

Markscheme

November 2023

Chemistry

Standard level

Paper 2

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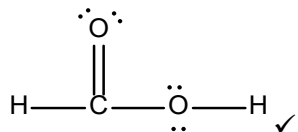
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Subject Details: Chemistry standard level Paper 2 Markscheme

Candidates are required to answer **ALL** questions. Maximum total = **[50 marks]**.

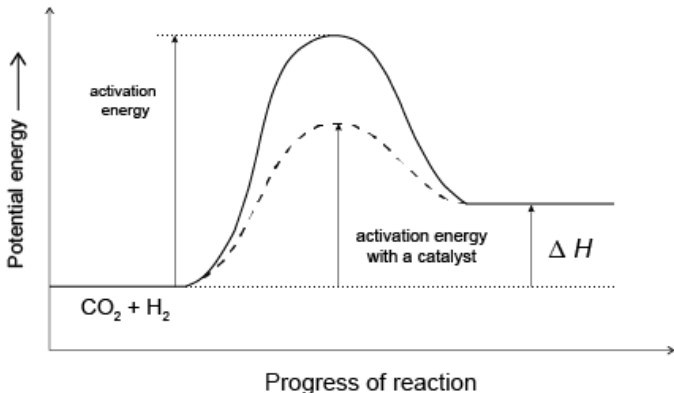
1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “**max**” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. An alternative word is indicated in the “Answers” column by a slash (/). Either word can be accepted.
6. An alternative answer is indicated in the “Answers” column by “**OR**”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading **ALTERNATIVE 1** etc. Either alternative can be accepted.
8. Words inside chevrons « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.
15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the “Notes” column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the “Notes” column.
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the “Notes” column.
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Question			Answers	Notes	Total
1	a		<p><i>Award [1] for two of the following:</i></p> <p>same functional group/family</p> <p>same general formula</p> <p>«successive members» differ by a common structural unit/CH₂ ✓</p>	<p><i>Accept “different chain lengths” for “differ by a common structural unit”.</i></p>	1
1	b			<p><i>Accept any combination of lines, dots and crosses to represent electron pairs.</i></p>	1
1	c		<p>$M_r \llcorner = 12.01 + (2 \times 1.01) + (2 \times 16.00) \llcorner = 46.03$ ✓</p> <p>«M_r of O in molecule = 2 x 16.00 = 32.00»</p> <p>«percentage O = $100 \times \frac{32.00}{46.03}$ » = 69.52% ✓</p>	<p><i>Award [2] for correct final answer.</i></p>	2
1	d	i	<p>«strongest intermolecular forces in» methanoic acid are hydrogen/H-bonds AND ethanal dipole-dipole forces ✓</p> <p>hydrogen/H-bonds stronger «than dipole-dipole forces so methanoic acid has higher boiling point» ✓</p>	<p><i>Do not award marks for answers based on difference in polarity or molar mass.</i></p> <p><i>Do not accept van der Waals' forces for dipole-dipole forces.</i></p>	2
1	d	ii	<p>«both can» form hydrogen bonds with water «molecules» ✓</p>		1

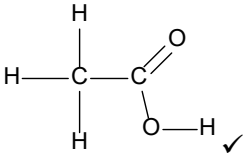
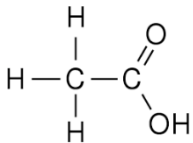
Question			Answers	Notes	Total
1	d	iii	<p><i>Relative electrical conductivity:</i> ethanal < methanoic acid < hydrochloric acid ✓</p> <p>conductivity depends on concentration/amount of ions OR solutions contain increasing concentrations/amounts of ions «in this order» ✓</p> <p>hydrochloric acid is a strong acid/fully dissociated AND methanoic acid is a weak acid/partially dissociated AND ethanal is not acidic/minimally dissociated/undissociated ✓</p>	<p><i>M2 should be awarded if implied through addressing extent of dissociation/ionization in the compounds.</i></p> <p><i>Accept equations with appropriate arrows for M3.</i></p>	3

Question			Answers	Notes	Total
2	a		<p>it removes CO₂ «from the atmosphere» ✓</p> <p>CO₂ is a «major» contributor to climate change / global warming</p> <p>OR</p> <p>CO₂ is a greenhouse gas ✓</p>	<p><i>Accept reduces CO₂ emissions for M1.</i></p> <p><i>Award [1] for reactants are cheap/readily available.</i></p> <p><i>Award [1] for atom economy is 100%.</i></p> <p><i>Award [1] for methanoic acid can be used to manufacture other useful products.</i></p> <p><i>Award [1] for reference to depletion of fossil fuels as a source of organic chemicals.</i></p>	2
2	b		$K_c = \frac{[\text{HCOOH}]}{[\text{CO}_2][\text{H}_2]} \checkmark$		1
2	c	i	<p>ALTERNATIVE 1</p> <p>«bond breaking» C=O + H-H / 804 + 436 / 1240 «kJ» ✓</p> <p>«bond forming» C-H + C-O + O-H / 414 + 358 + 463 / 1235 «kJ» ✓</p> <p>ΔH^\ominus «= 1240 – 1235» = «+»5 «kJ mol⁻¹» ✓</p> <p>ALTERNATIVE 2</p> <p>«bond breaking» 2C=O + H-H / 2(804) + 436 / 2044 «kJ» ✓</p> <p>«bond forming» C=O + C-H + C-O + O-H / 804 + 414 + 358 + 463 / 2039 «kJ» ✓</p> <p>ΔH^\ominus «= 2044 – 2039» = «+»5 «kJ mol⁻¹» ✓</p>	<p><i>Award [3] for correct final answer.</i></p>	3

Question			Answers	Notes	Total
2	c	ii	<p>ALTERNATIVE 1 sum of absolute uncertainties «= 0.804 + 0.436 + 0.414 + 0.358 + 0.463 =» 2.475 «kJ mol⁻¹» ✓</p> <p>percentage uncertainty «= $100 \times \frac{2.475}{5} = 49.5\% = \gg 50 \text{ «\%»}$ ✓</p> <p>ALTERNATIVE 2 sum of absolute uncertainties «= 3(0.804) + 0.436 + 0.414 + 0.358 + 0.463 =» 4.083 «kJ mol⁻¹» ✓</p> <p>percentage uncertainty «= $100 \times \frac{4.083}{5} = 81.7\% = 80 \text{ «\%»}$ ✓</p>	Award [2] for correct final answer.	2
2	d		<p>K_c increases AND endothermic OR K_c increases AND «equilibrium» shifts to the right ✓</p>		1

Question			Answers	Notes	Total
2	e	i	 <p>two curves, each passing through a maximum AND same finishing point ✓</p> <p>endothermic enthalpy change labelled ✓</p> <p>both activation energies correctly labelled ✓</p>	<p>Do not penalize curve showing multiple steps for the catalysis in M1.</p> <p>Accept double-headed arrows or lines in M2 and M3.</p> <p>Accept E_{cat} for catalysed E_a in M3.</p> <p>Award [1 max] for one curve drawn and correctly labelled.</p>	3
2	e	ii	increase pressure ✓	Accept increase «reactant» concentration but not increase amount of reactant.	1
2	f		+2 ✓	Do not accept 2 or 2+.	1

Question			Answers	Notes	Total
3	a		<p><i>Reagent:</i> methanol ✓</p> <p><i>Catalyst:</i> «concentrated» sulfuric acid ✓</p>	<p><i>Do not accept formula for M1.</i></p> <p><i>For M2 accept H₂SO₄/phosphoric acid/H₃PO₄/hydrochloric acid/HCl, but do not accept nitric acid.</i></p>	2
3	b		<p>ALTERNATIVE 1</p> <p>expected yield «$2.83 \times \frac{60.06}{46.03}$» = 3.69 «g» ✓</p> <p>percentage yield «$100 \times \frac{1.72}{3.69}$» = 46.6 «%» ✓</p> <p>ALTERNATIVE 2</p> <p>«amount of methanoic acid used = $\frac{2.83}{46.03}$ => 0.0615 «mol» ✓</p> <p>«expected amount of methyl methanoate = 0.0615 mol»</p> <p>«actual amount of methyl methanoate = $\frac{1.72}{60.06}$ = 0.0286 mol»</p> <p>percentage yield «$\frac{0.0286}{0.0615} \times 100$» = 46.5% ✓</p>	<p><i>Award [2] for correct final answer.</i></p> <p><i>Award [0] for 60.8% (simple ratio of starting and final masses).</i></p>	2

Question			Answers	Notes	Total
3	c	i	<p><i>Similarity:</i> «absorption at» 1700-1750 «cm⁻¹» OR absorption by the carbonyl/C=O bond OR «absorption at» 2850-3090 «cm⁻¹» OR absorption by carbon-hydrogen/C- H bond ✓</p> <p><i>Difference:</i> methanoic acid «has absorption at» 2500-3000 «cm⁻¹ which is absent for methyl methanoate» OR methanoic acid has absorption by the hydroxyl/O-H bond «which is absent for methyl methanoate» ✓</p>	<p>Do not accept the bond without the wavenumber or reference to the spectrum (e.g. absorption, peak, trough). Do not accept absorption of C-O bond at 1050-1410 cm⁻¹ for M1 as it is outside range.</p> <p>Do not accept hydroxide instead of hydroxyl for M2. Do not accept 3200-3600 cm⁻¹ for M2 as O-H is in carboxylic acid.</p>	2
3	c	ii	methyl methanoate AND the ratio «of areas under peaks» is 1:3 ✓	<p>Accept methyl methanoate AND methanoic acid would have a 1:1 ratio.</p> <p>Do not accept answers in terms of chemical shift.</p>	1
3	d		esters ✓		1
3	e			<p>Accept</p> 	1
3	f		<p>ethanal OR ethanol ✓</p>	Do not accept formulas.	1

Question			Answers	Notes	Total
4	a		$\llcorner \sum \Delta H^{\ominus}_{\text{f}} (\text{reactants}) = \gg +88.7 + 2(-241.8) / -394.9 \llcorner \text{kJ mol}^{-1} \gg$ AND $\llcorner \sum \Delta H^{\ominus}_{\text{f}} (\text{products}) = \gg -393.5 + 2(-20.6) / -434.7 \llcorner \text{kJ mol}^{-1} \gg \checkmark$ $\Delta H^{\ominus} \llcorner = -434.7 - (-394.9) \gg = -39.8 \llcorner \text{kJ mol}^{-1} \gg \checkmark$	<p>Award [2] for correct final answer.</p> <p>Award [1] for $+48.2 \llcorner \text{kJ mol}^{-1} \gg$ (obtained using $-285.8 \text{ kJ mol}^{-1}$ for $\text{H}_2\text{O}(\text{l})$).</p>	2
4	b		<p>Molecular geometry CS_2: linear</p> <p>AND</p> <p>Molecular geometry H_2S: bent/V-shaped \checkmark</p> <p>Reason for difference:</p> <p>$\llcorner \text{central atom in} \gg \text{H}_2\text{S}$ has $\llcorner \text{two} \gg$ lone/non-bonding $\llcorner \text{electron} \gg$ <u>pairs</u></p> <p>OR</p> <p>CS_2 has two AND H_2S has four electron domains/negative charge centres $\llcorner \text{around central atom} \gg \checkmark$</p>	<p>Do not accept diagrams for M1 or M2.</p> <p>Accept central atom sp hybridized in CS_2 AND sp^3 hybridized in H_2S for M2.</p>	2
4	c	i	$0.9 \times 32 + 0.01 \times 33 + 0.04 \times 34 + 0.05 \times 36 \checkmark$ $\llcorner A_{\text{r}} = \gg 32.29 \checkmark$	<p>Award [2] for correct final answer.</p> <p>Do not accept 32.07 which is the data booklet value.</p> <p>M2 can only be awarded for answer with two decimal places.</p>	2
4	c	ii	mass spectrometry / MS \checkmark	Accept mass spectroscopy but not mass spectrophotometry.	1
4	c	iii	<p>amount of $^{36}_{16}\text{S} \llcorner = \frac{0.0100}{100} \times \frac{1.00}{32.07} \gg = 3.12 \times 10^{-6} \llcorner \text{mol} \gg \checkmark$</p> <p>number of atoms $\llcorner = 3.12 \times 10^{-6} \text{ mol} \times 6.02 \times 10^{23} \text{ mol}^{-1} \gg = 1.88 \times 10^{18} \checkmark$</p>	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
5	a	i	«contains» mobile/free moving ions ✓	Accept has ions that can carry an «electric» current/charge.	1
5	a	ii	Electrode: cathode AND Polarity: negative ✓		1
5	a	iii	$2 \text{ Cl}^- \rightarrow \text{Cl}_2 + 2 \text{ e}^-$ ✓	Accept $\text{Cl}^- \rightarrow \frac{1}{2} \text{ Cl}_2 + \text{e}^-$. Accept e for e^- . Do not apply ECF.	1
5	b		nuclear charge / number of protons increases «for both» ✓ Li and Be «outer electrons have» same subshell/shielding ✓ electron in B lost from p-subshell whereas that in Be lost from s-subshell ✓ «outer electron in» B/p-subshell experiences greater shielding / has higher energy ✓	Do not accept explanations invoking distance of electrons from nucleus.	4