Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/41**

Paper 4 A Level Structured Questions **October/November 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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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: 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.

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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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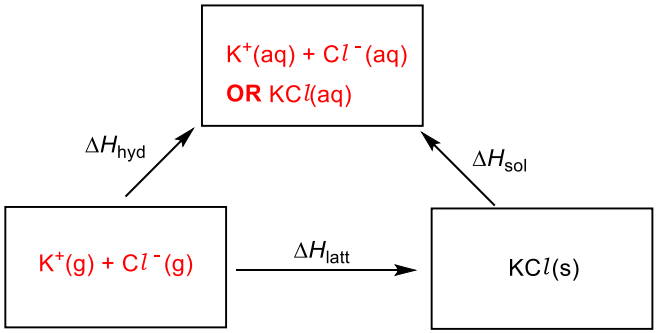
Question	Answer	Marks
1(a)	 M1 K^+ (g) and Cl^- (g) **AND** KCl (aq) **OR** K^+ (aq) + Cl^- (aq) M2 three correct directional arrows COND M1	**2**
1(b)	use of data –155, –2493 **AND** 2 × –364 [1] ΔH_{hyd} Mg^{2+} = **–1920** (kJ mol^{-1}) [1] min 3sf	**2**
1(c)	• Mg^{2+} is **smaller** (than K^+) • Mg^{2+} is **greater charge** (than K^+) • greater **attraction** between Mg^{2+} and Cl^-/**between the ions** (in $MgCl_2$) **OR** stronger ionic bonds (in $MgCl_2$)	**2**
1(d)(i)	enthalpy change when **one mole** of **gaseous atoms** formed from the **element** (in its standard state at 298 K)	**1**
1(d)(ii)	enthalpy change when every atom in one mole of gaseous atoms gains one electron **OR** one mole of gaseous atoms gains one mole of electrons	**1**
1(e)(i)	number of possible arrangements of particles and energy in a system	**1**

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Question	Answer	Marks
1(e)(ii)	ΔS is positive **AND** $KCl(s) \rightarrow K^+(aq) + Cl^-(aq)$ / ionic lattice solid forms aqueous **ions OWTTE** [1] **OR** ΔS is positive **AND** ΔG is (therefore becomes) negative / $T\Delta S$ is greater than ΔH_{sol} **OWTTE** [1]	**1**
1(e)(iii)	**more soluble** **AND** ΔG is more negative at higher T / $T\Delta S$ is more positive at higher T / $-T\Delta S$ is more negative at higher **ecf from (e)(ii)** [sign ΔS]	**1**

Question	Answer	Marks
2(a)(i)	(homogeneous is in the) same phase / state as reactants **AND (**heterogeneous is in a) different phase / state to reactants	**1**
2(a)(ii)	1 $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ [1] 2 $2I^- + 2Fe^{3+} \rightarrow 2Fe^{2+} + I_2$ [1]	**2**
2(a)(iii)	reactants are **both anions / negatively charged** **AND** so they **repel** each other **OWTTE**	**1**
2(b)(i)	rate = $k[NO]^2[O_2]$ **OR** rate = $8.6 \times 10^6 [NO]^2[O_2]$	**1**
2(b)(ii)	rate = $8.6 \times 10^6 \times (7.2 \times 10^{-4})^2 \times 1.9 \times 10^{-3}$ rate = 8.47×10^{-3} (mol dm^{-3} s^{-1}) min 2sf	**1**
2(c)(i)	(reaction is) first order wrt cisplatin / overall **OR** rate is directly proportional to concentration of cisplatin	**1**
2(c)(ii)	$0.693 / 2.50 \times 10^{-5}$ = (2.77×10^4 s) **OR** ln 2 / 2.50×10^{-5} = (2.77×10^4 s)	**1**

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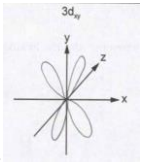
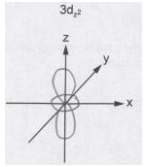
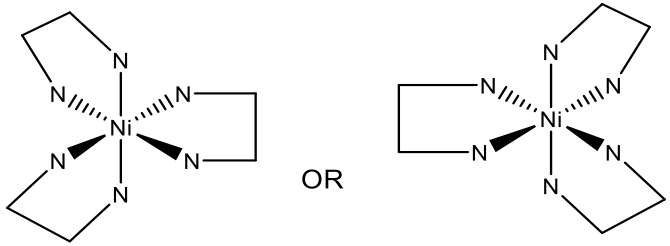
Question	Answer	Marks
2(c)(iii)	initial concentration is 8.0×10^{-5} mol dm^{-3} – five half-life periods have elapsed [1] time = $5 \times 27720 = 1.39 \times 10^{5}$ s [1] min 2 sf	**2**

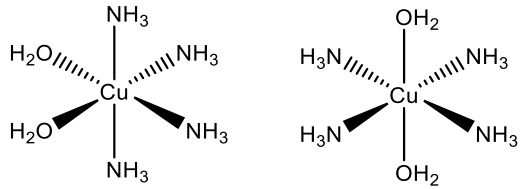
Question	Answer	Marks
3(a)(i)	(Ion (Sn^{2+}/Sn^{4+}) concentration) 1 mol dm^{-3} **AND** 298 K (25 °C)	**1**
3(a)(ii)	• **both** half-cells have Pt or C electrode • Sn^{2+} / Sn^{4+} **AND** H^+ solutions • feasible gas delivery system • H_2 label • V/voltmeter **AND** correct circuit **AND** salt bridge touching solution • salt bridge labelled	**3**
3(a)(iii)	no (reaction) **AND** both $E^{\ominus}$ values (Sn^{2+} / Sn) –0.14 and (Cl_2 / Cl^-) +1.36 [1] E_{cell} is –1.5 V / E_{cell} is negative **OR** $E^{\ominus}$ of Sn^{4+} / Sn^{2+} is more negative/smaller than $E^{\ominus}$ of Cl_2 / Cl^- [1]	**2**
3(a)(iv)	$Sn^{2+} \rightarrow Sn^{4+}$ and $VO^{2+} \rightarrow V^{3+}$ [1] $Sn^{2+} + 2VO^{2+} + 4H^+ \rightarrow Sn^{4+} + 2V^{3+} + 2H_2O$ [1]	**2**
3(b)	moles of Sn = 2.95 / 118.7 = 0.0249 moles moles of Al (is 2 / 3 moles of Sn) = 0.0166 moles [1] mass of Al = 0.0166 × **27 = 0.447 / 0.448** g **to 3sf** [1] ecf	**2**

Question	Answer	Marks

Question	Answer	Marks
4(a)(i)	ratio of concentration of the solute in two solvents at equilibrium [1]	**1**
4(a)(ii)	3.50 = (1.62 / 100) / (0.38 / x) [1] x= **82** (cm^3) (82.0987654) [1] ecf M1 min 2sf	**2**
4(b)(i)	pH resists change when **small** amount of acid or base added	**1**
4(b)(ii)	$CH_3CH_2CH_2COO^-$ / salt of butanoic acid / sodium butanoate **AND** NaOH	**1**
4(c)(i)	$K_{sp} = [Al^{3+}][OH^-]^3$	**1**
4(c)(ii)	$[OH^-] = 3 \times 2.47 \times 10^{-9}$ **OR** 7.41×10^{-9} [1] $K_{sp} = [2.47 \times 10^{-9}][7.41 \times 10^{-9}]^3$ $= \mathbf{1.01} \times \mathbf{10^{-33}}$ min 2sf ecf from 1st mark [1] $mol^4\,dm^{-12}$ [1]	**3**

Question	Answer	Marks
5(a)	$3d_{xy}$  $3d_{z^2}$ 	**1**
5(b)(i)	• **d orbital(s)** of different energy **/ d-d** splitting occurs • **electron**(s) promoted / excited • wavelength of visible light absorbed **AND** complementary colour seen • different energy gap / different ΔE **OR** different frequency/wavelength of light is absorbed	**4**
5(b)(ii)	 OR	**1**
5(b)(iii)	octahedral **AND** optical isomerism	**1**
5(c)	Fe^{2+} is smaller / has a smaller radius **OR** Fe^{2+} greater charge density [1] polarises/distorts the anion / $CO_3^{(2)-}$ more [1]	**2**
5(d)(i)	colourless / (pale) green **to** pink / purple	**1**

Question	Answer	Marks
5(d)(ii)	moles MnO_4^- = 0.0100 × 0.0350 **OR** 3.50×10^{-4} moles Fe^{2+} = 5 × 3.50×10^{-4} **OR** 1.75×10^{-3} [1] moles Fe^{2+} = $1.75 \times 10^{-3} \times 4 = 7.00 \times 10^{-3}$ % of Fe = ($7.00 \times 10^{-3} \times 55.8$) = 0.3906 g = 0.3906 / 2.62 × 100 = **14.9** % by mass [1] ecf M1 min 2sf	**2**

Question	Answer	Marks
6(a)(i)	$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow [Cu(OH)_2(H_2O)_4] + 2H_2O$ **OR** **OR** $[Cu(H_2O)_6]^{2+} + 2NaOH \rightarrow [Cu(OH)_2(H_2O)_4] + 2H_2O + 2Na^+$	**1**
6(a)(ii)	$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$ **OR** $[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$	**1**
6(b)(i)	 cis and trans drawn	**1**
6(b)(ii)	***cis*** *identified* as **polar AND** ***trans*** *identified* as **non-polar** *conditional on diagram*	**1**
6(c)(i)	the equilibrium (constant) for the formation of the complex ion in a solvent from its constituent ions or molecules	**1**
6(c)(ii)	$[Cu(NH_3)_4(H_2O)_2]^{2+}$ AND as K_{stab} is large **OWTTE**	**1**
6(c)(iii)	K_{stab} = $[[Cu(NH_3)_4(H_2O)_2]^{2+}] / [[Cu(H_2O)_6]^{2+}] [NH_3]^4$ [1] mol^{-4} dm^{12} [1] ecf M1	**2**

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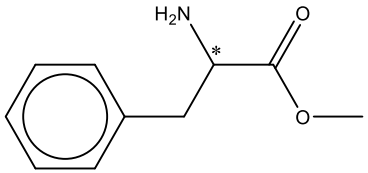
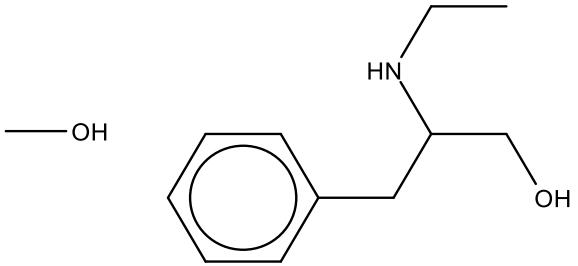
Question	Answer	Marks
6(c)(iv)	$[Cu(H_2O)_6]^{2+}] = (0.0074) \div (1.4 \times 10^{13} \times 0.57^4)$ $[Cu(H_2O)_6]^{2+}] =$ **5.01** $\times$ **10^{-15}** min 2sf ecf **6(c)(iii)**	**1**
6(d)	$[Ru(C_{12}H_8N_2)_2Cl_2]^+$ [1] $[Fe(C_2O_4)_3]^{3-}$ [1]	**2**

Question	Answer	Marks
7(a)(i)		**1**
7(a)(ii)	plane of polarised **light** will be **rotated** (in both isomers) [1] by same angle / **equal** amounts in **opposite directions** [1]	**2**
7(b)(i)	CH_3COCl **AND** HCl	**1**

Question	Answer	Marks
7(b)(ii)	 methanol [1] ester bond → primary alcohol **OR** amide → 2° amine **AND** benzene ring unchanged [1] rest of the structure of second compound is correct [1]	**3**
7(b)(iii)	Q < phenylamine < P [1] <u>any three from:</u> ability of N to **accept** a proton **OR donate** its lone pair to a proton phenylamine **lone pair of N** delocalised into ring **OR p-orbital on N** overlaps with π cloud of ring (and decreases electron density on N) compound P (2° amine) alkyl group has a positive inductive effect (and increases electron density on N) compound Q (amide) **lone pair of N** (in amide) delocalised by C=O **OR** overlap of **lone pair of N** with C=O (and decreases electron density on N)	**3**
7(c)(i)	conc. HNO_3 and H_2SO_4 (25 °C < T ⩽ 60 °C) [1] Sn and conc. HC*l* and reflux (followed by NaOH(aq)) [1]	**2**

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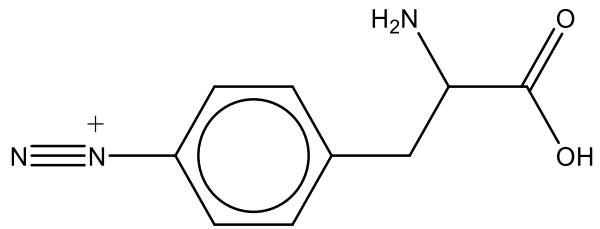
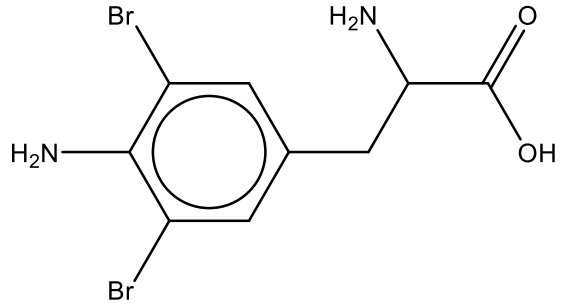
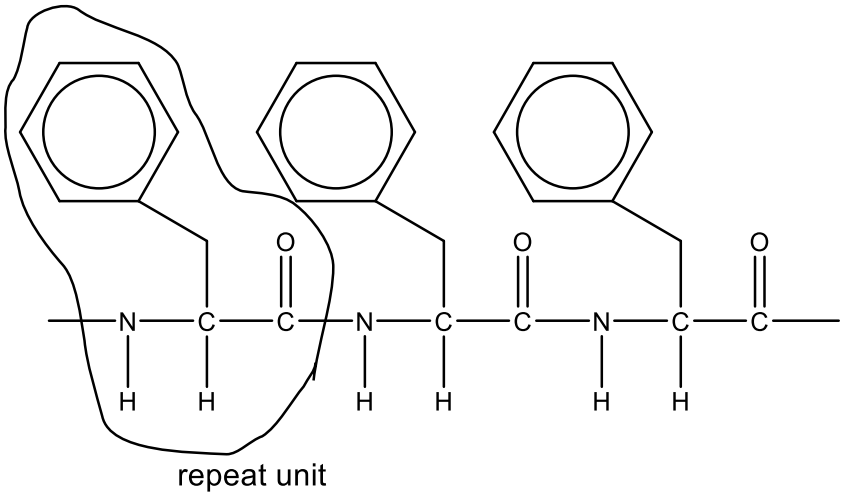
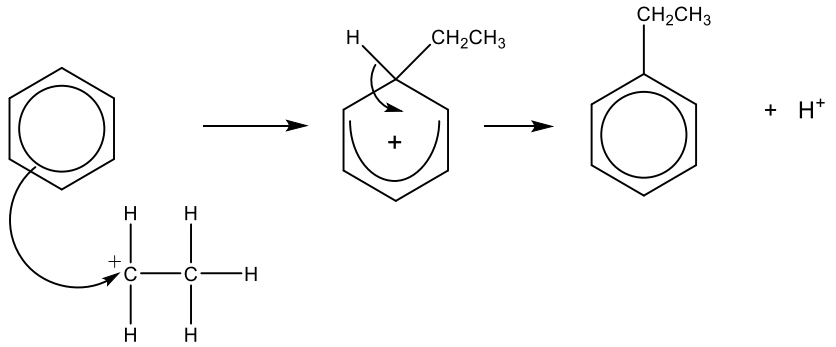
Question	Answer	Marks
7(c)(ii)	 NH_2 on ring gives diazonium ion [1]  dibromo compound with Br atoms 2,6 to amine group [1]	**2**
7(d)(i)	**pH** where the species is a zwitterion is the dominant form **OR pH** where the species is electrically neutral	**1**

Question	Answer	Marks
7(d)(ii)	 repeat unit identified by label / brackets / circle [1] three monomers complete all amide/peptide bonds correct all $CHCH_2C_6H_5$ / CHR groups correct trailing bonds or other convention(everything else correct) [1]	**2**

Question	Answer	Marks
8(a)	120° **AND** sp^2	**1**
8(b)(i)	$C_2H_5Cl + AlCl_3 \rightarrow CH_3CH_2^+ + AlCl_4^-$	**1**

Question	Answer	Marks
8(b)(ii)	 curly arrow 1 **AND** curly arrow 2 [1] correct intermediate structure [1] $C_6H_5C_2H_5$ **AND** H^+ [1]	**3**
8(c)(i)	(aqueous / alkaline) $AgNO_3$ / silver nitrate	**1**
8(c)(ii)	$C_2H_5Cl + H_2O \rightarrow C_2H_5OH + HCl$ **/** $C_2H_5Cl + NaOH \rightarrow C_2H_5OH + NaCl$ **AND** $Ag^+ + Cl^- \rightarrow AgCl$ **AND NO** equation shown for C_6H_5Cl	**1**
8(c)(iii)	lone pair / p-orbital from **Cl** overlaps with benzene ring **AND** stronger / partial double C-Cl bond **OR** difficult to break C-Cl bond	**1**

Question	Answer	Marks
9(a)(i)	**stationary**: non-volatile (non-polar) liquid **mobile**: nitrogen / argon / any inert gas	**1**
9(a)(ii)	the time that the substance stays in the column **OR** time between injection and detection **OWTTE**	**1**

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Question	Answer	Marks
9(a)(iii)	areas are 30, 100, 25 **OR** 30, 150, 25 (½ × b × h) **OR** 100 / 155 [1] % of B = 100 × (100 / 155) **OR** % of B = 100 × 150 / 205 = = **64.5** = **73.2** [1] ecf M1 *areas*	**2**
9(b)	5 5 5 4 4	**2**
9(c)	4 [1] singlet, (two) triplet(s), multiplet (any order) [1]	**2**
9(d)(i)	**D** = $CH_3CH_2CO_2CH_2CH_3$ [1] **E** = $(CH_3)_2CHCO_2CH_3$	**2**
9(d)(ii)	O-CH_2 **labelled F** **AND** three protons on neighbouring **carbon** / adjacent CH_3	**1**
9(d)(iii)	**both CH_3 in** isopropyl group **labelled G** **AND** alkane / alkyl (protons)	**1**

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