

# Markscheme

**May 2023**

**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]**.

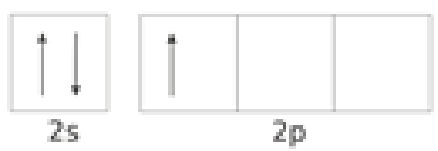
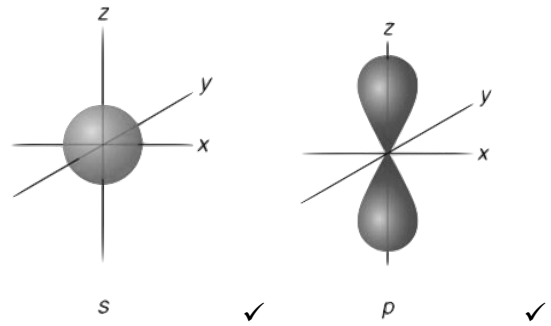
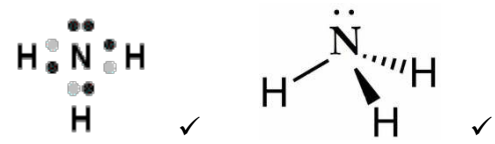
1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart 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)	$\text{H}_2\text{O}_{(l)} + \text{HCl}_{(g)} \rightarrow \text{Cl}^-_{(aq)} + \text{H}_3\text{O}^+_{(aq)}$ ✓✓	One for the equation and one for the state symbols. Do not accept $\text{H}_2\text{O}_{(l)} + \text{H}^+_{(g)} \rightarrow \text{H}_3\text{O}^+_{(aq)}$ Do not accept equilibrium sign.	2
1.	(a)	(ii)	«pH = $-\log_{10}[\text{H}^+] = -\log_{10}0.5 = 0.30$ ✓		1
1.	(a)	(iii)	«Ethanoic acid» partially ionizes/dissociates/OWTTE OR lower [H+] ✓	Do <b>not</b> accept weak acid only. Accept converse argument.	1
1.	(a)	(iv)	conductivity/conductance meter/probe OR ammeter «with power supply» ✓	Ignore any reference to indicators or any chemical methods. Accept Cl <sup>-</sup> or ethanoate ion selective probe.	1
1.	(a)	(v)	HCl higher conductivity «due to higher [ion]» ✓	Accept explanation if alternative given in a(iv). Accept converse argument. Apply ECF for incorrect method.	1

Question			Answers	Notes	Total
1.	(b)		Chemical test: use of carbonate/hydrogen carbonate/named metal <b>AND</b> Expected result: more bubbles per unit time/disappears faster/faster reaction in $\text{HCl}_{(\text{aq})}$ ✓ <b>OR</b> Chemical test: add alkali/hydroxide/metal oxide <b>AND</b> Expected result: higher temperature rise with $\text{HCl}$ ✓ <b>OR</b> Chemical test: add silver nitrate «solution»/ $\text{AgNO}_3$ «(aq)» <b>AND</b> Expected result: white precipitate/ppt. with $\text{HCl}$ ✓	Do <b>not</b> accept just metal. Accept active metal.  Accept greater temperature change in place of more bubbles.	1
1.	(c)	(i)	4.8 ✓	Accept 4.7–4.9	1

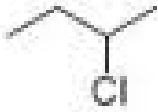

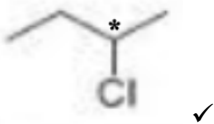
Question			Answers	Notes	Total
1.	(c)	(ii)	<p><b>ALTERNATIVE 1</b>  <math>\text{HA} + \text{OH}^- \rightleftharpoons \text{A}^- + \text{H}_2\text{O}</math> ✓            added <math>\text{OH}^-</math> neutralized by HA  <b>OR</b>            strong base «<math>\text{OH}^-</math>» replaced by weak base «<math>\text{A}^-</math>» ✓</p> <p><b>ALTERNATIVE 2</b>  <math>\text{HA} \rightleftharpoons \text{A}^- + \text{H}^+</math> ✓            added <math>\text{OH}^-</math> neutralized by <math>\text{H}^+</math>  <b>OR</b>            strong base «<math>\text{OH}^-</math>» replaced by weak base «<math>\text{A}^-</math>» ✓</p>	<p>Must show <math>\rightleftharpoons</math> for M1            Accept molecular equation.            Allow reference to Châtelier principle for M2</p>	2
1.	(c)	(iii)	<p><math>n(\text{NH}_3)_{\text{init}} = \ll 0.08 \text{ dm}^3 \times 0.1 \text{ mol dm}^{-3} \Rightarrow 0.008 \text{ mol}</math>  <b>AND</b>  <math>n(\text{HCl})_{\text{init}} = \ll 0.04 \text{ dm}^3 \times 0.1 \text{ mol dm}^{-3} \Rightarrow 0.004 \text{ mol}</math> ✓</p> <p><math>n(\text{NH}_3)_{\text{fin}} = \ll 0.008 \text{ mol} - 0.004 \text{ mol} \Rightarrow 0.004 \text{ mol}</math>  <b>AND</b>  <math>n(\text{NH}_4^+)_{\text{fin}} = 0.004 \text{ mol}</math> ✓</p> <p>«<math>V_{\text{fin}} = 0.08 \text{ dm}^3 + 0.04 \text{ dm}^3 = 0.12 \text{ dm}^3</math>»            «<math>c(\text{NH}_3)_{\text{fin}} = c(\text{NH}_4^+)_{\text{fin}} = 0.004 \text{ mol} / 0.12 \text{ dm}^3 = 0.033 \text{ mol dm}^{-3}</math>»</p> <p><math>\text{p}K_{\text{a}}(\text{NH}_4^+) = \ll 14 - \text{p}K_{\text{b}}(\text{NH}_3) = 14 - 4.75 \Rightarrow 9.25</math> ✓</p> <p><math>\text{pH} = \ll 9.25 + \log(0.033/0.033) \Rightarrow 9.25</math>  <b>OR</b>  <math>\text{pH} = \ll 9.25 + \log(0.004/0.004) \Rightarrow 9.25</math> ✓</p>	<p>Award [4] for the correct final answer.            Accept alternate working.</p>	4

Question			Answers	Notes	Total
2.	(a)	(i)	 <p>arrows <b>AND</b> identifies 2s <b>AND</b> 2p sub orbitals ✓</p>	Accept "hooks" to represent the electrons.	1
2.	(a)	(ii)	 <p>s ✓ p ✓</p>	<p><math>P_{x,y}</math> or <math>z</math> can be used.                      M2 cannot be awarded if labels of orbital types are missing or incorrect</p> <p>Node of p orbital must be at the origin</p>	2
2.	(b)		valence electron further from nucleus/«atomic» radius larger «down the group» ✓ «electron» more shielded/ less attractive force/easier to remove ✓		2
2.	(c)	(i)	tetrahedral ✓		1
2.	(c)	(ii)		<p>Accept a combination of dots /crosses /lines in the Lewis structure</p> <p>Lone pair not required for shape</p>	2

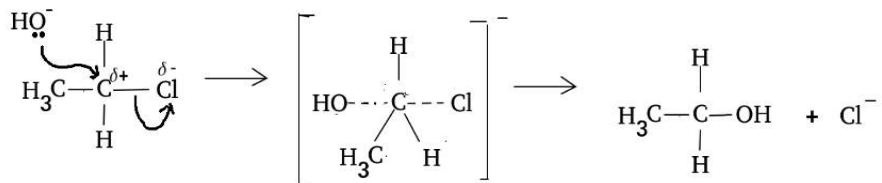


Question			Answers	Notes	Total
2.	(c)	(iii)	ammonia has intermolecular/IMF hydrogen bonds «phosphine does not» ✓ phosphine «and ammonia» dipole-dipole/London dispersion forces/instantaneous dipole attractions/Van der Waals forces ✓ hydrogen bonds stronger ✓	<i>Accept converse argument.</i>  <i>Award 1 for stating that NH<sub>3</sub> is more polar than phosphine so the dipole-dipole forces are stronger</i>	<b>3</b>
2.	(d)	(i)	«in a closed system» the rate of the forward reaction equals the rate of the reverse reaction. ✓		<b>1</b>
2.	(d)	(ii)	$[\text{NH}_3]^2/([\text{N}_2][\text{H}_2]^3)$ ✓		<b>1</b>
2.	(d)	(iii)	$\Delta S^\ominus = \Delta S^\ominus_{(\text{products})} - \Delta S^\ominus_{(\text{reactants})}$ <b>OR</b> $(2 \times 192.8 \text{ «J mol}^{-1} \text{ K}^{-1}\text{») - (3 \times 130.7 \text{ «J mol}^{-1} \text{ K}^{-1}\text{) + 191.6 \text{ «J mol}^{-1} \text{ K}^{-1}\text{») ✓}$ $-198.1 \text{ «J K}^{-1} \text{ mol}^{-1}\text{» ✓}$	<i>Award [2] for correct final answer with four significant figures.</i>  .	<b>2</b>
2.	(d)	(iv)	« $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ » $\Delta S^\ominus = -0.1981 \text{ kJ K}^{-1} \text{ mol}^{-1}$ <b>AND</b> $\Delta H^\ominus = -92.0 \text{ kJ mol}^{-1}$ ✓ « $0 \text{ kJ mol}^{-1} = (-92.0 \text{ kJ mol}^{-1}) - (T \text{ K} \times -0.1981 \text{ kJ K}^{-1} \text{ mol}^{-1})$ » 464«K» ✓  Alternate: $\Delta S^\ominus = -0.2100 \text{ kJ K}^{-1} \text{ mol}^{-1}$ <b>AND</b> $\Delta H^\ominus = -92.0 \text{ kJ mol}^{-1}$ ✓ « $0 \text{ kJ mol}^{-1} = (-92.0 \text{ kJ mol}^{-1}) - (T \text{ K} \times -0.2100 \text{ kJ K}^{-1} \text{ mol}^{-1})$ » 438«K» ✓  .	<i>M1 for conversion to common units for <math>\Delta H^\ominus</math> and <math>\Delta S^\ominus</math>.</i> <i>Award [2] for correct final answer.</i>	<b>2</b>

Question			Answers	Notes	Total
2.	(d)	(v)	«reaction» exothermic <b>AND</b> $K_c$ increases «as equilibrium moves right» ✓		1
2.	(d)	(vi)	« $\Delta G^\ominus = -RT \ln K_c$ » « $\Delta G^\ominus = (-8.31 \text{ J K}^{-1} \text{ mol}^{-1} \times 773 \text{ K} \times \ln 6.84 \times 10^{-5})/1000 =$ » «+» 61.6 «kJ mol <sup>-1</sup> » ✓ <b>OR</b> « $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ » « $\Delta G^\ominus = -92.0 \text{ kJ mol}^{-1} - 773 \text{ K} \times (-0.1981 \text{ kJ K}^{-1} \text{ mol}^{-1}) =$ » +61.1 «kJ mol <sup>-1</sup> » ✓	Award [2] for the correct final answer.	2
2.	(e)	(i)	alternate pathway <b>AND</b> lowers activation energy/ $E_a$ ✓		1
2.	(e)	(ii)	<p>correct shape curve starting at the origin, without touching the x axis at high energy. ✓                      (<math>E_a</math>) catalysed &lt; (<math>E_a</math>) uncatalysed on x axis. ✓</p>	Ignore any shading under the curve.	2

Question			Answers	Notes	Total
2.	(e)	(iii)	change in <b>AND</b> volume <b>OR</b> pressure <b>OR</b> temperature <b>OR</b> concentration of H <sub>2</sub> /N <sub>2</sub> /reactants/NH <sub>3</sub> /product ✓	<i>Do not accept pH. Accept any valid method.</i>	1
3.	(a)	(i)	compounds of the same family <b>AND</b> general formula <b>OR</b> compounds of the same family <b>AND</b> differ by a common structural unit/CH <sub>2</sub> ✓	<i>Accept contains the same functional group for same family.</i>	1
3.	(a)	(ii)	 2-chlorobutane ✓  1-chloro-2-methylpropane ✓	<i>Accept 1-chloromethylpropane for M2, but not 2-methyl-1-choloropropane.</i>	2
3.	(a)	(iii)	 ✓		1

Question			Answers	Notes	Total
3.	(a)	(iv)	$\left[ \begin{array}{cccc} \text{CH}_3 & \text{CH}_3 & \text{CH}_3 & \text{CH}_3 \\   &   &   &   \\ -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\   &   &   &   \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array} \right]_n \quad \checkmark$	<p>Allow any orientation of methyl groups. Ignore square brackets and "n". Continuation lines must be shown.</p>	1
3.	(b)		<p>Step 1:  <math>\text{KOH}_{(\text{aq})}/\text{NaOH}_{(\text{aq})}/\text{OH}^{-1}_{(\text{aq})} \checkmark</math>                      Step 2:  <math>\text{KMnO}_4</math>  <b>OR</b>                      acidified/<math>\text{H}^+</math> <b>AND</b> <math>\text{K}_2\text{Cr}_2\text{O}_7 \checkmark</math></p>	<p>Do <b>not</b> accept <math>\text{H}_2\text{O}</math> for <math>\text{KOH}_{(\text{aq})}/\text{NaOH}_{(\text{aq})}/\text{OH}^{-1}_{(\text{aq})}</math> for M1. Accept potassium permanganate/<math>\text{MnO}_4^-</math> /dichromate/<math>\text{Cr}_2\text{O}_7^{2-}</math> for M2. Accept <math>\text{H}_2\text{SO}_4</math> as acid. Do <b>not</b> allow any other acid.</p>	2
3.	(c)	(i)	<p>Nucleophilic <b>AND</b> substitution. <math>\checkmark</math></p>	<p>Allow <math>\text{S}_{\text{N}}2</math>. Do <b>not</b> allow <math>\text{S}_{\text{N}}1</math>. Do <b>not</b> allow hydrolysis.</p>	1

Question			Answers	Notes	Total
3.	(c)	(ii)	 <p>curly arrow going from lone pair/negative charge on O in <math>\text{OH}^-</math> to C ✓  curly arrow showing Cl leaving ✓  representation of transition state showing negative charge, square brackets and partial bonds ✓  correct products ✓</p>	<p>Accept <math>\text{OH}^-</math> with or without the lone pair.  Do not allow curly arrows originating on H in <math>\text{OH}^-</math>.  Accept curly arrows in the transition state.  Do not penalize if HO and Cl are not at <math>180^\circ</math>.  Do not award M3 if OH-C bond is represented.  If the answer in 3 (c) (i) is correct Award <b>[3 max]</b> for <math>\text{S}_{\text{N}}1</math> mechanism.  if answer in 3 (c) (i) is <math>\text{S}_{\text{N}}1</math>, award <b>[4]</b> for <math>\text{S}_{\text{N}}1</math> mechanism.</p>	4
3.	(c)	(iii)	ethyl ethanoate/ $\text{CH}_3\text{CH}_2\text{OOCCH}_3$ <b>AND</b> water/ $\text{H}_2\text{O}$ . ✓	Accept structural/skeletal formulae.	1
4.	(a)		+6/VI ✓	Do <b>not</b> accept 6/6+.	1
4.	(b)	(i)	Zinc more reactive/ <<better>> reducing agent/ <<more>> easily oxidized/loses electrons <<more>> easily. ✓	Accept "zinc higher in the activity «series»". Accept "zinc has a negative electrode potential/Cu has a positive electrode potential".	1

Question			Answers	Notes	Total
4.	(b)	(ii)	Anode (negative electrode): $\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+}_{(aq)} + 2e^- \checkmark$  Cathode (positive electrode): $\text{Cu}^{2+}_{(aq)} + 2e^- \rightarrow \text{Cu}_{(s)} \checkmark$	Award [1 max] for equilibria. Award [1 max] for equations at the wrong electrodes. State symbols not required for mark.	2
4.	(c)	(i)	$\ll E^{\ominus}_{\text{cell}} = +0.34 - (-0.76) = + \gg 1.10 \text{ «V» } \checkmark$	Accept ECF from 4 (b) (ii).	1
4.	(c)	(ii)	$\ll \Delta G^{\ominus} = -nFE^{\ominus} = \gg -2 \times 9.65 \times 10^4 \times 1.10 \checkmark$ $- 212.3 \text{ «kJ mol}^{-1}\text{» } \checkmark$ Alternate: $\ll \Delta G^{\ominus} = \gg -2 \times 9.65 \times 10^4 \times 1.05 \checkmark$ $-202.7 \text{ «kJ mol}^{-1}\text{» } \checkmark$	Award [2] for the correct final answer.	2
5.	(a)	(i)	$\left[ \begin{array}{c} \text{:O:} \\ \parallel \\ \text{:}\ddot{\text{O}}\text{---S---}\ddot{\text{O}}\text{:} \\ \parallel \\ \text{:O:} \end{array} \right]^{2-} \checkmark$	Accept any combination of dots, crosses and lines. Double bonds do not have to be opposite each other. Do <b>not</b> penalise missing square brackets.	1
5.	(a)	(ii)	$\ll 100 - (7.09 + 5.11 + 16.22 + 14.91) = \gg 56.67 \text{ «%» } \checkmark$		1

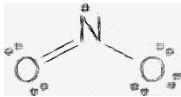
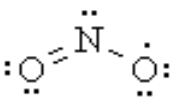
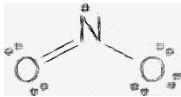
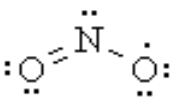
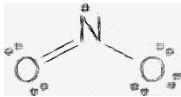
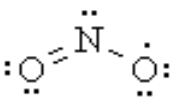
Question			Answers	Notes	Total
5.	(a)	(iii)	<p><math>n(\text{N}): 7.09\text{g}/14.01\text{g mol}^{-1}</math>, <math>n(\text{H}): 5.11\text{g}/1.01\text{ g mol}^{-1}</math>, <math>n(\text{S}): 16.22\text{g}/32.07\text{ g mol}^{-1}</math>,  <math>n(\text{Co}): 14.91\text{g}/58.93\text{ g mol}^{-1}</math> and <math>n(\text{O}): 56.67\text{g}/16.00\text{ g mol}^{-1}</math>  <b>OR</b>  <math>n(\text{N}): 0.506</math>, <math>n(\text{H}): 5.06</math>, <math>n(\text{S}): 0.506</math>, <math>n(\text{Co}): 0.253</math> and <math>n(\text{O}): 3.54</math> ✓</p> <p><math>0.506/0.253</math>, <math>5.06/0.253</math>, <math>0.506/0.253</math>, <math>0.253/0.253</math>, <math>3.54/0.253</math>  <b>OR</b>  <math>2.00</math>, <math>20.0</math>, <math>2.00</math>, <math>1.00</math> <math>14.00</math> ✓</p> <p><math>\text{N}_2\text{H}_{20}\text{S}_2\text{CoO}_{14}</math> ✓</p>	Award [3] for the correct final formula.	3
5.	(a)	(iv)	<p><math>(\text{NH}_4)_2\text{Co}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}</math>  <b>OR</b>  <math>\text{Co}(\text{NH}_4)_2(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}</math> ✓</p>	Accept $(\text{NH}_4)_2\text{Co}(\text{SO}_4)_2(\text{H}_2\text{O})_6$ .	1
5.	(b)	(i)	<p><math>\text{Ba}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightleftharpoons \text{BaSO}_4(\text{s})</math> ✓</p>	Accept single arrow in place of equilibrium sign.	1
5.	(b)	(ii)	<p>«<math>1.20\text{g}/395.29\text{ g mol}^{-1}</math> salt = <math>2 \times 3.04 \times 10^{-3}</math> «mol» <math>\text{SO}_4^{2-}</math> =» <math>6.08 \times 10^{-3}</math> «mol» ✓  «<math>233.40\text{ g mol}^{-1} \times 6.08 \times 10^{-3}</math> =» <math>1.42</math>«g» ✓  <b>OR</b>  «<math>(1.20\text{g}/400) \times 2\text{ g mol}^{-1}</math> =» <math>6.00 \times 10^{-3}</math> «mol» ✓  «<math>233.40\text{ g mol}^{-1} \times 6.00 \times 10^{-3}</math> =» <math>1.40</math>«g» ✓</p>	<p>Award [2] for correct final answer.  Accept x2 in any step.  Award [1] for half the answer, <math>0.70</math>«g».</p>	2
6.	(a)	(i)	<p>«<math>\Delta H^\circ_{\text{rxn}} = \sum \Delta H^\circ_{\text{f}}(\text{Products}) - \sum \Delta H^\circ_{\text{f}}(\text{Reactants})</math> =»  <math>-395.8 - (-296.8)</math>» = <math>-99.0</math>«kJ mol<sup>-1</sup>» ✓</p>		1

Question			Answers	Notes	Total
6.	(a)	(ii)	$\text{SO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{SO}_3(\text{aq})$ <b>AND</b> $\text{SO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{aq}) \checkmark$	Accept single arrow for the first equation.	1
6.	(a)	(iii)	significant/large/0.8 difference in <u>electronegativity/oxygen more electronegative</u> $\checkmark$ oxygen «dipole partially» negative/sulfur «dipole partially» positive <b>OR</b> oxygen more negative/higher electron density «around it than sulfur» $\checkmark$	Accept suitable diagram showing the O–S dipole.	2
6.	(b)	(i)	$\ll q = -mc\Delta T = 50.00\text{g} \times 4.18\text{J K}^{-1}\text{g}^{-1} \times (35.0-20.0)^\circ\text{C} \Rightarrow -3140.0 \ll \text{J} \gg \checkmark$ $\ll (3140/0.1)/1000 \Rightarrow -31.4 \ll \text{kJ mol}^{-1} \gg \checkmark$	Award <b>[1 max]</b> for $+31.4 \text{ kJ mol}^{-1}$ Award <b>[2]</b> for correct final answer.	2
6.	(b)	(ii)	Source of systematic error: heat loss «to the surroundings» $\checkmark$  Improvement: insulate reaction apparatus/put a lid on the beaker <b>OR</b> use a bomb/calibrated calorimeter <b>OR</b> use of windbreak around the dish/apparatus $\checkmark$		2
6.	(b)	(iii)	$\ll 1.0/15.0 \times 100 \Rightarrow 6.7 \ll \% \gg \checkmark$ <b>OR</b> $\frac{\sqrt{0.5^2 + 0.5^2}}{15.0} \times 100\% \approx 5\%$	Do not allow 6.6% Accept "5%" if the formula $\sqrt{\Sigma(\Delta A)^2}$ is used.	1



Question			Answers	Notes	Total						
6.	(b)	(iv)	more precise/more divisions per degree «on the thermometer» <b>OR</b> more precise balance <b>OR</b> larger quantities of sulfur/water <b>OR</b> larger temperature change ✓	<i>Do not accept more repetitions.</i>	1						
6.	(b)	(v)	« -297 kJ mol <sup>-1</sup> - -31.4kJ mol <sup>-1</sup> /-297 kJ mol <sup>-1</sup> x 100 => 89.4 «%» ✓  alternate: « -297 kJ mol <sup>-1</sup> - -50.0 kJ mol <sup>-1</sup> /-297 kJ mol <sup>-1</sup> x 100 => 83.2 «%» ✓		1						
7.	(a)	(i)	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%;">Name</th> <th style="width: 50%;">Number of signals</th> </tr> </thead> <tbody> <tr> <td>Ethyl methanoate</td> <td>3</td> </tr> <tr> <td>Methyl ethanoate</td> <td><b>AND 2</b></td> </tr> </tbody> </table> ✓	Name	Number of signals	Ethyl methanoate	3	Methyl ethanoate	<b>AND 2</b>		1
Name	Number of signals										
Ethyl methanoate	3										
Methyl ethanoate	<b>AND 2</b>										
7.	(a)	(ii)	same types of bonds «present in both molecules» <b>OR</b> same wavenumbers absorbed ✓		1						

Question	Answers	Notes	Total
8.	<p>«two construction lines shown on the graph, and slope calculated:  <math>\ll (-1.0 - (-3.0)) / (0.0032 - 0.0035) = \gg -6700 \checkmark</math></p> <p>«gradient <math>\times R = -E_a</math>»  <math>\ll 6700 \times 8.31 \text{ J K}^{-1} \text{ mol}^{-1} / 1000 = \gg 56</math>  <b>OR</b>  <math>\ll 6700 \times 8.31 \text{ J K}^{-1} \text{ mol}^{-1} = \gg 56000 \checkmark</math></p> <p><math>\text{kJ «mol}^{-1}\text{»} \checkmark</math>  <b>OR</b>  <math>\text{J «mol}^{-1}\text{»} \checkmark</math></p>	<p><i>Accept range 6400-7000 for M1.                  Accept range 53-59 or 53000-59000 for M2.                  Accept the unit as kJ or J without reference to per mol.                  Award [2] for final answer without units.                  Accept use of <math>\ln k_1/k_2 = -E_a/R (1/T_2 - 1/T_1)</math>.</i></p>	3

Question			Answers	Notes	Total																		
9.	(a)		Zn <sup>2+</sup> does not form coloured compounds/ has a complete d subshell/orbital ✓ 500 nm/«the setting on the colorimeter» in visible region <b>AND</b> no absorbance will be seen ✓		2																		
9.	(b)	(i)	«O <sub>3</sub> (g) → O <sub>2</sub> (g) + O•(g)» NO•(g) + O <sub>3</sub> (g) → NO <sub>2</sub> •(g) + O <sub>2</sub> (g) ✓ NO <sub>2</sub> •(g) + O <sub>3</sub> (g) → NO•(g) + 2O <sub>2</sub> (g) <b>OR</b> NO <sub>2</sub> •(g) + O•(g) → NO•(g) + O <sub>2</sub> (g) ✓	Accept radicals without • if consistent throughout.	2																		
9.	(b)	(ii)	« $v = E/h = 4.02 \times 10^{-19}/6.63 \times 10^{-34} \Rightarrow 6.06 \times 10^{14}$ «Hz» ✓		1																		
9.	(b)	(iii)	<table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th></th> <th>Structure A</th> <th>Structure B</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td>1 2</td> <td>1                  2</td> </tr> <tr> <td>Oxygen 1</td> <td>0</td> <td>0</td> </tr> <tr> <td>Nitrogen</td> <td>+1</td> <td>0</td> </tr> <tr> <td>Oxygen 2</td> <td>-1</td> <td>0</td> </tr> </tbody> </table> <p>✓</p>		Structure A	Structure B					1 2	1                  2	Oxygen 1	0	0	Nitrogen	+1	0	Oxygen 2	-1	0		1
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9.	(b)	(iv)	No <b>AND</b> Structure B has all atoms of formal charge 0 ✓		1																		