of electrons (in a d orbital) that repel so is less stable than Fe^{3+} (and has a lower $E^{\ominus}$ value)	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(b)(i)	An explanation that makes reference to the following points: • Mn **reduced** from (+)4 to (+)2 **(1)** • Cl **oxidised** from −1 to 0 **and** in Cl_2 **(1)**	Allow oxidation numbers shown under equation Allow Mn^{4+} and Mn^{2+} Allow Cl^{-} **Comments:** 0 must be linked to Cl_2 If no other mark is awarded, allow (1) for all oxidation numbers of Mn and Cl correct	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(b)(ii)	- calculation of mol O_2 **(1)** - calculation of concentration of H_2O_2 **(1)**	Example of calculation: Mol of $O_2 = \frac{86.0}{24000} = 0.0035833 / 3.5833 \times 10^{-3}$ (mol) Mol $H_2O_2 = 2 \times 0.0035833$ $= 0.0071667 / 7.1667 \times 10^{-3}$ (mol) **and** Conc $H_2O_2 = \frac{0.0071667 \times 1000}{100}$ $= 0.071667 / 7.1667 \times 10^{-2}$ (mol dm^{-3}) TE on mol O_2 Ignore SF except 1 SF Comment – if M1 is rounded to 0.00358 and carried through into M1 and M2, this gives a final answer of 0.0716	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(c)	• correct balanced equation	Example of equation: $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$ Allow multiples Allow reversible arrows provided reactants as shown are still on LHS Allow uncancelled electrons on either side Ignore state symbols even if incorrect Ignore oxidation states above atoms, even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
20(d)	An explanation that makes reference to the following points: • this reaction is (auto)catalysed by the Mn^{2+} ions formed **(1)** • (the reaction in) experiment 1 starts slowly because there is no Mn^{2+} / catalyst present initially (but speeds up as Mn^{2+} ions are formed) **(1)** • (the reaction in) experiment 2 is fast(est) at the start as Mn^{2+} ions / catalyst (already) present **(1)**	Mn^{2+} can be mentioned at any point Allow experiment 1 starts slowly but speeds up as Mn^{2+} / catalyst forms Allow rate decreases constantly as Mn^{2+} ions / catalyst (already) present	**(3)**

Question Number	Answer	Additional Guidance	Mark
20(e)(i)	• calculation of mol of $KMnO_4$ **(1)** • calculation of mol of $C_6H_5CH_3$ **(1)** • $KMnO_4$ is in excess because there are more than twice as many mol of $KMnO_4$ than mol of $C_6H_5CH_3$ **(1)**	Example of calculation: Mol $KMnO_4 = \frac{7.00}{158} = 0.044304$ (mol) Mol $C_6H_5CH_3 = \frac{1.73}{92} = 0.018804$ (mol) Accept 0.044304 mol $KMnO_4$ would react with 0.022152 mol $C_6H_5CH_3$ or reverse argument TE on M1 and M2 Allow other methods e.g. Mol $C_6H_5CH_3 = \frac{1.73}{92} = 0.018804$ (mol) (1) Minimum mass of $KMnO_4$ needed = 2 x 0.018804 x 158 = 5.9421 (g) (1) This is less than 7 g so $KMnO_4$ is in excess (1) Ignore SF except 1 SF in M1 and M2	**(3)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
20(e)(ii)	- add H^+ ions / acidify the solution / mixture	Allow correct name or formula of any strong acid e.g. HCl, H_2SO_4, HNO_3, H_3PO_4 Do not award carboxylic acids e.g. CH_3COOH Allow $C_6H_5CO_2^- + H^+ \rightarrow C_6H_5COOH$ Ignore references to concentration / heat / reflux Do not award 'acid hydrolysis' / acid catalyst / H^+ ions from water / inclusion of a second incorrect reagent e.g. H^+ and $LiAlH_4$	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
20(f)(i)	- anode half-equation **(1)** - cathode half-equation **(1)**	Examples of equations: $Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$ $2MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2OH^-$ Allow multiples / reversible arrows Ignore state symbols even if incorrect If no other mark is awarded allow (1) for anode and cathode half-equations written in wrong places If no other mark awarded allow 1 mark for Zn on the left-hand side of the anode reaction **and** MnO_2 on the left-hand side of the cathode reaction	**(2)**

Question Number	Answer	Additional Guidance	Mark
20(f)(ii)	• ($E^\ominus$ = +)0.15 (V)	Do not award − 0.15(V)	**(1)**

(Total for Question 20 = 19 marks)
(Total for Section C = 19 marks)

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