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CAMBRIDGE
International Education

# Cambridge International AS & A Level

**CHEMISTRY** **9701/42**

Paper 4 A Level Structured Questions **May/June 2026**

MARK SCHEME

Maximum Mark: 100

**Published**

This mark scheme contains the instructions and marking guidance that our examiners used to mark candidate responses for this component.

Before they start marking, examiners complete a standardisation process. They review a range of candidate responses and discuss the mark scheme in detail to agree which answers can and cannot be accepted. Examiners award marks where it is clear that candidate responses have met the requirements of the mark scheme. These requirements may vary between different components or different versions of the same component, depending on the exact requirements of the question and the candidate responses seen during the standardisation process.

Sometimes, our mark schemes may allow marks to be awarded to responses which contain elements that are factually incorrect or for content not covered by the syllabus. We do this in response to the demands of a specific question to support candidates and make sure that our assessments are fair. However, these allowances should not be used as a guide for teaching and learning.

We cannot discuss the mark scheme with schools, and we recommend that schools read the mark scheme together with the assessment material and the Principal Examiner Report for Teachers.

This document consists of **25** printed pages.

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**[Turn over**

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**General marking principles**

All examiners must apply these marking principles when marking candidate responses.

| | |
|---|---|
| 1 | Examiners must award marks for each response in line with:<br><br>• the specific **content** defined in the mark scheme<br>• the specific **skills** defined in the mark scheme or in the level descriptions<br>• the **standard of response** required as exemplified by the standardisation scripts. |
| 2 | Examiners must award **whole marks** (not half marks, or other fractions). |
| 3 | Examiners must award marks **positively**. This means that:<br><br>• marks are not deducted for errors or omissions<br>• marks are awarded for correct / valid answers as defined in the mark scheme and also for **other valid answers** which go beyond the scope of the syllabus and mark scheme referring to your team leader as appropriate<br>• the quality of spelling, punctuation and grammar are judged **only** when the mark scheme indicates that these features are **specifically assessed** in the question. However, the meaning of all responses must be unambiguous. |
| 4 | Examiners must **consistently** apply the requirements of the mark scheme and any rules for what to do when candidates have not followed instructions correctly. |
| 5 | Examiners must use the **full range of marks** defined in the mark scheme, unless limited by the quality of the candidate responses seen. |
| 6 | Examiners must award marks according to the mark scheme and **must not** award marks with grade thresholds or grade descriptions in mind. |

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**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 | <u>'List rule' guidance</u><br><br>For questions that require ***n*** responses (e.g. State **two** reasons …):<br><br>• The response should be read as continuous prose, even when numbered answer spaces are provided.<br>• Any response marked *ignore* in the mark scheme should not count towards ***n***.<br>• Incorrect responses should not be awarded credit but will still count towards ***n***.<br>• 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.<br>• Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science. |

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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.

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## Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

## Annotations

| Annotation | Meaning |
|---|---|
|  | Correct point or mark awarded |
|  | Incorrect point or mark not awarded |
|  | Unclear |
|  | Information missing or insufficient for credit |
| BOD | Benefit of the doubt given |
| CON | Contradiction in response otherwise markworthy, mark not given |
|  | Part of the correct answer has been seen. Full credit has not been awarded. |
| ECF | Error carried forward applied |
| I | Incorrect or insufficient point ignored while marking the rest of the response |
| RE | Rounding error |

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| Annotation | Meaning |
|---|---|
| REP | Repetition |
| SEEN | Blank page or part of script seen |
| SF | Error in number of significant figures |
| TE | Transcription error |

| | |
|---|---|
| / | alternative responses for the same marking point |
| **R** | reject the response |
| **A** | accept the response |
| **I** | ignore the response |
| ecf | error carried forward |
| AVP | any valid point |
| ora | or reverse argument |
| AW | alternative wording |
| underline | actual word given must be used by candidate (grammatical variants excepted) |
| ( ) | the word / phrase in brackets is not required but sets the context |
| max | indicates the maximum number of marks that can be given |
| M | marking point |
| DEP | Marking point is dependent on a linked marking point being scored |
| u / c | Unconditional mark – if seen award the mark |

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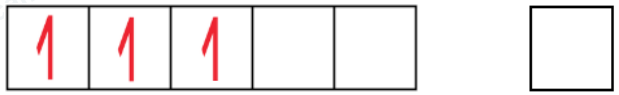
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 1(a)(i) | • they behave as **catalysts**<br>• (they form) **coloured** compounds / complexes / ions<br>**BOTH** [1] | **1** | **I** high melting point / high densities.<br>**I** form complex ions.<br>**I** variable / multiple oxidation states. |
| 1(a)(ii) | the **d** and **s** sub-shells / orbitals are close / similar in **energy**<br>**A** electrons in d and s sub-shells / orbitals available for bonding | **1** | **I** use of 'shells' for orbitals.<br>**A** (*n-1*)d **and** *n*s if any numbers see.n |
| 1(b)(i) |  | **1** | **A** use of ↑. |
| 1(b)(ii) | dative (covalent) / coordinate | **1** | |
| 1(c) | **vacant** (d) **orbital(s)** are energetically accessible<br>**or vacant** (d) **orbital(s)** can form dative bonds with ligands<br>**or vacant** (d) **orbital(s)** can accept a (lone) pair of electrons to form a dative bond | **1** | **I** subshells / shells / energy levels.<br>**I** partially filled d-orbital(s) are energy accessible.<br>**A** 'empty' / 'unoccupied' for **vacant.** |
| 1(d)(i) | NaOH / $OH^-$<br>**and** precipitation / **ligand** exchange / / neutralisation / deprotonation / acid-base **BOTH** | **1** | **A** $NH_3$ for NaOH.<br>**A ligand** substitution / **ligand.** replacement / **ligand** displacement.<br>**I** precipitate. |
| 1(d)(ii) | **M1** $[Cr(H_2O)_3(OH)_3] + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3H_2O + 3OH^-$<br>**M2 ligand** exchange / replacement / substitution / displacement | **2** | **A** use $[Cr(NH_3)_6](OH)_3$ as a product. |

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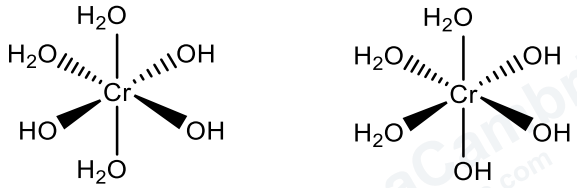
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 1(e) | **M1** one correct 3D structure of $[Cr(H_2O)_3(OH)_3]$<br><br>**M2** correct 3D structure of the **other** isomer<br><br> | **2** | **CON** use of $O_2H$ once only then apply ecf.<br><br>One isomer - two water & two OH ligands at 180°.<br><br>One isomer – all water & all OH ligands at 90°. |
| 1(f)(i) | **M1** $[Fe(H_2O)_6]^{3+}$ / $Fe^{3+}$ weakens O–H bonds / polarises O–H bonds<br><br>**M2** $[Fe(H_2O)_6]^{3+} \rightarrow [Fe(H_2O)_5OH]^{2+} + H^+$ | **2** | **A M1** $[Fe(H_2O)_6]^{3+}$ undergoes hydrolysis / deprotonation.<br>**A M1** one of the $H_2O$ **ligands** loses a $H^+$.<br>**A M1** $H_2O$ in the **complex** can donate a $H^+$.<br><br>**A other alternatives for M2 for example** $[Fe(H_2O)_6]^{3+} + H_2O \rightarrow [Fe(H_2O)_5OH]^{2+} + H_3O^+$. |
| 1(f)(ii) | **$Fe^{3+}$** has **lower** pH / **$Fe^{2+}$** has a **higher** pH<br>**and**<br>$Fe^{3+}$ has a higher charge / smaller radii / higher charge density (so easier to hydrolyse)<br>**BOTH ora** | **1** | **A** $Fe^{3+}$ is *more acidic* / $Fe^{2+}$ is *less acidic* for 'lower pH / higher pH". |
| 1(g) | **M1** ($Ag^+$) d-subshell is full / complete **or** $d^{10}$ **or** d-orbital**s** are full<br><br>**M2** no **d-d**$^{(*)}$ transition **or** no **d** electrons promoted / excited [1]<br>**or** cannot absorb light in the **visible** spectrum<br><br>(must imply promotion) '**d**' can be qualified from M1 for M2 | **2** | **A** use of 3d instead of 4d.<br><br>**I** d orbital is full for M1.<br>**I M1** no empty d subshells.<br><br>**CON M2** no d-d splitting / no $\Delta E$ gap**.**<br>**A M2** cannot absorb energy in the **visible** spectrum. |



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| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 1(h) | **M1 M2**<br>• moles $MnO_4^-$ = 0.025 × 0.02180 = $5.45 \times 10^{-4}$<br>• moles $C_2O_4^{2-}$ = 2.5 × $5.45 \times 10^{-4}$ = $1.3625 \times 10^{-3}$<br>ecf (moles $MnO_4^-$ × 2.5)<br>• moles $OH^-$ = 0.150 × 0.0136 = $2.04 \times 10^{-3}$<br>• moles $H_2C_2O_4$ = ½ × $2.04 \times 10^{-3}$ = $1.02 \times 10^{-3}$<br>ecf (moles $OH^-$ x ½)<br>any two [1] all four [2]<br><br>**M3** moles $Na_2C_2O_4$ = $1.3625 \times 10^{-3} - 1.02 \times 10^{-3} = 3.425 \times 10^{-4}$ ecf (in 25 $cm^3$ **A**) [1]<br><br>**M4** moles $Na_2C_2O_4$ = $3.425 \times 10^{-4} \times 20 = 6.85 \times 10^{-3}$ ecf (in 500 $cm^3$ **A**)<br>mass $Na_2C_2O_4$ = $6.85 \times 10^{-3} \times 134$ = 0.9179 g [1]<br><br>**M5** % = 0.9179 / 5.00 × 100 = **18.4 / 18.358** [1] min 2sf ecf<br>correct answer scores [5]<br><br>**A** 18.2(24) (from use of 3sf $1.36 \times 10^{-3}$) for correct answer | **5** | **A route 1 via 500 $cm^3$ in M3 & M4**<br>moles $C_2O_4^{2-}$ = $1.3625 \times 10^{-3} \times 20$ = 0.02725<br>moles $H_2C_2O_4$ = $1.02 \times 10^{-3} \times 20$ = 0.0204<br>moles $Na_2C_2O_4$ = 0.02725 – 0.0204 = 0.00685.<br><br>mass $Na_2C_2O_4$ = 0.00685 × 134 = 0.9179 g<br><br>**A route 2 in M4 & M3**<br>moles $C_2O_4^{2-}$ = $1.3625 \times 10^{-3} \times 20$ = 0.02725<br>moles $H_2C_2O_4$ = $1.02 \times 10^{-3} \times 20$ = 0.0204<br>mass $C_2O_4^{2-}$ = 0.02725 × 134 = 3.6515 g<br>moles $H_2C_2O_4$ = 0.0204 × 134 = 2.7336 g.<br><br>(M3) mass $Na_2C_2O_4$ = 3.6515 – 2.7336 = 0.9179 g.<br><br>**A ecf M4 answer to calculated value × 20 × 134.**<br><br>**A ecf M5** for (a calculated mass ÷ 5.0) × 100. |

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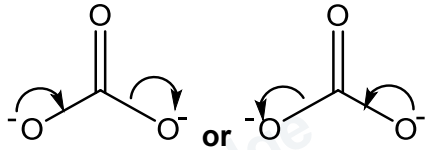
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 2(a) |  **or**  **BOTH** arrows [1] | 1 | **I** LP drawn / any charges on diagram.<br>**ARROW 1** from $O^-$ to C–O bond (arrow can start anywhere on O).<br><br>**ARROW 2** from C–O bond to the other $O^-$ . |
| 2(b) | • $PbCO_3$(most) $CaCO_3$ $CuCO_3$ (least)<br><br>• (stability increases) as (ionic) radii increases / size of $M^{2+}$ increases / **or** $Pb^{2+}$ largest radii **ora**<br><br>• less polarisation / distortion of carbonate **ion / anion /** $CO_3^{(2)-}$ **or** less weakening of CO bond / C-O / C=O • ✓ ✓ | 2 | **A** $Pb^{(2+)}$(most) $Ca^{(2+)}$ $Cu^{(2+)}$ (least).<br><br>**NO ecf.**<br>Bullets are all u / c.<br>**A bullet 2** charge density of $M^{2+}$ decreases.<br><br>**CON bullet 3** stronger **ionic bond** linked to larger ionic radii.<br>**I** C=O is less polarised.<br>**I** weaker ionic bond. |
| 2(c) | **M1** $\Delta H_{latt}$ and $\Delta H_{hyd}$ (both) become less exothermic / less negative [1]<br><br>**M2** $\Delta H_{hyd}$ changes **more /** changes faster / dominant factor / becomes less exothermic by a larger extent [1] **ora**<br><br>**M3** $\Delta H_{sol}$ becomes less exothermic / less negative **or** $\Delta H_{sol}$ becomes more endothermic / more positive | 3 | **A M1** $\Delta H_{latt}$ and $\Delta H_{hyd}$ decrease.<br>**A M1** $\Delta H_{latt}$ and $\Delta H_{hyd}$ become more endothermic / positive.<br><br>**CON** missing Δ or *H* <u>once</u> only then **ecf**.<br><br>**I M3** $\Delta H_{sol}$ decreases.<br>**I M3** $\Delta H_{solubility}$ becomes less exothermic. |
| 2(d)(i) | **M1** ($K_{sp}$ for $Mg(OH)_2$) = $[Mg^{2+}][OH^-]^2$ [1]<br>**M2** units $mol^3\ dm^{-9}$ [1] **ecf from M1** | 2 | **I** state symbols. |
| 2(d)(ii) | $[H^+] = 10^{-10.35} = 4.47 \times 10^{-11}$<br><br>$[OH^-] = 1 \times 10^{-14} \div 4.47 \times 10^{-11}$ = **$2.24 \times 10^{-4}$** min 2sf | 1 | |

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| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 2(d)(iii) | $K_{sp} = (0.5 \times 2.24 \times 10^{-4}) \times (2.24 \times 10^{-4})^2$<br>$K_{sp}$ = **5.61(2) / 5.62 × 10$^{-12}$** u / c min 2sf **ecf** for **2(d)(i)** and **2(d)(ii)** | **1** | **A ecf**<br>correct calculated answer of<br>$K_{sp} = (0.5 \times$ **2(d)(ii)**$) \times ($**2(d)(ii)**$)^2$.<br><br>**I** units even if incorrect<br>**NO ecf from** $K_{sp} = [Mg^{2+}][OH^-]$. |

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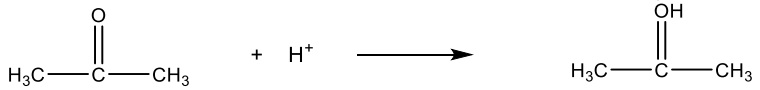
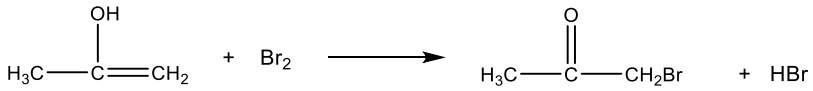
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 3(a)(i) | **M1 Exp 1 & 2** $[CH_3OH] \times 1.5$ rate $\times 1.5$ **or** $[CH_3OH] \times 2/3$ rate $\times 2/3$<br>**and** so first order to $[CH_3OH]$ [1] u / c<br><br>**M2 Exp 3 & 4** $[H^+] \times 1.33$ rate $\times 1.33$ **or** $[H^+] \times 3/4$ rate $\times 3/4$<br>**and** so first order to $[H^+]$ [1] u / c<br><br>**M3 Exp 2 & 3** $[CH_3CHO] \times 0.5$, $[CH_3OH] \times 2$ and $[H^+] \times 3$ rate $\times 3$<br>**and** so first order to $[CH_3CHO]$ [1] ecf<br><br>**A** second part of **M1 M2 M3**<br>'**and** first order' can be read in from their rate equation<br><br>**M4 Rate = k**$[CH_3OH][H^+][CH_3CHO]$ [1] u / c ecf<br>**or** rate = *1.25* $[CH_3OH][H^+][CH_3CHO]$<br><br>**I** any annotations on the table unless directed by the candidates | **4** | Reasoning must be linked to correct expts – **CON** once only for **M1-M3**.<br><br>**A** any viable mathematical approach.<br><br>**A** any correct alternates to **M3**.<br>–all conditional of orders in M1M2 e.g.<br>**Exp 2 & 4 M3** $[CH_3CHO] \times 2$, $[CH_3OH] \times 0.5$ and $[H^+] \times 1/4$ rate $\times 1/4$<br>**and** so first order to $[CH_3CHO]$.<br><br>**Exp 1 & 3 M3** $[CH_3CHO] \times 0.5$, $[CH_3OH] \times 3$ and $[H^+] \times 3$ rate $\times 9/2$<br>**and** so first order to $[CH_3CHO]$.<br><br>**Exp 1 & 4 M3** $[CH_3CHO] \times 0.5$, $[CH_3OH] \times 3$ and $[H^+] \times 4$ rate $\times 6$<br>**and** so first order to $[CH_3CHO]$. |
| 3(a)(ii) | $mol^{-2}dm^6s^{-1}$ u / c **ecf** from **3(a)(i)** | **1** | |
| 3(a)(iii) | initial rate = 0.0195 u / c ecf from **3(a)(i)** min 2sf | **1** | **A** methods with calculations of k first then rate. |
| 3(b) | step 1 <br>step 3 <br>each step 2 x [1] | **2** | **I** any curly arrows even if incorrect.<br><br>**A** $H^+ + Br^-$ for HBr. |

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| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 3(c) | • (reactants) **adsorb** (to surface of catalyst)<br>• bonds (in reactant) weaken<br>• (reaction occurs and the) **product(s)** are desorbed **or** reaction occurs and substances are desorbed **A product(s)** deadsorbed<br>● ✓ ✓ | **2** | **I** absorbed.<br>**A** bullet 1 'binds to the surface of the catalyst' for 'adsorbed'.<br>**I** lowers $E_a$.<br>**I** bonds between reactants.<br>**I** 'bonds are broken' (happens in all reactions). |

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| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 4(a) | (the) **ratio** of the **concentrations** of a **solute / substance / compound** between<br>**two** (immiscible) **solvents** / **two liquids**<br>(at) **equilibrium** | **1** | **CON** if in terms of concentration of '**solutes**'. |
| 4(b) | **EITHER**<br>Solution 1<br>**M1M2**<br>• Initial moles of $(COOH)_2$ = 2.7 / 90 **or** 0.03<br>• moles of NaOH = 0.0165 × 0.200 **or** 0.0033<br>• moles of $(COOH)_2$ in ether = 0.0033 / 2 **or** 0.00165<br>• moles of $(COOH)_2$ in water = 0.0300 – 0.00165 **or** 0.02835 ecf<br>● ✓● ✓<br>**M3** $K_{pc}$ = 0.00165 / 0.02835 = **0.058(2)** min 2sf ecf from bullets 3 & 4 only | **(3** | Bullet 3 subsumes bullet 2 → [1].<br>Bullet 4 subsumes bullets 1,2,3 → [2].<br><br>**A ecf for bullet 4** from calculated values of bullets 1 and 3, for example using the incorrect $M_r$ / the wrong ratio.<br><br>**NO ecf for M3** from bullets 1 and 2 for $K_{pc}$ = [0.033 / 0.03]. |
| | **or**<br>Solution 2<br>**M1M2**<br>• moles of NaOH = 0.0165 × 0.200 **or** 0.0033<br>• moles of $(COOH)_2$ in ether = 0.0033 / 2 **or** 0.00165<br>• mass of $(COOH)_2$ in ether = 0.00165 × 90 **or** 0.1485 g<br>• mass of $(COOH)_2$ in water = 2.70 – 0.1485 **or** 2.5515 g ecf<br>● ✓● ✓<br>**M3** $K_{pc}$ = (0.1485 ÷ 100) ÷ (2.5515 ÷ 100) = **0.058(2)** min 2sf ecf from bullets 3 & 4 only | **3)** | **A** reverse ratio = 17(.2) [3]. |

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| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 4(c) | • $K_{pc}$ would be higher / larger (if $K_{pc}$ < 1 in **4(b)**) (for butanedioic acid) (ecf from **4(b)**) **ora**<br>• butanedioic acid is less polar / more non-polar **ora**<br>• so less soluble in water / more soluble in ethoxyethane **ora** **or** dissolves less in water / dissolves more in ethoxyethane<br>● ✓✓ | **2** | **I** in terms of hydrophilic / phobic.<br>**A bullet 1** $K_{pc}$ would be lower (if $K_{pc}$ > 1 in **4(b)**).<br>**A** 'organic solvent' / 'ether' for ethoxyethane.<br>**I bullet 2** 'butanedioic acid is non-polar' alone.<br>**I bullet 3** concentration of butanedioic acid is lower in water.<br>**Bullet 2 / 3** – comparison needed. |

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| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 5(a) | **M1** emf / potential difference / voltage<br>**and** between / compared to<br>**and** a standard hydrogen electrode and another electrode<br><br>**M2** under standard conditions of<br>• 1 atm / 101 kPa / 100 kPa<br>• 298 K / 25 °C,<br>• (all solutions being) 1M / 1 mol $dm^{-3}$ u / c | **2** | **A** half-cell for electrode.<br><br>**CON** hydrogen cell. |
| 5(b)(i) | **M1M2**<br>• $Zn + 2Fe^{3+} \rightarrow Zn^{2+} + 2Fe^{2+}$<br>• $NO_3^- + 10H^+ + 8Fe^{2+} \rightarrow NH_4^+ + 3H_2O + 8Fe^{3+}$<br>• $NO_3^- + 10H^+ + 4Zn \rightarrow NH_4^+ + 3H_2O + 4Zn^{2+}$<br>● ✓✓<br><br>**M3** $E_{cell}$ is positive (to be feasible)<br>**or** $E^{\ominus}$ of $Fe^{3+}$ / $Fe^{2+}$ and $NO_3^-$ / $NH_4^+$ is **more** positive<br>**or** $E^{\ominus}$ of redox system 1 and 2 are **more** positive **ora** u / c | **3** | **A M3** two calculated $E_{cell}$<br>• bullet 1 $E_{cell}$ = 1.53 (V)<br>• bullet 2 $E_{cell}$ = +0.10 (V)<br>• bullet 3 $E_{cell}$ = +1.63 (V).<br><br>**I M3** use of 'greater' for more positive. |
| 5(b)(ii) | high $E_a$ for the reaction **OWTTE** | **1** | **I** rate is too slow.<br>**I** non-standard conditions are used. |

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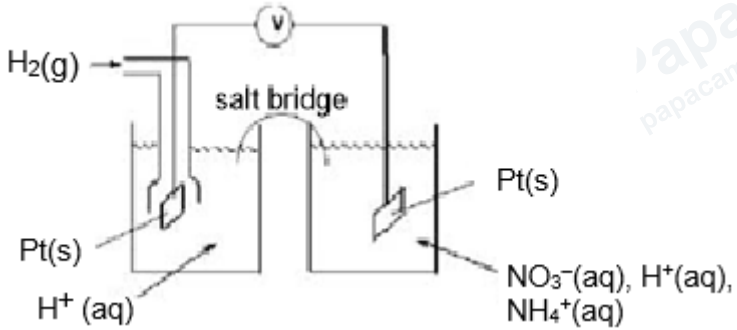
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 5(b)(iii) | <br>• labelled salt bridge<br>• voltmeter / V / potentiometer<br>• $H_2$<br>• good delivery system (of $H_2$)<br>• $H^+$(aq) / HC*l*(aq) solution labelled [state symbol not required]<br>• Pt electrode<br>• Pt electrode<br>• $NO_3$ **and** $NH_4^+$ **and** $H^+$ solution labelled **or** $HNO_3$ and $NH_4NO_3$<br>• complete circuit (salt bridge touches the solution & wires from V go to the electrodes)<br>● ● ✓ ● ● ✓ ● ● ✓ | **3** | **I** inclusion negative ion with SHE like $Cl^-$, $NO_3^-$, $SO_4^{2-}$.<br><br>**CON** bullet 2 & 9 battery in the circuit.<br><br>**A bullet 6 / 7** graphite / C for Pt.<br><br>State symbols not required. |
| 5(c) | **M1** $\Delta G^\ominus = -nE_{cell}F$<br>$-645.6 \times 1000 = -3 \times E \times 96\,500$<br>**M2** $E_{cell}$ = (+)**2.23** (V) min 2sf | **2** | **A M1** use of $G^\ominus = -nEF$ **and** use of –645.6.<br><br>**A ecf [1]** from<br>$\Delta G^\ominus = nE_{cell}F \rightarrow E_{cell} = -2.23$. |

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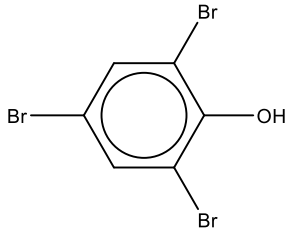
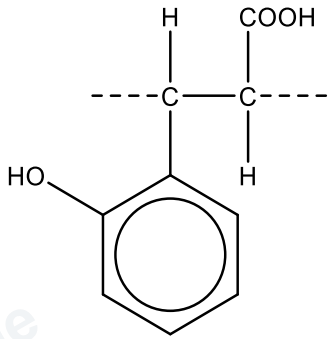
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 6(a)(i) | Observations:<br>white ppt.<br>**and** (solution) decolourises / turns colourless / orange colour disappears | **1** | **A** initial colour brown / yellow for 'orange' and variants of these.<br>**CON** fizzing.<br>**I** steamy fumes.<br>**I** discolouration / colour discharged.<br>**I** 'colour disappears'. |
| 6(a)(ii) | <br>structure | **1** | |
| 6(b) | **M1** lone pair on **oxygen / O** delocalised / overlaps<br>**and** into the ring / π system / delocalised system<br>**or** p-orbital on **oxygen / O** delocalised / overlaps<br>**and** with ring / π system / delocalised system [1]<br><br>**M2 weakens** O—H **and** phenol is more acidic<br>**or** (phenol forms) anion / conjugate base / phenoxide ion is **more stable**<br>**and** phenol is more acidic [1] | **2** | **I** donated / incorporated in reference to 'delocalised / overlaps'.<br><br>**I** '$H^+$ more easily lost' for more acidic.<br><br>**I** O–H is weak alone – comparison needed.<br><br>**A** phenol is a stronger (acid) for 'more acidic'. |
| 6(c)(i) |  | **1** | **I** connectivity errors to COOH.<br><br>Phenol must be 1,2-substituted **and** drawn.<br><br>Fully skeletal structures must have brackets if solid line continuation bonds . |

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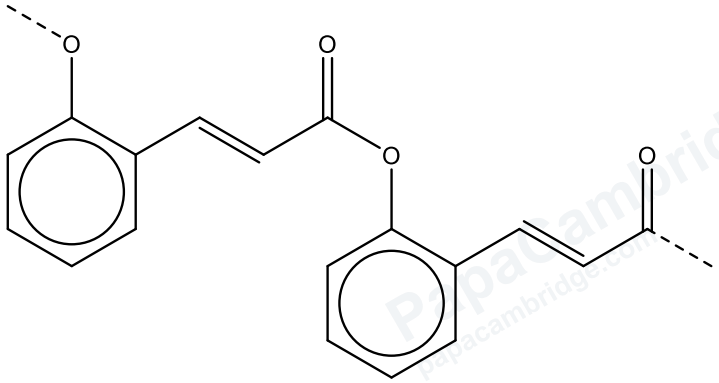
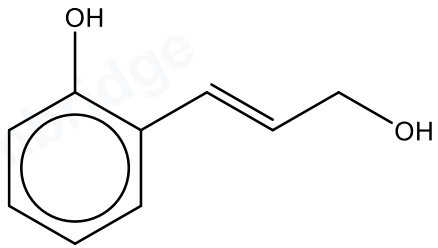
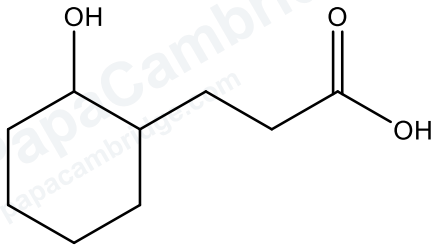
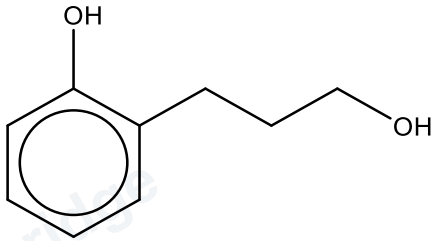
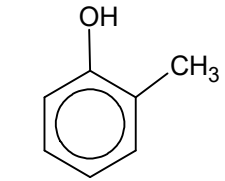
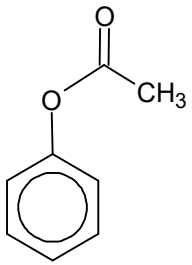
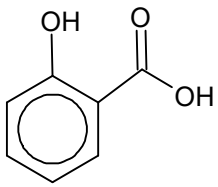
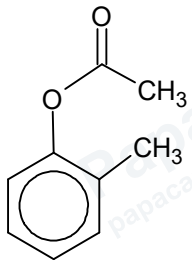
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 6(c)(ii) | <br>**M1** ester linkage shown between phenol & COOH [1]<br><br>**M2** rest of the structure correct [1] **DEP on M1** | **2** | **A M2** if structure (partly / fully) displayed / all the carbons shown with '–' continuation bond.<br><br>If structure fully skeletal: continuation bonds – must be dashed / wavy / different or have through brackets.<br><br>Phenol must be 1,2-substituted **and** drawn. |
| 6(d) | <br><br>**M1M2** | **2** | **A M1** for $LiAlH_4$ reduction [conjugated unsaturated carboxylic acid].<br> |

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 6(e)(i) | **D**  **OR**  **E**   **M1M2** | **2** | **D and E** are unconditional. |
| 6(e)(ii) | Mark based on **6(e)(i)**<br><br>step 1 $CH_3Cl$ (**and** $AlCl_3$) [1] **CON** (aq),<br>**CON** other reagents<br><br>step 2 **hot / reflux / heat / boil / T ⩾ 60 °C**<br>**and** (alkaline / acidified / neutral) **$MnO_4^-$ / $KMnO_4$** [1]<br><br>step 3 $CH_3COCl$ [1] **CON** (aq)<br>**CON** any other reagent e.g. $cH_2SO_4$ | **3** | **A** $CH_3Br$ / $CH_3I$ for alkylation.<br>**I** any halogen carrier for alkylation.<br><br>**I** heat / any temp for alkylation & acylation.<br><br>**CON** use of $KMNO_4$ for oxidation.<br>**CON** (aq) once only then apply ecf.<br>**CON** UV for acylation. |

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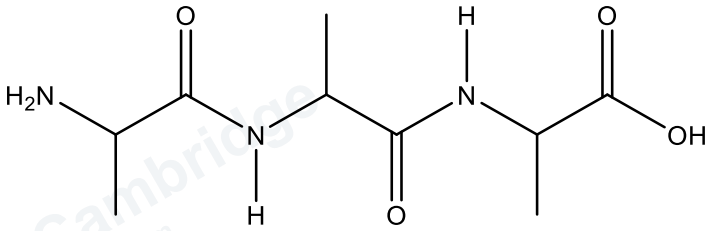
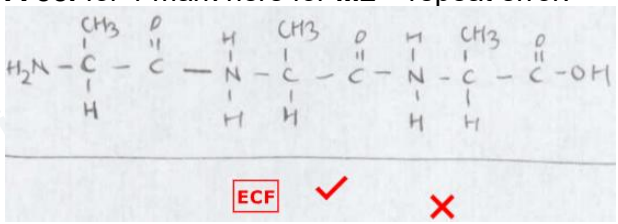
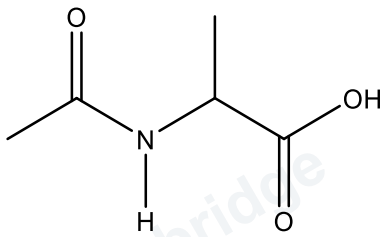
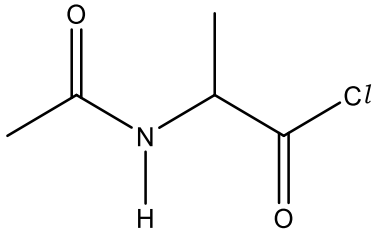
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 7(a)(i) | (a substance able to) **rotate plane polarised light** | **1** | **A** (a substance able to) **rotate plane** of (plane) **polarised light**.<br>**I** rotating an amino acid instead of plane of polarised light. |
| 7(a)(ii) | (a mixture containing) **equal** amounts / proportions / concentrations<br>**and**<br>of **optical** isomers / enantiomers / **stereo**isomers | **1** | |
| 7(b)(i) | **pH** at (which a molecule / amino acid) has<br>**and**<br>no **overall** charge / is neutral / is a zwitterion [1] | **1** | **I** 'pH when the molecule has no charge' alone. |
| 7(b)(ii) | $CH_3CH(NH_2)COO^-$ | **1** | |
| 7(c) | <br>**M1** two peptide linkage shown<br>(C=O needs to be displayed but allow NH not displayed)<br><br>**M2** rest of the structure correct<br>**DEP on M1** (except for specific ecfs in guidance)<br>**A** carboxylate ion / zwitterion / $NH_3^+$ ion | **2** | **A ecf** for 1 mark here for **M2** – repeat error.<br><br>**Also ecf M2** if **H** omitted on both **N** – repeat error.<br><br>**CON M1** -CO-HN -.<br><br>**A M1** if more than 2 amide links <u>but</u> M2 not available. |

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 7(d)(i) | **G**  **H**  **M1M2** | **2** | |
| 7(d)(ii) | **M1** step 1 $CH_3COCl$ **CON** (aq)<br>**CON** additional reagent e.g. $AlCl_3$, $cH_2SO_4$<br>**M2** step 2 $PCl_3$ + heat **or** $SOCl_2$ **or** $PCl_5$ **CON** (aq)<br>**M3** step 3 $C_6H_6$ **and** $AlCl_3$ **CON** (aq) | **3** | **ecf** penalise (aq) once only in step 1,2 and 3.<br>**A M1** $CH_3COOCOCH_3$ for '$CH_3COCl$'.<br>All u / c marking points.<br>**A** any viable halogen carrier for acylation (e.g. $FeBr_3$). |

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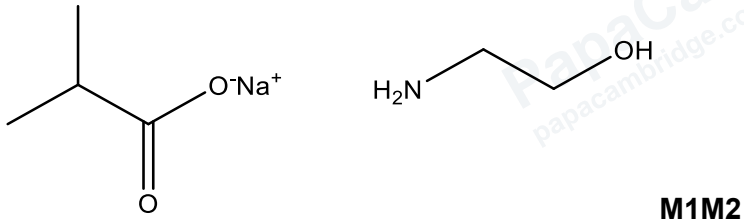
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>8(a)</td><td>tetramethylsilane</td><td>1</td><td>Only answer – correct spelling required.<br>I TMS, $(CH_3)_4Si$ .</td></tr>
<tr><td>8(b)(i)</td><td>5 / five</td><td>1</td><td></td></tr>
<tr><td>8(b)(ii)</td><td><table><tr><th>proton environment</th><th>name of splitting pattern</th></tr><tr><td>w</td><td>doublet</td></tr><tr><td>x</td><td>multiplet</td></tr><tr><td>y</td><td>triplet</td></tr><tr><td>z</td><td>triplet</td></tr></table>● ✓ ● ✓</td><td>2</td><td>A douplet.<br><br>I duplet, double, multiple, triple.<br><br>A heptet / septet for multiplet.</td></tr>
<tr><td>8(b)(iii)</td><td>M1 δ 5 –12 [1]<br><br>M2 (N-H peak appears and)<br>no proton / hydrogen exchanges / replaces / substitutes<br>with deuterium / D / D⁺ ora</td><td>2</td><td>M1 requires this range instead a single value.<br><br>A M2 (N-H) proton / hydrogen exchanges with deuterium / D / D⁺ <u>in $D_2O$</u>.<br>I proton / hydrogen is taken away / removed by the deuterium.</td></tr>
<tr><td>8(c)</td><td><br><br>M1M2</td><td>2</td><td>I carboxylic acid (products isolated at pH 10).<br><br>A carboxylate ion.<br>A -ONa.<br>CON –O–Na (covalent bond).</td></tr>
</table>

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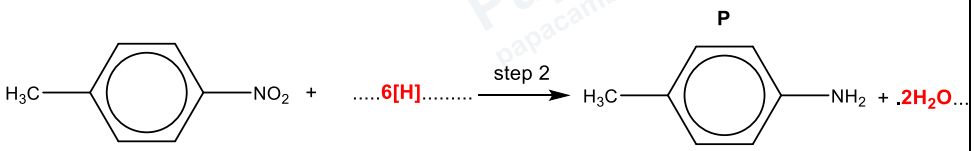
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 9(a) | **M1** **Q** ammonia **P**<br>*most basic* *least basic*<br><br>explanation<br>**M2** (basicity linked to) **ability** of **lone pair / p-orbital** to **accept / donate to / coordinate** **with** a **proton / $H^+$**<br><br>**Explanation M3 M4**<br>• lone pair / p-orbital from **N** (in **P**) **and** delocalised / overlaps with (π-)ring / benzene<br>• electron donating / +I **and** R / alkyl / $CH_2$ grp (in **Q**)<br>• increases electron density on **N or N** is more electron rich **or N** LP is more available (in **Q**) **ora** • ✓✓ | **4** | **I** 'attract' for accept.<br><br>**A** explanations in terms of hyperconjugation of alkyl group.<br>"alkyl group can donate electron density into empty (p) orbital on positively-charged carbon".<br><br>**I** incorporated / donated.<br><br>LP with N can be qualified anywhere in their answer.<br><br>**I** 'charge density' for electron density. |
| 9(b)(i) | **M1** step 1 $HNO_3$ **and** $H_2SO_4$ **and** conc. / concentrated<br><br>**M2** step 2 Sn **and** conc. HC*l* | **2** | **CON** omission of conc. once.<br><br>**I** temp.<br>but **CON** 10 °C or lower –**CON** once.<br><br>**CON** (aq) in step 1 only.<br><br>**CON** Sn catalyst in step 2.<br><br>**I** NaOH with step 2. |
| 9(b)(ii) |  | **1** | **CON** 6 [$H^+$] |



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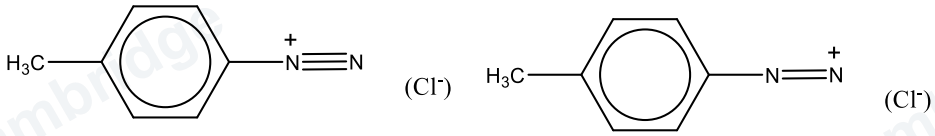
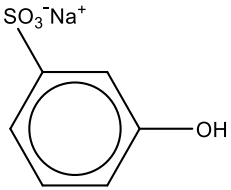
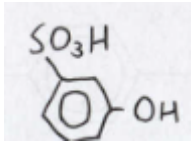
| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 9(c)(i) |  **or**  | 1 | **A** $-N_2Cl$ **or** $-N_2^+$ form.<br>**A** $-N{\equiv}NCl$ **or** $-N^+{\equiv}N$ form.<br>**A** $-N{=}NCl$ **or** $-N{=}N^+$ form.<br><br>if a Cl present - must be **electrically neutral.**<br><br>Position of + charge must be correct if seen.<br>**CON** covalent N–Cl bond seen. |
| 9(c)(ii) | **M1** step 1 $NaNO_2$ with HCl **or** $HNO_2$ **and** $\leqslant$10 °C [1]<br>**A** '$HNO_3$ / $H_2SO_4$' for HC*l*<br><br>**M2** step 2 alkaline / NaOH **and**<br> | 2 | **CON** heat at 10 ºC.<br>**I** $NaNO_3$.<br><br>**A M2** respective **phenoxide ion** for both reagents in step 2.<br><br>**I** 'base' alone.<br><br>**A** sulfonic acid phenol as an alternative with NaOH.<br><br>**A** structures with $SO_3^-$ (no $Na^+$).<br>**I** temp for **M2**. |

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