Cambridge Assessment International Education

Cambridge Pre-U

CHEMISTRY **9791/03**

Paper 3 Part B Written **May/June 2023**

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 2023 series for most Cambridge IGCSE, Cambridge International A and AS Level and Cambridge Pre-U components, and some Cambridge O Level components.

This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

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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.

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.

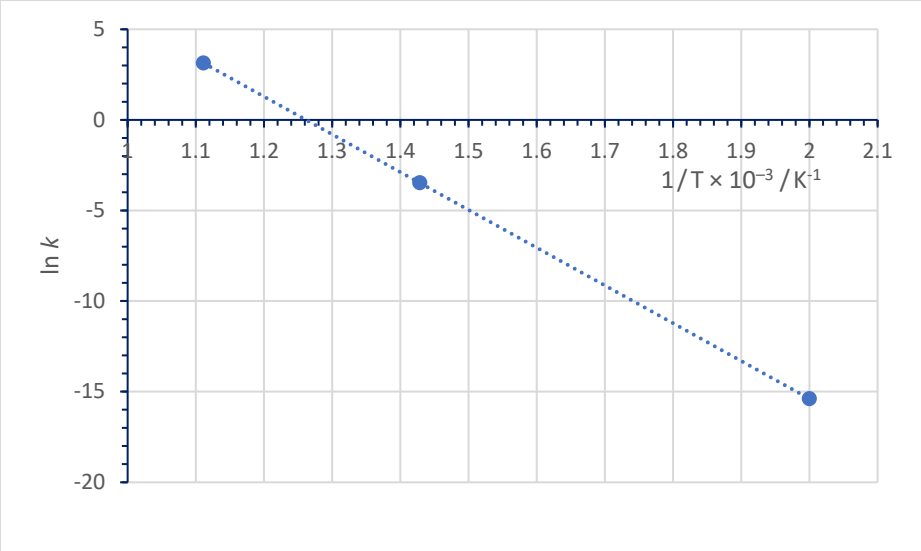
7 Guidance for chemical equations

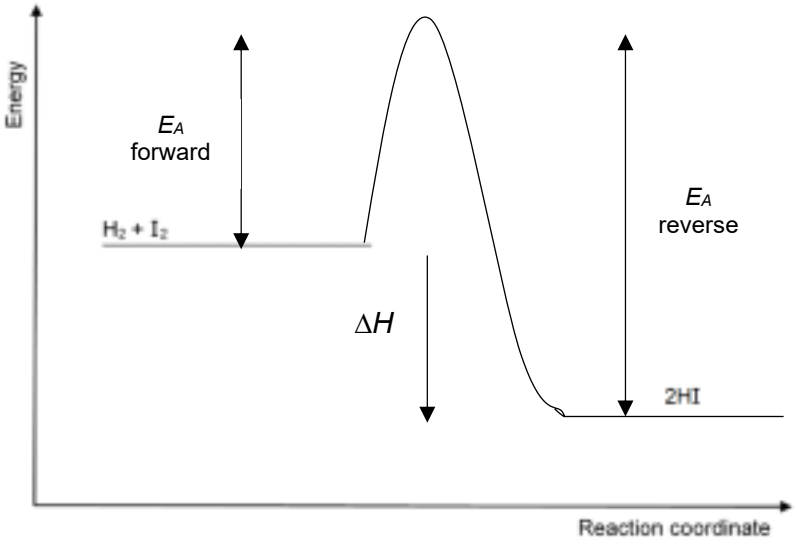
Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

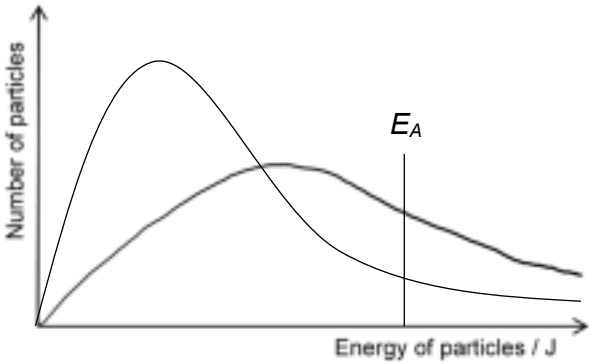
State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

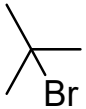
<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1(a)</td><td>$H_2 + I_2 \rightarrow 2HI$</td><td>1</td></tr>
<tr><td>1(b)(i)</td><td>high temperature AND low pressure</td><td>1</td></tr>
<tr><td>1(b)(ii)</td><td>it has stronger van der Waals / intermolecular forces ✓

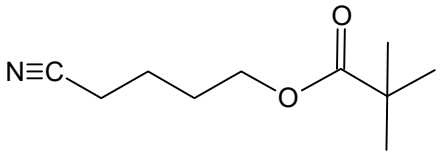
(because) it has more electrons ✓</td><td>2</td></tr>
<tr><td>1(c)(i)</td><td>1st order AND
when $[H_2]$ remains the same $[I_2]$ doubles / comparison of experiment 1 and 2 where
the rate doubles</td><td>1</td></tr>
<tr><td>1(c)(ii)</td><td>1st order AND
ratio of rates and concentrations or other valid (mathematical) method (must consider the change in $[I_2]$)</td><td>1</td></tr>
<tr><td>1(c)(iii)</td><td>(rate =) $k[H_2]\,[I_2]$</td><td>1</td></tr>
<tr><td>1(c)(iv)</td><td>$2.56 \times 10^{-3} / (0.1 \times 0.2) = 0.128$ AND $mol^{-1}\ dm^3\ s^{-1}$ min 3 significant figures</td><td>1</td></tr>
<tr><td>1(c)(v)</td><td>(answer to (c)(iv)) $\times 0.5 \times 0.5$ (= 0.032) OR
$1.28 \times 10^{-3} \times 5 \times 5$ (= 0.032)</td><td>1</td></tr>
<tr><td>1(d)(i)</td><td><table><tr><th>$1 / T$ in K^{-1}</th><th>ln k</th></tr><tr><td>(2.00×10^{-3})</td><td>(–15.39)</td></tr><tr><td>1.43×10^{-3}</td><td>–3.47</td></tr><tr><td>1.11×10^{-3}</td><td>3.14</td></tr></table></td><td>1</td></tr>
</table>

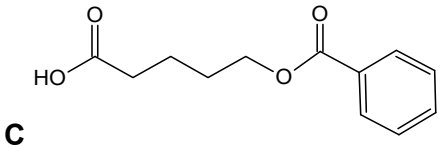
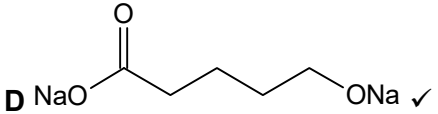
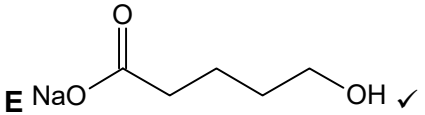
Question	Answer	Marks
1(d)(ii)	 correct plotting within half a small square ✓ straight line of best fit ✓	**2**
1(d)(iii)	gradient of line calculated from graph **AND** must be negative and approximately –20 000 ✓ gradient × –8.31 ✓ answer / 1000 to give kJ mol^{-1} ✓ correct answer with no working scores [1] min 2 significant figures correct answer with / 1000 clearly used scores [3]	**3**

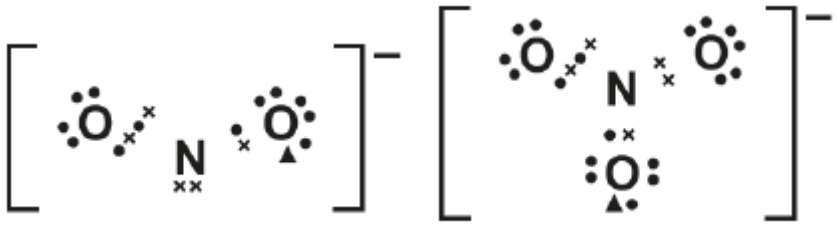
Question	Answer	Marks
1(e)(i)	 E_A forward (ignore arrow heads) ✓ E_A reverse (ignore arrow heads) ✓ ΔH (arrow must go from reactant to product line) ✓ 170.2 – 182.8 = –12.6 (kJ mol^{-1}) ✓	**4**

Question	Answer	Marks
1(f)(i)	 500 K curve correct shape (all correct) ✓ 900 K curve starts at the origin and peaks to the right and below the first ✓ curves cross once only and do not touch the x-axis ✓	**3**
1(f)(ii)	a smaller proportion of/fewer particles are above E_A / have energy to react ✓ so there is a lower frequency of successful collisions ✓ draw E_A on diagram and reference to the area to the right of E_A ✓	**3**

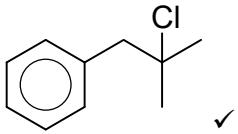
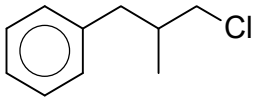
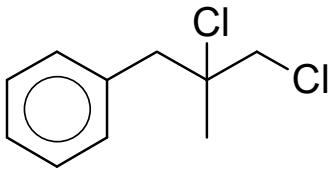
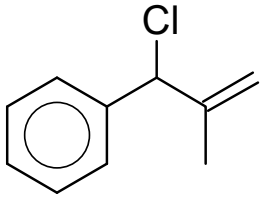
Question	Answer	Marks
2(a)(i)	 structure ✓ 2-bromomethylpropane ✓	**2**
2(a)(ii)	CO_2	**1**

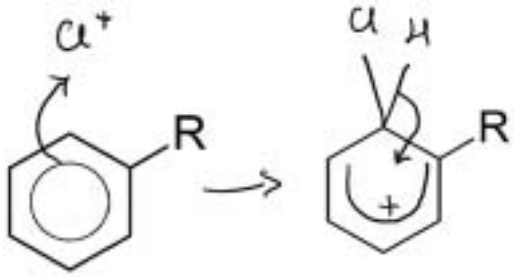
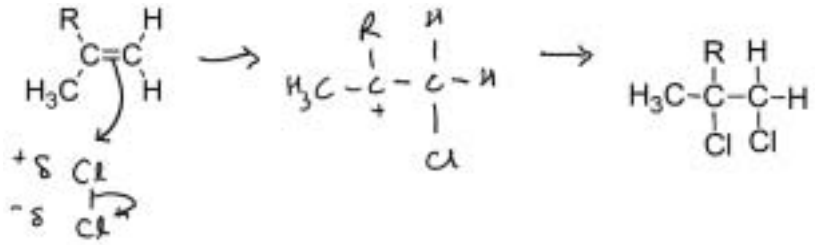
Question	Answer	Marks
2(b)	M_r = 102 g mol^{-1} moles in 200 cm^3 = 5 × (0.4 / 102) = 0.0196 mol dm^{-3} ✓ K_a = $10^{-5.03}$ **OR** = 9.33 × 10^{-6} ✓ [H$^+$] = √(9.33 × 10^{-6} × 0.0196) = 4.28 × 10^{-4} ✓ pH = –log(4.28 × 10^{-4}) = 3.37 ✓ (min 3 significant figures) Correct answer scores [4]	**4**
2(c)	pentanoic acid is stronger / pivalic acid is weaker ✓ (branched chain gives) stronger positive inductive/+I/electron donating effect ✓ which strengthens the O–H bond / destabilises anion (for pivalic acid) ✓	**3**
2(d)(i)	$SOCl_2$ / PCl_3 / PCl_5	**1**
2(d)(ii)	condensation	**1**
2(d)(iii)	 intermediate **B** ✓	**1**
2(d)(iv)	KCN / NaCN	**1**
2(d)(v)	H$^+$ **AND** H_2O **OR** named dilute acid ✓ hydrolysis ✓	**2**

Question	Answer	Marks
2(e)	 **C** ✓  **D** ✓  **E** ✓	**3**

Question	Answer	Marks
3(a)	 1 mark for each structure	**2**
3(b)	(as it is a) lone / electron pair donor **OR** (it has a) lone / electron pair which it can donate	**1**
3(c)(i)	(central) metal atom / ion datively bonded to ligands **OR** (central) metal atom / ion bonded to ligands with coordinate bonds	**1**
3(c)(ii)	octahedral complex and central Co and overall charge (2+) ✓ ligands correct and in correct orientation ✓ shape named as 'octahedral' ✓ complex ion formula $[Co(NH_3)_5(NO_2)]^{2+}$ ✓	**4**

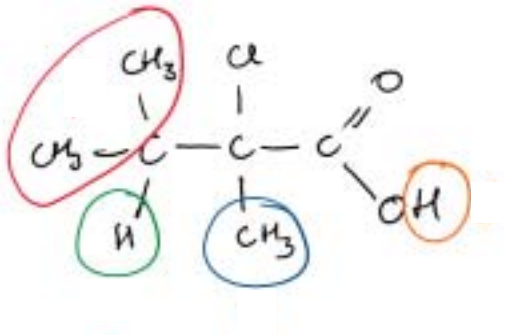
Question	Answer	Marks
3(d)(i)	stoichiometry correct ✓ cycle correct (can be shown in calculation) and final answer ✓ +426.6 + 414.2 – 33.2 – (2 × 358.7) = (+) 90.2 (kJ mol^{-1}) min 3 significant figures correct answer scores [2]	**2**
3(d)(ii)	103.8 (J K^{-1} mol^{-1}) min 3 significant figures	**1**
3(d)(iii)	straight line with a negative gradient ✓ passing through the x-axis at T>0 or approaching x-axis ✓	**2**
3(d)(iv)	use of $\Delta G = \Delta H - T\Delta S$ to give T= $\Delta H/\Delta S$ ✓ 426.6 × 1000 **OR** 318.2 / 1000 ✓ 426600 / 318.2 = 1341 K ✓ Correct answer scores [3] min 3 significant figures	**3**
3(e)(i)	$HNO_2 + H^+ + e^- \rightarrow NO + H_2O$ ✓ (+)0.94 V ✓	**2**
3(e)(ii)	**F** salt bridge / description of a salt bridge ✓ **G** $Fe^{2+}(aq)$ 1mol dm^{-3} and $Fe^{3+}(aq)$ 1 mol dm^{-3} ✓ **H** Pt electrode ✓ arrow on diagram showing electron flow right to left ✓	**4**
3(e)(iii)	(in the $Fe^{3+} \mid Fe^{2+}$ half-cell) the equilibrium moves to the right ✓ this makes $Fe^{3+} \mid Fe^{2+}$ E^θ more positive / larger / increases **AND** makes E^θ_{cell} more negative / less positive / smaller / decreases ✓	**2**

Question	Answer	Marks
4(a)(i)	major  ✓ minor  ✓	**2**
4(a)(ii)	reagent: Cl_2 and conditions: UV light	**1**
4(a)(iii)	only 1 circle on the dichloro product  and on: 	**1**

Question	Answer	Marks
4(b)(i)	$AlCl_3 + Cl_2 \rightarrow AlCl_4^- + Cl^+$ ✓ first curly arrow to Cl^+ **AND** second curly arrow to release H^+ ✓ correct intermediate **AND** H^+ in final box ✓  $AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$ ✓	**4**
4(b)(ii)	electrophilic substitution	**1**
4(c)(i)	 partial charges on Cl_2 ✓ arrow from C=C to Cl and arrow breaking Cl-Cl ✓ structure and charge of intermediate ✓ final arrow to complete structure (from charge or lone pair on Cl^-) ✓	**4**
4(c)(ii)	electrophilic addition	**1**

Question	Answer	Marks
4(d)(i)	2-chloropropane / $CH_3CHClCH_3$	**1**
4(d)(ii)	dehydrogenation / elimination	**1**

Question	Answer	Marks
5(a)(i)	3:1 **OR** 75% to 25%	**1**
5(a)(ii)	$ClCCH_3COOH$ = 107 (for ^{35}Cl) 150 – 107 = 43 C_3H_7 = 43 37 + 12(3+x) + 16(2) + (4+y) = 152 **OR** 35 + 12(3+x) + 16(2) + (4+y) = 150 12x + y = 152 – 47 = 43 C_3H_7 = 43	**1**
5(a)(iii)	$C_6H_{11}O_2{}^{37}Cl + e^- \rightarrow C_6H_{11}O_2{}^{37}Cl^+ + 2e^-$ **OR** $C_6H_{11}O_2{}^{37}Cl \rightarrow C_6H_{11}O_2{}^{37}Cl^+ + e^-$	**1**
5(b)(i)	*Any three from:* non-toxic volatile (so is removed with warming) gives a single peak peak is to the right of most others / peak at 0 so easily compared with others non-reactive / inert	**3**
5(b)(ii)	1	**1**

Question	Answer	Marks
5(b)(iii)	 structure ✓ assignment of **U** and **V** ✓ assignment of **S** and **T** ✓	**3**
5(b)(iv)	(peak **U** hydrogen) is closer to a chlorine/oxygen (which is e^- withdrawing) electron density is withdrawn from proton / deshielded (for peak **U** compared to **S**) peak **U** proton experiences a higher external magnetic field this pushes the peak downfield / away from TMS peak / to the left / increases δ / increases chemical shift	**4**
5(b)(v)	peak **V** / OH / COOH disappears ✓ $RCOOH + D_2O \rightleftharpoons RCOOD + DHO$ ✓	**2**