



# Mark Scheme (Results)

October 2022

Pearson Edexcel International Advanced Level  
In Chemistry (WCH14)  
Paper 01: Rates, Equilibria and Further Organic  
Chemistry

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## General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:
  - i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  - ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  - iii) organise information clearly and coherently, using specialist vocabulary when appropriate

## Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:

- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.

( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.

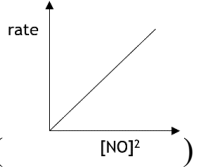
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

## Section A

| Question Number | Answer                                                                                                                                                                                                                                                                                                         | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1               | <p><b>The only correct answer is A</b> (electrical conductivity)</p> <p><i>B is not correct because none of the reactants or products is coloured</i><br/> <i>C is not correct because there is no change in mass</i><br/> <i>D is not correct because titration is not a continuous monitoring method</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                          | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(a)            | <p><b>The only correct answer is D</b> (27)</p> <p><i>A is not correct because the reaction is not overall first order</i><br/> <i>B is not correct because the reaction is not overall second order</i><br/> <i>C is not correct because the reaction is second order with respect to NO and first order with respect to H<sub>2</sub></i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(b)            | <div style="display: flex; align-items: center;"> <div style="flex: 1;"> <p><b>The only correct answer is D</b> (</p> <p><i>A is not correct because the reaction is not zero order with respect to H<sub>2</sub></i><br/> <i>B is not correct because the reaction is not zero order with respect to H<sub>2</sub></i><br/> <i>C is not correct because the concentration of NO decreases with time</i></p> </div> <div style="flex: 0.5; text-align: center;">  </div> <div style="flex: 0.5;"> <p>)</p> </div> </div> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                  | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(c)            | <p><b>The only correct answer is B (Step 2)</b></p> <p><i>A is not correct because hydrogen is involved in the rate-determining step</i><br/> <i>C is not correct because only 1 mol of hydrogen appears in the rate-determining step</i><br/> <i>D is not correct because enough information has been provided</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(a)            | <p><b>The only correct answer is C (the second ionisation energy of strontium is <math>+1614 \text{ kJ mol}^{-1}</math>)</b></p> <p><i>A is not correct because lattice energies are always exothermic</i><br/> <i>B is not correct because <math>-590</math> is twice the first electron affinity of iodine</i><br/> <i>D is not correct because the standard enthalpy change of atomisation of strontium is <math>+164 \text{ kJ mol}^{-1}</math></i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(b)            | <p><b>The only correct answer is D (+107)</b></p> <p><i>A is not correct because the sign of the enthalpy change of atomisation of strontium has not been reversed and the answer has not been divided by two</i><br/> <i>B is not correct because the sign of the enthalpy change of atomisation of strontium has not been reversed</i><br/> <i>C is not correct because <math>+214</math> is the enthalpy change in producing 2 mol of <math>\text{I(g)}</math></i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                       | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(c)            | <p><b>The only correct answer is B (<math>-1937</math>)</b></p> <p><i>A is not correct because this is the standard enthalpy change of formation of strontium iodide</i><br/> <i>C is not correct because this is the experimental lattice energy</i><br/> <i>D is not correct because the theoretical lattice energy is less exothermic than the experimental value</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 4               | <p><b>The only correct answer is A</b> (the enthalpy change of hydration of an ion is always negative)</p> <p><i>B is not correct because the enthalpy change of solution of an ionic compound can be positive</i><br/> <i>C is not correct because some ionic compounds with an endothermic enthalpy change of solution are soluble</i><br/> <i>D is not correct because enthalpy change of hydration and the entropy change of solution also determine the solubility of an ionic compound</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                   | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5               | <p><b>The only correct answer is C</b> (<math>\text{Os(s)} &lt; \text{Hg(l)} &lt; \text{He(g)} &lt; \text{O}_2\text{(g)}</math>)</p> <p><i>A is not correct because solids and liquids have lower entropy than gases</i><br/> <i>B is not correct because these elements are arranged by decreasing standard entropy</i><br/> <i>D is not correct because oxygen has greater entropy than helium</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                   | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(a)            | <p><b>The only correct answer is D</b> (low temperature and low pressure)</p> <p><i>A is not correct because the forward reaction is exothermic and there are more moles of gas on the product side</i><br/> <i>B is not correct because the forward reaction is exothermic</i><br/> <i>C is not correct because there are more moles of gas on the product side</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(b)            | <p><b>The only correct answer is D</b> (the reaction is highly exothermic)</p> <p><i>A is not correct because catalysts do not affect the position of equilibrium</i><br/> <i>B is not correct because the reaction needs to provide energy to maintain the temperature</i><br/> <i>C is not correct because the energy requirements do not depend on the thermodynamic feasibility</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(c)            | <p><b>The only correct answer is B (atm)</b></p> <p><i>A is not correct because this is for the reverse reaction</i><br/> <i>C is not correct because this is for <math>K_c</math> for the reverse reaction</i><br/> <i>D is not correct because this is for <math>K_c</math></i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7               | <p><b>The only correct answer is C (<math>\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-</math>)</b></p> <p><i>A is not correct because <math>\text{H}_2\text{O}</math> is acting as a Brønsted-Lowry base</i><br/> <i>B is not correct because <math>\text{H}_2\text{O}</math> is acting as a Brønsted-Lowry base</i><br/> <i>D is not correct because <math>\text{H}_2\text{O}</math> is acting as both a Brønsted-Lowry acid and a Brønsted-Lowry base</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8               | <p><b>The only correct answer is B (13.0)</b></p> <p><i>A is not correct because the concentration of hydroxide ions is not <math>0.2 \text{ mol dm}^{-3}</math></i><br/> <i>C is not correct because the concentration of hydroxide ions is not <math>0.050 \text{ mol dm}^{-3}</math></i><br/> <i>D is not correct because the concentration of hydroxide ions is not <math>0.025 \text{ mol dm}^{-3}</math></i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 9               | <p><b>The only correct answer is A (5.06)</b></p> <p><i>B is not correct because this is the pH of an equimolar solution of <math>\text{CH}_3\text{COOH}</math> and <math>\text{CH}_3\text{COONa}</math></i><br/> <i>C is not correct because this is the pH when the concentrations are reversed</i><br/> <i>D is not correct because this is the pH of a <math>0.100 \text{ mol dm}^{-3}</math> solution of <math>\text{CH}_3\text{COOH}</math></i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 10              | <p><b>The only correct answer is B</b> (bromocresol green (<math>pK_{in} = 4.7</math>))</p> <p><i>A is not correct because the pH range would not lie within the vertical section of a strong acid weak base titration</i><br/> <i>C is not correct because the pH range would not lie within the vertical section of a strong acid weak base titration</i><br/> <i>D is not correct because the pH range would not lie within the vertical section of a strong acid weak base titration</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 11              | <p><b>The only correct answer is A</b> (<math>CH_3COOH</math>)</p> <p><i>B is not correct because <math>CH_3COCH_3</math> has a lower boiling temperature than water</i><br/> <i>C is not correct because <math>CH_3CH_2CH_2CHO</math> is not completely miscible in water and has a lower boiling temperature than water</i><br/> <i>D is not correct because <math>CH_3CH_2COOCH_2CH_3</math> is not completely miscible in water and has a lower boiling temperature than water</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 12              | <p><b>The only correct answer is B</b> (ethanal)</p> <p><i>A is not correct because methanal does not form a precipitate with iodine in the presence of alkali</i><br/> <i>C is not correct because propanone does not form a precipitate with Benedict's solution</i><br/> <i>D is not correct because butanone does not form a precipitate with Benedict's solution</i></p> | 1    |

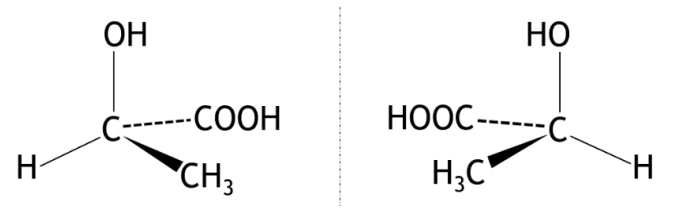
| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                          | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 13              | <p><b>The only correct answer is C</b> (<math>((CH_3)_3CCOC(CH_3)_3 + LiAlH_4)</math>)</p> <p><i>A is not correct because one of the products of this reaction is 2-methylpropan-2-ol</i><br/> <i>B is not correct because one of the products of this reaction is 2-methylpropan-2-ol</i><br/> <i>D is not correct because one of the products of this reaction is 2-methylpropan-2-ol</i></p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 14              | <p><b>The only correct answer is B</b> (increasing the carrier gas flow rate)</p> <p><i>A is not correct because decreasing the column temperature increases retention time</i><br/><i>C is not correct because the amount of sample does not affect retention time</i><br/><i>D is not correct because increasing the column length increases retention time</i></p> | 1    |

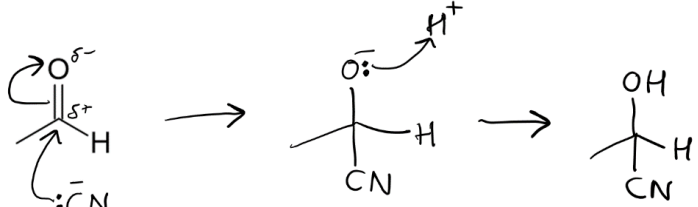
**Total for Section A = 20 marks**

## Section B

| Question Number | Answer                                                                                                                                  | Additional Guidance                                                                                                                                                                                    | Mark     |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(a)</b>    | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>2-hydroxypropanoic acid</li> </ul> | <p>Allow spaces, use of commas and omission of hyphen (eg 2,hydroxy propanoic acid)</p> <p>Allow propaneic for propanoic</p> <p>Allow hydroxyl for hydroxy</p> <p>Do not award hydroxo for hydroxy</p> | <b>1</b> |

| Question Number | Answer                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                  | Mark     |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(b)</b>    | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>one enantiomer</li> <li>second enantiomer</li> </ul> | <p>Example of correct diagram:</p>  <p>Allow groups in any order</p> <p>Allow CO<sub>2</sub>H for COOH</p> <p>Ignore all connectivity errors</p> | <b>2</b> |

| Question Number | Answer                                                                                                                                                                                    | Additional Guidance                                                                                                                                                                                                                                                                                                                                                         | Mark     |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(c)(i)</b> | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"><li>• (mixture containing) equal amounts of (both) enantiomers (of lactic acid)</li></ul> | <p>Accept equimolar/50:50 mixture for equal amounts</p> <p>Accept optical isomers / non-superimposable mirror images / + and – / R and S / dextrorotatory/D/d and laevorotatory/L/l for enantiomers</p> <p>Allow stereoisomers for enantiomers</p> <p>Allow isomers / both forms of lactic acid for enantiomers</p> <p>Ignore any reference to lack of optical activity</p> | <b>1</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                  | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 15(c)(ii)       | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• curly arrow from <b>lone pair on carbon</b> of cyanide ion (1)</li> <li>• correct C=O bond dipole shown <b>and</b> curly arrow from C=O bond to O or just beyond (1)</li> <li>• correct intermediate (1)</li> <li>• curly arrow from lone pair on O atom of intermediate to H<sup>+</sup> <b>and</b> correct product (1)</li> </ul> | <p>Example of correct mechanism:</p>  <p>Ignore absence of lone pair<br/>Do not award omission of negative charge</p> <p>Allow curly arrow from negative charge on O atom<br/>Allow curly arrow to H atom of HCN (and ignore second curly arrow and cyanide by-product)</p> <p>Ignore all C–OH connectivity errors in product</p> | 4    |

| Question Number   | Answer                                                                                                                                                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Mark     |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(c)(iii)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• H<sub>2</sub>O and H<sup>+</sup> reactants<br/><b>and</b><br/>NH<sub>4</sub><sup>+</sup> product</li> <li>• correct organic species<br/><b>and</b><br/>correct balancing</li> </ul> | <p>Example of correct equation:</p> $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2\text{O} + \text{H}^+ \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NH}_4^+$ <p>Accept H<sub>3</sub>O<sup>+</sup> for H<sup>+</sup><br/> Allow H<sup>+</sup> shown above arrow<br/> Allow any strong acid (eg HCl) for H<sup>+</sup><br/> Allow correct ammonium salt (eg NH<sub>4</sub>Cl) for NH<sub>4</sub><sup>+</sup></p> <p><b>M2 dependent on M1</b><br/> Allow any combination of structural, displayed or skeletal formulae and ignore vertical connectivity of OH/CN/COOH<br/> Allow omission of brackets around OH<br/> Allow any order of groups in structural formulae, eg CH<sub>3</sub>CCN(OH)H<br/> Allow multiples</p> $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{COOH} + \text{NH}_3 \text{ scores (1)}$ <p>Ignore state symbols, even if incorrect</p> | <b>2</b> |

| Question Number  | Answer                                                                                                                                                                                                                                                                                    | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark     |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(c)(iv)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>cyanide/<math>\text{CN}^-</math>/nucleophile attacks from above and below <b>(1)</b></li> <li>(as trigonal) planar around the <math>\text{C}(\delta^+)</math> <b>(1)</b></li> </ul> | <p>Accept from either side / both sides / front and back / top and bottom for above and below</p> <p>Ignore from both directions / two directions</p> <p>Do not award from any side</p> <p>Allow planar around reaction site / <math>\text{C}=\text{O}</math> / <math>\text{CHO}</math> / carbonyl functional group for <math>\text{C}(\delta^+)</math></p> <p>Allow flat for planar</p> <p>Ignore ethanal / carbonyl compound is planar</p> <p>Do not award intermediate / carbocation is planar</p> | <b>2</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                          | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark     |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(d)(i)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>conversion of pH to <math>[H^+]</math><br/><b>and</b><br/>conversion of <math>pK_a</math> to <math>K_a</math></li> <li><math>K_a</math> expression rearranged for <math>[HA]</math></li> <li>calculation of equilibrium <math>[HA]</math></li> <li>conversion of moles to mass</li> </ul> | <p>Example of calculation:</p> <p><math>[H^+] = 10^{-3.00} = 1.00 \times 10^{-3} / 0.00100 \text{ (mol dm}^{-3}\text{)}</math><br/> Allow 1SF (ie <math>1 \times 10^{-3} / 0.001</math>)<br/> <math>K_a = 10^{-3.86} = 1.3804 \times 10^{-4} / 0.00013804 \text{ (mol dm}^{-3}\text{)}</math><br/> Ignore SF except 1 SF</p> <p><math>[HA] = \frac{[H^+]^2}{K_a}</math></p> <p><math>[HA] = \frac{(1 \times 10^{-3})^2}{1.3804 \times 10^{-4}} = 7.2444 \times 10^{-3} / 0.0072444 \text{ (mol dm}^{-3}\text{)}</math><br/> Ignore SF except 1 SF<br/> TE on <math>K_a</math> from M1 (eg use of 3.86)<br/> No TE on incorrect <math>K_a</math> expression</p> <p><math>(7.2444 \times 10^{-3} \times 90.0 =) 0.65199 / 0.6520 / 0.652 / 0.65 \text{ (g)}</math><br/> Ignore SF except 1 SF<br/> Allow units of <math>\text{g dm}^{-3}</math><br/> Do not award incorrect units</p> <p>Correct answer with some working scores (4)</p> | <b>4</b> |

| Question Number  | Answer                                                                                                                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Mark     |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(d)(ii)</b> | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li><math>[HA]_{\text{equilibrium}} &lt; [HA]_{\text{initial}}</math> <b>(1)</b></li> <li>(so) greater mass (of acid required) <b>(1)</b></li> </ul> | <p>Allow any indication that [HA] is underestimated (in the calculation)<br/> Allow just [HA] is lower<br/> Do not award [HA]<sub>initial</sub> is lower</p> <p>Accept <math>[HA]_{\text{initial}} (= 7.2444 \times 10^{-3} + 1 \times 10^{-3})</math><br/> <math>= 8.2444 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}</math></p> <p>Allow dissociation of the (lactic) acid is not negligible / is significant</p> <p><b>M2 dependent on M1</b><br/> Accept actual mass required is 0.74199 (g)<br/> Allow just more (acid required)</p> | <b>2</b> |

| Question Number   | Answer                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mark     |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>15(d)(iii)</b> | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>(hydroxyl) OH group is electron withdrawing</li> </ul> | <p>Accept OH group has negative inductive effect<br/> Allow OH group attracts electrons<br/> Allow OH group weakens (carboxylic) O–H bond<br/> Allow lactic acid anion is more stable (than ethanoate)</p> <p>Ignore any reference to electronegativity<br/> Ignore any reference to intermolecular forces<br/> Ignore reference to degree of dissociation / <math>pK_a</math> / <math>K_a</math></p> <p>Do not award lactic acid has two acidic protons</p> | <b>1</b> |

**Total for Question 15 = 19 marks**

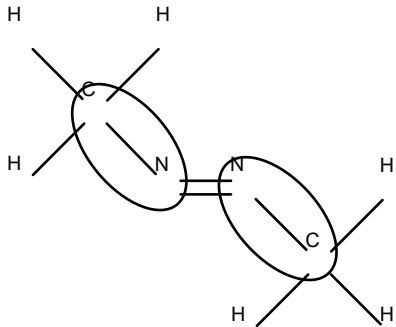
| Question Number | Answer                                                                                                                                                                     | Additional Guidance                                                                                                                                          | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(a)           | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(rate =) <math>k[\text{CH}_3\text{N}_2\text{CH}_3]</math></li> </ul> | <p>Accept rate = <math>k[\text{azomethane}]</math><br/>           Ignore state symbols even if incorrect<br/>           Do not award non-square brackets</p> | 1    |

| Question Number | Answer                                                                                                                                                                                                                                                                                                          | Additional Guidance                                                                                                                                                                                                                                       | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(b)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>determination of one half-life (with some working shown on graph)</li> <li>second half-life (with some working shown on graph)</li> <li>and constant (half-life shows reaction is first order)</li> </ul> | <p>Example of working on graph:</p> <p>(1) Allow half-life value between 126 and 138<br/>Ignore units even if incorrect</p> <p>(1) Allow half-life value between 126 and 138<br/>Ignore units even if incorrect</p> <p>(1) Allow similar for constant</p> | 2    |

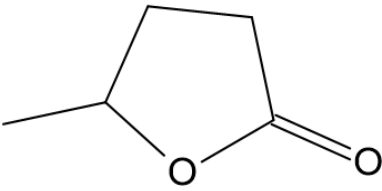
| Question Number  | Answer                                                                                                                                                                                                                                              | Additional Guidance                                                                                                                                                                                                                                                                                                                                                      | Mark     |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>16(b)(ii)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li><math>t_{1/2}</math> expression rearranged for <math>k</math></li> <li>calculation of <math>k</math> in <math>\text{s}^{-1}</math></li> </ul> | <p>Example of calculation:</p> $k = \frac{\ln 2}{t_{1/2}}$ <p>(1)</p> $k = \frac{0.69315}{(132 \times 60)} = 8.7519 \times 10^{-5} / 0.000087519 (\text{s}^{-1})$ <p>(1)</p> <p>TE on (b)(i)<br/>         Ignore SF except 1SF<br/>         Do not award <math>0.0052511 (\text{s}^{-1} / \text{min}^{-1})</math></p> <p>Correct answer with some working scores (2)</p> | <b>2</b> |

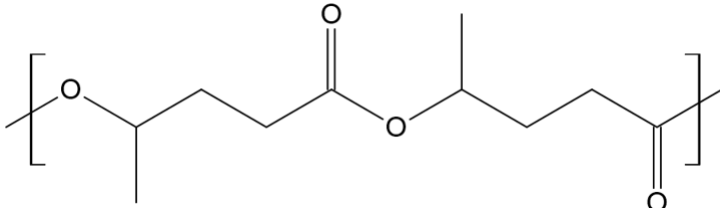
| Question Number | Answer                                                                                                                                                                                                                                                  | Additional Guidance                                                                                                                                                                                                                                                                                         | Mark     |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>16(c)(i)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>at a higher temperature more particles/collisions have <math>(E \geq E_a)</math></li> <li>(therefore the) rate (of reaction) is higher</li> </ul> | <p>Accept reverse arguments in M1 and M2</p> <p>Ignore reference to successful collisions<br/>         Ignore just particles/collision have more energy<br/>         Ignore reference to collision frequency</p> <p><b>M2 is standalone mark</b><br/>         Allow (therefore the) half-life decreases</p> | <b>2</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                             | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(c)(ii)       | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>substitution of <math>k</math> and <math>T</math> values into expression</li> <li>calculation of <math>E_a</math></li> <li>units of <math>\text{J mol}^{-1}</math> or <math>\text{kJ mol}^{-1}</math><br/><b>and</b><br/>calculated answer to 2SF</li> </ul> | <p>Example of calculation:</p> $\log \left[ \frac{1.1 \times 10^{-6}}{3.5 \times 10^{-3}} \right] = - \frac{E_a}{2.3 R} \left[ \frac{1}{523} - \frac{1}{623} \right]$ <p><b>or</b></p> $\log \left[ \frac{3.5 \times 10^{-3}}{1.1 \times 10^{-6}} \right] = - \frac{E_a}{2.3 R} \left[ \frac{1}{623} - \frac{1}{523} \right]$ <p>(1) <math>E_a = 218\,130 \text{ (J mol}^{-1}\text{)} / 218.13 \text{ (kJ mol}^{-1}\text{)}</math><br/> Ignore sign<br/> Ignore units<br/> Ignore SF except 1SF<br/> TE on transposition of <math>k</math> and <math>T</math> values</p> <p>(1) <math>E_a = (+)220\,000 \text{ J mol}^{-1} / (+)220 \text{ kJ mol}^{-1}</math></p> <p>Correct answer with some working scores (3)</p> | 3    |

| Question Number | Answer                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                    | Mark     |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>16(d)</b>    | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>a diagram that shows C–N bond(s) must break</li> </ul> |  <p>Only one C–N bond needs to be identified</p> <p>Allow any indication of C–N bond, including unambiguous use of curly arrows</p> | <b>1</b> |

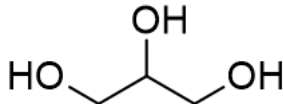
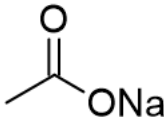
**Total for Question 16 = 11 marks**

| Question Number | Answer                                                                                                                                                      | Additional Guidance                                                                                                                                                                                   | Mark     |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 17(a)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>correct structure of cyclic ester <b>B</b></li> </ul> | <p>Example of structure:</p>  <p>Allow displayed or structural formula, or any correct combination of formulae</p> | <b>1</b> |

| Question Number | Answer                                                                                                                                                                                | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                               | Mark     |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 17(a)(ii)       | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>ester linkage</li> <li>rest of structure <b>and</b> two repeat units</li> </ul> | <p>Example of structure:</p>  <p>Allow displayed or structural formula, or any correct combination of formulae</p> <p>(1) If more than one ester linkage shown all must be correct</p> <p><b>M2 dependent on M1</b><br/>         Allow omission of brackets around extension bonds<br/>         Allow the -O- to be at either end but not both ends<br/>         Ignore n</p> | <b>2</b> |

| Question Number   | Answer                                                                                                                                                                                                                                                                                 | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mark     |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>17(a)(iii)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(as) one molecule (of reactant) forms two molecules (of product) in reaction 1 <b>(1)</b></li> <li>(as) no change in the number of molecules in reaction 2 <b>(1)</b></li> </ul> | <p>Accept moles for molecules<br/>           Allow particles for molecules<br/>           Ignore any reference to physical states</p> <p>Allow number of molecules increases in reaction 1</p> <p>Do not award no change in number of molecules in reaction 1</p> <p>Do not award standard entropy of ester B is greater than polymer C</p> <p>Allow number of molecules does not increase in reaction 2</p> <p>Do not award number of molecules decreases in reaction 2</p> | <b>2</b> |

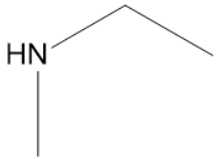
| Question Number | Answer                                                                                                                                                          | Additional Guidance                                                       | Mark     |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------|
| <b>17(b)(i)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li><math>\text{C}_9\text{H}_{14}\text{O}_6</math></li> </ul> | <p>Allow C, H and O in any order</p> <p>Do not award any other answer</p> | <b>1</b> |

| Question Number  | Answer                                                                                                                                                                                                                                   | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Mark     |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>17(b)(ii)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>correct structure of propane-1,2,3-triol (1)</li> <li>correct structure of sodium ethanoate (1)</li> <li>mole ratio (1)</li> </ul> | <p>Allow structural, displayed or skeletal formulae, or any combination<br/>Do not award molecular formulae</p>  <p>Allow missing H from OH groups in skeletal formula<br/>Ignore connectivity, including horizontal C–HO</p>  <p>Accept ionic <math>\text{O}^-\text{Na}^+</math> / <math>\text{CH}_3\text{COO}^-</math> and <math>\text{Na}^+</math> shown separately<br/>Do not award covalent <math>\text{O–Na}</math></p> <p>3 mol NaOH<br/><b>and</b><br/>3 mol sodium ethanoate/ethanoate/ethanoic acid<br/><b>and</b><br/>1 mol propane-1,2,3-triol</p> <p>Allow multiples<br/>Ignore state symbols, even if incorrect</p> | <b>3</b> |

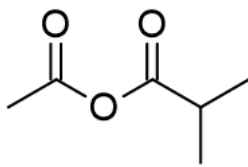
| Question Number | Answer                                                                                                                                | Additional Guidance                                           | Mark     |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|----------|
| <b>17(c)(i)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>water/H<sub>2</sub>O</li> </ul> | <p>Ignore state symbols<br/>Do not award any other answer</p> | <b>1</b> |

| Question Number  | Answer                                                                                                                                                                                                          | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Mark     |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>17(c)(ii)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>NH<sub>3</sub> reactant</li> <li>NH<sub>4</sub>Cl product<br/><b>and</b><br/>balanced equation</li> </ul> | <p>Example of correct equation:</p> $\text{CH}_3\text{COCl} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CONH}_2 + \text{NH}_4\text{Cl}$ <p>Allow structural, displayed, skeletal or molecular formulae<br/>Ignore state symbols, even if incorrect</p> <p><b>M1 dependent on CH<sub>3</sub>COCl / an organic reactant</b></p> <p><b>M2 dependent on M1</b><br/>Allow HCl<br/>Allow multiples</p> <p><math>\text{CH}_3\text{COCl} + \text{NH}_3 \rightarrow \text{CH}_3\text{CONH}_2 + \text{HCl}</math> scores (2)</p> <p><math>\text{C}_2\text{H}_3\text{ClO} + \text{NH}_3 \rightarrow \text{C}_2\text{H}_5\text{NO} + \text{HCl}</math> scores (2)</p> | <b>2</b> |

| Question Number   | Answer                                                                                                                           | Additional Guidance                                                                                                                                               | Mark     |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>17(c)(iii)</b> | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>CH<sub>3</sub>SH</li> </ul> | <p>Allow displayed formula<br/>Allow skeletal formula provided H attached to S shown</p> <p>Ignore name even if incorrect</p> <p>Do not award CH<sub>4</sub>S</p> | <b>1</b> |

| Question Number | Answer                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                            | Mark     |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 17(c)(iv)       | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"><li>skeletal formula of <i>N</i>-methylethylamine</li></ul> | <p>Example of correct structure:</p>  <p>Allow displayed N–H bond</p> <p>Allow omission of NH proton</p> <p>Ignore any other type of formula</p> <p>Ignore bond angles and bond lengths</p> | <b>1</b> |

| Question Number                                                                                                             | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Additional Guidance                                | Mark                                                  |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------------------|---|---|-----|---|-----|---|---|---|---|---|--|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|---|---------------------------------------------------------------------------|---|------------------------------------------------------------|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 17(d)                                                                                                                       | <p>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> <table><tr><th></th><th>Number of marks awarded for structure and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr></table> | Number of indicative marking points seen in answer | Number of marks awarded for indicative marking points | 6 | 4 | 5-4 | 3 | 3-2 | 2 | 1 | 1 | 0 | 0 |  | Number of marks awarded for structure and sustained lines of reasoning | Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. | 2 | Answer is partially structured with some linkages and lines of reasoning. | 1 | Answer has no linkages between points and is unstructured. | 0 | <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s).</p> <p>Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.</p> | 6 |
| Number of indicative marking points seen in answer                                                                          | Number of marks awarded for indicative marking points                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| 6                                                                                                                           | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| 5-4                                                                                                                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| 3-2                                                                                                                         | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| 1                                                                                                                           | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| 0                                                                                                                           | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
|                                                                                                                             | Number of marks awarded for structure and sustained lines of reasoning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| Answer is partially structured with some linkages and lines of reasoning.                                                   | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |
| Answer has no linkages between points and is unstructured.                                                                  | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |   |

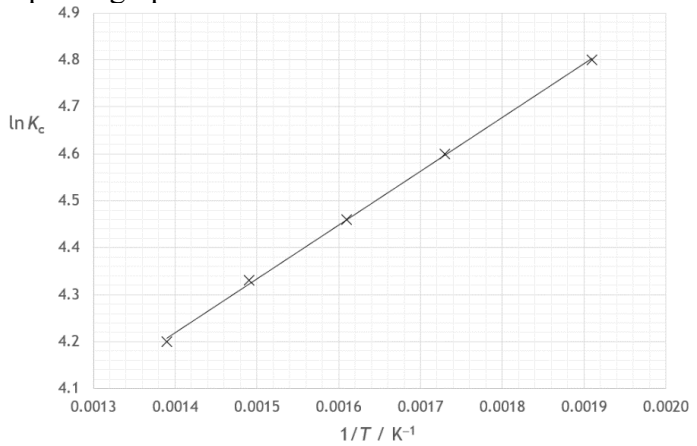
|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |  |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
|  | <p>Indicative points:</p> <ul style="list-style-type: none"> <li>• <b>IP1:</b> confirmation of RMM/molar mass/molecular formula (from molecular ion peak)</li> <li>• <b>IP2:</b> interpretation of IR data</li> <li>• <b>IP3:</b> interpretation of carbon-13 NMR data</li> <li>• <b>IP4:</b> identification of fragment causing singlet proton NMR peak</li> <li>• <b>IP5:</b> identification of fragment causing doublet NMR peak<br/>and<br/>septet NMR peak</li> <li>• <b>IP6:</b> structure of Z</li> </ul> | <p><math>M_r = 130</math> / (molar) mass is 130 (<math>\text{g mol}^{-1}</math>)<br/><b>or</b><br/>molecular formula is <math>\text{C}_6\text{H}_{10}\text{O}_3</math></p> <p><b>C=O</b> (carboxylic acid, anhydrides as has)<br/>peak(s) at 1820 (<math>\text{cm}^{-1}</math>)<br/><b>or</b><br/>1754 (<math>\text{cm}^{-1}</math>)</p> <p>(five peaks so) five carbon environments</p> <p>singlet / peak at <math>\sim 2.1</math> ppm / peak with 3H<br/>due to <b><u>CH</u><sub>3</sub>CO</b></p> <p>doublet / peak at <math>\sim 1.1</math> ppm /<br/>peak with 6H due to (<b><u>CH</u><sub>3</sub></b>)<sub>2</sub>CH<br/><b>and</b><br/>septet/heptet/multiplet / peak at <math>\sim 2.5</math> ppm<br/>/ peak with 1H due to (<math>\text{CH}_3</math>)<sub>2</sub><b><u>CH</u></b></p>  <p>Allow any unambiguous structure</p> |  |
|--|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|

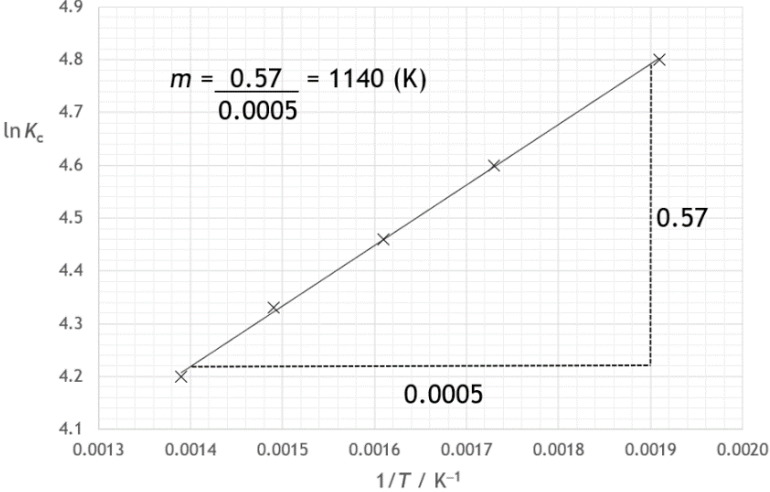
Total for Question 17 = 20 marks

| Question Number | Answer                                                                                                                      | Additional Guidance                                                                                                                                                                                       | Mark     |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(a)</b>    | An answer that makes reference to the following point: <ul style="list-style-type: none"> <li>correct expression</li> </ul> | Example of correct expression:<br>$(K_c =) \frac{[HI(g)]^2}{[H_2(g)][I_2(g)]}$<br>Allow omission of state symbols<br>Ignore any reference to units, even if incorrect<br>Do not award non-square brackets | <b>1</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                          | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Mark     |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(b)</b>    | An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>moles H<sub>2</sub> and I<sub>2</sub> reacting (1)</li> <li>equilibrium moles H<sub>2</sub> <b>and</b> equilibrium moles I<sub>2</sub> (1)</li> <li>calculation of K<sub>c</sub> (1)</li> <li>calculated answer to 3SF or 2SF <b>and</b> no units (1)</li> </ul> | Correct answer with some working scores (4)<br><br>Example of calculation:<br><br>$\frac{9.68 \times 10^{-3}}{2} = 4.84 \times 10^{-3} \text{ (mol)}$<br><br>$n(H_2) = 5.00 \times 10^{-3} - 4.84 \times 10^{-3} = 1.6 \times 10^{-4} \text{ (mol)}$<br>$n(I_2) = 1.00 \times 10^{-2} - 4.84 \times 10^{-3} = 5.16 \times 10^{-3} \text{ (mol)}$<br>TE on moles reacting provided +ve moles<br><br>(Because volume is 1 dm <sup>3</sup> , mol = concentration)<br>$(K_c =) \frac{(9.68 \times 10^{-3})^2}{(1.6 \times 10^{-4} \times 5.16 \times 10^{-3})} = 113.496$<br>TE on equilibrium moles<br>TE on K <sub>c</sub> expression from (a) for inverted expression or use of [HI] for [HI] <sup>2</sup> only<br>Do not award -ve K <sub>c</sub> value<br><br>(K <sub>c</sub> =) 113 / 110 <b>and</b> no units<br>Allow 114 <b>and</b> no units if 9.7 × 10 <sup>-3</sup> moles reacting<br>TE on M3<br>TE on units from any K <sub>c</sub> expression in (a) | <b>4</b> |

| Question Number | Answer                                                                                                                                                                             | Additional Guidance                                                                                                                                       | Mark     |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(c)(i)</b> | An answer that makes reference to the following points: <ul style="list-style-type: none"> <li><math>1/T</math> value to 3SF</li> <li><math>\ln K_c</math> value to 3SF</li> </ul> | <b>Penalise SF once only</b><br>0.00191<br>Accept $1.91 \times 10^{-3}$<br>Calculator value is 0.001912045889<br>4.60<br>Calculator value is 4.5971138014 | <b>2</b> |

| Question Number  | Answer                                                                                                                                                                                                                | Additional Guidance                                                                                                                                                                                                                                                                                                                              | Mark     |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(c)(ii)</b> | An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>linear scales</li> <li>five points correctly plotted</li> <li>straight line of best fit covering all points</li> </ul> | Example of graph:<br> <ul style="list-style-type: none"> <li>points plotted must cover at least half of grid in each direction</li> <li>Allow accuracy to <math>\pm</math> half a small square</li> <li>Ignore extrapolations of line of best fit</li> </ul> | <b>3</b> |

| Question Number   | Answer                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                                                    | Mark     |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(c)(iii)</b> | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>calculation of gradient (with some working)</li> </ul> | <p>Example of working on graph:</p>  <p>gradient = (+)1140 (K)<br/> Allow any value between 1060 and 1220</p> <p>Allow use of data from the table provided points used lie on line of best fit</p> <p>Ignore units even if incorrect<br/> Ignore SF except 1 SF</p> | <b>1</b> |

| Question Number  | Answer                                                                                                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                          | Mark     |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(c)(iv)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>rearrangement of expression for <math>\Delta H</math> <b>(1)</b></li> <li>calculation of <math>\Delta H</math> <b>(1)</b></li> </ul> | <p>Example of calculation:</p> <p><math>\Delta H = -\text{gradient} \times R</math></p> <p><math>\Delta H = -1140 \times 8.31 = -9473.4 \text{ (J mol}^{-1}\text{)}</math><br/> Accept <math>-9.4734 \text{ kJ mol}^{-1}</math><br/> Accept use of 8.314 for <math>R</math></p> <p>TE on value of gradient from (c)(iii)</p> <p>Ignore SF except 1SF</p> <p>Do not award incorrect units</p> | <b>2</b> |

| Question Number | Answer                                                                                                                                                                                            | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 18(c)(v)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• calculation of <math>\Delta G</math></li> <li>• units of <math>\Delta G</math></li> </ul> | <p>Example of calculation:</p> <p>(1) <math>\Delta G = -RT \ln K_c</math><br/> <math>= -8.31 \times 620 \times 4.46</math><br/> <math>= -22979 \text{ (J mol}^{-1}\text{)}/-22.979 \text{ (kJ mol}^{-1}\text{)}</math><br/> Accept <math>-22980/-22.980</math> from use of <math>\ln(86.5)</math> for 4.46</p> <p>Accept use of 8.314 for <math>R</math></p> <p>Ignore SF except 1SF</p> <p>Do not award omission of <math>-ve</math> sign</p> <p>(1) <b>M2 dependent on use of <math>R \times T</math> in M1</b><br/> <math>\text{J mol}^{-1}</math> (from <math>8.31 \times 620</math>)<br/> OR<br/> <math>\text{kJ mol}^{-1}</math> (from <math>8.31/1000 \times 620</math>)</p> <p>Calculation of <math>\Delta G</math> at any other temperature with correct units scores (1)</p> | 2    |

| Question Number  | Answer                                                                                                                                                                                                                                                                         | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mark     |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(c)(vi)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• rearrangement of expression for <math>\Delta S_{\text{system}}</math> <b>(1)</b></li> <li>• calculation of <math>\Delta S_{\text{system}}</math> <b>(1)</b></li> </ul> | <p>Example of calculation:</p> $\Delta S_{\text{system}} = \frac{(\Delta H - \Delta G)}{T}$ $\Delta S_{\text{system}} = \frac{(-9473.4 - (-22979))}{620}$ $= (+)21.783 \text{ (J mol}^{-1} \text{ K}^{-1}, \text{ units can be in any order)}$ <p>Accept 0.021783 (kJ mol<sup>-1</sup> K<sup>-1</sup>, units can be in any order)</p> <p>TE on <math>\Delta H</math> from (c)(iv) and <math>\Delta G</math> from (c)(v)</p> <p>Ignore SF except 1SF</p> <p>Do not award incorrect units</p> <p>Correct answer scores (2)</p> | <b>2</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                               | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark     |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| <b>18(d)</b>    | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• <math>\Delta S_{\text{surroundings}}</math> is (always) positive<br/><b>and</b><br/>(as) <math>\Delta H</math> is negative</li> <li>• <math>\Delta S_{\text{system}}</math> is positive</li> <li>• (so) <math>\Delta S_{\text{total}}</math> is (always) positive</li> </ul> | <p>(1) Allow (as) reaction is exothermic</p> <p>Allow <math>\Delta S_{\text{surroundings}}</math> is (always) negative<br/><b>and</b><br/>(as) <math>\Delta H</math> is positive / reaction is endothermic as TE on (c)(iv)</p> <p>(1) Allow <math>T\Delta S</math> is positive</p> <p>Allow <math>\Delta S_{\text{system}} / T\Delta S</math> is negative as TE on (c)(vi)</p> <p>(1) <b>M3 dependent on positive <math>\Delta S_{\text{surroundings}}</math> and positive <math>\Delta S_{\text{system}}</math></b><br/>Accept (so) <math>\Delta S_{\text{total}} &gt; 0</math></p> | <b>3</b> |

Total for Question 18 = 20 marks

Total for Section C = 20 marks

Total for Paper = 90 marks

