

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]**.

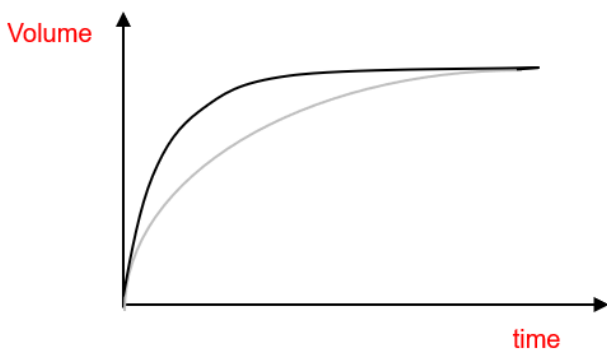
1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart 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)	elements contain only one type of atom / atoms with same atomic number/same number of protons OR cannot be chemically broken down «into simpler substances» ✓ compounds contain different types of atoms «chemically» bonded together OR consist of different elements «chemically» bonded together «in fixed ratios» ✓	Accept combined/joined for bonded in M2.	2
1.	(b)	<<electronegativity difference>> $\Delta X = 0.8$ AND average <<electronegativity >> $X = 2.2$ ✓		1
1.	(c)	Any one of: Fe is electrical/thermal conductor AND FeS is not ✓ Fe is malleable/ductile AND FeS is brittle/not malleable/ductile ✓ Fe is magnetic AND FeS is not ✓ Fe has higher melting point «than FeS» ✓ Fe is denser «than FeS» ✓	Do not accept atomic or molar mass. Do not accept any chemical properties. Accept colour or shininess Accept iron is sonorous	1
1.	(d)	«$IE(\text{Fe}) = 762 \text{ kJ mol}^{-1}$ » E for 1 atom «$= \frac{762 \times 10^3 \text{ J mol}^{-1}}{6.02 \times 10^{23} \text{ mol}^{-1}}$ » = 1.266×10^{-18} «J» ✓ f «$= \frac{E}{h} = \frac{1.266 \times 10^{-18} \text{ J}}{6.63 \times 10^{-34} \text{ J s}}$ » = $1.91 \times 10^{15} \text{ «s}^{-1}\text{»}$ ✓ λ «$= \frac{c}{f} = \frac{3.0 \times 10^8 \text{ m s}^{-1}}{1.91 \times 10^{15} \text{ s}^{-1}}$ » = $1.57 \times 10^{-7} \text{ «m»}$ ✓	Award [3] for correct final answer.	3

Question			Answers	Notes	Total
2.	(a)		$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$ / [Ar] $3d^7$ ✓		1
2.	(b)	(i)	no effect on K AND mixture has more $[\text{CoCl}_4]^{2-}$ /product OR no effect on K AND equilibrium shifts to the right ✓		1
2.	(b)	(ii)	endothermic AND equilibrium shifts to right OR endothermic AND forward reaction is favoured ✓	Accept endothermic as forward reaction removes heat Accept endothermic and more products formed	1
3.	(a)		$\ll K = \gg \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]}$ ✓		1
3.	(b)		$n(\text{H}_2) = 1.5$ «mol» AND $n(\text{CO}) \ll = 2.7 - 1.5 \gg = 1.2$ «mol» AND $n(\text{H}_2\text{O}) \ll = 2.9 - 1.5 \gg = 1.4$ «mol» ✓ « $V = 1 \text{ dm}^3$, so numerical values of n equal concentrations in mol dm^{-3} » $\ll K = \frac{(1.5 \text{ mol dm}^{-3})(1.5 \text{ mol dm}^{-3})}{(1.2 \text{ mol dm}^{-3})(1.4 \text{ mol dm}^{-3})} = \gg$ 1.3 ✓	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
3.	(c)		Anode: $\text{CO}_3^{2-} + \text{H}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + 2\text{e}^-$ ✓ Cathode: $\text{CO}_2 + \frac{1}{2} \text{O}_2 + 2\text{e}^- \rightarrow \text{CO}_3^{2-}$ ✓	Accept doubling of all coefficients for cathode half-equation.	2
3.	(d)		zero net carbon «dioxide» emissions OR does not contribute to global warming ✓	Ignore references to water.	1
4.	(a)	(i)	$\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ correct products AND state symbols ✓ correct balancing ✓	Do not accept $\text{H}_2\text{CO}_3(\text{aq})$ for M1. Accept ionic equation.	2
4.	(a)	(ii)	$n(\text{CaCO}_3) \llcorner = \frac{3.162 \text{ g}}{100.09 \text{ g mol}^{-1}} \llcorner = 0.0316 \llcorner \text{mol} \llcorner$ AND $n(\text{HCl}) \llcorner = 4.00 \text{ mol dm}^{-3} \times 20.0 \times 10^{-3} \text{ dm}^3 \llcorner$ $= 0.0800 \llcorner \text{mol} \llcorner$ ✓ CaCO_3 is limiting ✓	Do not award M2 without working/answer seen for M1	2
4.	(a)	(iii)	$\llcorner V = 0.0316 \text{ mol} \times 22.7 \text{ dm}^3 \text{mol}^{-1} = \llcorner$ 0.717 «dm³» ✓		1

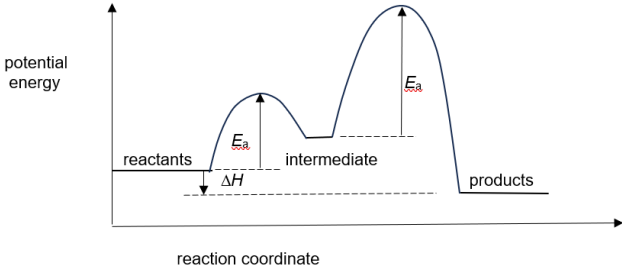
Question			Answers	Notes	Total
4.	(b)	(i)	 Greater gradient AND from origin AND same final volume ✓	Lines must not cross.	1
4.	(b)	(ii)	ethanoic acid weak / HCl strong OR ethanoic acid partially ionizes «in water» / HCl fully ionizes ✓	Accept lower $[H^+]$.	1

Question	Answers	Notes	Total
4. (c) (i)	Ca²⁺(g) + 2e⁻ + 2Cl(g) Processes: first AND second ionization energy «of Ca» ✓ Ca(g) + 2Cl(g) energies of atomisation Species present: Ca(s) AND Cl₂(g) ✓ enthalpy of formation CaCl₂(s) electron affinity(es) Species present: Ca²⁺(g) AND 2Cl⁻(g) ✓ lattice enthalpy	<i>Do not accept ionization energy for Processes.</i> <i>Accept ionization energies for Processes.</i>	3
4. (c) (ii)	Ca²⁺ has larger ionic radius «than Mg²⁺» OR greater distance between ion centres «in CaCl₂» ✓	<i>Must be clear reference to ionic for M1</i>	1

Question	Answers	Notes	Total
5. (a)	Curve drawn by me non-symmetrical sigmoidal curve AND buffer region near pH 5 ✓ curve starting at pH 2-4 AND flattening out at pH>12 ✓ equivalence point pH 8-10 AND at volume of 15 cm³ ✓	<i>Actual equivalence point is a 9.2</i> <i>Near pH5 will be above 4 and</i> <i>below 6 and reasonably flat. The</i> <i>actual half neutralization point is</i> <i>pH 4.75.</i>	3

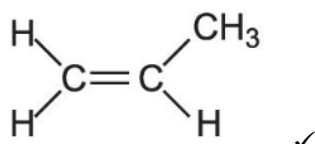
Question			Answers	Notes	Total
5.	(b)	(i)	high concentration of «both» acid AND «conjugate» base ✓ $n(\text{CH}_3\text{COOH}):n(\text{NaOH}) = 2:1$ OR $n(\text{acid}):n(\text{conjugate base}) = 1:1$ OR half-equivalence ✓	<i>Award 2 for “maximum possible/0.5 mol dm⁻³ concentration of acid AND conjugate base”</i>	2
5.	(b)	(ii)	<i>Addition of strong acid:</i> $\text{CH}_3\text{COO}^- + \text{H}^+ \rightarrow \text{CH}_3\text{COOH}$ OR $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$ AND reverse reaction favoured ✓ <i>Addition of strong base:</i> $\text{CH}_3\text{COOH} + \text{OH}^- \rightarrow \text{CH}_3\text{COO}^- + \text{H}_2\text{O}$ OR $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ AND more H^+ is released OR H^+ replaced <<by the acid>> OR $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$ AND forward reaction favoured ✓	<i>Accept equilibrium arrows only if statement of direction of shift is also given.</i>	2

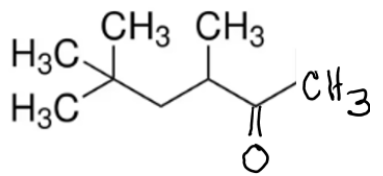
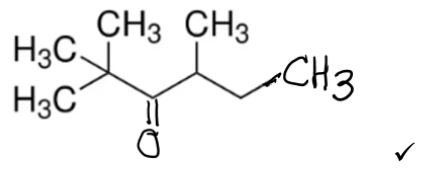
Question			Answers	Notes	Total
6.	(a)	(i)	+2/II ✓	<i>Do not accept 2, 2+,.</i>	1
6.	(a)	(ii)	<i>Any three of:</i> partially filled d-orbitals ✓ «ligand causes» d-orbitals «to» split ✓ light is absorbed as electrons transit to a higher energy level «in d-d transition» OR light is absorbed as electrons are promoted ✓ energy gap corresponds to light in visible region of the spectrum ✓ the colour seen is complementary to the colour of light absorbed ✓	<i>Accept “energy absorbed” for M3 only.</i> <i>Accept a stated wavelength in the range of 575nm to 585nm for M4.</i> <i>Accept “yellow light is absorbed” for M4</i> <i>M5 should only be accepted if absorption of light is mentioned in the answer anywhere.</i>	3
6.	(a)	(iii)	«catalyst provides» alternative reaction pathway ✓ «catalyst» lower(s) activation energy ✓	<i>M1 requires a description of the reaction going from reactants to products if exact wording not given.</i> <i>Accept explanation of how a transition metal catalyst works for M1</i>	2
6.	(a)	(iv)	<i>Oxidation half-equation:</i> $\text{S}_2\text{O}_3^{2-} + \text{H}_2\text{O} \rightarrow 2\text{SO}_2 + 2\text{H}^+ + 4\text{e}^-$ ✓ <i>Overall redox equation:</i> $\text{S}_2\text{O}_3^{2-} + 4\text{Fe}^{3+} + \text{H}_2\text{O} \rightarrow 2\text{SO}_2 + 4\text{Fe}^{2+} + 2\text{H}^+$ ✓	<i>Allow ECF for M2</i>	2

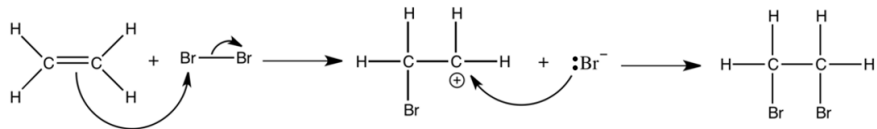
Question	Answers	Notes	Total
6. (a) (v)	 products lower than reactants ✓ intermediate at an energy minimum ✓ E_a of both steps correctly marked ✓ ΔH from reactants down to products ✓	Accept any combination of peak heights. Accept double-headed arrows or lines with no heads. M1 and M4 may be awarded for a curve with a single maximum. Ignore the energy position of the intermediate.	4
6. (b) (i)	Ionic bonding: electrostatic attraction between oppositely charged ions/cations AND anions ✓ Covalent bonding: electrostatic attraction between shared electron pair and positively charged nuclei ✓	Do not accept answers referring to transfer of electrons for M1. Penalize missing “electrostatic attraction once only.	2

Question			Answers	Notes	Total
6.	(b)	(ii)	$\left[\begin{array}{c} \text{:}\ddot{\text{O}}\text{:} \\ \\ \ddot{\text{O}}=\text{N}-\ddot{\text{O}}\text{:} \end{array} \right]^{-}$ ✓	<i>Do not accept resonance structure.</i> <i>Negative charge must be shown.</i> <i>Accept single negative charges on two O atoms AND a single positive charge on the N atom.</i> <i>Accept any combination of lines, dots or crosses</i>	1
6.	(b)	(iii)	trigonal planar ✓	<i>Accept triangular planar.</i> <i>Apply ECF for any N containing species in 6(b)(ii).</i>	1
6.	(b)	(iv)	124 «x 10⁻¹² m» ✓ delocalized electrons / resonance structure ✓	<i>Accept any length between 115 «x 10⁻¹² m» and 135 «x 10⁻¹² m» for M1.</i> <i>Accept 'intermediate between single and double', or 'bond order greater than 1 but less than 2' for M2.</i>	2

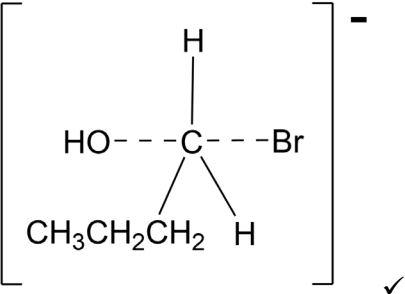
Question			Answers	Notes	Total
7.	(a)		$n(\text{C}) \llcorner n(\text{CO}_2) = \frac{9.49 \text{ g}}{44.01 \text{ g mol}^{-1}} \gg = 0.216 \llcorner \text{mol} \gg$ AND $n(\text{H}) \llcorner 2n(\text{H}_2\text{O}) = 2 \times \frac{5.18 \text{ g}}{18.02 \text{ g mol}^{-1}} \gg = 0.575 \llcorner \text{mol} \gg \checkmark$ OR $H = 0.581 \llcorner \text{g} \gg$ AND $\text{C} = 2.59 \llcorner \text{g} \gg \checkmark$ $\llcorner m(\text{O}) = 4.32 - (m(\text{C}) + m(\text{H}))$ $= 4.32 - (2.59 + 0.581) = 1.15 \text{ g} \gg$ $n(\text{O}) = \frac{1.15 \text{ g}}{16.00 \text{ g mol}^{-1}} \quad / 0.0718 \llcorner \text{mol} \gg \checkmark$ $\llcorner n(\text{C}):n(\text{H}):n(\text{O}) = 0.216 : 0.575 : 0.0718 = 3 : 8 : 1 \gg$ $\text{C}_3\text{H}_8\text{O} \checkmark$	<i>M2 for finding mass of oxygen</i> <i>M3 for finding empirical formula</i> Award [3] for correct final answer.	3

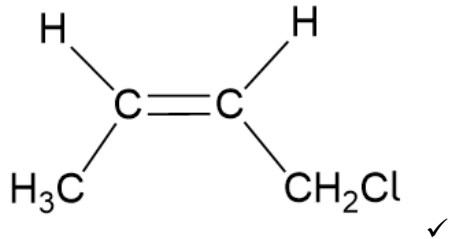
Question			Answers	Notes	Total
7.	(b)	(i)	$T = 373 \text{ K}$ AND $V = 5.57 \times 10^{-5} \text{ m}^3$ OR $T = 373 \text{ K}$ AND 0.0557 dm^3 and $1 \times 10^2 \text{ kPa}$ ✓ $\ll n = \frac{PV}{RT} = \frac{1.00 \times 10^5 \text{ Pa} \times 5.57 \times 10^{-5} \text{ m}^3}{8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 373 \text{ K}} \gg$ $n = 0.00180 \text{ «mol»}$ ✓	Award [2] for correct final answer.	2
7.	(b)	(ii)	$\ll M = \frac{0.108 \text{ g}}{0.00180 \text{ mol}} \gg$ 60.0 / 60.1 «g mol⁻¹» ✓	If $n = 0.00220 \text{ mol}$ is used, $M = 49.1 \text{ «g mol}^{-1}\text{»}$ Accept mass of 60	1
8.	(a)	(i)	 ✓	Accept any correct structural representation including skeletal formulas	1
8.	(a)	(ii)	«chemically» inert/unreactive ✓	Accept “non-biodegradable” Do not accept physical properties such as strength	1
8.	(b)	(i)	carbonyl ✓	Do not accept aldehyde.	1
8.	(b)	(ii)	3,5,5-trimethylhexanal ✓	Accept 5,5,3 instead of 3,5,5 do not penalize missing hyphen/dash	1

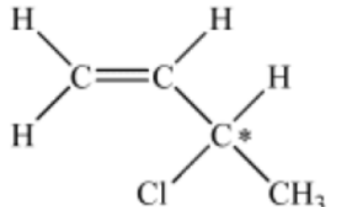
Question			Answers	Notes	Total
8.	(b)	(iii)	<i>Number of signals:</i> 6 ✓ <i>Relative areas:</i> 9:2:1:3:2:1 ✓	Accept ratio in any order.	2
8.	(b)	(iv)	 OR  ✓	Accept any ketone, unsaturated alcohol/ether or cyclic alcohol/ether, with molecular formula $C_9H_{18}O$. Accept any correct representation including skeletal structures. Ignore connectivity of methyl groups	1

Question			Answers	Notes	Total
8.	(b)	(v)	<i>Product of reaction with oxidizing agent:</i> RCOOH ✓ <i>Product of reaction with reducing agent:</i> RCH₂OH ✓	<i>Award [1 max] for 'carboxylic acid and primary alcohol'.</i> <i>Award [1 max] if correct products are reversed.</i> <i>Accept full and correct structures for both products.</i> <i>Accept any correct representation including skeletal structures.</i>	2
8.	(c)	(i)	1,2-dibromoethane ✓	<i>Accept name or structure.</i>	1
8.	(c)	(ii)	 curly arrow from C=C bond to Br AND curly arrow showing Br-Br bond breaking ✓ carbocation with charge on correct atom ✓ curly arrow from lone pair/negative charge on Br⁻ to C⁺ ✓		3

Question			Answers	Notes	Total
8.	(c)	(iii)	high electron density of the carbon-carbon double bond OR C=C double bond can undergo addition reactions	<i>Accept C=C double bond susceptible to electrophilic attack.</i> <i>Accept “Pi electrons available”</i>	1
8.	(c)	(iv)	C _n H _{2n} ✓	<i>Subscripts of numbers not essential</i>	1
8.	(c)	(v)	London (dispersion) forces «only» ✓ stronger forces of attraction with increasing chain length / larger electron cloud / molar mass ✓	<i>Accept dispersion forces/ instantaneous / transient / induced dipole attractions for M1. Do not accept van der Waals' forces for M1.</i> <i>Accept “more electrons” for “larger electron cloud” in M2.</i> <i>Accept increased surface area.</i>	2
8.	(d)	(i)	nucleophilic substitution ✓	<i>Allow S_N2 but not S_N1.</i>	1

Question	Answers	Notes	Total
8. (d) (ii)		Charge and square bracket must be included. Accept two partial negative charges on Br AND O in HO, shown either as δ^- or $\frac{1}{2}-$. Partial bonds from HO to C AND from C to Br must be shown. Accept any angle for the partial bonds. Accept carbocation, or a valid transition state, if S_N1 named in (d)(I). Accept any correct representation including skeletal structures.	1
8. (d) (iii)	«rate =» $k[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}][\text{OH}^-]$ ✓	«rate =» $k[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}]$ if S_N1 named in (d)(I). Accept NaOH for OH^-	1

Question			Answers	Notes	Total
8.	(d)	(iv)	rate doubled AND rate is proportional to $[\text{OH}^-]$ OR rate doubled AND reaction is first order with respect to OH^- ✓	Accept answers describing increased frequency of collisions. Accept 'rate stays the same AND reaction is zero order with respect to OH^- ' if $\text{S}_{\text{N}}1$ named in (d)(i). Accept NaOH for OH^-	1
8.	(d)	(v)	1-bromobutane reacts faster AND C-Br bond weaker «than C-Cl bond» ✓ OR 1-bromobutane reacts faster AND bromine is a better leaving group ✓	Accept '1-bromobutane reacts faster AND C-Br bond longer «than C-Cl bond»'.	1
8.	(e)	(i)		Accept any correct representation including skeletal structures.	1
8.	(e)	(ii)	dipoles/polar bonds do not cancel OR vector sum of bond dipoles is non-zero OR non-symmetrical molecule ✓	Ignore references to electronegativity.	1

Question			Answers	Notes	Total
8.	(e)	(iii)	 correct isomer ✓ chiral C ✓	<i>Accept any correct representation including skeletal structures.</i> <i>Accept any correct indication of chiral carbon.</i>	2
8.	(f)	(i)	ALTERNATIVE 1: Bonds broken: 1 C=C + 4 C-H + 2 O-H / 614 + 4(414) + 2(463) / 3196 «kJ» ✓ Bonds formed: 1 C-C + 1 C-O + 5 C-H + 1 O-H / 346 + 358 + 5(414) + 463 / 3237 «kJ» ✓ $\Delta H = \text{«}3196 - 3237 = \text{» } -41 \text{ «kJ» } \checkmark$ ALTERNATIVE 2: Bonds broken: 1 C=C + 1 O-H / 614 + 463 / 1077 «kJ» ✓ Bonds formed: 1 C-C + 1 C-O + 1 C-H / 346 + 358 + 414 / 1118 «kJ» ✓ $\Delta H = \text{«}1077 - 1118 = \text{» } -41 \text{ «kJ» } \checkmark$	<i>Award [3] for correct final answer.</i> <i>Award [2 max] for +41 «kJ».</i>	3

Question			Answers	Notes	Total
8.	(f)	(ii)	$\ll \Delta H^{\ominus} = \Sigma(\Delta H_f^{\ominus} \text{ products}) - \Sigma(\Delta H_f^{\ominus} \text{ reactants}) \gg$ $= -235 - (+52 + (-242)) \checkmark$ $= -45 \text{ «kJ» } \checkmark$	<i>Award [2] for correct final answer.</i> <i>Award [1 max] for +45 «kJ»</i>	2
8.	(f)	(iii)	bond enthalpies are average values OR bond enthalpies vary «slightly» among compounds $\checkmark$		1
