Cambridge Assessment International Education

# Cambridge International AS & A Level

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

Paper 4 A Level Structured Questions **May/June 2022**

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.

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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.

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|---|
| GENERIC MARKING PRINCIPLE 5:<br><br>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:<br><br>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<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. |

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.

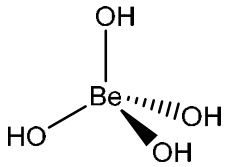
For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient ($a$) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

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.

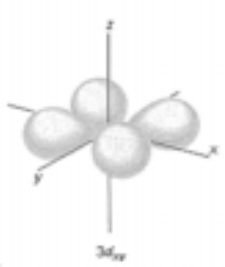
7 Guidance for chemical equations

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** $\Delta H_{latt}$ and $\Delta H_{hyd}$ both become less exothermic / less negative<br><br>**M2** $\Delta H_{hyd}$ changes less / becomes less exothermic by a smaller extent<br>**OR** $\Delta H_{latt}$ changes more / dominant factor / changes faster<br><br>**M3** $\Delta H_{sol}$ becomes more exothermic / more negative<br>**OR** $\Delta H_{sol}$ becomes less endothermic / less positive | **3** |
| 1(b)(i) | **M1** $K_{sp} = [Be^{2+}][OH^-]^2$<br>**M2** $mol^3\ dm^{-9}$ ecf | **2** |
| 1(b)(ii) | **M1** solubility of $Be(OH)_2 = 2.40 \times 10^{-6} / 43 = 5.58 \times 10^{-8}$ ($mol\ dm^{-3}$) ecf (b)(i)<br>**M2** $K_{sp} = 4 \times (5.58 \times 10^{-8})^3 = 6.95 \times 10^{-22}$ ecf min 2sf | **2** |
| 1(c)(i) | as a molecule or ion formed by a central metal atom / metal ion dative bonded to / surrounded by one or more ligands | **1** |
| 1(c)(ii) |  <br>tetrahedral and correct 3D structure | **1** |
| 1(d)(i) | d orbitals that are energetically accessible<br>**OR** empty / vacant d orbitals **AND** form dative bonds / accept a lone pair from a ligand | **1** |

| Question | Answer | Marks |
|---|---|---|
| 1(d)(ii) | <table><tr><th>complex ion</th><th>shape</th><th>coordination number</th><th>polarity</th></tr><tr><td>cis-[Pt(en)C$l_2$]</td><td>square planar</td><td>4</td><td>polar</td></tr><tr><td>$[Ag(NH_3)_2]^+$</td><td>linear</td><td>2</td><td>non-polar</td></tr><tr><td>$[Fe(C_2O_4)_3]^{3-}$</td><td>octahedral</td><td>6</td><td>non-polar</td></tr></table> three for one mark, six for two marks | **2** |
| 1(e)(i) | the equilibrium constant for the formation of the complex ion in a solvent (from its constituent ions or molecules) | **1** |
| 1(e)(ii) | **M1** $K_{stab}$ = $[Ni(en)_3^{2+}] / [Ni(H_2O)_6^{2+}][en]^3$<br>**M1** units = $mol^{-3}\ dm^9$ ecf | **2** |
| 1(e)(iii) | the equilibria lie to the right / product side **OR** equilibrium 1 lies more to the right<br>**AND**<br>*en* complex is more stable / $[Ni(en)_3]^{2+}$ is more stable | **1** |

| Question | Answer | Marks |
|---|---|---|
| 2(a) | the d and s sub-shells / orbitals are close / similar in energy | **1** |
| 2(b) |  | **1** |

| Question | Answer | Marks |
|---|---|---|
| 2(c) | **M1** (in a complex / in the presence of ligands) the d-orbitals are split into two sets of orbitals<br><br>**M2** as an electron is excited / promoted<br><br>**M3** visible light is absorbed **AND** colour seen is complementary | **3** |
| 2(d)(i) | $Cu(OH)_2$: (pale / light) blue<br>$[Cu(H_2O)_2(NH_3)_4]^{2+}$: dark / deep blue | **1** |
| 2(d)(ii) | (addition of $OH^-$) increases $[OH^-]$ **AND** shifts equilibrium to the right | **1** |
| 2(e) |  <br><br>**M1** one correct 3D diagram with the six correct ligands<br>**M2** both 3D diagrams correct | **2** |

| Question | Answer | Marks |
|---|---|---|
| 3(a)(i) | • enthalpy change / energy change<br>• one mole of electrons<br>• (gained by) **one mole** of **gaseous atoms**<br><br>two for one mark, three for two marks | **2** |
| 3(a)(ii) | (energy required to overcome) the repulsion between the electron and anion / negative ion | **1** |

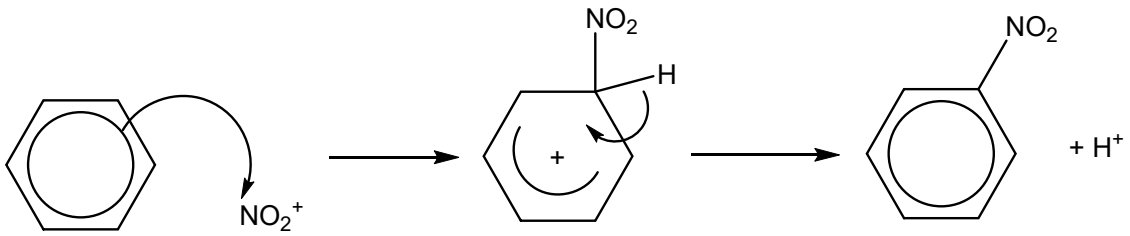
| Question | Answer | Marks |
|---|---|---|
| 3(a)(iii) | • less negative / less exothermic down the group<br>• greater the distance between the nucleus and (the shells of the) electrons<br>**OR** atomic radii increases<br>**OR** more shielding by inner shells<br>• the less **attraction** between nucleus<br>and incoming electron (and the less energy released)<br><br>two for one mark, three for two marks | **2** |
| 3(b) | **M1** use of correct seven numbers only in calculation / energy cycle<br>**M2** only 2 × used correctly<br>**M3** correct signs and evaluation ecf<br><br>–208 = 131 + 906 + 1733 + 62 + 151 + 2x – 2605<br>2x = –586<br>x = –293 kJ $mol^{-1}$ | **3** |
| 3(c) | first box ticked<br>**AND** $Cd^{2+}$ larger / $Cd^{2+}$ lower charge density<br>**AND** less attraction between the ions / weaker ionic bonds | **1** |

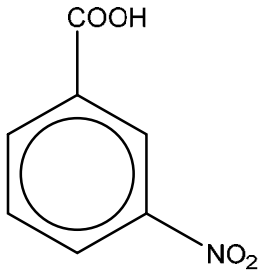
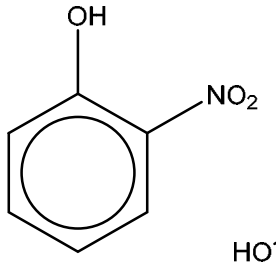
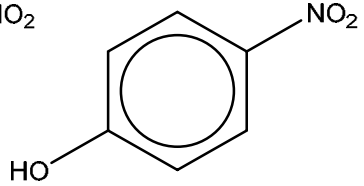
| Question | Answer | Marks |
|---|---|---|
| 4(a)(i) | **M1** all five points plotted correctly<br>**M2** best-fit straight line (ruler) with negative gradient drawn | **2** |
| 4(a)(ii) | **M1** gradient correctly calculated **OR** gradient working seen<br><br>**M2** gradient = $-\Delta S^o$<br>$\Delta S^o$ evaluated correctly ecf $\Delta S^o$ = (+)160 ± 10 (J $K^{-1}$ $mol^{-1}$) | **2** |
| 4(b)(i) | $2HCO_3^- \rightarrow CO_3^{2-} + CO_2 + H_2O$ | **1** |

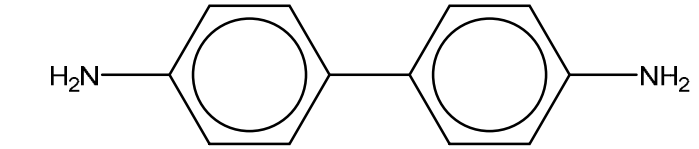
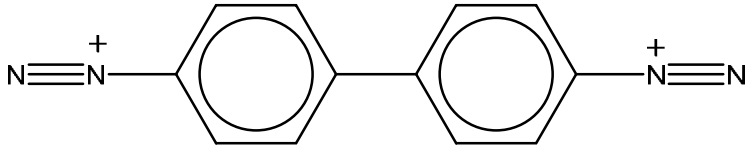
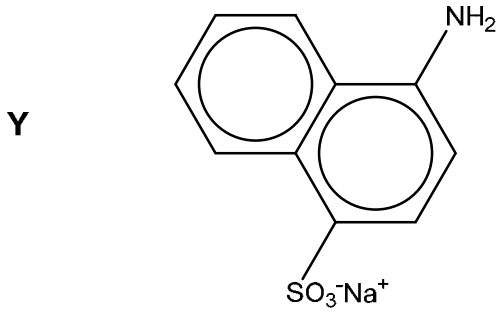
| Question | Answer | Marks |
|---|---|---|
| 4(b)(ii) | **M1** ionic radius of $M^+$ / cationic radius increases<br>**OR** charge density of ion / $M^+$ decreases down Group 1<br><br>**M2** less distortion / polarisation of the anion / $HCO_3^-$<br>**OR** CO bond / C-O / C=O less weakened | **2** |
| 4(c)(i) | **M1** solution which resists changes in pH when<br>opposes / resists change in pH<br><br>**M2** when small amount of acid / $H^+$ or alkali / base / $OH^-$ is added | **2** |
| 4(c)(ii) | **M1** (with acid) $HCO_3^- + H^+ \rightarrow H_2CO_3$ **OR** $HCO_3^- + H_3O^+ \rightarrow H_2CO_3 + H_2O$<br><br>**M2** (with alkali) $H_2CO_3 + OH^- \rightarrow HCO_3^- + H_2O$ | **2** |
| 4(c)(iii) | **M1** $K_a = 10^{-6.35} = 4.47 \times 10^{-7}$<br><br>**M2** $[H^+] = 4.47 \times 10^{-7} / 14.1 = 3.17 \times 10^{-8}$ ecf<br><br>**M3** pH = –log $[H^+]$ = 7.5 ecf from a calculated $[H^+]$ min 2sf | **3** |

| Question | Answer | Marks |
|---|---|---|
| 5(a) | <table><tr><th>electrolyte</th><th>substance liberated at the anode</th><th>substance liberated at the cathode</th></tr><tr><td>$PbBr_2(l)$</td><td>$Br_2$ / bromine</td><td>Pb / lead</td></tr><tr><td>concentrated $NaCl(aq)$</td><td>$Cl_2$ / chlorine</td><td>$H_2$ / hydrogen</td></tr><tr><td>$Cu(NO_3)_2(aq)$</td><td>$O_2$ / oxygen (+ $H_2O$)</td><td>Cu / copper</td></tr></table>two for one mark, four for two marks, six for three marks | **3** |

| Question | Answer | Marks |
|---|---|---|
| 5(b)(i) | $F = Le$ **OR** F is directly proportional to L | **1** |
| 5(b)(ii) | number of $Cu^{2+}$ formed = 0.35 / 63.5 = $5.51 \times 10^{-3}$<br><br>$Q = I \times t = 0.60 \times 30 \times 60 = 1080$ C<br><br>number of electrons = $1080 / 1.6 \times 10^{-19} = 6.75 \times 10^{21}$ ecf<br><br>number of $Cu^{2+}$ ions = $6.75 \times 10^{21} / 2 = 3.375 \times 10^{21}$ ecf<br><br>number of $Cu^{2+}$ ions per mole ($L$) = $3.375 \times 10^{21} / 5.51 \times 10^{-3} = 6.12 \times 10^{23}$ ecf min 2sf<br><br>all five points for four marks<br>**ALLOW** valid alternate calculations of $L$ | **4** |

| Question | Answer | Marks |
|---|---|---|
| 6(a)(i) |  <br>**M1** first curly arrow from within hexagon to N of the $NO_2^+$<br>**M2** correct intermediate<br>**M3** second curly arrow from C-H bond into the ring **AND** $H^+$ formed / lost | **3** |
| 6(a)(ii) | $HSO_4^- + H^+ \rightarrow H_2SO_4$ | **1** |

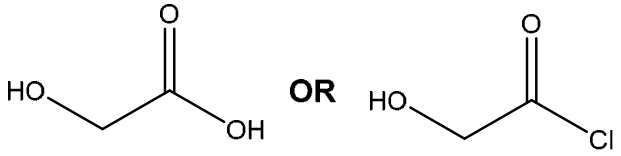
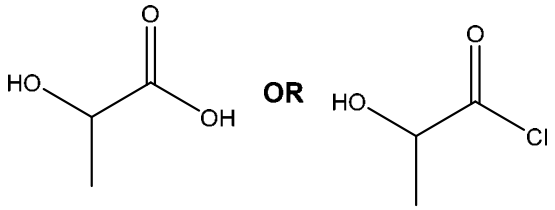
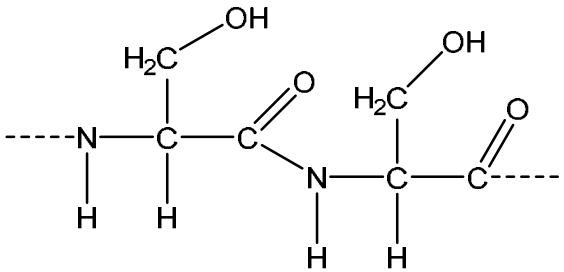
| Question | Answer | Marks |
|---|---|---|
| 6(b) | **M1** *benzoic acid* **M2** *phenol*<br>  <br><br>  <br><br>  <br><br>**OR** | **2** |
| 6(c) | **M1** phenol > benzene > benzoic acid<br><br>**M2** / **M3**<br><u>phenol:</u><br>• lone pair / p-orbital on oxygen<br>delocalises into the ring / overlaps with π-delocalised ring<br>• accepts / attracts / polarises $NO_2^+$ / electrophiles better<br><br><u>benzoic acid:</u><br>• COOH / C=O is an electron-withdrawing / positive inductive effect<br><br>two for one mark, three for two marks<br><br>**M4**<br>(phenol-oxygen) increases electron density in the ring *(as compared to benzene as a result of the OH group)*<br>**OR**<br>(benzoic acid–COOH) decreases electron density in the ring *(as compared to benzene as a result of the COOH group)* | **4** |

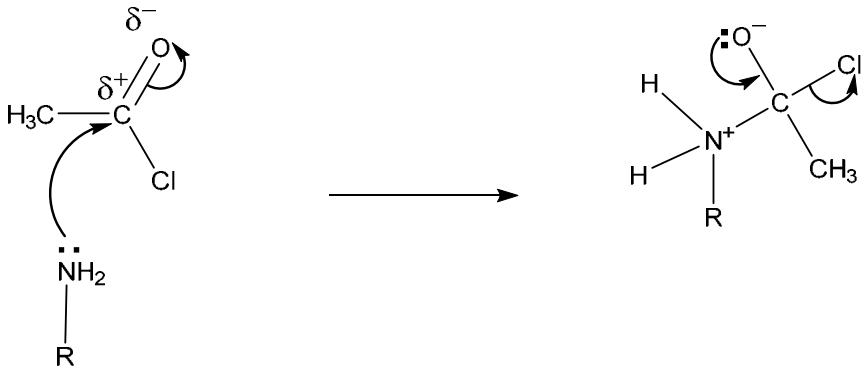
| Question | Answer | Marks |
|---|---|---|
| 6(d)(i) | **X**   **Z**   **Y**   | **3** |
| 6(d)(ii) | step 1 **M1** Sn and hydrochloric acid / HC*l*<br>**M2** concentrated (HC*l*) + heat / reflux (followed by NaOH)<br><br>step 2 **M3** $HNO_2$ and (HC*l*) ⩽10°C<br>**OR** $NaNO_2$, HC*l* and ⩽10°C | **3** |

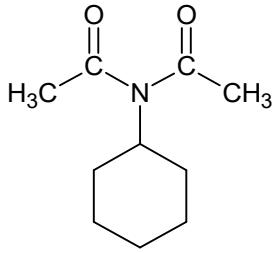
| Question | Answer | Marks |
|---|---|---|
| 7(a) | TMS reference **OR** standard **OR** to define d = 0<br>$D_2O$ solvent **OR** identification of **O-H / N-H** protons / group | **1** |

| Question | Answer | Marks |
|---|---|---|
| 7(b)(i) | <table><tr><th>ketone</th><th>number of peaks observed in proton NMR spectrum</th><th>number of peaks observed in carbon-13 NMR spectrum</th></tr><tr><td>pentan-2-one</td><td>4</td><td>5</td></tr><tr><td>pentan-3-one</td><td>2</td><td>3</td></tr><tr><td>3-methylbutanone</td><td>3</td><td>4</td></tr></table><br>three for one mark, six for two marks | **2** |
| 7(b)(ii) | **M1** 3-methylbutanone<br>**M2** 3-methylbutanone **AND** pentan-2-one | **2** |
| 7(c)(i) | six / 6 | **1** |
| 7(c)(ii) | $C_{21}H_{34}O_5$ | **1** |
| 7(c)(iii) | a substance that is able to <u>rotate</u> the plane of polarised light in opposite directions | **1** |

| Question | Answer | Marks |
|---|---|---|
| 8(a) | **M1** chloroethanoic acid > ethanoic acid > phenol > ethanol<br><br>**M2** correct link of acidity once can be implied from M1<br>weakens O—H / carboxylate anion stabilised<br><br>**M3** / **M4** explanation linked to structure<br>• ($Cl$CH$_2$CO$_2$H > ethanoic acid) due to electronegative / electron withdrawing / negative inductive effect of $Cl$<br>• (ethanoic acid > phenol) due to electronegative / electron withdrawing / negative inductive effect of COOH / C=O<br>• (phenol > ethanol) due to lone pair of oxygen overlapping / delocalised into the ring<br>• (ethanol weakest) alkyl group is electron donating / positive inductive effect<br><br>two for one mark, four for two marks | **4** |

| Question | Answer | Marks |
|---|---|---|
| 8(b) | • oxidation<br>• (solution) decolourises **OR** purple → colourless / pale pink **OR** bubbles<br>• $HOOCCOOH + [O] \rightarrow 2CO_2 + H_2O$<br>**OR** $5HOOCCOOH + 2MnO_4^- + 6H^+ \rightarrow 10CO_2 + 8H_2O + 2Mn^{2+}$<br>two for one mark, three for two marks | **2** |
| 8(c) | **M1**  <br>**M2**  | **2** |
| 8(d) |  <br>**M1** peptide linkage shown displayed with saturated C each side<br>**M2** rest of structure correct **AND** continuation bonds | **2** |

| Question | Answer | Marks |
|---|---|---|
| 8(e) | addition polymers do not hydrolyse<br>**OR** condensation polymers can hydrolyse | **1** |
| 9(a) | cyclohexylamine > ammonia > phenylamine<br><br>• (order of basicity) linked to ability of N to accept a proton / donate its lone pair (to a proton)<br>• alkyl / cyclo / hexyl group is electron donating group / positive inductive group (and increases electron density on N)<br>• lone pair / p-orbital from N in phenylamine delocalised / overlaps with ring (and decreases electron density on N)<br><br>two for one mark, three for two marks | **3** |
| 9(b)(i) | (nucleophilic) addition-elimination | **1** |
| 9(b)(ii) |  <br><br>**M1** / **M2**<br>• lone pair on N<br>• correct arrow from (lone pair) N to C (of C=O)<br>• dipole on C=O<br>• correct arrow on C=O<br>two for one mark, four for two marks<br><br>**M3** correct intermediate<br><br>**M4** arrow from lone pair on $O^-$ to C-O bond **AND** arrow from C-C$l$ to C$l$ | **4** |

| Question | Answer | Marks |
|---|---|---|
| 9(b)(iii) |  | **1** |