Cambridge Assessment International Education

Cambridge Pre-U

CHEMISTRY **9791/03**

Paper 3 Part B Written **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 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.

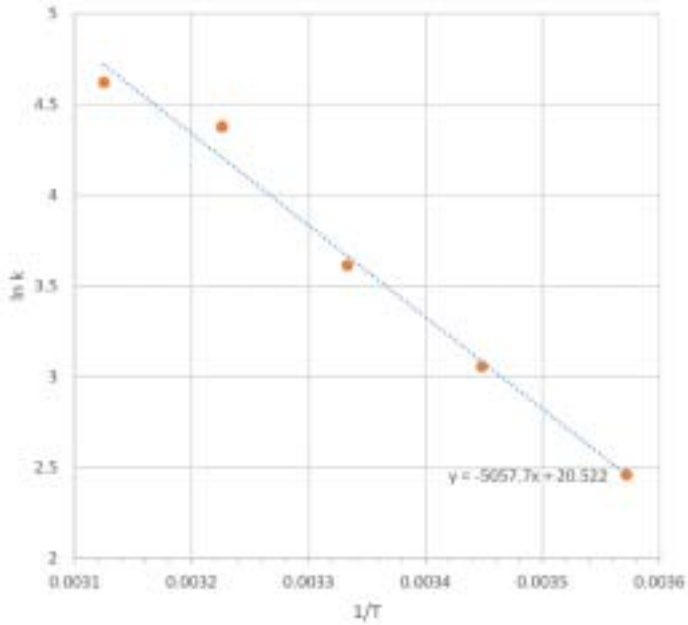
Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

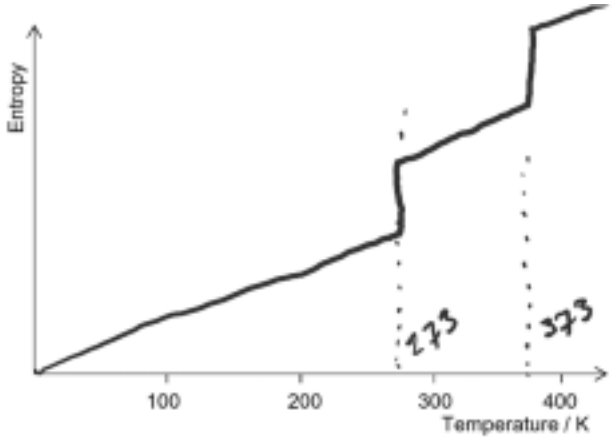
Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

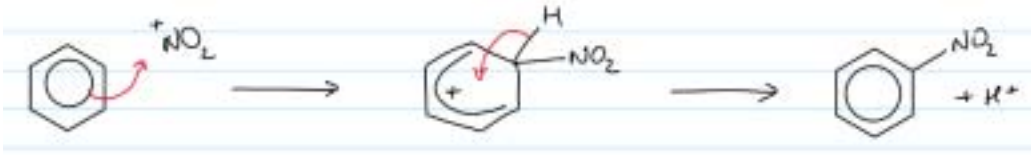
State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

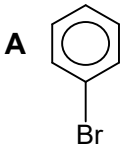
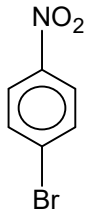
Question	Answer	Marks
1(a)	Hydrolysis	**1**
1(b)	(experiments 1 and 3) As the volume / conc of HCO_2CH_3 doubles, the rate doubles So first order w.r.t. HCO_2CH_3 ✓ (experiments 1 and 2) As the volume / conc of H^+ increases by 1.5, the rate increases by 1.5 So first order w.r.t. H^+ ✓ Rate = $k[HCO_2CH_3][H^+]$ ✓	**3**
1(c)	$n(HCO_2CH_3) = (5 \times 0.974) \div 60 =$ **0.0812** (0.08116666) ✓ $[HCO_2CH_3] = 0.0812 \div (20 / 1000) =$ **4.06** (4.0583333) ✓ $[HCl] = 2.00 \times (10 / 20) = 1.00$ k = rate / $([HCO_2CH_3] \times [HCl])$ $= 9.37 \times 10^{-3} / 4.06$ = **2.31×10^{-3} dm^3 mol^{-1} s^{-1}** min 2sf ✓	**3**
1(d)	Temperature	**1**
1(e)	$HCO_2CH_3 + H^+ \rightarrow C_2H_5O_2^+$ $C_2H_5O_2^+ + H_2O \rightarrow HCO_2H + CH_3OH + H^+$ Step 1 has only **HCO_2CH_3 + H^+ / HCl** as reactants ✓ Sensible intermediate **AND** overall equation correct ✓	**2**
1(f)(i)	$HCO_2CH_3 + OH^- \rightarrow HCO_2^- + CH_3OH$	**1**

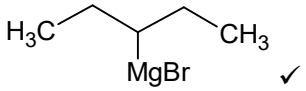
Question	Answer	Marks
1(f)(ii)	 Plotting and line of best fit ✓ Gradient ~ –5000 (K) ✓ Re-arrangement $k = A.\exp(-E_a / RT) \rightarrow \ln k = \ln A + (-E_a / R).(1 / T)$ or use of ✓ $E_a = (5000\ K \times 8.31\ J\ K^{-1}\ mol^{-1}) / 1000 = 41.55\ (kJ\ mol^{-1})$ ✓	**4**
1(g)(i)	Straight line, directly proportional	
1(g)(ii)	decay curve	**1**
1(g)(iii)	horizontal line	**1**

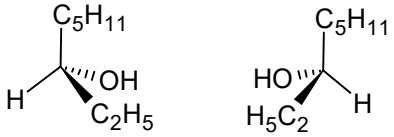
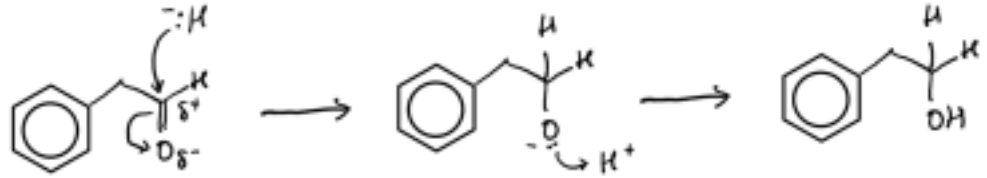
Question	Answer	Marks
2(a)(i)	CO_2 (has the largest *S* as it) is a gas (and K_2CO_3 is a solid) ✓	**1**
2(a)(ii)	(H_2O has a low *S* due to) hydrogen bonding (ordering the liquid) ✓	**1**
2(a)(iii)	155.5 + 213.6 + 69.9 – 2*x* = 208 **OR** 2*x* = (208 – 155.5 – 213.6 – 69.9) ✓ ÷ 2 = (+) **115.5** ✓	**2**
2(a)(iv)	Use of $\Delta G = \Delta H - T\Delta S$ **OR** $\Delta G = 0$ **OR** $T = -\Delta H / \Delta S$ ✓ T = 96 100 ÷ 208 = 462 (K) ✓ T = 462 – 273 = **189** must be 3sf ✓	**3**
2(a)(v)	ΔG = 96 100 – (523 × 208) = –12 684 (J mol^{-1}) **OR** ΔG = 96.1 – (523 × 0.208) = –12.684 (kJ mol^{-1}) ✓ Use of $\Delta G = -RT\ln K$ *K* = exp(–ΔG / RT) = exp–(–12684 ÷ (8.31 × 523)) = **18.51** min 2sf ✓ (Value is > 1) (as you would expect) **AND** eqm to the right ✓ (must be consistent with their decomposition temp from **2(a)(iv)** and K > 1)	**3**

Question	Answer	Marks
2(b)	 Graph starting at origin ✓ General increase ✓ Step-up at 273 and 373 ✓	**3**
2(c)(i)	$K_2CO_3(s) \rightarrow 2K^+(aq) + CO_3^{2-}(aq)$ ✓	**1**
2(c)(ii)	RFM = 2(39.1) + 12 + 3(16) = **138.2** ✓ 138.2 × (1.62 / 2) = **111.9** (g dm^{-3}) ✓	**2**
2(c)(iii)	$K_{sp} = [K^+]^2[CO_3^{2-}]$ ✓ $[CO_3^{2-}]$ = 1.62 ÷ 2 **OR** $[CO_3^{2-}]$ = 0.81 ✓ $K_{sp} = 1.62^2 \times 0.81$ = **2.13** (2.125764) ✓	**3**
2(c)(iv)	(White) ppt forms ✓ Common ion effect due to increase in $[K^+]$ ✓	**2**

Question	Answer	Marks
3(a)	Carbon-carbon σ bonds (in a ring) ✓ Carbons and hydrogens joined by σ bonds ✓ (Overlapping p-orbitals to give a ring of) delocalised p electrons / bonds ✓ Above and below the plane of the molecule ✓	**4**
3(b)	Benzene does not react directly with Br_2 / halogen ✓ So there are no C=C / it is less reactive than Kekule ✓ Benzene is a regular hexagon **OR** all C-C bonds are equivalent in length **OR** C-C bond length is in between C-C and C=C ✓ So does not contain C=C or C-C / C=C are shorter than C-C ✓ Hydrogenation energy is less than expected ✓ So benzene is more stable (to hydrogenation) than expected ✓	**6**
3(c)(i)	$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$ **OR** $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$ ✓  Curly arrow from delocalised ring to NO_2^+ ✓ Structure of intermediate ✓ Curly arrow from C-H and product + H^+ ✓ $HSO_4^- + H^+ \rightarrow H_2SO_4$ ✓	**5**
3(c)(ii)	$C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O$	**1**
3(c)(iii)	NO_2 group is electron-withdrawing ✓ NO_2 group draws electron density from the ring / is deactivating ✓ Ring is less attractive to electrophiles / unable to polarise electrophiles / less susceptible to electrophilic attack ✓	**3**

Question	Answer	Marks
3(d)(i)	**A**  **B** 	**2**
3(d)(ii)	*Reagents depend on answers to* ***(d)(i)*** Step 1: Br_2 and $AlBr_3$ / $FeBr_3$ / Fe ✓ Step 3: conc HCl and Sn ✓	**2**
3(d)(iii)	3 peaks / environments / signals ✓ 2 peaks split into doublets **AND** one singlet / unsplit ✓ Singlet / NH_2 (peak) disappears with D_2O ✓	**3**
3(d)(iv)	4 peaks	**1**

Question	Answer	Marks
4(a)(i)	 ✓	**1**
4(a)(ii)	Mg(OH)Br	**1**
4(b)(i)	carbon bonded to four different atoms / groups	**1**

Question	Answer	Marks
4(b)(ii)	 One isomer correct ✓ The other a mirror image ✓	**2**
4(b)(iii)	No effect (on plane-polarised light) **AND** It is a racemic mixture / it is a racemate / each enantiomer rotates the plane in opposite directions ✓	**1**
4(b)(iv)	The reagent can attack above or below / front or back the <u>planar</u> aldehyde ✓ With equal probability / chance / amount ✓	**2**
4(c)(i)	CO_2 ✓ H^+ ✓	**2**
4(c)(ii)	$LiAlH_4$	**1**
4(c)(iii)	$C_6H_5CH_2COOH + 4[H] \rightarrow C_6H_5CH_2CH_2OH + H_2O$ Species ✓ All correct ✓	**2**
4(c)(iv)	 δ + and δ– on C=O and arrow on C=O ✓ lone pair on H^- and arrow to d^+C ✓ Structure of intermediate ✓ Final arrow to H^+ and lone pair or negative charge on O and correct product ✓	**4**

Question	Answer	Marks
5(a)(i)	$K_a = 10^{-2.55} =$ **2.82×10^{-3}** (ignore units) min 3sf	**1**
5(a)(ii)	$CH_3COCO_2H \rightleftharpoons CH_3COCO_2^- + H^+$ ✓ $K_a = \frac{[CH3COCOO–][H+]}{[CH3COCOOH]}$ ✓	**2**
5(a)(iii)	Pyruvic acid is more acidic / dissociates more / stronger acid / has a lower pH (as pKa is lower) ✓ O-H bond is weaker OR anion / conjugate base is stabilised ✓ As additional C=O / 2 C=O electron withdrawing / –I ✓	**3**
5(b)	$CH_3COCO_2H + H_2SO_4 \rightleftharpoons CH_3COCO_2^+H_2 + HSO_4^-$ base 1 acid 2 acid 1 base 2	**1**
5(c)(i)	Resists / minimises changes in pH ✓ on addition of small / moderate amounts of acid or base / alkali ✓	**2**
5(c)(ii)	$NaOH(s) + CH_3COCOOH(aq) \rightarrow CH_3COCOO^-Na^+(aq) + H_2O(l)$ 1 for species and balancing 1 for state symbols	**2**

Question	Answer	Marks
5(c)(iii)	Initial amounts (1 mark) n(NaOH) = 8.00 ÷ 40 = **0.20** mol n($CH_3COCOOH$) = 2.00 × 0.25 **= 0.50** mol ✓ Eqm amounts (2 marks) NaOH + $CH_3COCOOH$ → $CH_3COCOO^-Na^+$ + H_2O Start 0.2 0.5 0 Change –0.2 –0.2 + 0.2 End 0 **0.3** ✓ **0.2** ✓ (HA) (A^-) pH calculation (3 marks) $K_a = [H^+][A^-] / [HA]$ or use of ✓ $[H^+] = K_a \times ([HA] / [A^-])$ $= 2.82 \times 10^{-3} \times (0.3 / 0.2)$ $= \mathbf{4.23 \times 10^{-3}}$ ✓ pH = $-\log(4.23 \times 10^{-3})$ = **2.37** (2.373659633) min 2dp ✓	**6**