



Cambridge International AS & A Level

CHEMISTRY

9701/42

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 **16** printed pages.

PUBLISHED**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.

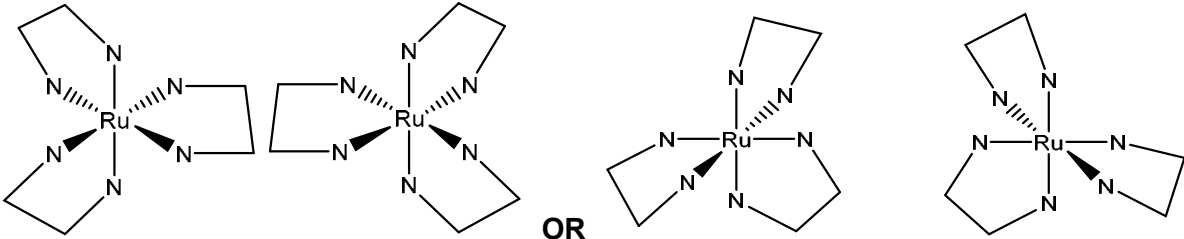
7 Guidance for chemical equations

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.

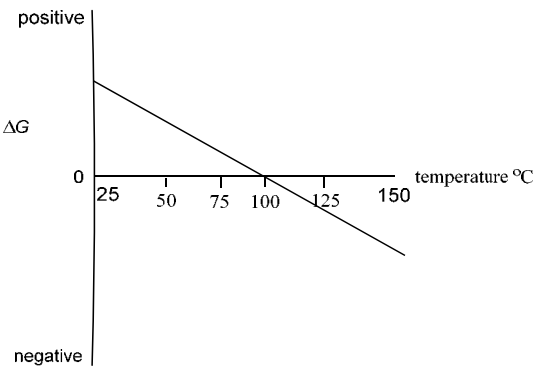
| Question | Answer | Marks | | | | | | | | | | | | |
|---|--|---|------------------------------------|------------------|------------|--|---------------|-------------------------------------|--|-------------------|-----------------------------------|---------------------------------|---------------------|---|
| 1(a)(i) | $[1s^2] 2s^2 2p^6 3s^2 3p^6 3d^3$ | 1 | | | | | | | | | | | | |
| 1(a)(ii) | (a molecule or ion formed by a central) metal atom/ion surrounded by / bonded to one or more ligands | 1 | | | | | | | | | | | | |
| 1(b) | <table border="1"> <thead> <tr> <th>$[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$</th> <th>formula of chromium species formed</th> <th>type of reaction</th> </tr> </thead> <tbody> <tr> <td>+ NaOH(aq)</td> <td>$\text{Cr}(\text{OH})_3$ or $\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3$</td> <td>precipitation</td> </tr> <tr> <td>+ $\text{H}_2\text{O}_2(\text{aq})$</td> <td>$\text{Cr}_2\text{O}_7^{2-}$ / CrO_4^{2-}</td> <td>redox / oxidation</td> </tr> <tr> <td>+ excess $\text{NH}_3(\text{aq})$</td> <td>$\text{Cr}(\text{NH}_3)_6^{3+}$</td> <td>ligand substitution</td> </tr> </tbody> </table> <p>chromium species: one mark for each correct species type of reaction: two correct for one mark and three correct for two marks</p> | $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ | formula of chromium species formed | type of reaction | + NaOH(aq) | $\text{Cr}(\text{OH})_3$ or $\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3$ | precipitation | + $\text{H}_2\text{O}_2(\text{aq})$ | $\text{Cr}_2\text{O}_7^{2-}$ / CrO_4^{2-} | redox / oxidation | + excess $\text{NH}_3(\text{aq})$ | $\text{Cr}(\text{NH}_3)_6^{3+}$ | ligand substitution | 5 |
| $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ | formula of chromium species formed | type of reaction | | | | | | | | | | | | |
| + NaOH(aq) | $\text{Cr}(\text{OH})_3$ or $\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3$ | precipitation | | | | | | | | | | | | |
| + $\text{H}_2\text{O}_2(\text{aq})$ | $\text{Cr}_2\text{O}_7^{2-}$ / CrO_4^{2-} | redox / oxidation | | | | | | | | | | | | |
| + excess $\text{NH}_3(\text{aq})$ | $\text{Cr}(\text{NH}_3)_6^{3+}$ | ligand substitution | | | | | | | | | | | | |
| 1(c) | <p>M1: ΔE is different OR energy gap between d-orbitals is different</p> <p>M2: different frequency / wavelength is absorbed OR different energy / light in visible region is absorbed</p> | 2 | | | | | | | | | | | | |
| 1(d)(i) | ethanoate ions are bidentate whereas as H_2O are monodentate OR ethanoate ions form two dative bonds whereas H_2O forms one (dative) bond OR ethanoate ions donate two lone pairs whereas H_2O donates one (lone) pair | 1 | | | | | | | | | | | | |
| 1(d)(ii) | (coordination number) six AND (geometry around Cr) octahedral | 1 | | | | | | | | | | | | |
| 1(d)(iii) | coordinate / (dative) covalent | 1 | | | | | | | | | | | | |
| 1(e)(i) | $4\text{Cr}^{2+} + \text{O}_2 + 4\text{H}^+ \rightarrow 4\text{Cr}^{3+} + 2\text{H}_2\text{O}$ OR $2\text{Cr}^{2+} + \text{O}_2 + 2\text{H}^+ \rightarrow 2\text{Cr}^{3+} + \text{H}_2\text{O}_2$ M1: correct species M2: balancing | 2 | | | | | | | | | | | | |
| 1(e)(ii) | $E^\ominus_{\text{cell}} = 1.23 - (-0.41) = (+)1.64 \text{ V}$ OR $E^\ominus_{\text{cell}} = 0.68 - (-0.41) = (+)1.09 \text{ V}$ value linked to (e)(i) | 1 | | | | | | | | | | | | |

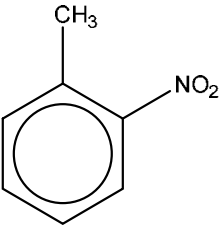
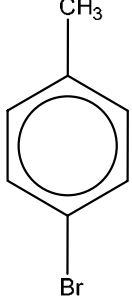
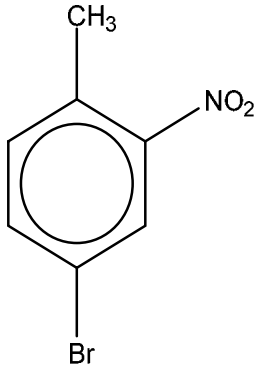
| Question | Answer | Marks |
|----------|--|-------|
| 2(a) | <p>M1: increases down the group</p> <p>M2: radius / size of cation / M^{2+} increases OR charge density of cation / M^{2+} decreases</p> <p>M3: less polarisation / less distortion of anion / NO_3^- ion OR less weakening of NO bond</p> | 3 |
| 2(b)(i) | $\text{Pb}(\text{NO}_3)_2 \rightarrow \text{PbO} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$ | 1 |
| 2(b)(ii) | lead nitrate / $\text{Pb}(\text{NO}_3)_2$ would decompose more / easier AND as Pb^{2+} is smaller / Pb^{2+} has larger charge density (so more polarising) | 1 |
| 2(c)(i) | $\text{BaC}_2\text{O}_4 \rightarrow \text{BaO} + \text{CO}_2 + \text{CO}$ OR $\text{BaC}_2\text{O}_4 \rightarrow \text{BaO} + 2\text{CO} + \frac{1}{2}\text{O}_2$ | 1 |
| 2(c)(ii) | <p>M1: [a] initial moles $\text{MnO}_4^- = 0.0200 \times 0.050 = 1.00 \times 10^{-3}$ [b] moles $\text{Fe}^{2+} = 0.050 \times 0.0304 = 1.52 \times 10^{-3}$</p> <p>M2: [a] moles MnO_4^- unreacted = $1.52 \times 10^{-3} / 5 = 3.04 \times 10^{-4}$ [b] moles MnO_4^- reacted = $1.00 \times 10^{-3} - 3.04 \times 10^{-4} = 6.96 \times 10^{-4}$</p> <p>M3: moles $\text{C}_2\text{O}_4^{2-}$ reacted = $6.96 \times 10^{-4} \times 5/2 = 1.74 \times 10^{-3}$</p> <p>M4: mass of $\text{BaC}_2\text{O}_4 = 225.3 \times 1.74 \times 10^{-3} = 0.392 \text{ g}$ % Purity of $\text{BaC}_2\text{O}_4 = 100 \times 0.392/0.50 = 78.4$</p> | 4 |
| 2(d) | <p>M1: $[\text{OH}^-] = 2 \times 0.12 = 0.24 \text{ (mol dm}^{-3}\text{)}$ $[\text{H}^+] = 1 \times 10^{-14}/0.24 = 4.17 \times 10^{-14} / \text{pOH} = -\log(0.24)$ OR 0.62</p> <p>M2: $\text{pH} = -\log[\text{H}^+] = 13.4$ OR $\text{pH} = 14 - 0.6 = 13.4$</p> | 2 |

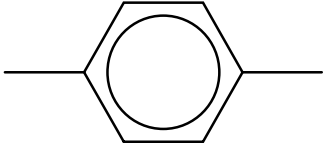
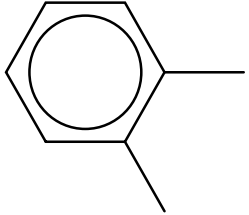
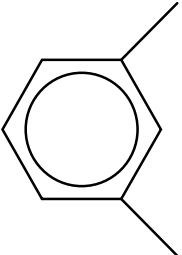
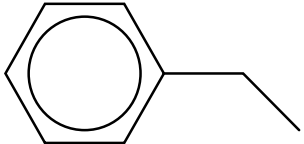
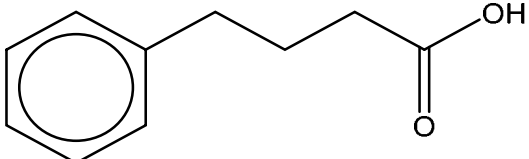
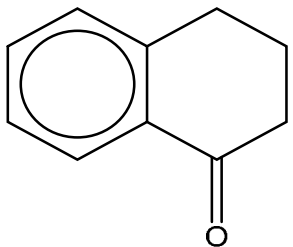
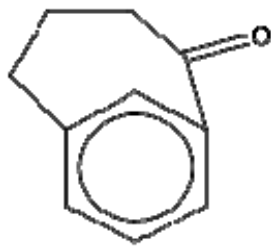
| Question | Answer | Marks | | | | | | | | |
|----------------|--|-------------|--------------|---------------|---|---|---|----------------|---|---|
| 3(a)(i) | <p>M1: voltage of an electrode / a half-cell compared to / connected to (standard) hydrogen electrode / half-cell</p> <p>M2: (at concentration of) 1 mol / dm³ AND (pressure of) 1 atm / 101 kPa (or in Pa) AND 298 K / 25°C</p> | 2 | | | | | | | | |
| 3(a)(ii) | <table border="1" data-bbox="338 359 692 667"> <thead> <tr> <th data-bbox="338 359 517 443">E^\ominus</th> <th data-bbox="517 359 692 443">redox system</th> </tr> </thead> <tbody> <tr> <td data-bbox="338 443 517 518">Most negative</td> <td data-bbox="517 443 692 518">B</td> </tr> <tr> <td data-bbox="338 518 517 593">↑</td> <td data-bbox="517 518 692 593">C</td> </tr> <tr> <td data-bbox="338 593 517 667">Least negative</td> <td data-bbox="517 593 692 667">A</td> </tr> </tbody> </table> | E^\ominus | redox system | Most negative | B | ↑ | C | Least negative | A | 1 |
| E^\ominus | redox system | | | | | | | | | |
| Most negative | B | | | | | | | | | |
| ↑ | C | | | | | | | | | |
| Least negative | A | | | | | | | | | |
| 3(a)(iii) |  <p>M1 / M2: two 3D isomers of $[\text{Ru}(\text{en})_3]^{3+}$</p> <p>M3: optical / enantiomerism</p> | 3 | | | | | | | | |
| 3(b)(i) | <p>$E^\ominus_{\text{cell}} = 1.07 - 0.80 = (+)0.27 \text{ V}$</p> <p>AND direction of electron flow = Ag^+ / Ag to $\text{Br}_2 / \text{Br}^-$</p> | 1 | | | | | | | | |
| 3(b)(ii) | <p>M1: E^\ominus_{cell} 3rd box ticked</p> <p>M2: $[\text{Ag}^+]$ decreases AND so $(\text{Ag}^+ / \text{Ag})$ equilibrium shifts to the left OR $[\text{Ag}^+]$ decreases AND E for $(\text{Ag}^+ / \text{Ag})$ becomes less positive / more negative</p> | 2 | | | | | | | | |

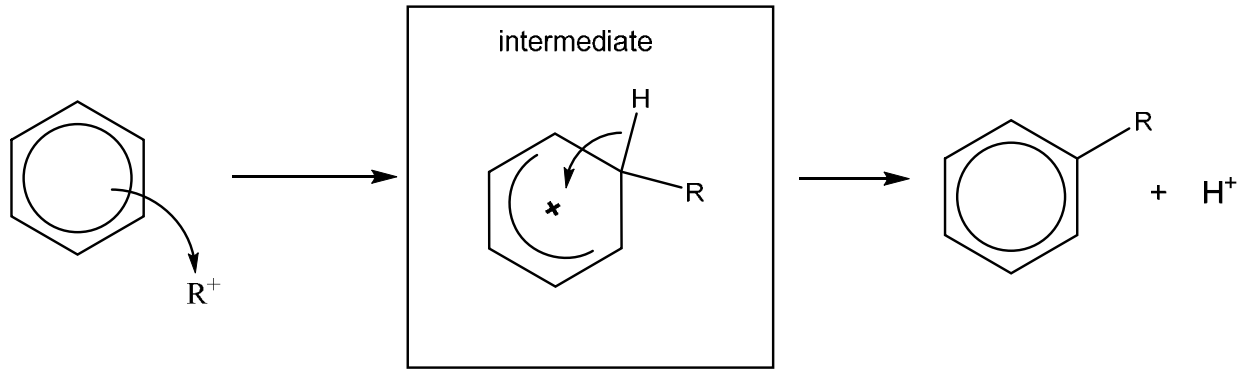
| Question | Answer | Marks |
|-----------|--|-------|
| 3(c)(i) | (a species) that uses / shares a lone pair of electrons to form a coordinate bond to a metal atom / ion | 1 |
| 3(c)(ii) | $K_c = [\text{Ag}(\text{S}_2\text{O}_3)_2^{3-}] [\text{Br}^-] / [\text{S}_2\text{O}_3^{2-}]^2$ | 1 |
| 3(c)(iii) | M1: $K_c = K_{\text{stab}} \times K_{\text{sp}} = 15.7$ M2: 1 OR none / no units | 2 |
| 3(d) | M1: highest $[\text{Ag}(\text{CN})_2]^-$ $[\text{Ag}(\text{S}_2\text{O}_3)_2]^{3-}$ $[\text{Ag}(\text{NH}_3)_2]^+$ lowest M2: K_{stab} $[\text{Ag}(\text{CN})_2]^-$ is highest / $[\text{Ag}(\text{CN})_2]^-$ is the most stable OR higher K_{stab} forms the more stable complex | 2 |

| Question | Answer | Marks |
|-----------|---|-------|
| 4(a)(i) | M1: energy change when 1 mole of a ionic compound is formed M2: from its gaseous ions under standard conditions | 2 |
| 4(a)(ii) | $\Delta H_{\text{sol}} = (-2099) + (2 \times -378) - (-2824)$ $\Delta H_{\text{sol}} = -31 \text{ kJ mol}^{-1}$ M1: use of $\times 2$ as only multiplier M2: correct signs and evaluation | 2 |
| 4(a)(iii) | M1: Cu^{2+} is smaller OR Cu^{2+} has a higher charge density M2: Cu^{2+} attracts water molecules more / stronger OR (Cu^{2+}) forms stronger ion-dipole forces to water molecules | 2 |
| 4(b)(i) | anode: chlorine / Cl_2 cathode: hydrogen / H_2 | 1 |
| 4(b)(ii) | M1: $Q = 0.75 \times 60 \times 60 = 2700 \text{ C}$ AND 96 500 or 193 000 used M2: [a] moles of Ca = $2700 / 193\ 000 = 0.0140$ [b] mass = $0.0140 \times 40.1 = 0.56 \text{ g}$ | 2 |

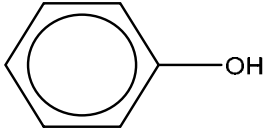
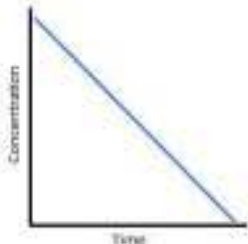
| Question | Answer | Marks | | | | | | | | | | | | |
|---------------------------|---|------------|----------------|------------|----------------|---------------------------|--|--|---|--------------------------|---|--|--|---|
| 4(c)(i) | measure / degree of (dis)order / randomness (of a system) OR the number of possible arrangements of the particles and their energy (in a given system) | 1 | | | | | | | | | | | | |
| 4(c)(ii) | <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;"></th> <th style="width: 20%;">ΔS is negative</th> <th style="width: 20%;">ΔS is zero</th> <th style="width: 30%;">ΔS is positive</th> </tr> </thead> <tbody> <tr> <td>solid dissolving in water</td> <td></td> <td></td> <td style="text-align: center;">✓</td> </tr> <tr> <td>water solidifying to ice</td> <td style="text-align: center;">✓</td> <td></td> <td></td> </tr> </tbody> </table> | | ΔS is negative | ΔS is zero | ΔS is positive | solid dissolving in water | | | ✓ | water solidifying to ice | ✓ | | | 1 |
| | ΔS is negative | ΔS is zero | ΔS is positive | | | | | | | | | | | |
| solid dissolving in water | | | ✓ | | | | | | | | | | | |
| water solidifying to ice | ✓ | | | | | | | | | | | | | |
| 4(c)(iii) |  <p><i>two correct for 1 mark, three correct for two marks:</i></p> <ul style="list-style-type: none"> starting at +8.6 kJ / in positive region close to the y-axis line passes through x-axis around 100°C negative gradient straight / curve line through the x-axis (no clear positive inflexions) | 2 | | | | | | | | | | | | |
| 4(d) | <p>M1: ΔH negative / – , ΔS negative / –</p> <p>M2: as temperature increase, ΔG becomes (more) positive / less negative ora OR at low(er) T, (ΔH more negative than TΔS) so ΔG is negative OR at high(er) T, (ΔH less negative than TΔS) so ΔG is positive</p> | 2 | | | | | | | | | | | | |

| Question | Answer | Marks |
|-----------|---|----------|
| 5(c)(ii) | <p data-bbox="338 220 864 523">E =  OR </p> <p data-bbox="338 528 689 895">F = </p> | 2 |
| 5(c)(iii) | <p data-bbox="338 932 875 963">M1: step 1 conc. H₂SO₄ and conc. HNO₃</p> <p data-bbox="338 1002 667 1034">M2: step 2 Br₂ and AlBr₃</p> <p data-bbox="338 1072 987 1104">M3: step 3 hot (alkaline / acidified) MnO₄⁻ / KMnO₄</p> | 3 |

| Question | Answer | Marks |
|----------|--|-------|
| 6(a) | <p>three peaks  four peaks </p> <p>five peaks  six peaks </p> <p>correct isomers and correct assignment to peaks: mark as •✓•✓•✓•✓</p> | 4 |
| 6(b)(i) | <p>$RCl + AlCl_3 \rightarrow R^+ + AlCl_4^-$</p> <p>OR $Cl(CH_2)_3COOH + AlCl_3 \rightarrow ^+(CH_2)_3COOH + AlCl_4^-$</p> | 1 |
| 6(b)(ii) | <p>W  X $C_{10}H_{10}O$  OR </p> | 2 |

| Question | Answer | Marks |
|-----------|--|-------|
| 6(b)(iii) | SOCl ₂ OR PCl ₅ ALLOW PCl ₃ AND heat | 1 |
| 6(b)(iv) |  <p>M1: arrow to R⁺ OR arrow to positive carbon of ⁺(CH₂)₃COOH M2: correct structure of intermediate M3: arrow from C-H bond into the ring AND H⁺</p> | 3 |

| Question | Answer | Marks |
|-----------|--|-------|
| 7(a)(i) | the power to which a concentration of a reactant is raised in the rate equation / law | 1 |
| 7(a)(ii) | M1: (using expt 1 and 3) as [ClO ₂] × 2.5 rate × 6.25 so 2nd order M2: (using expt 1 and 2) as [OH ⁻] × 4 rate × 4 so 1st order | 2 |
| 7(a)(iii) | rate = k[ClO ₂] ² [OH ⁻] | 1 |
| 7(a)(iv) | M1: k = rate / [ClO ₂] ² [OH ⁻] k = 7.20 × 10 ⁻⁴ / (0.02) ² (0.03) k = 60 M2: mol ⁻² dm ⁶ min ⁻¹ | 2 |

| Question | Answer | Marks |
|----------|--|----------|
| 7(b)(i) | structure of phenol: C ₆ H ₅ OH OR  | 1 |
| 7(b)(ii) | tangent drawn correctly AND rate = $0.015 / 260 = 5.8 \times 10^{-5}$ ALLOW values consistent with tangent drawn at 100 sec | 1 |
| 7(c) |  AND half-life decreases (1st box) | 1 |

| Question | Answer | | | | Marks |
|-------------------|-----------------------------|---|------------------------------------|---|----------|
| 8(c)(ii) | chemical shift (δ) | environment of proton | splitting pattern (words required) | number of ^1H atoms responsible for the peak | 3 |
| | 0.95 | alkane / CH_3 | doublet | 6 | |
| | 1.90 | alkane / CH ALLOW alkyne | multiplet | 1 | |
| | 2.20 | R / alkyl / CH_2 next to $\text{C}=\text{O}$ / COOH | doublet | 2 | |
| mark as ••✓••✓••✓ | | | | | |