Cambridge Assessment International Education

Cambridge International AS & A Level

CHEMISTRY **9701/41**

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.

Cambridge International is publishing the mark schemes for the May/June 2022 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

This document consists of **15** 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.

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.

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.

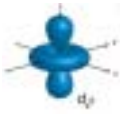
7 Guidance for chemical equations

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.

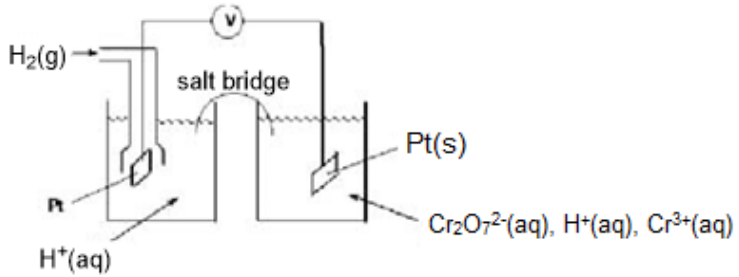
Question	Answer	Marks
1(a)	**M1** ΔH_{latt} and ΔH_{hyd} decrease / both become less exothermic / less negative **M2** ΔH_{latt} decreases / changes less/becomes less exothermic by a smaller extent **OR** ΔH_{hyd} decreases / changes more / dominant factor **M3** ΔH_{sol} becomes less exothermic / less negative **OR** ΔH_{sol} becomes (more) endothermic / (more) positive **OR** $\Delta H_{sol} = \Delta H_{hyd} - \Delta H_{latt}$ expression **AND** reaction becomes less exothermic	**3**
1(b)	Mg: fizzing Ba: (fizzing and) white solid/ppt forms	**1**
1(c)	**M1** solubility of $BaSO_4$ $= \sqrt{1.08 \times 10^{-10}} = 1.04 \times 10^{-5}$ (mol dm^{-3}) **M2** $= 1.04 \times 10^{-5} \times 233.4 / 10 = 2.43 \times 10^{-4}$ (g per 100 cm^3 of solution) min 2sf	**2**
1(d)(i)	$-1473 = 180 + 503 + 965 + \Delta H^{\ominus}_f - 2469$ $\Delta H^{\ominus}_f$ of $SO_4^{2-}(g) = -652$ kJ mol^{-1} **M1** correct five values used [1] **M2** only correct five values used [1] **M3** correct signs and evaluation [1]	**3**
1(d)(ii)	• $BaSO_4$ is more negative/bigger • as Ba^{2+} is smaller **OR** Ba^{2+} has a larger charge • stronger force of attraction between the ions One mark for two correct Two marks for all three correct	**2**

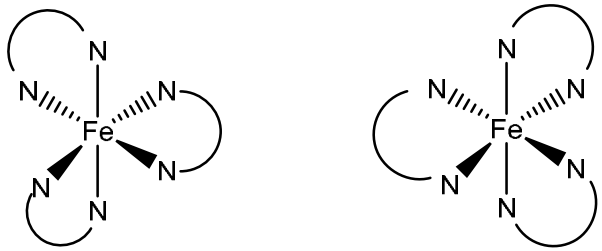
Question	Answer	Marks
1(e)(i)	**M1** $\Delta G^{\ominus} = 0$ so T = $\Delta H_r^{\ominus} / \Delta S^{\ominus}$ **M2** T = 132 / 0.616 = 214.3 K T = –58.7 °C min 2sf	**2**
1(e)(ii)	**M1** $\Delta S^{\ominus}$ = (203 + (70 × 8) + (2 × 192)) – (427 – (2 × 95)) = +530 J K^{-1} mol^{-1} **M2** $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ **M3** $\Delta G^{\ominus}$ = 133 – (298 × 0.530) = –24.9 kJ mol^{-1} ecf 1dp min	**3**

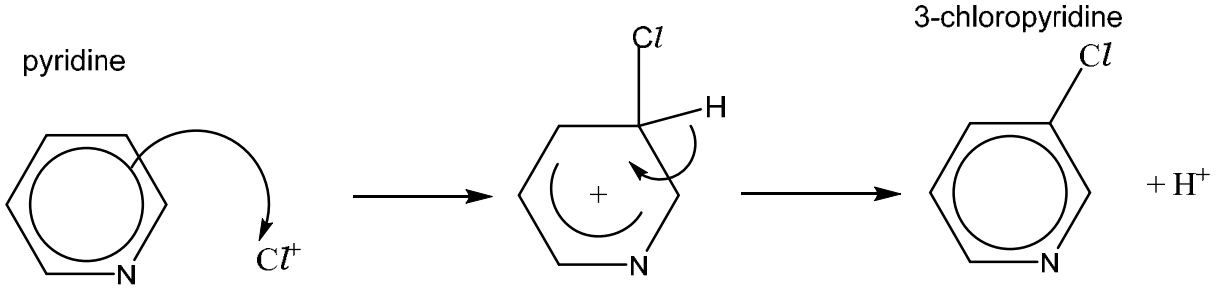
Question	Answer	Marks
2(a)	forms one or more stable ions / compounds / oxidation states with incomplete / partially filled (3)d-orbital(s) / d-shell / d-subshell	**1**
2(b)	 **OR** 	**1**
2(c)(i)	the catalyst and the reactants are in a different state / phase	**1**
2(c)(ii)	**M1** adsorption of reactants to the surface of the catalyst **M2** bonds in the reactants weaken (lowering the activation energy) **M3** reaction occurs and the products are desorbed	**3**

Question	Answer	Marks
2(d)	**M1** reaction 1: $2KMnO_4 + H_2SO_4 \rightarrow Mn_2O_7 + H_2O + K_2SO_4$ **OR** $2KMnO_4 + 2H_2SO_4 \rightarrow Mn_2O_7 + H_2O + 2KHSO_4$ **M2** reaction 2: $Mn_2O_7 \rightarrow 2MnO_2 + 1.5O_2$	**2**
2(e)(i)	**M1** $[Mn(H_2O)_6]^{2+} + 2OH^- \rightarrow Mn(OH)_2 + 6H_2O$ **M2** precipitation / acid-base / deprotonation	**2**
2(e)(ii)	**M1** $[Mn(H_2O)_6]^{2+} + 4Cl^- \rightarrow [MnCl_4]^{2-} + 6H_2O$ **M2** ligand exchange / substitution / replacement / displacement	**2**
2(e)(iii)	MnO_2 **AND** redox	**1**

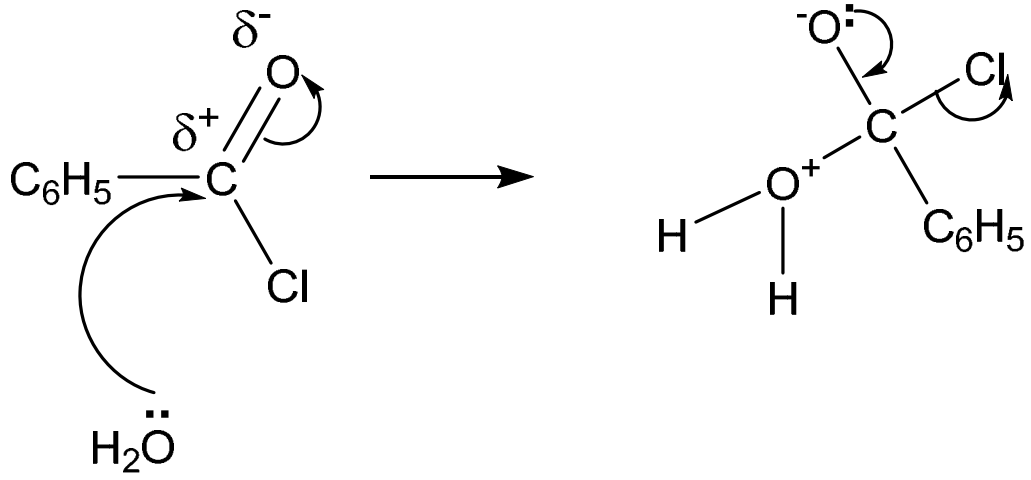
Question	Answer	Marks
3(a)(i)	evidence of tangent drawn at t = 40 s and calculation of gradient = 0.000170 (mol dm^{-3} s^{-1}) min 2sf	**1**
3(a)(ii)	**M1** evidence of construction lines and calculation of two $t_{1/2}$ **OR** evidence of construction lines and times for halving of concentration **M2** deduction: constant half-life / constant time between halving of concentration → 1st order	**2**
3(b)	**M1** two half-lives in 320 s so $t_{1/2}$ = 160 s **M2** k = 0.693 / 160 = 0.00433 s^{-1} ecf min 2sf	**2**
3(c)(i)	voltage / EMF / potential difference when a half-cell is connected to a (standard) hydrogen electrode under standard conditions	**1**
3(c)(ii)	ions move (from the salt bridge) to maintain charge balance / complete the circuit	**1**

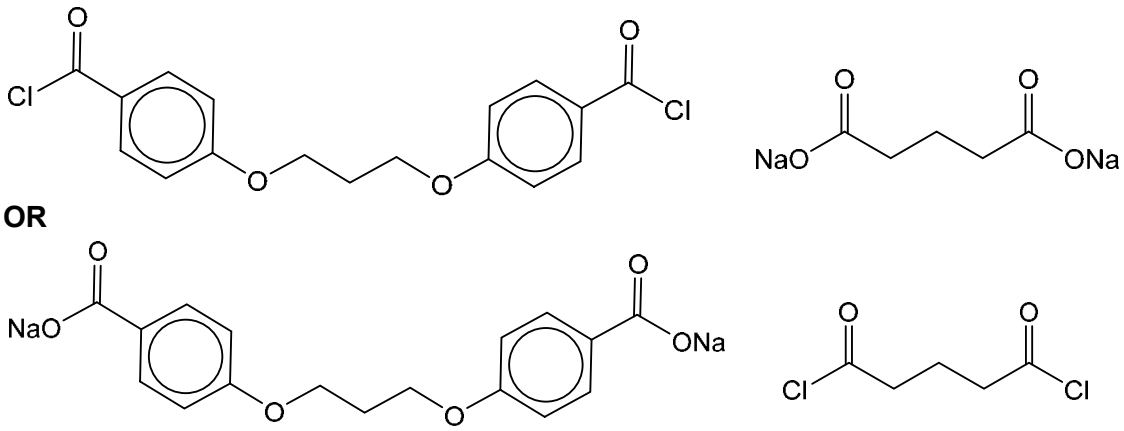
Question	Answer	Marks
3(c)(iii)	 298K, 1 atm, 1 mol dm^{-3} Pt, $H_2(g)$, good delivery system, 298 K, 1 atm Pt, $Cr_2O_7^{2-}(aq)$, $H^+(aq)$ / $Cr^{3+}(aq)$, 1 mol dm^{-3} seen once, voltmeter three for one mark, six for two marks, nine for three marks	**3**
3(c)(iv)	SHE labelled negative **AND** arrow in the external circuit moving away from this electrode	**1**
3(d)(i)	**M1** $Cr_2O_7^{2-} + 3CH_3CHO + 8H^+ \rightleftharpoons 2Cr^{3+} + 3CH_3COOH + 4H_2O$ **ALLOW** $Cr_2O_7^{2-} + 3CH_3CHO + 5H^+ \rightleftharpoons 2Cr^{3+} + 3CH_3COO^- + 4H_2O$ **M1** $E_{cell}^{\ominus} = +2.27$ (V)	**2**
3(d)(ii)	**M1** $\Delta G^{\ominus} = -nFE_{cell}^{\ominus}$ **M2** $\Delta G^{\ominus} = -4 \times 96\,500 \times 2.01 = -775\,860$ J mol^{-1} $\Delta G^{\ominus} = -776$ kJ mol^{-1} min 3sf	**2**

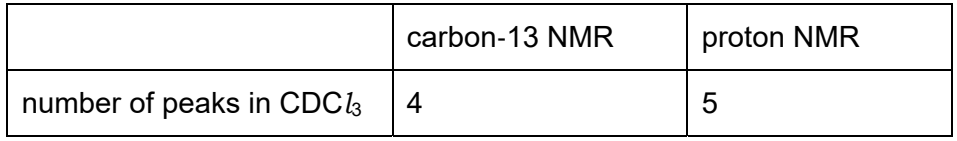
Question	Answer	Marks
4(a)	• five 3d orbitals in the isolated Fe^{2+} ion of same energy • splitting two higher and three lower d orbitals • energy of non-degenerate d orbitals in the complex more than degenerate d orbitals in isolated ion two for one mark, three for two marks	**2**
4(b)(i)	**M1** (a species) that donates / uses two lone pairs **M2** to form dative / coordinate bonds to a metal atom / metal ion / TM / TE / metal	**2**
4(b)(ii)	 **M1** one correct 3D diagram with three bipy ligands **M2** both diagrams correct **M3** optical isomerism	**3**
4(c)	$[Fe(CN)_6]^{3-}$ **AND** equilibrium lies most to the left / lowest $E^{\ominus}$ value	**1**
4(d)	**M1** N sp^2 **AND** C sp^2 **M2** σ bonds are formed by end-on-end overlap orbitals between C-H / C-C / C-N **M3** π bonds are formed by sideways overlap of p orbitals between C-N / C-C	**3**

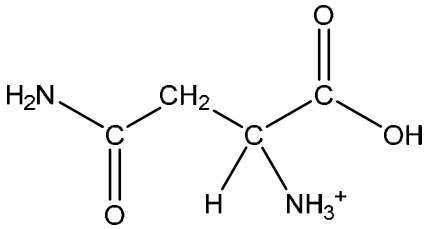
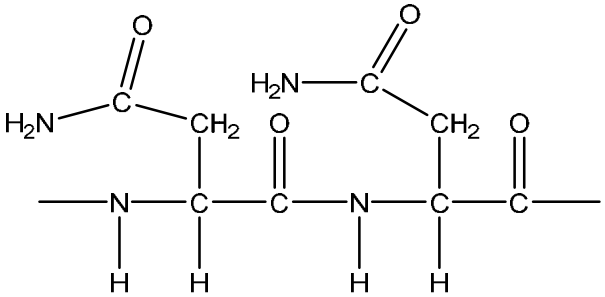
Question	Answer	Marks
4(e)	 **M1** first curly arrow to Cl^+ **M2** correct intermediate **M3** second curly arrow **AND** H^+ formed / lost	**3**

Question	Answer	Marks
5(a)	**M1** benzoic acid > phenol > phenylmethanol **M2** / **M3** *Any two of:* • in benzoic acid negative inductive effect of C=O **AND** O-H bond is weakened **OR** due to delocalisation of minus charge by C=O / 2O carboxylate ion is stabilised • in phenol lone pair on oxygen is delocalised into the ring **AND** O-H bond is weakened • in phenyl methanol positive inductive effect of CH_2 group **AND** O-H bond is strengthened	**3**
5(b)	<table><tr><th></th><th>benzoic acid</th><th>phenylmethanol</th><th>phenol</th></tr><tr><td>Na(s)</td><td>✓</td><td>✓</td><td>✓</td></tr><tr><td>NaOH(aq)</td><td>✓</td><td>×</td><td>✓</td></tr><tr><td>Na_2CO_3(aq)</td><td>✓</td><td>×</td><td>×</td></tr></table> Three correct for one mark, six correct for two marks, nine correct for three marks	**3**

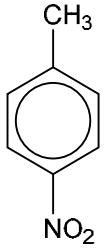
Question	Answer	Marks
5(c)(i)	$POCl_3$ and HCl **AND** SO_2 and HCl	**1**
5(c)(ii)	all the by-products / SO_2 and HCl are gaseous **OR** no liquid by-products formed	**1**
5(d)(i)	 On the left-hand side: • lone pair on O • correct arrow from O to C (of C=O) • dipole on C=O • correct arrow on C=O **M1** / **M2** Two correct for one mark, four correct for two marks On the right-hand side: **M3** correct intermediate **M4** arrow from lone pair on O^- to C-O bond **AND** arrow from C-Cl to Cl	**4**
5(d)(ii)	addition-elimination	**1**

Question	Answer	Marks
5(e)(i)	 **OR**	**2**
5(e)(ii)	hydrolysis **OR** heating in dilute acid / alkali	**1**

Question	Answer	Marks
6(a)	a mixture containing equal amounts of each optical isomer	**1**
6(b)		**1**
6(c)(i)	the pH at which an amino acid exists as a zwitterion **OR** the pH at which an amino acid has no overall charge	**1**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>6(c)(ii)</td><td>  </td><td>1</td></tr>
<tr><td>6(d)</td><td> 
M1 peptide bond displayed
M2 rest of the structure correct + continuation bonds</td><td>2</td></tr>
<tr><td>6(e)</td><td><table><tr><th>spot</th><th>identity</th></tr><tr><td>E</td><td>Asn</td></tr><tr><td>F</td><td>Lys-Asn</td></tr><tr><td>G</td><td>Lys</td></tr></table>
M1 table correctly completed
M2 Lys and Lys-Asn are positively charged OR Asn is (nearly) uncharged
M3 Lys-Asn has the highest M_r</td><td>3</td></tr>
<tr><td>6(f)(i)</td><td>aluminum oxide / silica (on solid support) AND inert gas / named inert gas e.g. N_2</td><td>1</td></tr>
<tr><td>6(f)(ii)</td><td>S AND R_f is the same as the unknown amino acid in both solvents</td><td>1</td></tr>
</table>

Question	Answer	Marks
6(g)	mass of L = 58 / 44 * 5.52 × 10^{-2} = 7.28 × 10^{-2} g conc. of L = 7.28 × 10^{-2} / 116 = 6.27 × 10^{-4} (mol dm^{-3}) min 2sf	**1**

Question	Answer	Marks
7(a)(i)	phenylamine **AND** amine **AND** ester	**1**
7(a)(ii)	sp carbons = 0, sp^2 carbons = 7, sp^3 carbons = 6	**1**
7(b)	6	**1**
7(c)	lone pair on the N can accept a proton	**1**
7(d)(i)		**1**
7(d)(ii)	step 1 **M1** concentrated HNO_3 and H_2SO_4 step 2 **M2** hot (alkaline) $KMnO_4$ (followed by addition of H^+)	**2**
7(e)	step 4 **M1** $HOCH_2CH_2N(CH_2CH_3)_2$ step 5 **M2** Sn **AND** HC*l* **M3** concentrated (HC*l*) **AND** heat / reflux	**3**
7(f)(i)	**M1** ratio of the concentration of a solute in two solvents **M2** at equilibrium	**2**

Question	Answer	Marks
7(f)(ii)	**M1** K_{pc} = [procaine]$_{oct}$ / [procaine]$_{water}$ 1.77 = (x / 50)/(0.5 – x / 75) **M2** 1.77 = 1.5x / 0.5 – x 0.885 –1.77x = 1.5x x = 0.271 g min 2sf	**2**