CAMBRIDGE
International Education

Cambridge International AS & A Level

CHEMISTRY **9701/42**

Paper 4 A Level Structured Questions **February/March 2025**

MARK SCHEME

Maximum Mark: 100

Published

This document consists of **14** 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 descriptions 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 <u>‘List rule’ guidance</u>

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.

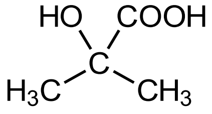
7 Guidance for chemical equations

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.

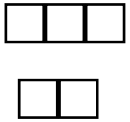
Question	Answer	Marks
1(a)	($Ag^{(2+)}$ is a) forms stable ion(s) with incomplete d orbitals / an incomplete d subshell	**1**
1(b)(i)	$Ag(s) \rightarrow Ag(g)$ $Ag(s) + ½F_2(g) \rightarrow AgF(s)$	**2**
1(b)(ii)	ΔH/energy change when 1 mole of an ionic solid / lattice / crystal / compound is formed from gas phase ions / gaseous ion(s) (under standard conditions)	**2**
1(b)(iii)	**M1**: 5 numbers and no multipliers $-203 = +289 + 732 + 79 + EA_1 + (-955)$ **M2** correct sign and evaluation $\therefore EA_1 = \mathbf{-}348$ (kJ mol^{-1}) ecf min 3sf	**2**
1(c)(i)	enthalpy change of solution of AgF $= -(-955) + (-464) + (-506)$ $= \mathbf{-}15$ (kJ mol^{-1})	**1**
1(c)(ii)	AgF is (slightly) soluble / yes **AND** (the enthalpy change of solution is slightly) exothermic / negative ecf from **Q1(c)(i)**	**1**
1(d)(i)	greater the distance between the nucleus and (the shells of the) electrons **OR** atomic radii increases / atomic size increases / more shells **OR** more shielding by inner shells the less attraction between nucleus / protons **AND** incoming electron / added electron	**2**
1(d)(ii)	halide/X^-/ions get larger (down the group) **AND** decreasing attraction between ions / weaker ionic bond	**1**
1(e)(i)	$E^{\ominus}_{cell} = +0.342 - (+0.222) = (+)0.120$ (V) min 2sf	**1**
	$Cu^{2+} + 2Ag + 2Cl^- \rightarrow Cu + 2AgCl$	**1**

Question	Answer	Marks
1(e)(ii)	**M1:** $[Cl^-(aq)] = 10 \times 36.0 / 74.6 = 4.83\ (4.8257)\ mol\ dm^{-3}$ **M2:** $E = 0.222 + \frac{0.059}{1} \log \frac{1}{M1}$ ecf **M1** **M3:** E = (+)**0.182** (V) min 2sf ecf **M1**	**3**

Question	Answer	Marks
2(a)(i)	$[CH_3COCH_3]$ concentration stays (almost) constant / does not change **OR** $[CH_3COCH_3]$ concentration does not affect rate	**1**
2(a)(ii)	**M1:** first order w.r.t. H^+ **AND** rate × 4 / 3 and $[H^+]$ × 4 / 3 (in expts 2 and 3) **M2:** first order w.r.t. CH_3OH **AND** $[H^+] \times 1.5$, $[CH_3OH] \times 1.5$ and rate $\times 2.25 / 1.5^2$ (expts 1 and 2) / $[H^+] \times 2$, $[CH_3OH] \times 1.5$ and rate $\times 3 / (2 \times 1.5)$ (expts 1 and 3)	**2**
2(a)(iii)	two quoted half-lives within range / 155–170 s **AND** (roughly) constant	**1**
2(b)	**M1:** proposed mechanism = 4 **M2:** slow step contains only species from the rate equation/law **OR** slow step contains CH_3COCH_3 and H^+ from the rate equation/law **M3:** stoichiometric / (mole) ratio / amounts **AND** corresponds to order of reaction / to that in the rate equation	**3**
2(c)(i)		**1**

Question	Answer	Marks
2(c)(ii)	$K_a = 10^{-3.95} = 1.122 \times 10^{-4}$ $[H^+]^2 = (1.122 \times 10^{-4} \times 0.5)$ $[H^+] = \sqrt{(1.122 \times 10^{-4} \times 0.5)} = 7.49 \times 10^{-3}$ pH = –log (7.49×10^{-3}) pH = 2.13 min 2sf	**2**
2(d)(i)	a solution that resists / minimises / opposes changes in pH when small amounts of (strong) acid or base are added	**2**
2(d)(ii)	**M1:** moles of conjugate base = 20 / 1000 × 1.00 = 0.0200 mol **AND** moles of acid **C** left = 50 / 1000 × 0.500 – 0.0200 = 0.0300 mol **M2:** $K_a = [H^+] \times 0.0200 / 0.0300$ $[H^+] = 3 / 2 \times 10^{-3.95} = 1.68 \times 10^{-4}$ ecf from **M1** **M3:** pH = –log (1.68×10^{-4}) pH = 3.77 min 2sf ecf from a calculated $[H^+]$ **M2**	**3**

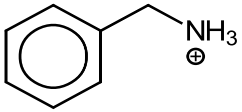
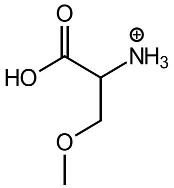
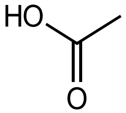
Question	Answer	Marks
3(a)(i)	(central) metal / transition element atom / ion **AND** surrounded by / bonded to ligands	**1**

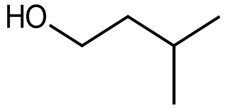
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>3(a)(ii)</td><td>
<table>
<tr><th>complex</th><th>ion</th><th>ligand</th><th>coordination number</th><th>formula and charge of complex</th></tr>
<tr><td>E</td><td>Fe^{2+}</td><td>NH_3</td><td>6</td><td>$[Fe(NH_3)_6]^{2+}$</td></tr>
<tr><td>F</td><td>Fe^{2+}</td><td>Cl^-</td><td>4</td><td>$[FeCl_4]^{2-}$</td></tr>
<tr><td>G</td><td>Fe^{3+}</td><td>en</td><td>6</td><td>$[Fe(en)_3]^{3+}$</td></tr>
</table>
any two [1] any four [2] all six [3]</td><td>3</td></tr>
<tr><td>3(a)(iii)</td><td>three(3) higher AND two(2) lower boxes / energy levels
</td><td>1</td></tr>
<tr><td rowspan="2">3(b)(i)</td><td>d–d energy gap / ΔE) is different</td><td>1</td></tr>
<tr><td>different frequency / wavelength (of light) absorbed / transmitted / reflected</td><td>1</td></tr>
<tr><td>3(b)(ii)</td><td>$K_{stab} = \dfrac{[[Fe(H_2O)_5SCN]^{2+}]}{[[Fe(H_2O)_6]^{3+}]\,[SCN]^-]}$</td><td>1</td></tr>
<tr><td>3(b)(iii)</td><td>$K_c = 2.40 \times 10^5 / 1.40 \times 10^2 = 1714$ min 2sf</td><td>1</td></tr>
<tr><td>3(b)(iv)</td><td>M1: solution turns (violet / purple to) colourless
AND solution then remains / stays colourless / no change

M2: K_{stab} of $[Fe(H_2O)_5F]^{2+} > [Fe(H_2O)_5SCN]^{2+}$
OR $[Fe(H_2O)_5F]^{2+}$ is most stable (more stable than $[Fe(H_2O)_5SCN]^{2+}$)</td><td>2</td></tr>
</table>

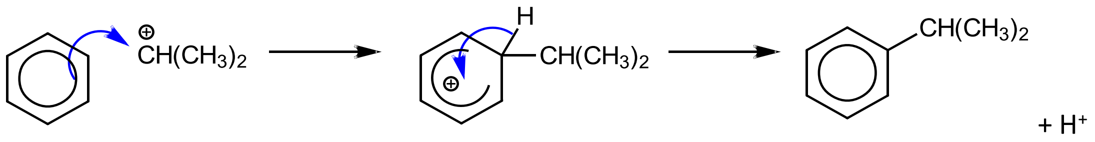
Question	Answer	Marks
3(c)(i)	$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	**2**
3(c)(ii)	**M1** moles of manganate = 12.20 / 1000 × 0.0200 = 2.44×10^{-4} mol **AND** moles of ethanedioate = 5 / 2 × 2.44×10^{-4} = 6.10×10^{-4} mol **M2** moles of $K_3Fe(C_2O_4)_3$ = $6.10 \times 10^{-4} \div 3$ = 2.03×10^{-4} mol **AND** mass of $K_3Fe(C_2O_4)_3$ = 437.1 × 2.03×10^{-4} = 0.0889 g **M3** mass of water = 0.100 – 0.0889 = 0.0111 g **AND** moles of water = 0.0111 / 18.0 = 6.18×10^{-4} mol **M4** x = molar ratio = $6.18 \times 10^{-4} / 2.03 \times 10^{-4}$ = 3	**4**

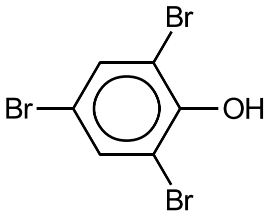
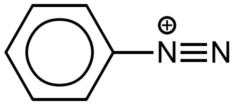
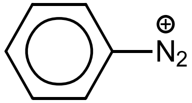
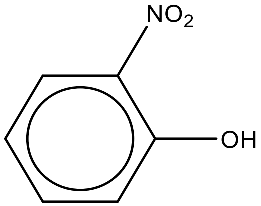
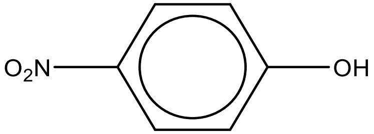
Question	Answer	Marks
4(a)	propanamide < ammonia < propylamine (basicity linked to) p orbital of N / lone pair on N **AND** being accept / donate to / coordinate to a proton/H^+ (propanamide) lone pair / p-orbital on N is delocalised **AND** into C=O group / over N-C-O group / across the two electronegative O & N (propylamine) R / alkyl / propyl group **AND** is electron donating / positive inductive effect	**4**
4(b)	**K** = CH_3CH_2COCl / propanoyl chloride **L** = CH_3CH_2CN / propanenitrile **M** = $LiAlH_4$ **OR** H_2 / Ni / correct names	**3**

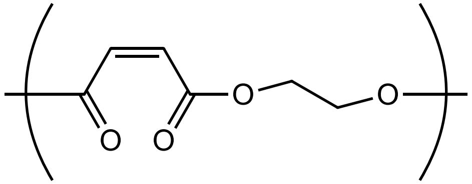
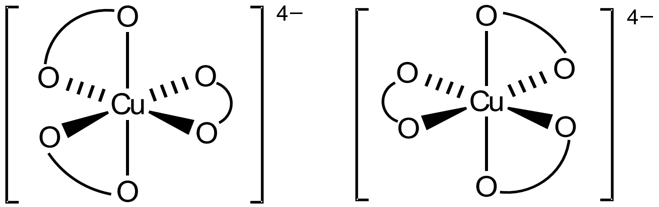
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>4(c)</td><td>  
M1: (un)protonated benzylamine
M2: (un)protonated amine as above
M3: ethanoic acid

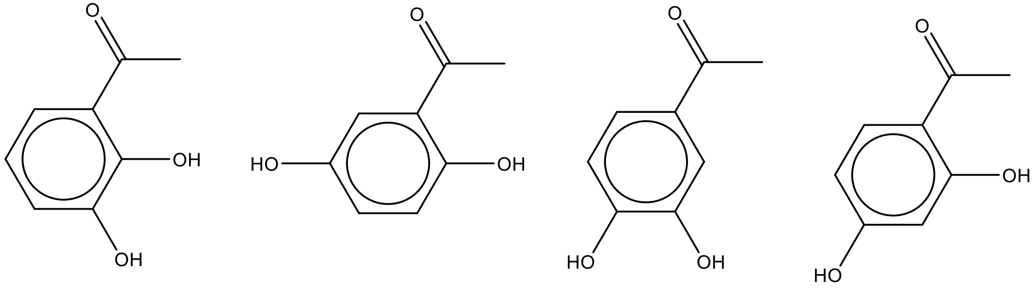
M4: all amine groups protonated (—NH_3^+) AND all acid groups as —COOH</td><td>4</td></tr>
<tr><td>4(d)(i)</td><td>$C_7H_7NO_2 + 6[H] \rightarrow C_7H_7NH_2 + 2H_2O$</td><td>1</td></tr>
<tr><td>4(d)(ii)</td><td>
<table>
<tr><th>step</th><th>reagents and conditions</th><th>type of reaction</th></tr>
<tr><td>1</td><td>• Sn & conc. HC<i>l</i> (+ heat)</td><td>reduction</td></tr>
<tr><td>2</td><td>• CH_3Br / CH_3Cl / CH_3I (in ethanol)</td><td>• (nucleophilic) substitution</td></tr>
<tr><td>3</td><td>• hot MnO_4^-/$KMnO_4$</td><td>• oxidation</td></tr>
<tr><td>4</td><td>•  (+ conc. H_2SO_4)</td><td>condensation</td></tr>
</table>
[1] x 6</td><td>6</td></tr>
</table>

Question	Answer	Marks
5(a)	sp^2 = 6 / six sp^3 = 3 / three	**1**

Question	Answer	Marks
5(b)(i)	electrophilic substitution	**1**
5(b)(ii)	$\mathrm{A}l\mathrm{Br}_3$	**1**
5(b)(iii)	 **M1**: curly arrow from inside the hexagon ring **AND** towards positively charged carbon atom (in the electrophile $(CH_3)_2CH^+$) **M2**: structure of the intermediate **M3**: curly arrow from C–H bond into the ring **AND** formation / loss of H^+	**3**
5(b)(iv)	2° carbocation / $(CH_3)_2CH^+$ **AND** is more stable due to greater positive inductive effect (of alkyl groups)	**1**
5(c)(i)	$\Delta S = 146 + 200 - 205 - 278 = \mathbf{-137}$ (J K^{-1} mol^{-1})	**1**
5(c)(ii)	$\Delta G = \Delta H - T\Delta S$ **AND** T = 298 / 298.15 used $\Delta G = -371 - (25+273)\times(-0.137) = \mathbf{-330}$ (kJ mol^{-1}) [so feasible] ecf **M1**	**2**
5(d)(i)	**M1**: conditions for phenol = • aqueous / aq • bromine water • no $\mathrm{A}l\mathrm{Br}_3$ needed **M2**: lone pair (of e^-)/p-orbital on oxygen **AND** overlap / delocalised with ring / π system **M3**: electron density in ring increases / ring becomes more electron rich (and attracts electrophiles) **M4**: (phenol is more reactive so) polarises Br_2 / bromine / electrophiles more	**4**

Question	Answer	Marks
5(d)(ii)	**Q** = 	**1**
5(d)(iii)	**R** =  **/**  **/** benzene diazonium chloride	**1**
5(d)(iv)	azo	**1**
5(d)(v)	structure / name of 2-nitrophenol and 4-nitrophenol   —OH / hydroxyl group is electron donating group **AND** 2,4-directing / ortho / para directing	**2**

Question	Answer	Marks
6(a)(i)	 **M1**: ester group in middle displayed between two monomers **M2:** rest of molecule correct (only one repeat unit)	**2**
6(a)(ii)	cold acidified dilute $KMnO_4$ / MnO_4^-	**1**
6(b)(i)	condensation **OR** dehydration **OR** elimination	**1**
6(b)(ii)	species with two lone pairs / LP of electrons) that form **dative** (covalent) **/** co-ordinate bond(s) to a (central) transition element / metal atom / ion	**2**
6(b)(iii)	 **M1** one correct diagram **M2** correct diagram of the other optical isomer	**2**
6(c)(i)	8 / eight	**1**
6(c)(ii)	to remove peaks / signals / absorptions from acidic protons / OH / COOH / labile protons	**1**

Question	Answer	Marks
6(c)(iii)	Molecule must not be symmetrical (as eight different C environments) Viable structures of **X**  • methyl ketone / CH_3CO group because (yellow) ppt / CHI_3 formed (with alkaline I_2(aq)) any two linked statements: • two —OH groups because ^{1}H NMR signals lost in D_2O • ketone / carbonyl / $CH_3\underline{C}O$ as (^{13}C NMR) signal with Δ = 205 / 190–220 ppm • methyl / carbon next to C=O because (^{13}C NMR) signal with Δ = 30–65 ppm	**4**