

Markscheme

May 2025

Chemistry

Higher level

Paper 2

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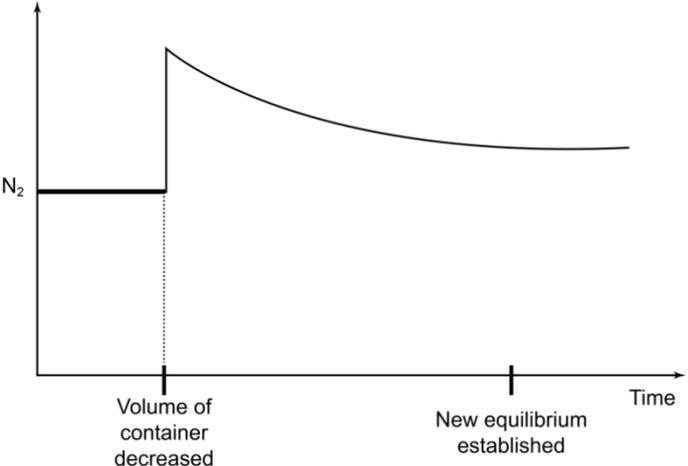
Subject Details: Chemistry higher level Paper 2 Markscheme

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

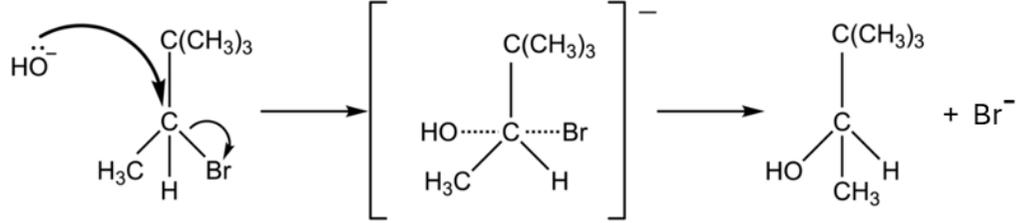
Question			Answers	Notes	Total
1.	(a)	(i)	hydroxyl ✓	Accept hydroxy. Do not accept alcohol, phenol, or hydroxide.	1
1.	(a)	(ii)	Phenol red: «red hence it absorbs complementary colour» green ✓ Bromocresol green: «blue hence it absorbs complementary colour» orange ✓		2
1.	(b)	(i)	Molecular formula: C ₂₀ H ₁₄ O ₄ ✓ Empirical formula: C ₁₀ H ₇ O ₂ ✓		2
1.	(b)	(ii)	Absorption X: O-H «in phenols» ✓ Absorption Y: C=O ✓ Absorption Z: C-O ✓		3
1.	(c)		C ₆ H ₅ OH + OH ⁻ → C ₆ H ₅ O ⁻ + H ₂ O OR C ₆ H ₅ OH + H ₂ O ⇌ C ₆ H ₅ O ⁻ + H ₃ O ⁺ OR C ₆ H ₅ OH ⇌ C ₆ H ₅ O ⁻ + H ⁺ ✓		1

Question		Answers	Notes	Total
1.	(d)	<p>HInd (aq) + H₂O (l) \rightleftharpoons H₃O⁺ (aq) + Ind⁻ (aq) AND HInd and Ind⁻ have different colours OR HInd (aq) \rightleftharpoons H⁺ (aq) + Ind⁻ (aq) AND HInd and Ind⁻ have different colours ✓</p> <p>equilibrium shifts when acid or base is added «to give one of the colours» OR HInd colour in acid/low pH AND Ind⁻ colour in alkali/high pH ✓</p>	<p>Accept equation for an ionic or molecular reaction with a base AND HInd and Ind⁻ have different colours for M1.</p>	2
2.		<p>liquids flow / shape not fixed AND molecules/particles free to move ✓</p> <p>non-compressible / fixed volume AND molecules/particles are close/touching/strongly attracted to each other ✓</p>	<p>Award [1] for two correct macroscopic properties.</p>	2
3.	(a) (i)	<p>[N₂] = 0.545 AND [H₂] = 0.727 AND [NH₃] = 0.112 «mol dm⁻³» ✓</p> $K = \frac{[NH_3]^2}{[N_2][H_2]^3} \quad \checkmark.$ $\ll K = \frac{0.112^2}{0.545 \times 0.727^3} \Rightarrow 0.0599 \quad \checkmark.$	<p>Award [3] for correct final answer.</p> <p>Award [3] for $K_p = 1.66 \times 10^{-9}$.</p>	3

Question			Answers	Notes	Total
3.	(a)	(ii)	 <p>sharp increase at time volume of container decreased ✓</p> <p>gradual decrease to second reference point ✓</p> <p>final constant concentration above initial concentration ✓</p>	<p>Accept straight line or curve for M2.</p>	3
3.	(a)	(iii)	<p>«$\Delta G^\ominus = -RT \ln K$»</p> <p>«$\Delta G^\ominus = -8.31 \times 723 \times \ln(0.0599) \Rightarrow 16900$ ✓</p> <p>J mol⁻¹ ✓</p>	<p>Award [2] for correct final answer. Accept J for M2.</p> <p>Accept 16.9 with the corresponding unit, kJ mol⁻¹/kJ.</p> <p>If K=0.200 used, answer is 9670 J mol⁻¹.</p>	2
3.	(b)	(i)	<p>it donates an electron/lone pair «to Cu²⁺» ✓</p>	<p>Accept diagram showing coordination bond from lone pair on N to Cu²⁺.</p>	1

Question			Answers	Notes	Total
3.	(b)	(ii)	<p>«NH₃ (aq) + H₂O (l) ⇌ NH₄⁺ (aq) + OH⁻ (aq)»</p> <p>ALTERNATIVE 1: $K_b = 10^{-4.75} = 1.8 \times 10^{-5}$ ✓</p> <p>«$1.8 \times 10^{-5} = [\text{OH}^-]^2 / 0.350$» $[\text{OH}^-] = 0.0025$ «mol dm⁻³» ✓</p> <p>pH «= 14.00 – (– log 0.0025) »= 11.40 OR pH «= – log (1.00 x 10⁻¹⁴ / 0.0025) »= 11.40 ✓</p> <p>ALTERNATIVE 2: «$[\text{OH}^-]^2 = K_b \times [\text{NH}_3]$» pOH = 0.5 pK_b – 0.5(log [NH₃]) OR pOH = (0.5 x 4.75) – (0.5 x log 0.350) ✓</p> <p>pOH = 2.60 ✓</p> <p>pH = 14.00 – 2.60 = 11.40 ✓</p>	<p><i>Award [3] for correct final answer.</i></p> <p><i>Do not award ECF for M3 if pH < 7.</i></p>	3
4.	(a)		3-bromo-2,2-dimethylbutane ✓	<p><i>Accept</i> 2-bromo-3,3-dimethylbutane or 2,2-dimethyl-3-bromobutane or 3,3-dimethyl-2-bromobutane.</p>	1

Question		Answers	Notes	Total
4.	(b)		<p><i>Award [1 max] for the two structural isomers showing correct bond angles if non-3-D (wedge-dash representation is omitted).</i></p> <p><i>Do not accept structures with bond angles of 90°.</i></p>	2
4.	(c)	<p>«molar mass => 165.09 ✓</p> <p>«% H = 13.13 x 100/ 165.09 => 7.953% ✓</p>	<p><i>Award M2 only if answer has four significant figures.</i></p> <p><i>Award [2] for correct final answer.</i></p>	2

Question			Answers	Notes	Total
4.	(d)	(i)	 <p>curly arrow from lone pair/negative charge on O in OH^- to C attached to Br ✓</p> <p>curly arrow from C–Br bond to Br ✓</p> <p>transition state showing negative charge AND partial bonds ✓</p> <p>products (Br AND $\text{CH}_3\text{CH}(\text{OH})\text{C}(\text{CH}_3)_3$) ✓</p>	<p>Award [3 max] if $\text{S}_{\text{N}}1$ mechanism is given.</p> <p>Accept curly arrows in the transition state.</p> <p>Do not penalize if HO and Br are not at 180°.</p> <p>Accept NaBr as part of the products only if Na^+ is shown at the start.</p>	4
4.	(d)	(ii)	<p>C–I «bond» is weaker than C–Br «bond» ✓</p> <p>due to large atomic radius of I</p> <p>OR</p> <p>I is a better leaving group «than Br»</p> <p>OR</p> <p>activation energy of reaction is lower ✓</p>		2
4.	(d)	(iii)	<p><i>Homolytic fission:</i></p> <p>each atom receives one «bonding» electron «when bond breaks»</p> <p>OR</p> <p>generates «neutral» free radicals ✓</p> <p><i>Heterolytic fission:</i></p> <p>one atom receives both «bonding» electrons «when bond breaks»</p> <p>OR</p> <p>generates «charged» ions ✓</p>	<p>Award [1 max] if correct descriptions are reversed.</p>	2

Question		Answers	Notes	Total
4.	(e)	any structural isomer of $CH_3CHBrC(CH_3)_3$. ✓		1
5.	(a) (i)	<p>«ΔH°_c values: $C_2H_2 = -1301$, $H_2 = -286$, $C_2H_6 = -1561$ kJ mol^{-1}» «$\sum (\Delta H^\circ_c \text{ reactants}) = \text{» } (-1301) + 2(-286) / -1873$ «kJ mol^{-1}» AND «$\sum (\Delta H^\circ_c \text{ products}) = \text{» } -1561$ «kJ mol^{-1}» ✓ «$\Delta H^\circ = \sum (\Delta H^\circ_c \text{ reactants}) - \sum (\Delta H^\circ_c \text{ products}) = -1873 - (-1561)$» «$\Delta H^\circ = -312$ «kJ mol^{-1}» ✓</p>	Award [2] for correct final answer.	2
5.	(a) (ii)	<p>«$\Delta S^\theta = -233 \times 10^{-3}$ «$\text{kJ K}^{-1} \text{ mol}^{-1}$» OR «$\Delta H^\theta = -312000$ «J mol^{-1}» ✓ «$\Delta G^\theta = \Delta H^\theta - T\Delta S^\theta$ » «$0 = (-312) - T(-233 \times 10^{-3})$» OR «$0 = (-312000) - T(-233)$» T = 1340 «K or above» ✓</p>	<p>Award [2] for correct final answer. If the alternative data is used the answer is 343 K. Do not award ECF for M2 if the answer is a negative Kelvin temperature.</p>	2
5.	(b)	<p>hydrogen is the limiting reactant OR $2H_2:1C_2H_6$ ✓ 80.0 cm^3 ✓</p>	<p>Award [2] for correct final answer. Accept answers expressed in dm^3.</p>	2
5.	(c) (i)	$H - C \equiv C - H$ ✓	Accept any combination of dots or crosses to represent electrons, or lines to represent electron pairs.	1
5.	(c) (ii)	sp ✓		1
6.	(a) (i)	<p>$Li \rightarrow Li^+ + e^-$ OR $LiC_6 \rightarrow C_6 + Li^+ + e^-$ ✓</p>	<p>Do not accept 6C. Do not penalize equilibrium arrows.</p>	1

Question			Answers	Notes	Total
6.	(a)	(ii)	negative sign AND large value ✓ oxidation/reverse reaction is «highly» spontaneous/favourable ✓	<i>Accept Li is a good reductant/reducing agent for M2.</i>	2
6.	(b)		arrow from cathode to anode in the external circuit ✓	<i>Do not award mark if any arrows are in the electrolyte.</i>	1
6.	(c)		«battery» stores «surplus» energy «from solar panel» ✓	<i>Accept “stores charge/power for night use”. Accept “charges battery”.</i>	1
6.	(d)		«1000.0 C / 96500 C mol ⁻¹ =» 0.0104 «mol of electrons/Li» ✓ «1 mol electrons releases 1 mol of Li ⁺ » «0.0104 x 6.02 x 10 ²³ => 6.24 x 10 ²¹ «Li ⁺ ions» ✓	<i>Award [2] for correct final answer.</i>	2
7.	(a)		H ₂ N(CH ₂) ₆ NH ₂ ✓ HOOC(CH ₂) ₄ COOH / ClOC(CH ₂) ₄ COCl ✓	<i>Accept any type of structural or skeletal formula. Penalize clear incorrect bond connections only once in the paper.</i>	2
7.	(b)	(i)	O of C=O with H of H-N on opposite chain ✓	<i>Do not penalize multiple correct H-bonds.</i>	1

Question			Answers	Notes	Total
7.	(b)	(ii)	H that is «covalently» bonded to a «highly» electronegative atom ✓ is attracted to the electronegative atom of neighbouring molecule ✓	<i>Accept a labelled diagram for both marks.</i> <i>Accept “F, O or N” for “electronegative atom”.</i>	2
7.	(c)		covalent bonds between silicon atoms ✓ London/dispersion forces between poly(ethene) «chains/molecules» ✓ covalent bonds «much» stronger than London/dispersion/intermolecular forces «hence Si has higher melting point» ✓	<i>M3: Do not accept “bonding in silicon is stronger than poly(ethene)” without named bonding/forces.</i>	3
8.	(a)	(i)	C AND E ✓		1

Question			Answers	Notes	Total
8.	(a)	(ii)	<p>profile shows two transition states ✓</p> <p>E_a of second step is larger AND products lower potential energy than reactants ✓</p> <p>correct labels for reactants, products, both transition states and the intermediate ✓</p>	<p>E_a and ΔH labels are not required.</p> <p>Do not penalize if intermediate is at lower potential energy than the reactant.</p>	3
8.	(a)	(iii)	<p>A: first order AND B: second order ✓</p> <p>«rate =» $k[A][B]^2$ ✓</p>	<p>Award [2] for correct rate equation.</p>	2
8.	(b)		<p>Any 3 of the following:</p> <p>temperature increases kinetic energy/speed of molecules ✓</p> <p>more frequent collisions ✓</p> <p>more molecules have $E \geq E_a$ at higher temperature ✓</p> <p>larger ratio/percentage of collisions are successful ✓</p>	<p>M2 requires time reference for probability, chance, or number of collisions.</p>	3 max

Question			Answers	Notes	Total
9.	(a)		$6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) + 6\text{O}_2(\text{g}) \checkmark$		1
9.	(b)	(i)	<p>Any two:</p> <p>«ethanol is» renewable / sustainable resource \checkmark</p> <p>«ethanol has» low/zero carbon footprint / produces less CO_2 \checkmark</p> <p>less sulfur dioxide «than fossil fuels» OR less acid rain «than fossil fuels» \checkmark</p> <p>less incomplete combustion «than fossil fuels» OR less carbon monoxide/soot «than fossil fuels» \checkmark</p>	<p>Accept “ethanol is biodegradable /less toxic than gasoline”.</p> <p>Do not accept just “less harmful”.</p>	2 max
9.	(b)	(ii)	<p>«bond breaking» $1 \text{ C-C} + 5 \text{ C-H} + 1 \text{ C-O} + 1 \text{ O-H} + 3 \text{ O=O}$ OR $346 + 5(414) + 358 + 463 + 3(498)$ OR $4731 \text{ «kJ» } \checkmark$</p> <p>«bond forming» $4 \text{ C=O} + 6 \text{ O-H}$ OR $4(804) + 6(463)$ OR $5994 \text{ «kJ» } \checkmark$</p> <p>«$\Delta H = 4731 - 5994 = -1263 \text{ «kJ mol}^{-1}\text{» } \checkmark$</p>	Award [3] for correct final answer.	3
9.	(c)		<p>«$Q = (4.00 / 46.08) \times 1367 = 119 \text{ kJ} / 119000 \text{ J } \checkmark$</p> <p>«$\Delta T = Q / mc = 119000 / (500.0 \times 4.18) = 56.9 \text{ «K» } \checkmark$</p>	<p>Accept 56.8 «K».</p> <p>Allow use of ΔH_c calculated in (b)(ii) without penalty. Answer is $\Delta T = 52.5 / 52.6 \text{ «K»}$.</p>	2

Question			Answers	Notes	Total
9.	(d)		hydrogen has one shell only ✓ O has greater «effective» nuclear charge / more protons than C ✓ O and C have the same shielding effect/occupied energy levels ✓		3
10.	(a)	(i)	$1s^2 2s^2 2p^6 3s^2 3p^4$ OR [Ne] $3s^2 3p^4$ ✓		1
10.	(a)	(ii)	$:\ddot{\text{O}}-\ddot{\text{S}}=\ddot{\text{O}}$ OR $\ddot{\text{O}}=\ddot{\text{S}}=\ddot{\text{O}} \quad \checkmark$	<p><i>Accept the Lewis formulas with the formal charges.</i></p> <p><i>Accept any combination of dots or crosses to represent electrons, or lines to represent electron pairs.</i></p>	1
10.	(a)	(iii)	<p><i>Electron domain geometry:</i> trigonal planar ✓</p> <p><i>Molecular domain geometry:</i> bent / V-shaped / angular ✓</p>	<i>Apply ECF from Lewis formula.</i>	2

Question			Answers	Notes	Total
10.	(a)	(iv)	<p>«both» bonds are polar / electronegativity difference «between O and S» ✓</p> <p>«bond» dipoles do not cancel each other / there is a net dipole «because bonds are at an angle less than 180° » ✓</p>	<p><i>Accept unsymmetrical distribution of charge OR dipoles add to give a «partial» positive «charge» on S and a «partial» negative «charge» on the O atoms for M2.</i></p> <p><i>Apply ECF from molecular geometry.</i></p>	2
10.	(b)		<p>$2\text{SO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{SO}_4(\text{aq})$</p> <p>correct product AND state symbols for reactants and product ✓</p> <p>correct balancing ✓</p>		2