

Markscheme

May 2023

Chemistry

Higher level

Paper 2

19 pages

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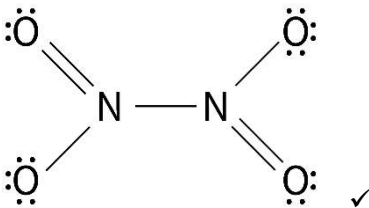
Subject Details: Chemistry higher level Paper 2 Markscheme

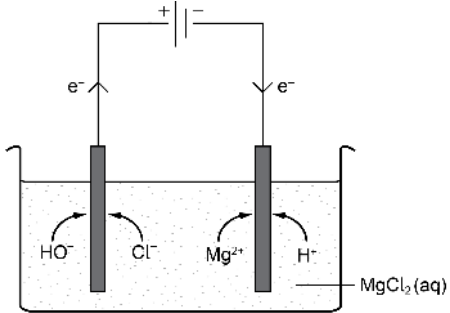
Candidates are required to answer **ALL** questions. Maximum total = [90 marks].

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)	(i)	<p>«n(C) => 4.05 «mol» AND «n(O) => 2.70 «mol» ✓</p> <p>«% H => 8.2% OR «n(H) => 8.12 «mol» ✓</p> <p>«empirical formula => C₃H₆O₂ ✓</p>	Award [2] for the simplest ratio "1.5 C: 3 H: 1 O".	3
1.	(a)	(ii)	<p>m/z 74: molecular ion / M⁺ / C₃H₆O₂⁺ ✓</p> <p>m/z 45: COOH⁺ / C₂H₅O⁺ ✓</p>	Accept loss of CH ₃ CH ₂ / C ₂ H ₅ / CHO for m/z 45.	2
1.	(a)	(iii)	<p>A: O-H «in carboxylic acids» ✓</p> <p>B: C=O ✓</p>		2
1.	(a)	(iv)	$\text{CH}_3 - \text{CH}_2 - \underset{\text{O}}{\underset{\parallel}{\text{C}}} - \text{OH}$ <p style="text-align: right;">✓</p>	Do not accept molecular formula/C ₂ H ₆ O ₂ .	1

Question			Answers	Notes	Total
1.	(b)		<p>T=368 K AND P = 100.0 kPa AND V = 0.0810 dm³ OR T=368 K AND P = 100 000 Pa AND V = 8.1 x 10⁻⁵ m³ ✓</p> $n \ll = \frac{PV}{RT} = \frac{100.0 \times 0.0810}{8.31 \times 368} \gg = 0.00265 \text{ «mol» } \checkmark$ $M \ll = \frac{m}{n} = \frac{0.363 \text{ g}}{0.00265 \text{ mol}} \gg = 137 \text{ «g mol}^{-1}\text{» } \checkmark$	Award [3] for correct final answer.	3
2.	(a)	(i)	reaction hardly proceeds OR reverse reaction/formation of NO ₂ is favoured OR «concentration of» reactants greater than «concentration of» products «at equilibrium» ✓	Accept equilibrium lies to the left.	1
2.	(a)	(ii)	$\Delta G^\ominus = \ll -RT \ln K = -8.31 \times 373 \times \ln(0.0665) \gg = 8.40 \text{ «kJ mol}^{-1}\text{» } \checkmark$		1
2.	(a)	(iii)	$\ll K_c = \frac{1}{0.0665} \gg = 15.0 \checkmark$		1
2.	(a)	(iv)	$\ll \Delta H^\ominus = 2(33.18) - 9.16 \gg = \ll + \gg 57.20 \text{ «kJ mol}^{-1}\text{» } \checkmark$		1

Question			Answers	Notes	Total
2.	(a)	(v)	$\ll \Delta S^\ominus = 2(240.06) - 304.29 = \gg$ $\ll + \gg 175.83 \ll \text{J K}^{-1} \text{ mol}^{-1} \gg \checkmark$		1
2.	(b)			Accept any combination of dots, crosses or lines to represent electron pairs.	1
2.	(c)	(i)	it has resonance structures \checkmark	Accept bond order = 1.5. Accept delocalized electrons «in NO bonds».	1
2.	(c)	(ii)	110-120° \checkmark	Accept any value in the range given. (Bond angle is actually 112.3°.)	1
2.	(d)		$2\text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HNO}_2(\text{aq}) + \text{HNO}_3(\text{aq}) \checkmark$	Accept $\text{N}_2\text{O}_4(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HNO}_2(\text{aq}) + \text{HNO}_3(\text{aq})$	1

Question			Answers	Notes	Total
3.	(a)	(i)	 <p>electron flow from anode to battery OR from battery to cathode ✓</p> <p>Mg²⁺/H⁺ ions to – electrode AND Cl⁻/OH⁻ ions to + electrode ✓</p>	<p>Do not award M1 if electrons are shown in electrolyte.</p>	2
3.	(a)	(ii)	<p><i>Positive electrode:</i> $\text{H}_2\text{O}(\text{l}) \rightarrow \frac{1}{2} \text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^-$ OR $2\text{OH}^-(\text{aq}) \rightarrow \frac{1}{2}\text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + 2\text{e}^-$ ✓</p> <p><i>Negative electrode:</i> $2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ OR $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ ✓</p>	<p>Accept $2\text{Cl}^-(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$ for M1.</p> <p>Award [1max] for correct equations at wrong electrodes.</p>	2

Question			Answers	Notes	Total
3.	(a)	(iii)	layers «of carbon atoms in a giant structure» ✓ delocalized electrons «flow along layers» ✓	Accept suitable diagram for M1. Accept two-dimensional network for M1. Accept electrons are mobile/flow for M2.	2
3.	(b)	(i)	« $n(\text{S}_2\text{O}_3^{2-}) = 0.00500 \text{ mol dm}^{-3} \times 0.0360 \text{ dm}^3 \Rightarrow 0.000180 / 1.80 \times 10^{-4}$ «mol» ✓ « $n(\text{O}_2) = \frac{n(\text{S}_2\text{O}_3^{2-})}{4} / 0.0000450 / 4.50 \times 10^{-5}$ «mol» ✓ « $[\text{O}_2] = \frac{4.50 \times 10^{-5} \text{ mol}}{0.150 \text{ dm}^3} \Rightarrow 0.000300 / 3.00 \times 10^{-4}$ «mol dm ⁻³ » ✓	Award [3] for correct final answer.	3
3.	(b)	(ii)	titrate/measure dissolved oxygen in «another» water sample «stored under controlled conditions five days» later ✓ difference between two values «is BOD» ✓		2
3.	(b)	(iii)	low levels of «organic/oxygen consuming» water pollution ✓		1

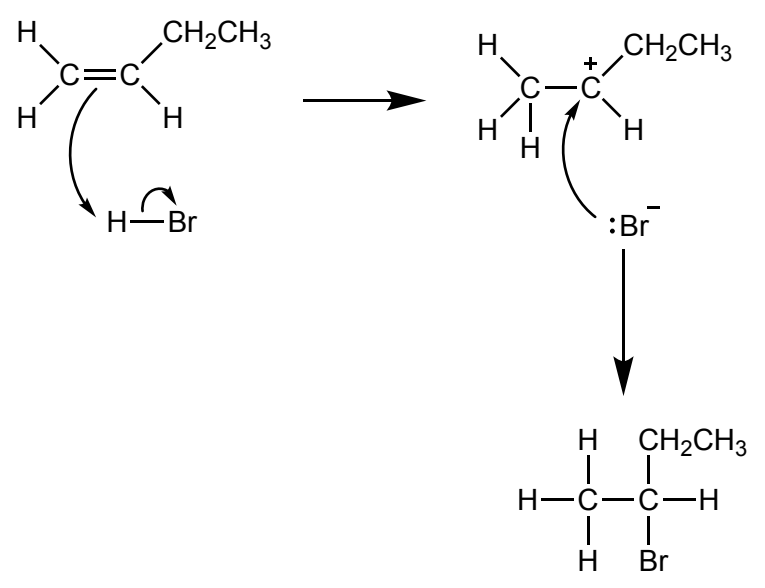
Question			Answers	Notes	Total
4.	(a)		<p><i>Any two of the following:</i></p> <p>«group 15 so Bi has» 5 valence electrons ✓</p> <p>«period 6 so Bi has» 6 «occupied» electron shells/energy levels ✓</p> <p>«in p-block so» p orbitals are highest occupied ✓</p> <p>occupied d/f orbitals ✓</p> <p>has unpaired electrons ✓</p> <p>has incomplete shell(s)/subshell(s) ✓</p>	<p>Award [1] for full or condensed electron configuration, $[Xe] 4f^{14} 5d^{10} 6s^2 6p^3$.</p> <p>Accept other valid statements about the electron configuration.</p>	2 max
4.	(b)		<p>«layers of» cations slide over each other without disrupting bonding</p> <p>OR</p> <p>attraction between metal ions and delocalized electrons/metallic bonding is not disrupted by changing position of metal ions</p> <p>OR</p> <p>metallic bonds are non-directional</p> <p>OR</p> <p>changing the shape does not disrupt the bonding ✓</p>		1
4.	(c)		<p>«heat energy = $11.98 \text{ g} \times 0.902 \text{ J g}^{-1} \text{ K}^{-1} \times 22.0 \text{ K} =$» 238 «J» ✓</p>		1
4.	(d)	(i)	<p>mass spectrometry</p> <p>OR</p> <p>mass spectroscopy</p> <p>OR</p> <p>mass spectrum</p> <p>OR</p> <p>MS ✓</p>		1

Question			Answers	Notes	Total
4.	(d)	(ii)	$(0.0034 \times 36) + (0.0006 \times 38) + (0.996 \times 40) \checkmark$ $39.99 \checkmark$	<p><i>Do not accept 39.96 which is the data booklet value.</i></p> <p><i>M2 can only be awarded for answer with 2 decimal places.</i></p> <p><i>Award [2] for correct final answer.</i></p>	2
5.	(a)	(i)	<p>«[OH⁻] = 0.200 mol dm⁻³»</p> <p>ALTERNATIVE 1: «pOH = -log₁₀(0.200) =» 0.699 ✓ «pH = 14.000 - 0.699 =» 13.301 ✓</p> <p>ALTERNATIVE 2: $\ll[\text{H}^+] = \frac{1.00 \times 10^{-14}}{0.200} = \gg 5.00 \times 10^{-14} \ll \text{mol dm}^{-3} \gg \checkmark$ «pH = -log₁₀(5.00 × 10⁻¹⁴) = 13.301 ✓</p>	<p><i>Award [2] for correct final answer.</i></p>	2
5.	(a)	(ii)	$\text{HCOOH(aq)} + \text{NaOH(aq)} \rightarrow \text{HCOONa(aq)} + \text{H}_2\text{O(l)} \checkmark$	<p><i>Accept ionic equation or net ionic equation.</i></p>	1
5.	(a)	(iii)	<p>«n(acid) = n(OH⁻)»</p> <p>«[acid] = $\frac{0.200 \text{ mol dm}^{-3} \times 22.5 \times 10^{-3} \text{ dm}^3}{25.0 \times 10^{-3} \text{ dm}^3}$ = 0.180 «mol dm⁻³» ✓</p>		1

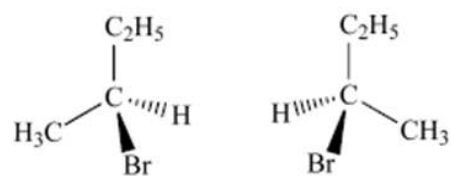
Question			Answers	Notes	Total
5.	(a)	(iv)	<p>ALTERNATIVE 1: $\ll K_a = 10^{-3.75} = 1.78 \times 10^{-4} \gg$ $[H^+] = \sqrt{K_a \times [HCOOH]} / \sqrt{1.78 \times 10^{-4} \times 0.180} / 5.66 \times 10^{-3} \ll \text{mol dm}^{-3} \gg \checkmark$ $\text{pH} \ll = -\log_{10}(5.66 \times 10^{-3}) \gg = 2.247 \checkmark$</p> <p>ALTERNATIVE 2: $\text{pH} = 0.5(\text{p}K_a - \log_{10}[HCOOH]) \checkmark$ $\text{pH} = 2.247 \checkmark$</p>	Award [2] for correct final answer.	2
5.	(a)	(v)	<p>phenolphthalein OR phenol red \checkmark</p> <p>colour change in the pH range of equivalence point \checkmark</p>	Accept pH «at equivalence» > 7 for M2	2
5.	(b)		$\text{HCOO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HCOOH}(\text{aq}) + \text{OH}^-(\text{aq}) \checkmark$	Accept $\text{HCOO}^-(\text{aq}) + \text{Na}^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HCOOH}(\text{aq}) + \text{Na}^+(\text{aq}) + \text{OH}^-(\text{aq})$	1

Question		Answers	Notes	Total
6.	(a)	«measure change in» mass OR pressure OR volume of gas/CO ₂ produced OR «intensity of» colour OR «electrical» conductivity OR pH ✓ with time ✓	Accept any of the following for M1: perform experiment on balance OR use pressure probe OR collect gas/gas syringe OR use colorimeter OR use conductivity meter OR use pH meter Do not accept “measure rate of change” for M2.	2
6.	(b)	provides an alternative reaction pathway AND lower activation energy/ E_a ✓ larger fraction/number of molecules with $E \geq E_a$ /enough energy «for a successful collision» ✓		2
6.	(c)	(i) <i>Structural formula:</i> $ \begin{array}{ccccccc} & & & \text{H} & & \text{H} & \\ & & & & & & \\ \text{H} & - & \text{C} & - & \text{O} & - & \text{C} & - & \text{C} & - & \text{H} \\ & & & & & & & & & & \\ & & \text{O} & & & & \text{H} & & \text{H} & & \\ & & & & & & & & & & \checkmark \end{array} $ <i>Name:</i> ethyl methanoate ✓		2

Question			Answers	Notes	Total
6.	(c)	(ii)	<p>Number of signals: 3 ✓</p> <p>Splitting patterns: singlet/1 AND quartet/4 AND triplet/3 ✓</p>		2
6.	(c)	(iii)	<p>Any two of the following: chemical shift/signal outside range of common chemical shift/signal ✓</p> <p>strong signal/12/all H atoms in same environment ✓</p> <p>singlet/no splitting of signal ✓</p> <p>volatile/easily separated/easily removed ✓</p> <p>inert/stable ✓</p> <p>soluble in most organic solvents ✓</p>	Do not accept chemical shift = 0.	2 max
6.	(d)	(i)	$\text{CH}_3\text{CH}_2\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{g})$ ✓	Accept $\text{C}_2\text{H}_6\text{O}$ for ethanol.	1
6.	(d)	(ii)	<p>«bond breaking» 1 C-C + 5 C-H + 1 C-O + 1 O-H + 3 O=O / 346 + 5(414) + 358 + 463 + 3(498) / 4731 «kJ» ✓</p> <p>«bond forming» 4 C=O + 6 O-H / 4(804) + 6(463) / 5994 «kJ» ✓</p> <p>$\Delta H \llcorner = 4731 - 5994 \llcorner = -1263 \llcorner \text{kJ mol}^{-1} \llcorner$ ✓</p>	Award [3] for correct final answer.	3

Question			Answers	Notes	Total
7.	(a)		«electrophilic» addition/A _E ✓	Do not accept nucleophilic addition.	1
7.	(b)	(i)	 <p>curly arrow going from C=C to H of HBr AND curly arrow showing Br leaving ✓ correct representation of carbocation ✓ curly arrow going from lone pair/negative charge on Br- to C⁺ ✓ CH₃CHBr(CH₂CH₃)/correct final product ✓</p>	Award [3 max] for the correct mechanism of formation of the minor product.	4

Question			Answers	Notes	Total
7.	(b)	(ii)	carbocation with ethyl group is stabilized OR secondary carbocation more stable «than primary carbocation» ✓ greater electron releasing/inductive effect of «two» electron releasing alkyl groups «on secondary carbocation compared to one on primary carbocation» ✓	Do not accept 'Markovnikov's rule' /C with most hydrogen atoms without reference to stability of carbocation.	2
7.	(c)		$ \begin{array}{cccccc} \text{H} & \text{C}_2\text{H}_5 & \text{H} & \text{C}_2\text{H}_5 & \text{H} & \text{C}_2\text{H}_5 \\ & & & & & \\ \text{---C---} & \text{C---} & \text{C---} & \text{C---} & \text{C---} & \text{C---} \\ & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $ ✓	Ignore brackets and 'n'. Continuation bonds must be shown. Ethyl groups do not all have to be on one side. Accept head-to-tail or head-to-head orientation of monomer units.	1
7.	(d)		«both» sp ² ✓		1

Question		Answers	Notes	Total
7.	(e)	<p>Any three of the following:</p> <p>mixing of an s AND two p orbitals forms «three» sp^2 /hybrid orbitals ✓</p> <p>σ bond is overlap «of sp^2 orbitals» along axial/internuclear axis OR head-on/end-to-end overlap «of sp^2 orbitals» ✓</p> <p>one p electron from each C does not hybridize ✓</p> <p>π bond is overlap «of p-orbitals» above and below internuclear axis OR sideways overlap «of parallel p orbitals» ✓</p>	Accept suitable diagrams.	3
7.	(f)	 <p>correct isomer ✓ mirror image shown clearly ✓</p>	Do not accept Fischer projections.	2

Question			Answers	Notes	Total
8.	(a)	(i)	<p>correct boxes ✓</p> <p>A: enthalpy of solution / $\Delta H_{\text{solution}}$ / ΔH_{sol} AND B: lattice enthalpy / $\Delta H_{\text{lattice}}$ AND C: enthalpy of hydration / $\Delta H_{\text{hydration}}$ ✓</p>		2
8.	(a)	(ii)	$\ll \Delta H_{\text{solution}} = \Delta H_{\text{lattice}} + \Delta H_{\text{hydration}}$ $= 2540 + (-1963) + 2(-359) = \gg$ $-141 \ll \text{kJ mol}^{-1} \gg \checkmark$		1
8.	(b)		ionic radius Ba^{2+} is greater than that of Mg^{2+} ✓ weaker attraction between « Ba^{2+} and Cl^- » ions ✓		2
8.	(c)	(i)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$ ✓		1

Question			Answers	Notes	Total
8.	(c)	(ii)	<p>Type of bond: coordinate/dative/covalent ✓</p> <p>How the bond forms: oxygen/water molecule /ligand donates e⁻ pair to cobalt«(II) ion» ✓</p>		2
8.	(c)	(iii)	<p>magnitude of ΔE/energy gap between split d-orbitals differs «according to ligand» ✓</p> <p>ΔE/energy gap determines the wavelength of light absorbed/colour «of complex» OR energy absorbed by electrons «to transition/to be promoted to higher levels» corresponds to different wavelengths of light/colour ✓</p>	Reference to different energy gap/splitting of d-orbitals needed for M1.	2
9.	(a)		<p>H⁺: second order AND BrO₃⁻: first order AND Br⁻: first order ✓</p> <p>«rate =>» k[Br⁻][BrO₃⁻][H⁺]² ✓</p>	Award [2] for correct rate equation.	2

Question		Answers	Notes	Total
9.	(b)	$\ll \ln \left(\frac{k_1}{k_2} \right) = \frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \gg$ $\ln \left(\frac{1}{3} \right) = \frac{E_a}{8.31} \left(\frac{1}{323} - \frac{1}{298} \right) \checkmark$ $\ll E_a = \frac{\ln \left(\frac{1}{3} \right) \times 8.31}{\left(\frac{1}{323} - \frac{1}{298} \right)} \gg$ $\ll E_a = \gg 35.1 \ll \text{kJ mol}^{-1} \gg \checkmark$	<p>Award [2] for correct final answer.</p>	<p>2</p>