Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/41**

Paper 4 A Level Structured Questions **October/November 2021**

MARK SCHEME

Maximum Mark: 100

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

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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)	moles of H_2 = 462 / 24 000 = 0.01925[1] molecules of H_2 = $0.019 \times 6.02 \times 10^{23}$ = **1.16×10^{22}** (1.1×10^{22} / 1.2×10^{22}) [1] **min 2sf** ecf M1	**2**
1(b)	number of electrons = $1.16 \times 10^{22} \times 2$ = **2.32×10^{22}** [1] min 2sf ecf 1a	**1**
1(c)	Q = $2.32 \times 10^{22} \times 1.6 \times 10^{-19}$ = **3.71×10^{3}** [1] min 2sf ecf 1b	**1**
1(d)	x = $3.71 \times 10^{3} / (14 \times 60)$ = **4.4** (A) [1] min 2sf ecf 1c	**1**
1(e)(i)	ΔS = 262 + 205 – 140 = (+) **327** (J K^{-1} mol^{-1}) [1]	**1**
1(e)(ii)	ΔG = ΔH – TΔS **OR** use of Gibbs equation [1] ΔG = 572 – (298×0.327) = (+)**474.6** (kJ mol^{-1}) [1] min 3sf ecf 1e(i)	**2**
1(e)(iii)	becomes more feasible / spontaneous as TΔS is more positive / –TΔS becomes more negative • ✓	**1**

Question	Answer	Marks
2(a)(i	$K_a = \frac{\left[H^+\right]\left[Cl(CH_2)_3CO_2^-\right]}{\left[Cl(CH_2)_3CO_2H\right]}$ [1]	**1**
2(a)(ii)	pK_a = – logK_a **OR** $K_a = 10^{-pKa}$ [1]	**1**
2(a)(iii)	$[H^+] = 10^{-4.0}$ = **1×10^{-4}** [1]	**1**

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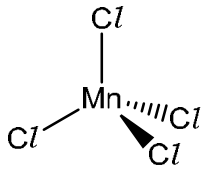
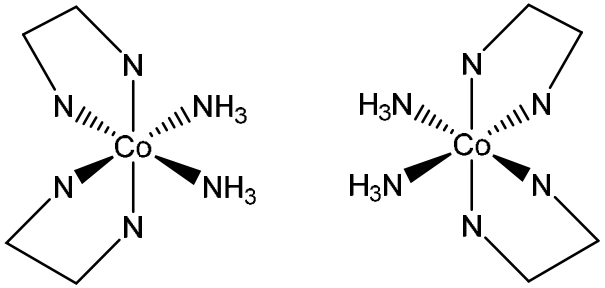
Question	Answer	Marks
2(a)(iv)	• [HC*l*] = 1×10^{-4} ecf 2(a)(iii) • $K_a = 10^{-4.52} = 3.02 \times 10^{-5}$ • [C*l*$(CH_2)_3CO_2H$] = $(1 \times 10^{-4})^2 / 3.02 \times 10^{-5}$ = 3.3×10^{-4} ecf • $\frac{[HCl]}{[Cl(CH_2)_3CO_2H]} = \frac{1\times10^{-4}}{3.3\times10^{-4}} = \mathbf{0.302}$ min 2sf ecf	**2**
2(b)	M1 $[H^+] = 10^{-5}$ **OR** 1×10^{-5} $K_a = [H^+][A^-] / [HA]$ **OR** pH = p*K*a + log $[A^-] / [HA]$ • ✓ [1] M2 moles of A^- = $(1.35 \times 10^{-5})(5 / 74) / (1 \times 10^{-5})$ moles of A^- = 0.0912 [1] ecf M3 mass of sodium propanoate = 0.0912×96 = **8.76** [1] min 2sf ecf	**3**
2(c)	all of the (sodium) **propanoate** (ion) has been protonated / converted to (propanoic) acid / neutralised [1] **H^+** is in excess / **H^+** is 0.1 mol dm^{-3} (from the H_2SO_4) [1]	**2**

Question	Answer	Marks
3(a)	• enthalpy/energy change • one mole of electrons gained • by one mole of atoms • gaseous (atoms)	**2**
3(b)	$Ca^+(g) \rightarrow Ca^{2+}(g) + e^-$ [1]	**1**

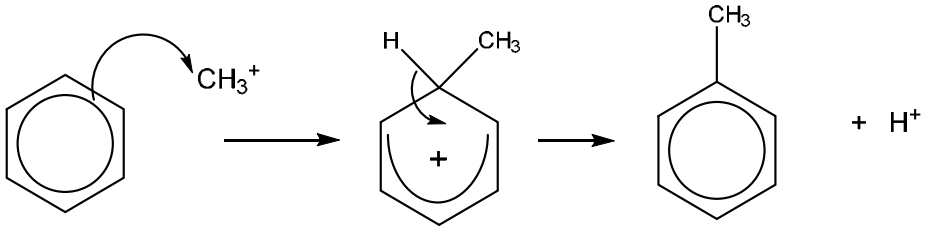
Question	Answer	Marks
3(c)	M1: selecting correct data 951, 844, 142 only M2: evaluation to give 249 (ΔH_{atom}) **OR** 2(951) = BE – 2(142) + 2(844) M3: evaluation to 498 (2×249) ecf M2 951 = ΔH_{atom} –142 + 844 ΔH_{atom} = 249 BE = **498** (kJ mol^{-1}) [3]	**3**
3(d)(i)	**attraction** between nucleus / protons / nuclear charge **and** electron [1]	**1**
3(d)(ii)	**repulsion** between 1– ion / electrons of O^- **and** electron [1]	**1**
3(e)	M1: selecting correct data 951, 1933, 3517 only (ignore signs) M2: evaluation to give –633 (ΔH_f) ecf ΔH_f = 951 + 1933 – 3517 = **–633** (kJ mol^{-1}) [2]	**2**
3(f)	ionic charge / charge density (of the ions) [1] greater (attractive) force between the ion**s** [1]	**2**

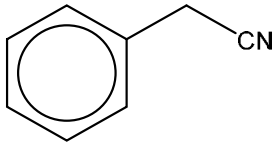
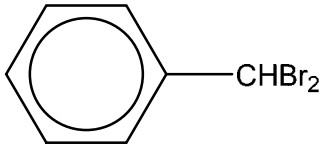
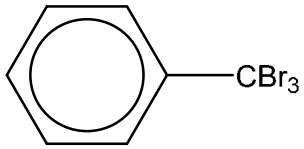
Question	Answer	Marks
4(a)	• barium carbonate / Ba / $BaCO_3$ • larger ionic radius **OR** smaller charge density of cation / M^{2+} [1] • anion / CO_3^{2-} / carbonate ion is less distorted / less polarised **OR** C-O / C=O less weakened [1]	**2**
4(b)	• calcium oxide / calcium hydroxide • Ca**SO_4** / calcium **sulfate** is more soluble **OR** Ba**SO_4** is less soluble [1] • ΔH_{latt} and ΔH_{hyd} are less exothermic / more endothermic (for $BaSO_4$) [1] • ΔH_{hyd} is dominant factor / ΔH_{hyd} change is greater **OR** ΔH_{latt} changes less [1]	**3**
4(c)(i)	mass of CO_2 = 0.02×44 = **0.88** g [1]	**1**
4(c)(ii)	(writes correct equation, deduces 3 CO_2 per mole) moles of propane = 0.02 / 3 **OR** 0.00667 **OR** 1 / 150 [1] mass of propane = $0.02 / 3 \times 44$ = **0.293** g [1] ecf M1 $\times$ 44 3sf needed	**2**

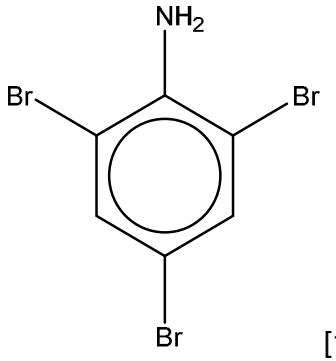
Question	Answer	Marks
5(a)(i)	+2 [1]	**1**
5(a)(ii)	 [1] bond angle labelled 109.5° [1]	**2**

Question	Answer	Marks
5(b)(i)	$[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(H_2O)_4(OH)_2 + 2H_2O$ **OR** $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2 + 6H_2O$ [1] **blue** precipitate [1]	**2**
5(b)(ii)	$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$ [1] yellow / brown / straw solution [1]	**2**
5(b)(iii)	$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$ [1] blue solution [1]	**2**
5(b)(iv)	**ligand** exchange [1]	**1**
5(c)(i)	(a species) that **donates <u>two</u> lone pairs** to form **<u>two</u> dative bonds** [1] **to** a (transition) **metal atom / metal ion** [1]	**2**
5(c)(ii)	 M1 one correct 3D structure – trans or cis [1] M2 a correct optical isomer of M1 [must 3D] [1]	**2**

Question	Answer	Marks
6(a)	$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$ **OR** $2CuSO_4 + 4NaI \rightarrow 2CuI + I_2 + 2Na_2SO_4$ [1]	**1**
6(b)(i)	M1: **d-d orbital** splitting occurs [1] M2: **electron**(s) promoted / excited [1] M3: wavelength / frequency of light is **absorbed** [1] M4: colour seen is complementary **OR** wavelength / frequency of light **not** absorbed is seen [1]	**4**
6(b)(ii)	(for Cu^+) $3d^{10}$ **OR** 3d subshell full [1]	**1**
6(c)	M1: (Cu^{2+} / Cu^+) $E^\ominus$ = (+)0.15 V **AND** (I_2 / I^-) $E^\ominus$ = (+)0.54 V [1] M2: No, since ($E^\ominus_{cell}$) negative / –0.39 V **OR** No, since (I_2 / I^-) is more positive than (Cu^{2+} / Cu^+) **OR** No, I_2 is more easily reduced **OR** No, I_2 stronger oxidant ORA [1]	**2**
6(d)	M1: Cu^{2+} / Cu^+ *E* becomes more positive as equilibrium shifts to the right [1] M2: The **new** E for Cu^{2+} / Cu^+ is more positive **than 0.54** / ***E*$^\ominus$ (I_2 / I^-)** [1]	**2**

Question	Answer	Marks
7(a)	6 [1]	**1**
7(b)	M1: trend phenylethanoic acid > phenol > ethanol [1] M2: *why phenylethanoic acid is the strongest* • negative inductive electron withdrawing effect of C=O which weakens O-H bond / stabilises anion [1] M3: *why phenol is stronger than ethanol / weaker than phenylethanoic acid* • oxygen lone pair is delocalised into the ring system which weakens O-H bond / stabilises anion [1] M4: *why ethanol is the weakest* • electron donating alkyl / ethyl group which strengthens O-H bond / destabilises anion [1]	**4**
7(c)(i)	$CH_3Cl + AlCl_3 \rightarrow {}^{+}CH_3 + AlCl_4^-$ [1]	**1**
7(c)(ii)	 M1: arrow to CH_3^+ (arrow must come from inside the hexagon) [1] M2: correct structure of intermediate [1] M3: arrow <u>from</u> C-H bond into the ring **AND** H^+ seen [1]	**3**
7(d)(i)	Br_2 + UV light [1]	**1**

Question	Answer	Marks
7(d)(ii)	 [1]	**1**
7(d)(iii)	**CHECK Q** is correct step 2 – KCN in ethanol + heat [1] step 3 – HCl(aq) + heat/reflux/boil [1]	**2**
7(d)(iv)	 OR  [1] **ALLOW** any viable organic by-product from this radical substitution reaction, e.g. $C_6H_5CH_2CH_2C_6H_5$	**1**

Question	Answer	Marks
8(a)	bromine decolourised **OR** orange / brown to colourless [1] white precipitate [1]	**2**
8(b)	no change [1]	**1**
8(c)	 [1]	**1**
8(d)	2,4,6-tribromophenylamine [1] **ECF** 8(c) for a bromophenylamine	**1**

Question	Answer	Marks
9(a)	PCl_5 **OR** PCl_3 **OR** $SOCl_2$ [1]	**1**
9(b)(i)	amide [1]	**1**
9(b)(ii)	HCl / hydrogen chloride **OR** $C_2H_5NH_3Cl$ / ethylammonium chloride [1]	**1**
9(c)(i)	$LiAlH_4$ [1]	**1**
9(c)(ii)	reduction [1]	**1**
9(d)(i)	relative abundance = 2 carbons $\times$ 1.1 $\times$ 0.62 = **1.36** / **1.4** [1] min 2sf	**1**
9(d)(ii)	$CH_3CH_2^+$ / $C_2H_5^+$ [1]	**2**

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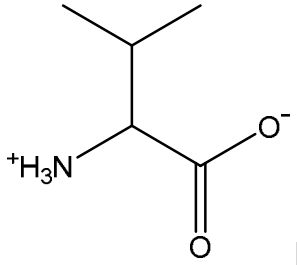
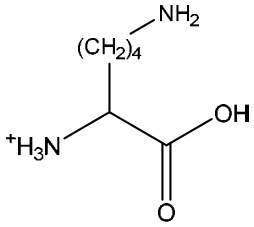
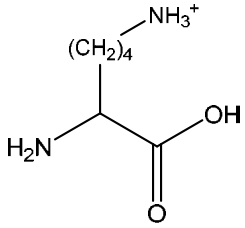
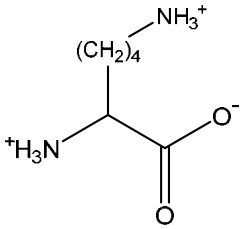
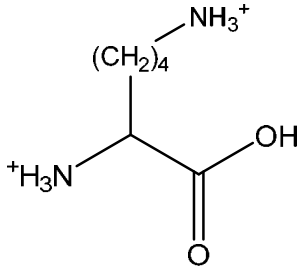
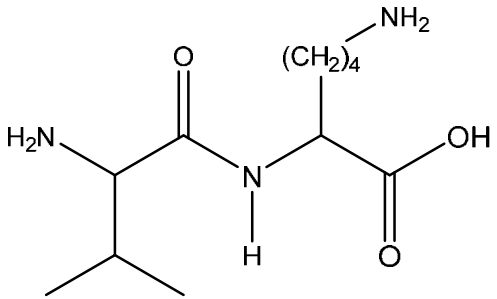
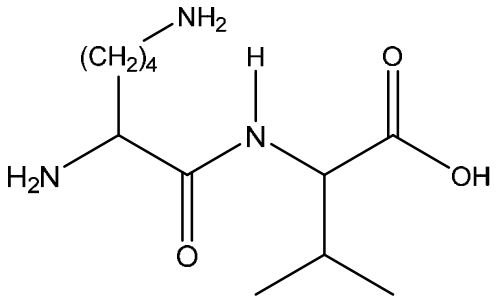
Question	Answer	Marks
	$C_6H_5CH_2^+$ [1]	
9(e)(i)	a [1]	**1**
9(e)(iii)	d [1]	**1**
9(e)(iii)	b, c, f [1]	**1**
9(e)(iv)	f [1]	**1**

Question	Answer	Marks
10(a)	 [1]	**1**

Question	Answer	Marks
10(b)	**A** and **B** any two from: [all net single positive charge]    [1] × 2 **C** at pH 1.0 [2+ positive charge]  [1]	**3**

Question	Answer	Marks
10(c)	M1: peptide link correct and displayed unit including C=O M2: everything else correct  **OR**  [2]	**2**