

Markscheme

May 2024

Chemistry

Higher level

Paper 2

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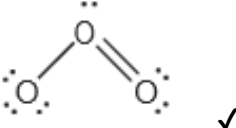
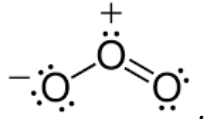
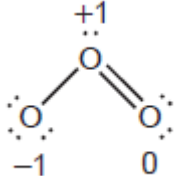
Subject Details: Chemistry higher level Paper 2 Markscheme

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.

Ignore missing or incorrect state symbols in an equation unless directed otherwise in the “Notes” column.

Question		Answers	Notes	Total
1.	(a)	percentages do not add up to 100% OR contains oxygen ✓		1
1.	(b)	oxygen/O content = «100 – 71.93 – 12.10 =» 15.97% OR C: « $\frac{71.93}{12.01}$ =» 5.99 mol AND H: « $\frac{12.10}{1.01}$ =» 11.98 mol ✓ C ₆ H ₁₂ O ✓	Award [2] for correct formula.	2
1.	(c)	« $M = \frac{d \times RT}{p} = \frac{2.544 \times 10^3 \text{ g m}^{-3} \times 8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 473 \text{ K}}{1.00 \times 10^5 \text{ Pa}}$ =» OR $n = \frac{pV}{RT} = \frac{1.00 \times 10^5 \text{ Pa} \times 1.00 \text{ m}^3}{8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 473 \text{ K}} = \text{» } 25.4 \text{ «mol per m}^3\text{» ✓}$ « $M = \text{» } 1.00 \times 10^2 \text{ «g mol}^{-1}\text{» AND C}_6\text{H}_{12}\text{O ✓}$		2
1.	(d)	O–H ✓		1
1.	(e)	carboxyl OR COOH/CO ₂ H ✓	Accept carboxylic acid.	1
1.	(f)	primary alcohol with C=C AND 6 carbons and 12 hydrogens ✓	Accept “primary alcohol with ring/cyclic structure AND 6 carbons and 12 hydrogens”.	1

Question			Answers	Notes	Total
2.	(a)		<p>Electron configuration: $1s^2 2s^2 2p^4$ ✓</p> <p>Unpaired electrons: 2 ✓</p>		2
2.	(b)	(i)		<p>Accept any combination of dots, crosses and lines for electron pairs, including an arrow for the coordinate bond. Do not accept delocalized structures.</p> <p>Accept </p>	1
2.	(b)	(ii)	 <p>formal charge of central O = +1 ✓</p> <p>formal charge of single bonded O = -1 AND double bonded O = 0 ✓</p>		2

(continued...)

(Question 2 continued)

Question			Answers	Notes	Total
2.	(b)	(iii)	bent/angular/V-shaped ✓ any estimated value in the range 110° – 119° ✓	Accept a bent diagram for M1.	2
2.	(b)	(iv)	sp ² ✓		1
2.	(c)		«both equal and» any estimated value in the range 122–147 «pm» ✓ resonance OR delocalization OR bond order is 1.5 ✓		2
2.	(d)		shorter wavelength radiation/UV needed to break the bond in O ₂ ✓ O ₂ has stronger bond ✓		2
2.	(e)	(i)	negative/inverse «correlation» OR one concentration increases as the other decreases ✓	Do not accept an answer that includes the term “proportional”.	1

(continued...)

(Question 2 continued)

Question			Answers	Notes	Total
2.	(e)	(ii)	<p>Any two of: evidence/supports «the claim» but does not prove the claim OR correlation does not imply causation ✓ mechanism/explanation of the link is needed ✓ other factor«s» may have caused these changes ✓</p>	<p>Accept $Cl\cdot + O_3 \rightarrow ClO\cdot + O_2$ OR $ClO\cdot + O_3 \rightarrow Cl\cdot + 2O_2$ OR $ClO\cdot + O_3 \rightarrow ClO_2 + O_2$ for M2 (without penalizing missing radical symbols). Accept CFCs/Cl radicals deplete ozone AND ClO is part of the depletion mechanism for M2.</p>	2 max
2.	(e)	(iii)	<p>«$c=v\lambda$» «$\frac{3.00 \times 10^8 m s^{-1}}{4.53 \times 10^{-7} m} = \gg 6.62 \times 10^{14} \text{ «Hz» } \checkmark$» «$E=hf = (6.62 \times 10^{-34} s^{-1}) (6.63 \times 10^{14} Hz) = \gg 4.39 \times 10^{-19} \text{ «J» } \checkmark$»</p>		2

Question			Answers	Notes	Total
3.	(a)	(i)	<p>acid rain/deposition OR smog ✓</p>	<p>Accept any specific environmental problem caused by acid deposition or smog.</p>	1

(continued...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	(a)	(ii)	$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$ OR $\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_3(\text{aq})$ OR $2\text{SO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{SO}_4(\text{aq}) \quad \checkmark$		1
3.	(b)	(i)	$\text{H}_2\text{O}(\text{l}) + \text{Na}_2\text{O}(\text{s}) \rightarrow 2\text{NaOH}(\text{aq}) \quad \checkmark$		1
3.	(b)	(ii)	<p>«$[\text{OH}^-] = 2 \times 0.100 = 0.200 \text{ mol dm}^{-3}$»</p> <p>Alternative One:</p> $[\text{H}^+] = \ll \frac{1.00 \times 10^{-14}}{0.200} = \gg 5.00 \times 10^{-14} \text{ «mol dm}^{-3}\text{»} \quad \checkmark$ <p>«$\text{pH} = -\log 5.00 \times 10^{-14} = \gg 13.30 \quad \checkmark$</p> <p>Alternative Two:</p> <p>«$\text{pOH} = -\log 0.200 = \gg 0.699 \quad \checkmark$</p> <p>«$\text{pH} = 14.00 - 0.699 = \gg 13.30 \quad \checkmark$</p>		2

(continued...)

(Question 3 continued)

Question			Answers	Notes	Total
3.	(c)		$[H^+] = \sqrt{K_a \times [HCN]} / \sqrt{6.17 \times 10^{-10} \times 0.202} \checkmark$ $[H^+] = 1.116 \times 10^{-5} \text{ «mol dm}^{-3}\text{»} \checkmark$ pH = 4.95 \checkmark	Award [3] for correct final answer.	3
3.	(c)	(ii)	$[H^+] \ll 0.202$ / negligible dissociation OR $[H^+]$ from dissociation of H ₂ O negligible \checkmark	Accept $[HCN]_{initial} = [HCN]_{eqm.}$	1
3.	(c)	(iii)	combine «HCN» with «a similar concentration of» its conjugate base/CN ⁻ OR partial neutralization «with strong base/OH ⁻ » \checkmark	Accept CN ⁻ salts.	1

Question		Answers	Notes	Total
4.	(a)	$\llcorner K_c = \frac{[[CuCl_4]^{2-}]}{[Cu^{2+}][Cl^-]^4} \checkmark$		1
4.	(b)	$\frac{[[CuCl_4]^{2-}]}{[Cu^{2+}]} = 4.2 \times 10^5 \times 0.210^4 \checkmark$ $= 820 \checkmark$	Award [2] for correct final answer.	2
4.	(c)	<p>Any three from: partially filled d-orbital«s» ✓</p> <p>d-orbitals split ✓</p> <p>light /energy is absorbed as electrons transit to a higher energy level «in d–d transitions» OR light /energy is absorbed as electrons are promoted ✓</p> <p>energy gap / light absorbed corresponds «to light in» the visible region of the spectrum ✓</p>		3 max

(continued...)

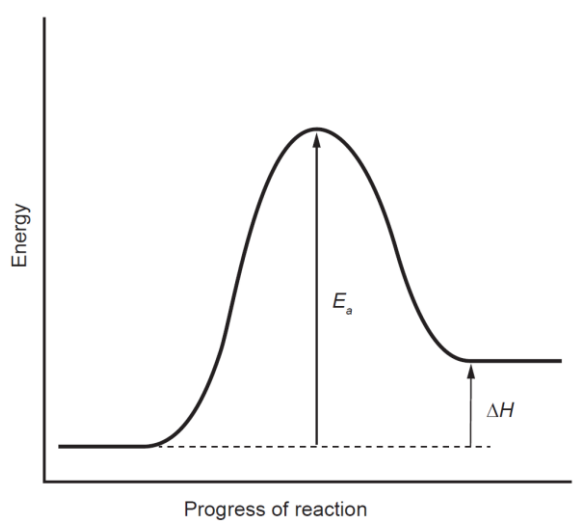
(Question 4 continued)

Question		Answers	Notes	Total
4.	(d)	K_c increases AND «forward» reaction is endothermic ✓	.	1
4.	(e)	reaction shifts to right AND to remove excess Ag^+ ✓	Accept “reaction shifts to left AND to replace Cl^- removed” (as candidates may refer to effect on equilibrium reaction in 4(a)).	1

Question		Answers	Notes	Total
5.	(a)	Any two of: eth: contains two carbon atoms ✓ en: contains a carbon-carbon double bond / $\text{C}=\text{C}$ ✓ one: contains a carbonyl / $\text{C}=\text{O}$ ✓	Accept “alkene” for $\text{C}=\text{C}$ and “ketone” for $\text{C}=\text{O}$. Award [1 max] if two structural features given without relating to the relevant part of IUPAC name.	2 max
5.	(b)	both have «similar» London/dispersion forces «due to having same number of electrons/similar M_r » ✓ ethenone has dipole-dipole forces «and carbon dioxide does not» ✓		2
5.	(c)	(i) « $\Delta H^\circ = \sum \Delta H^\circ_{f \text{ products}} - \sum \Delta H^\circ_{f \text{ reactants}}$ » = $-74.0 - 87.2 + 248$ ✓ = «+»86.8 «kJ» ✓	Award [2] for correct final answer. Award [1] for -86.8 «kJ».	2

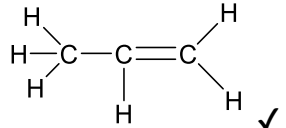
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(Question 5 continued)

Question			Answers	Notes	Total
5.	(c)	(ii)	 <p>endothemic graph AND labelled arrow/line showing ΔH ✓</p> <p>labelled arrow/line showing E_a ✓</p>		2
5.	(d)		<p>CH_3COOH / ethanoic acid ✓</p> <p><i>Award [2 max] for any two of:</i></p> <ul style="list-style-type: none"> «m/z=» 60 due to molecular ion/CH_3COOH^+ ✓ «m/z=» 15 due to CH_3^+ / due to loss of COOH^+ ✓ «m/z=» 43 due to CH_3CO^+ / due to loss of OH^+ ✓ «m/z=» 45 due to COOH^+ / due to loss of CH_3^+ ✓ 	<p><i>Accept molar/molecular mass is 60.</i></p>	3 max

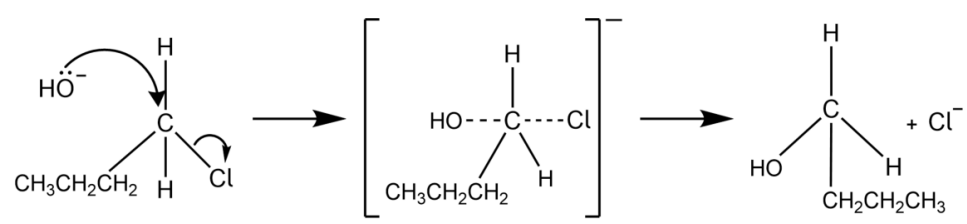
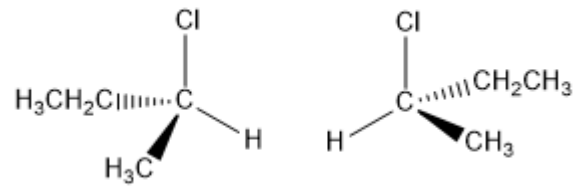
(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	(e)		20.0 «cm ³ » of O ₂ (g) reacts OR 80.0 «cm ³ » of O ₂ (g) remains OR 20.0 «cm ³ » of CO ₂ (g) produced ✓ 100 «cm ³ » ✓	Award [2] for correct final answer.	2
5.	(f)		intermolecular forces no longer negligible/OWTTE OR volume occupied by molecules no longer negligible «compared to the total volume» ✓		1
5.	(g)				1
5.	(h)	(i)	S _N 2 ✓		1

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	(h)	(ii)	 <p>curly arrow going from lone pair/negative charge on «O in» OH^- to C AND curly arrow showing Cl leaving ✓</p> <p>representation of transition state showing negative charge, square brackets, and partial bonds ✓</p> <p>$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ AND Cl^- / correct final products ✓</p>	<p>Accept curly arrow showing Cl^- leaving in the transition state.</p> <p>Award [2 max] for correct $\text{S}_{\text{N}}2$ mechanism.</p> <p>Do not penalize if OH and Cl are not at 180°.</p>	3
5.	(i)	(i)	<p>✓</p> 		1

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	(i)	(ii)	«use a» polarimeter OR rotate «plane of» polarized light ✓ in opposite directions/rotations ✓		2

Question			Answers	Notes	Total
6.	(a)	(i)	[RCl]: 6.00×10^{-6} «mol dm ⁻³ as this is y intercept» ✓ <i>Initial rate:</i> «is equal to –» gradient of tangent at time 0s OR tangent drawn at time 0 AND evidence of gradient calculation ✓ 6.4×10^{-8} «mol dm ⁻³ s ⁻¹ » ✓		3
6.	(a)	(ii)	«order with respect to» OH ⁻ = 1 ✓ «order with respect to» RCl = 1 ✓		2

(continued...)

(Question 6 continued)

Question			Answers	Notes	Total
6.	(a)	(iii)	$K = \frac{3.20 \times 10^{-8} \text{ «mol dm}^{-3} \text{ s}^{-1}\text{»}}{3.00 \times 10^{-6} \text{ «mol dm}^{-3}\text{»} \times 2.00 \times 10^{-2} \text{ «mol dm}^{-3}\text{»}} \text{»} 0.533 \checkmark$ dm ³ mol ⁻¹ s ⁻¹ ✓		2
6.	(b)		more particles will possess the necessary activation energy OR more particles with $E > E_a$ ✓ more «successful» collisions per unit time OR the frequency of collisions increases ✓		2

Question			Answers	Notes	Total
7.	(a)		X-ray crystallography ✓		1
7.	(b)		NaBr: ionic AND electrostatic attraction between oppositely charged ions/ Na ⁺ «ions»/cations and Br ⁻ «ions»/anions ✓ Na: metallic AND electrostatic attraction between Na ⁺ «ions»/cations and delocalized electrons ✓	Award [1 max] for “NaBr is ionic” AND “Na is metallic”.	2

(continued...)

(Question 7 continued)

Question		Answers	Notes	Total
7.	(c)	<p>Positive electrode (anode): $2\text{Br}^- \rightarrow \text{Br}_2 (\text{g}) + 2\text{e}^- \checkmark$</p> <p>Negative electrode (cathode): $\text{Na}^+ + \text{e}^- \rightarrow \text{Na} (\text{l}) \checkmark$</p>	<p>Award [1 max] if equations are given for wrong electrodes.</p>	2
7.	(d)	<p>Positive electrode (anode): bromine/$\text{Br}_2 \checkmark$</p> <p>Negative electrode (cathode): hydrogen gas/$\text{H}_2 \checkmark$</p>	<p>Award [1max] for correct products at inverted electrodes.</p>	2
7.	(e)	<p>anode: Mg AND Electrolyte: $\text{Mg}^{2+} \text{ «(aq)» } \checkmark$</p> <p>cathode: Zn AND Electrolyte: $\text{Zn}^{2+} \text{ «(aq)» } \checkmark$</p>	<p>Accept specific salts as electrolytes.</p>	2
7.	(f)	<p>$\text{«}\frac{1}{2} \Delta H^\circ_{\text{Br-Br}} = \frac{1}{2} (193 \text{ kJ mol}^{-1}) \Rightarrow 96.5 \text{ «kJ mol}^{-1}\text{»}$</p> <p>OR</p> <p>$\text{«}\frac{1}{2} \Delta H^\circ_{\text{atom,Br}} = \frac{1}{2} (30 \text{ kJ mol}^{-1}) \Rightarrow 15 \text{ «kJ mol}^{-1}\text{» } \checkmark$</p> <p>$\text{«}\Delta H^\circ_{\text{IE,Na}} = 496 \text{ «kJ mol}^{-1}\text{» } \text{AND } \text{«}\Delta H^\circ_{\text{AEBr}} = -325 \text{ «kJ mol}^{-1}\text{» } \checkmark$</p> <p>$\text{«}\Delta H^\circ_{\text{lattice}} = \Delta H^\circ_{\text{atom,Na}} + \Delta H^\circ_{\text{atom,Br}_2} + \Delta H^\circ(\text{Br-Br}) + \Delta H^\circ_{\text{IE}}(\text{Na}) + \Delta H^\circ_{\text{EA}}(\text{Br}) + \Delta H^\circ_{\text{formation}}\text{»}$</p> <p>$\text{«}107 + 96.5 + 15 + 496 - 325 + 361.5 = \text{» } 751 \text{ «kJ mol}^{-1}\text{» } \checkmark$</p>	<p>Award [3] for correct final answer.</p> <p>Do not accept $+754 \text{ «kJ mol}^{-1}\text{»}$ the value given in the data booklet.</p>	3

(continued...)

(Question 7 continued)

Question		Answers	Notes	Total
7.	(g)	$\Delta H^{\circ}_{\text{solution}}(\text{NaBr}) = \Delta H^{\circ}_{\text{lattice}}(\text{NaBr}) + \Delta H^{\circ}_{\text{hydration}}(\text{Na}^+) + \Delta H^{\circ}_{\text{hydration}}(\text{Br}^-)$ <p>OR</p> $\Delta H^{\circ}_{\text{solution}}(\text{NaBr}) = 751 - 424 - 328 \checkmark$ $= -1 \text{ «kJ mol}^{-1}\text{» } \checkmark$	<p>Award [2] for correct final answer.</p> <p>Award [1 max] for +1 «kJ mol⁻¹».</p>	2
7.	(h)	<p><i>Iodine:</i> no reaction AND I₂/iodine less reactive than Br₂/ bromine ✓</p> <p><i>Chlorine:</i> produces Br₂/ NaCl AND Cl₂/ chlorine more reactive ✓</p>		2