



Cambridge International AS & A Level

CHEMISTRY

9701/41

Paper 4 A Level Structured Questions

May/June 2021

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the May/June 2021 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

This document consists of **17** printed pages.

Generic Marking Principles

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1 Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.

2 The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.

3 Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).

4 The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.

5 'List rule' guidance

For questions that require ***n*** responses (e.g. State **two** reasons ...):

- The response should be read as continuous prose, even when numbered answer spaces are provided.
- Any response marked *ignore* in the mark scheme should not count towards ***n***.
- Incorrect responses should not be awarded credit but will still count towards ***n***.
- Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response.
- Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

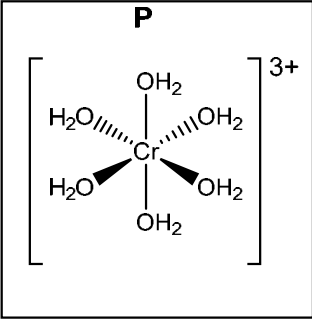
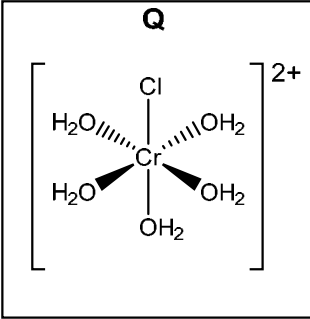
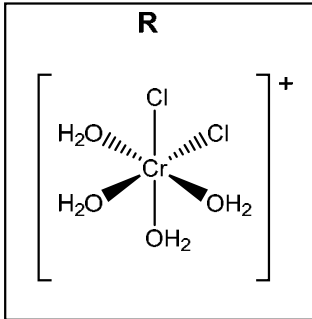
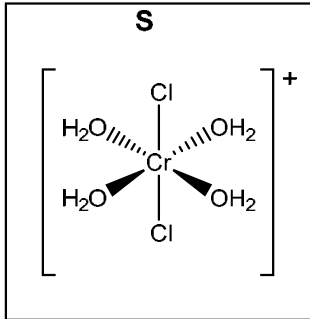
7 Guidance for chemical equations

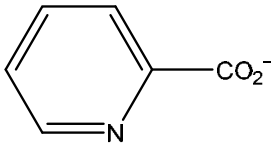
Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

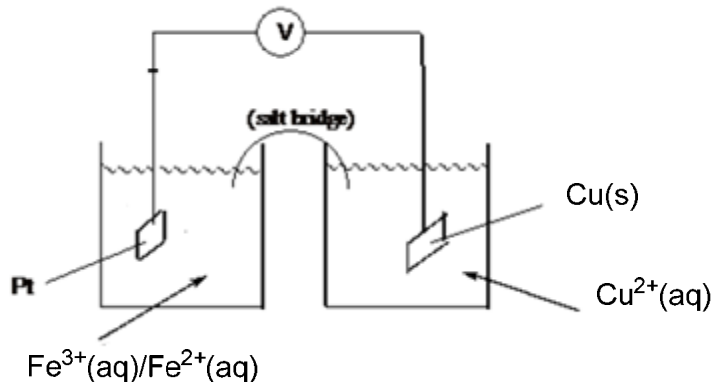
Question	Answer	Marks
1(a)	M1: increases down the group M2: radius / size of (cat)ion / M^{2+} increases M3: less polarisation / distortion of anion / hydroxide ion / hydroxide group / OH^- / OH	3
1(b)(i)	$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$	1
1(b)(ii)	M1: $K_{sp} = [Ca^{2+}][OH^-]^2$ OR $K_{sp} = 4x^3$ M2: $x = \sqrt[3]{5.02 \times 10^{-6} / 4} = 0.0108 / 0.011 / 1.08 \times 10^{-2} / 1.1 \times 10^{-2} \text{ (mol dm}^{-3}\text{) min 2 sf}$	2
1(b)(iii)	less soluble / decreases due to the common ion effect OR decreases as equilibrium in (b)(i) has shifted to the left OR decreases as $[OH^-]$ increases causing $[Ca^{2+}][OH^-]^{(2)}$ to exceed its K_{sp}	1

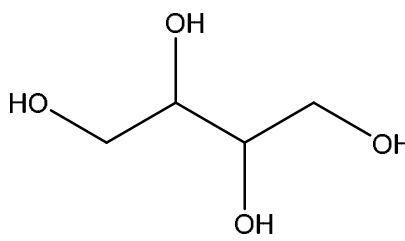
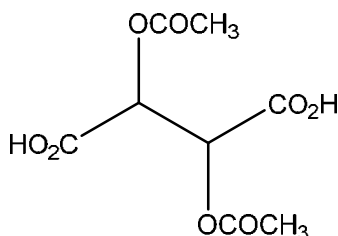
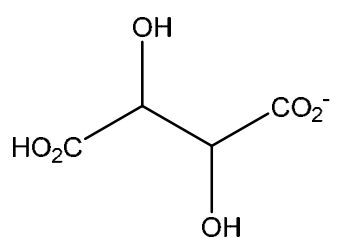
Question	Answer	Marks
2(a)	<p>M1: (complexes have two sets of) d orbital(s) of different energy / d-d splitting occurs OR d orbital(s) / d (sub)-shell splits OR (inferred from a movement of an electron) from a lower d to higher d orbital</p> <p>M2: electron(s) promoted / excited OR electron(s) moves to higher (d-)orbital OR electron(s) jumps up (to d-orbital) / jumps to higher (d-orbital)</p> <p>M3: wavelength / frequency / light / photon / $h\nu$ absorbed OR radiation / energy from <u>visible</u> (region) absorbed</p> <p>M4: colour seen is complementary (to colour absorbed) OR wavelength / frequency / colour / light not absorbed is transmitted / reflected / seen</p>	4

Question	Answer	Marks
2(b)(i)	<div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;"> <p>P</p>  </div> <div style="text-align: center;"> <p>Q</p>  </div> </div> <div style="display: flex; justify-content: space-around; align-items: flex-start; margin-top: 20px;"> <div style="text-align: center;"> <p>R</p>  </div> <div style="text-align: center;"> <p>S</p>  </div> </div> <p>M1: All charges M2: One octahedral with correct 3D M3: All formulae M4: R is cis, S is trans</p>	4
2(b)(ii)	dipoles cancel	1
2(c)(i)	<p>M1: (a species) that donates <u>two</u> lone pairs / forms two coordinate bonds / two dative bonds</p> <p>M2: to a metal atom / metal ion</p>	2

Question	Answer	Marks
2(c)(ii)	 structure of the picolinate anion ligand	1
2(c)(iii)	(coordination number) six AND (geometry around Cr) octahedral	1
2(d)(i)	$(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ +6 Cr_2O_3 +3	1
2(d)(ii)	$(\text{NH}_4)_2\text{Cr}_2\text{O}_7 \rightarrow \text{N}_2 + \text{Cr}_2\text{O}_3 + 4\text{H}_2\text{O}$	1

Question	Answer	Marks
3(a)(i)	(an element) forming stable ion / ions / compound(s) / oxidation state(s) AND with partially filled / incomplete AND d orbitals / d subshell / d shell	1
3(a)(ii)	(melting point) higher AND (density) higher	1
3(b)(i)	M1: emf / potential difference / difference in electrode potential between two half-cells / two electrodes (in a cell) M2: (all solutions being) 1 mol dm^{-3} AND either 1 atm OR 298 K	2

Question	Answer	Marks
3(b)(ii)	<p>salt bridge, voltmeter, Cu(s), Cu²⁺(aq), Pt(s), Fe²⁺ and Fe³⁺(aq) two for one mark, four for two marks, six for three marks</p> 	3
3(c)(i)	<p>M1: $2\text{I}^- + 2\text{Fe}^{3+} \rightarrow \text{I}_2 + 2\text{Fe}^{2+}$</p> <p>M2: $\text{S}_2\text{O}_8^{2-} + 2\text{Fe}^{2+} \rightarrow 2\text{SO}_4^{2-} + 2\text{Fe}^{3+}$</p>	2
3(c)(ii)	<p>M1: $\text{I}_2 / \text{I}^- +0.54 \text{ V}$ AND $\text{Fe}^{3+} / \text{Fe}^{2+} + 0.77 \text{ V}$ AND $[\text{Fe}(\text{CN})_6]^{3-} / [\text{Fe}(\text{CN})_6]^{4-} +0.36 \text{ V}$</p> <p>M2: E° of I_2 / I^- is more positive / greater than E° of $[\text{Fe}(\text{CN})_6]^{3-} / [\text{Fe}(\text{CN})_6]^{4-}$ OR $E^\circ_{\text{cell}} = -0.18 \text{ V}$ so no reaction occurs OR E° of $\text{Fe}^{3+} / \text{Fe}^{2+}$ is more positive / greater than E° of I_2 / I^- OR $E^\circ_{\text{cell}} = 0.23 \text{ V}$ so reaction occurs [1]</p>	2
3(d)(i)	<p>$\text{S}_2\text{O}_8^{2-}$ and tartrate ions are both negatively charged / both reactants same charge AND so repel each other OR have a high E_a</p>	1
3(d)(ii)	$\text{C}_4\text{H}_4\text{O}_6^{2-} + 2\text{H}_2\text{O} \rightleftharpoons 2\text{CO}_2 + 2\text{HCO}_2^- + 6\text{H}^+ + 6\text{e}^-$	1

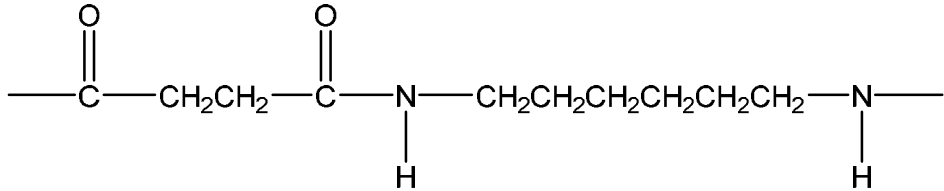
Question	Answer			Marks
3(e)(i)	reagent	structure of organic product	type of reaction	3
	an excess of LiAlH_4		reduction	
	an excess of CH_3COCl		condensation	
	M1: product with LiAlH_4 M2: product with CH_3COCl M3: both types of reaction			
3(e)(ii)	 $\text{C}_6\text{H}_5\text{CH}(\text{NH}_3^+)\text{CH}_3$			1
OR dianion of tartrate with two cations present				

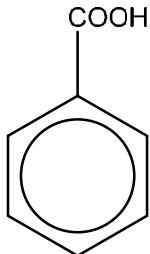
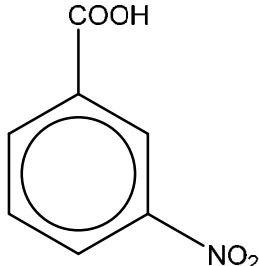
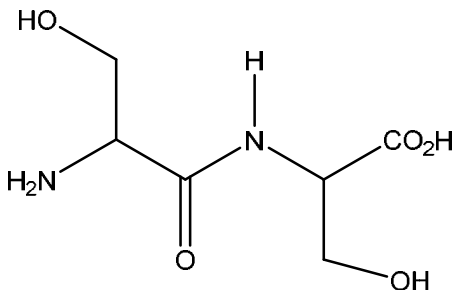
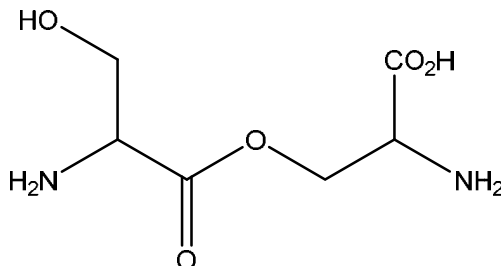
Question	Answer	Marks
4(a)(i)	M1: blue solid / blue ppt M2: $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2 + 6\text{H}_2\text{O}$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{H}_2\text{O}$ M3: precipitation / acid-base	3
4(a)(ii)	M1: dark blue solution / deep blue solution M2: $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ M3: ligand exchange / substitution / displacement / replacement	3
4(b)	M1: X CuSO_4 and Y Cu M2: <i>type of reaction</i> = redox / disproportionation	2

Question	Answer	Marks
5(a)	measure volume / amount of oxygen formed / mass lost / and time / against time / per unit time OR measure absorbance / transmission against time / per unit time	1
5(b)(i)	time taken for the concentration / mass / amount of a reactant to fall to half (its original value) / to halve	1
5(b)(ii)	$t_{1/2} = 150 \text{ s}$ AND evidence on graph / paper of one half-life	1
5(b)(iii)	no change	1
5(c)(i)	M1: evidence on graph of tangent AND 4 to 5×10^{-4} M2: $\text{mol dm}^{-3} \text{ s}^{-1}$	2

Question	Answer	Marks
5(c)(ii)	(c)(i) / 0.10 AND s ⁻¹	1
5(d)	M1: NO ₂ + O ₃ → NO ₃ + O ₂ M2: NO ₂ + NO ₃ → N ₂ O ₅	2

Question	Answer	Marks									
6(a)	<p>M1: ethanoic acid > butanoic acid > water > ethanol</p> <p>M2: a reason given in terms of an electron donating or an electron withdrawing group for one of: strengthening of O–H bond OR weakening of O–H bond OR stability of anion</p> <p><i>Two out of the three alternatives M3, M4 and M5:</i></p> <p>M3: <u>ethanol</u>: positive inductive effect / electron donating effect of ethyl / alkyl / R group</p> <p>M4: <u>butanoic acid</u>: positive inductive effect / electron donating effect of propyl / alkyl / R group</p> <p>M5: (either ethanoic or butanoic) <u>acid</u>: negative inductive effect of either C=O or carbonyl OR negative charge delocalised over COO⁻</p>	4									
6(b)(i)	<table border="1"> <thead> <tr> <th></th><th>reagents and conditions</th><th>observed change</th></tr> </thead> <tbody> <tr> <td>test 1</td><td>Tollen's reagent, warm OR Fehling's solution, warm</td><td>silver mirror (brick) red ppt / solid</td></tr> <tr> <td>test 2</td><td>acidified MnO₄⁻, warm</td><td>decolourises OR bubbles</td></tr> </tbody> </table> <p>M1 / M2: reagents and conditions × 2</p> <p>M3: observations both correct</p>		reagents and conditions	observed change	test 1	Tollen's reagent, warm OR Fehling's solution, warm	silver mirror (brick) red ppt / solid	test 2	acidified MnO ₄ ⁻ , warm	decolourises OR bubbles	3
	reagents and conditions	observed change									
test 1	Tollen's reagent, warm OR Fehling's solution, warm	silver mirror (brick) red ppt / solid									
test 2	acidified MnO ₄ ⁻ , warm	decolourises OR bubbles									

Question	Answer	Marks												
6(b)(ii)	<table border="1"> <thead> <tr> <th>compound</th><th>number of peaks in proton NMR</th><th>number of peaks in carbon-13 NMR</th></tr> </thead> <tbody> <tr> <td>HCO₂H</td><td>2</td><td>1</td></tr> <tr> <td>HO₂CCO₂H</td><td>1</td><td>1</td></tr> <tr> <td>HO₂CCH₂CH₂CO₂H</td><td>2</td><td>2</td></tr> </tbody> </table> <p>one mark for three, four or five correct two marks for six correct</p>	compound	number of peaks in proton NMR	number of peaks in carbon-13 NMR	HCO ₂ H	2	1	HO ₂ CCO ₂ H	1	1	HO ₂ CCH ₂ CH ₂ CO ₂ H	2	2	2
compound	number of peaks in proton NMR	number of peaks in carbon-13 NMR												
HCO ₂ H	2	1												
HO ₂ CCO ₂ H	1	1												
HO ₂ CCH ₂ CH ₂ CO ₂ H	2	2												
6(b)(iii)	OH peak disappears AND proton / H exchanges with deuterium	1												
6(c)(i)	G = HOCH ₂ CH ₂ CH ₂ CH ₂ OH H = NCCH ₂ CH ₂ CH ₂ CH ₂ CN	2												
6(c)(ii)	M1 : step 1 NaOH(aq) + heat M2 : step 2 acidified KMnO ₄ + heat / acidified K ₂ Cr ₂ O ₇ + heat M3 : step 3 CN ⁻ / KCN / NaCN + heat M4 : step 4 LiAlH ₄ ALLOW Na in ethanol or H ₂ + Ni / Pd / Pt	4												
6(d)	 <p>M1: correct displayed amide linkage M2: the rest of the repeat unit correct including trailing bonds</p>	2												

Question	Answer	Marks				
7(a)(i)	<div><div>M </div><div>N </div></div>	2				
7(a)(ii)	<p>M1: step 1 hot $\text{KMnO}_4 / \text{MnO}_4^-$</p> <p>M2: step 2 conc. H_2SO_4 and conc. HNO_3</p> <p>M3: step 3 Sn and conc. HCl (heat)</p>	3				
7(b)(i)	<div><div></div><div></div></div> <p>M1 / M2: each structure</p> <p>M3: both displayed linkage</p>	3				
7(b)(ii)	<table><tr><td>molecular formula</td><td>number of structural isomers formed</td></tr><tr><td>$\text{C}_9\text{H}_{19}\text{N}_3\text{O}_4$</td><td>4</td></tr></table>	molecular formula	number of structural isomers formed	$\text{C}_9\text{H}_{19}\text{N}_3\text{O}_4$	4	1
molecular formula	number of structural isomers formed					
$\text{C}_9\text{H}_{19}\text{N}_3\text{O}_4$	4					

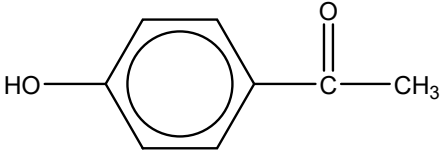
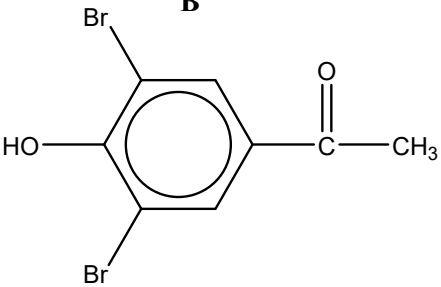
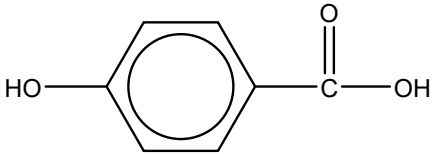
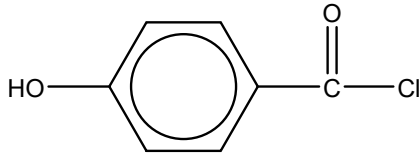
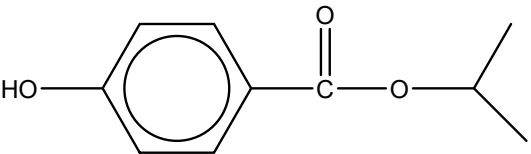
Question	Answer	Marks
7(c)(i)		1
7(c)(ii)	<p>one mark for two correct two marks for three correct</p>	2

Question	Answer	Marks
8(a)(i)	<p>M1: $\text{CH}_3\text{CO}_2\text{H}$ and CH_3CO_2^-</p> <p>M2: due to buffering action / acting as a buffer solution</p> <p>M3: $\text{CH}_3\text{CO}_2\text{H}$ reacts with $\text{NaOH} / \text{OH}^-$ (forming CH_3CO_2^- and water) OR OH^- reacts with H^+ and <u>equilibrium</u> $\text{CH}_3\text{CO}_2\text{H} \rightleftharpoons \text{CH}_3\text{CO}_2^- + \text{H}^+$ shifts to the right</p>	3
8(a)(ii)	<p>identifying CH_3CO_2^- is present (with water) at the equivalence point OR CH_3CO_2^- react with water forming OH^- OR titrating a weak acid with a strong base</p>	1

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Question	Answer	Marks
8(b)	<p>M1: moles $\text{MnO}_4^- = 0.025 \times 0.0201 = 5.025 \times 10^{-4}$</p> <p>moles $\text{V}^{2+} = 5.025 \times 10^{-4} \times 5/3 = 8.375 \times 10^{-4}$</p> <p>M2: moles $\text{VO}_3^- = 8.375 \times 10^{-4}$</p> <p>mass of $\text{NH}_4\text{VO}_3 = 116.9 \times 8.375 \times 10^{-4} = 0.0979 \text{ g}$</p> <p>M3: % Purity of $\text{NH}_4\text{VO}_3 = 100 \times 0.0979 / 0.15 = 65.3$ must be 3 sf</p>	3

Question	Answer	Marks
9(a)	<div style="display: flex; flex-direction: column; align-items: center;"> <div style="display: flex; justify-content: space-around; width: 100%;"> <div style="text-align: center;"> <p>A</p>  </div> <div style="text-align: center;"> <p>B</p>  </div> </div> <div style="display: flex; justify-content: space-around; width: 100%; margin-top: 20px;"> <div style="text-align: center;"> <p>C</p> <p>CH₃</p> <p>D</p>  </div> <div style="text-align: center;"> <p>E</p>  </div> </div> <div style="text-align: center; margin-top: 20px;"> <p>F</p>  </div> <p>one mark for each structure</p> </div> <div></div>	6