



# Mark Scheme (Results)

January 2024

Pearson Edexcel International Advanced Level  
In Chemistry (WCH14)

Paper 01 Rates, Equilibria and Further Organic  
Chemistry

## Section A

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(a)            | <p><b>The only correct answer is B</b> (the collisions do not have sufficient energy)</p> <p><i>A is incorrect because low reactant concentrations will reduce the number of collisions but not the proportion that are successful</i></p> <p><i>C is incorrect because at equilibrium both the forward and reverse reactions occur at the same rate</i></p> <p><i>D is incorrect because the reacting ratio does not reflect the mechanism of the reaction</i></p> | (1)  |
| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Mark |
| 1(b)            | <p><b>The only correct answer is A</b> (atm)</p> <p><i>B is incorrect because the expression for <math>K_p</math> is inverted</i></p> <p><i>C is incorrect because the different state of one of the products has not been taken into account</i></p> <p><i>D is incorrect because the expression for <math>K_p</math> is inverted and the different state of one of the products has not been taken into account</i></p>                                           | (1)  |
| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Mark |
| 2               | <p><b>The only correct answer is D</b> (0.125)</p> <p><i>A is incorrect because this is the amount that has decomposed after three half-lives</i></p> <p><i>B is incorrect because this is the concentration remaining after one half-life</i></p> <p><i>C is incorrect because this is the concentration remaining after two half-lives</i></p>                                                                                                                    | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(a)            | <p><b>The only correct answer is C</b> (it alters the enthalpy change of the reaction)</p> <p><i>A is incorrect because a catalyst does lower the activation energy of the reaction</i></p> <p><i>B is incorrect because a catalyst has no effect on the equilibrium constant for the reaction</i></p> <p><i>D is incorrect because a catalyst does reduce the energy cost of the reaction</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(b)            | <p><b>The only correct answer is B</b> (a temperature of 400 K and a pressure of 200 atm)</p> <p><i>A is incorrect because the pressure is lower and there is a reduction in volume in the forward direction</i></p> <p><i>C is incorrect because the temperature is higher and the forward reaction is exothermic and the pressure is lower and there is a reduction in volume in the forward direction</i></p> <p><i>D is incorrect because the temperature is higher and the forward reaction is exothermic</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 4               | <p><b>The only correct answer is C</b> (K , J , L)</p> <p><i>A is incorrect because J has a smaller reduction of gaseous moles than K</i></p> <p><i>B is incorrect because L has an increase in gaseous moles</i></p> <p><i>D is incorrect because L has an increase in gaseous moles</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                           | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5               | <p><b>The only correct answer is D (+174)</b></p> <p><i>A is incorrect because the standard entropy of products has been subtracted from that of reactants</i></p> <p><i>B is incorrect because the stoichiometry has not been considered</i></p> <p><i>C is incorrect because the stoichiometry has not been considered and the standard entropy of products has been subtracted from that of reactants</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                       | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6               | <p><b>The only correct answer is C (negative, positive)</b></p> <p><i>A is incorrect because a gas is changing to a liquid so <math>\Delta S_{\text{system}}</math> is reduced</i></p> <p><i>B is incorrect because a gas is changing to a liquid so <math>\Delta S_{\text{system}}</math> is reduced and condensation is exothermic</i></p> <p><i>D is incorrect because condensation is exothermic</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7               | <p><b>The only correct answer is B (neutral with a pH of 6.6)</b></p> <p><i>A is incorrect because this is the pH of water at 25 °C</i></p> <p><i>C is incorrect because the water is neutral <math>[H^+] = [OH^-]</math></i></p> <p><i>D is incorrect because the water is neutral and the pH has been calculated incorrectly</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                         | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8               | <p><b>The only correct answer is B (CH<sub>2</sub>ClCOOH)</b></p> <p><i>A is incorrect because hydrogen is not as electronegative as chlorine so acid is less dissociated</i></p> <p><i>C is incorrect because bromine is not as electronegative as chlorine so acid is less dissociated</i></p> <p><i>D is incorrect because iodine is not as electronegative as chlorine so acid is less dissociated</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 9               | <p><b>The only correct answer is C (H<sub>2</sub>PO<sub>4</sub><sup>-</sup>)</b></p> <p><i>A is incorrect because H<sub>3</sub>PO<sub>4</sub> is the conjugate acid of H<sub>2</sub>PO<sub>4</sub><sup>-</sup></i></p> <p><i>B is incorrect because H<sub>3</sub>O<sup>+</sup> is the conjugate acid of H<sub>2</sub>O</i></p> <p><i>D is incorrect because PO<sub>4</sub><sup>3-</sup> is the conjugate base of HPO<sub>4</sub><sup>2-</sup></i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 10              | <p><b>The only correct answer is B (13.6)</b></p> <p><i>A is incorrect because the concentration of hydroxide ions has been ignored</i></p> <p><i>C is incorrect because only one mole of hydroxide ions has been used</i></p> <p><i>D is incorrect because the hydroxide ion concentration has been squared</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 11(a)           | <p><b>The only correct answer is C</b> (optical isomerism only)</p> <p><i>A is incorrect because carvone does not show geometric isomerism</i></p> <p><i>B is incorrect because does not show geometric isomerism and has optical isomers</i></p> <p><i>D is incorrect because carvone has optical isomers</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                         | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 11(b)           | <p><b>The only correct answer is D</b> (2,4-dinitrophenylhydrazine)</p> <p><i>A is incorrect because ammoniacal silver nitrate does not react with a ketone or C=C</i></p> <p><i>B is incorrect because sodium carbonate does not react with a ketone or C=C</i></p> <p><i>C is incorrect because iodine in the presence of an alkali only reacts with a methyl ketone</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 11(c)           | <p><b>The only correct answer is A</b> (10)</p> <p><i>B is incorrect because no carbon is equivalent to any other</i></p> <p><i>C is incorrect because no two carbons are equivalent to any others</i></p> <p><i>D is incorrect because no three carbons are equivalent to any others</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 12              | <p><b>The only correct answer is A</b> (butanoic acid and pentan-1-ol)</p> <p><i>B is incorrect because the alcohol from which the ester is made must have five carbon atoms</i></p> <p><i>C is incorrect because aldehydes do not react with alcohols to form esters</i></p> <p><i>D is incorrect because the acid from which the ester is made must have four carbon atoms</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                   | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 13              | <p><b>The only correct answer is C</b> (reduction)</p> <p><i>A is incorrect because the reaction involves addition of hydrogen and reduction</i></p> <p><i>B is incorrect because the reaction is reduction of the ethanoic acid by lithium tetrahydridoaluminate(III)</i></p> <p><i>D is incorrect because the reaction is reduction of the ethanoic acid by lithium tetrahydridoaluminate(III)</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 14              | <p><b>The only correct answer is A</b> (propanal)</p> <p><i>B is incorrect because both the oxygen and the hydrogen of the -OH group in propan-1-ol can form hydrogen bonds with water</i></p> <p><i>C is incorrect because propanoic acid is partially dissociated and both the ions and the acid can form hydrogen bonds with water</i></p> <p><i>D is incorrect because the salt is dissociated and the sodium ion is hydrated and the propanoate ion can form ion-dipole and hydrogen bonds with water</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 15(a)           | <p><b>The only correct answer is A</b> (2-methylpropan-2-ol)</p> <p><i>B is incorrect because <math>M_r</math> of pentane is 72, and loss of <math>CH_3</math> would give the major ion at <math>m/z = 57</math></i></p> <p><i>C is incorrect because <math>M_r</math> of propanal is 58, so the major ion cannot be at <math>m/z = 59</math></i></p> <p><i>D is incorrect because <math>M_r</math> of propanone is 58, so the major ion cannot be at <math>m/z = 59</math>.</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 15(b)           | <p><b>The only correct answer is D</b> (propanone)</p> <p><i>A is incorrect because there is no peak due to an O-H stretching vibration</i></p> <p><i>B is incorrect because pentane spectrum does not have a peak due to a C=O stretching vibration</i></p> <p><i>C is incorrect because propanal reacts with acidified aqueous sodium dichromate.</i></p> | (1)  |

**TOTAL FOR SECTION A = 20 MARKS**

## Section B

| Question Number | Answer                                                                                                                | Additional Guidance                   | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------|------|
| 16(a)(i)        | An answer that makes reference to the following point: <ul style="list-style-type: none"> <li>Blue(-)black</li> </ul> | Accept (dark) blue /black/ black-blue | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                  | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(a)(ii)       | An explanation that makes reference to the following points: <ul style="list-style-type: none"> <li>the thiosulfate must be used up (before the concentration of the other reagents change significantly)</li> <li>so the rate is unaffected by changes in concentration of the reagents during the reaction</li> </ul> | <p>(1) Allow the thiosulfate/it reacts completely/Reaction 1 is complete/ there must be (some) iodine produced to react with starch</p> <p>(1) Allow (before) the concentration of the other reactants changes appreciably/so that the concentration of other reactants does not change much/so that the initial rate is determined</p> <p>If no other mark scored allow :<br/>if the concentration is high then no iodine produced / no complex formed/no colour change scores 1</p> <p>Do not award references to an increase in the rate of the reaction of sodium thiosulfate and iodine if the concentration is high.</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(b)(i)        | <p>An answer that makes reference to three of the following points:</p> <ul style="list-style-type: none"> <li>(reaction is) first order in hydrogen peroxide because as the concentration is halved, the reciprocal of time/the rate is halved</li> <li>(reaction is) zero order in hydrogen ions as the rate does not change with a change in concentration of hydrogen ions</li> <li>(reaction is) first order in iodide ions because as the concentration is doubled the reciprocal of time/rate is doubled</li> </ul> | <p>Marks can be scored from annotation on table</p> <p>(1) Allow as the concentration of hydrogen peroxide is halved (changed in mixtures one and two) the time is doubled<br/>Allow reverse argument</p> <p>(1) Allow as the concentration of hydrogen ions is changed (between mixtures one and four) (by a factor of ten) there is little/no change in rate</p> <p>(1) Allow as the concentration of iodide ions is doubled (in mixtures one and three) the time is halved<br/>Allow reverse argument<br/>If no other mark is scored award one mark if all three orders of reaction are correct with no or incorrect justification.</p> | (3)  |

| Question Number | Answer                                                                                                                                                                  | Additional Guidance                                                                                                                  | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(b)(ii)       | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>rate = <math>k[\text{H}_2\text{O}_2][\text{I}^-]</math></li> </ul> | <p>Allow rate = <math>k[\text{H}_2\text{O}_2][\text{I}^-][\text{H}^+]^0</math><br/>Allow species in any order<br/>TE from (b)(i)</p> | (1)  |

| Question Number | Answer                                                                                                                   | Additional Guidance                                                                                                                                                   | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(b)(iii)      | <ul style="list-style-type: none"> <li>calculation of the amount of iodine which reacted with the thiosulfate</li> </ul> | <u>Example of calculation</u><br>$8.50 \times 10^{-5} \div 2 = 4.25 \times 10^{-5} \text{ (mol)}$<br>Correct answer with no working scores 1<br>Ignore SF except 1 SF | (1)  |

| Question Number | Answer                                                                                                                                                                                                                         | Additional Guidance                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(b)(iv)       | <ul style="list-style-type: none"> <li>calculation of rate of loss of amount of iodine / loss of hydrogen peroxide in mols</li> <li>calculation of reaction rate in <math>\text{mol dm}^{-3} \text{ s}^{-1}</math>)</li> </ul> | <u>Example of calculation</u><br>$4.25 \times 10^{-5} \div 195 = 2.1795 / 2.18 / 2.2 \times 10^{-7} \text{ (mol s}^{-1}\text{)}$<br>$2.1795 \times 10^{-7} \div 0.05 = 4.3590 / 4.36 / 4.4 \times 10^{-6} \text{ (mol dm}^{-3} \text{ s}^{-1}\text{)}$<br>Correct answer with no working scores 2<br>Ignore SF except 1SF<br>TE from (iii) | (2)  |

| Question Number | Answer                                                                                                                                   | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(b)(v)        | <ul style="list-style-type: none"> <li>rearrangement of the rate equation and calculation of the rate constant</li> <li>units</li> </ul> | <p><u>Example of calculation</u></p> <p>(1) <math>k = \text{rate} \div ([\text{H}_2\text{O}_2] \times [\text{I}^-])</math></p> <p><math>k = 4.359 \times 10^{-6} \div (5.4 \times 10^{-2} \times 8.2 \times 10^{-3})</math><br/> <math>= 4.359 \times 10^{-6} \div 4.428 \times 10^{-4}</math><br/> <math>= 9.844 \times 10^{-3}</math></p> <p>Ignore SF except 1SF</p> <p>(1) <math>\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}</math></p> <p>Accept units in any order</p> <p>Correct answer with no working and units scores 2</p> <p>TE from (ii) (iii) and (iv)</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Additional Guidance                                                                                                                                                                                                      | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(c)(i)        | <ul style="list-style-type: none"> <li>axes correct with scales allowing plot to cover at least half the grid and <math>\ln</math> rate values becoming more negative down the axis</li> <li>both axes labelled with units <math>\text{K}^{-1}</math> on x axis</li> <li>points correctly plotted and best fit line drawn</li> <li>gradient in the range <math>-7200</math> to <math>-6800</math></li> <li> <math>E_a = -(-7000 \times 8.31) \div 1000</math><br/> <math>= +58.2 \text{ (kJ mol}^{-1}\text{)}</math><br/> range 56.5 to 59.9<br/> TE on incorrect gradient value but <math>E_a</math> must be positive<br/> Ignore SF except 1 SF </li> </ul> | <p><u>Example of calculation</u></p> <p>Allow horizontal axis at bottom of graph<br/> Ignore extrapolation</p> <p>Allow plotting of all points except the incorrect one<br/> TE on incorrect gradient<br/> Ignore SF</p> | (5)  |

| Question Number | Answer                                                                                                                                                                                                                | Additional Guidance                                                                                                                         | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16(c)(ii)       | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• correct value of <math>1/T</math> from the graph (1)</li> <li>• conversion to temperature (1)</li> </ul> | <p><math>0.00331 \pm 0.00001</math></p> <p>302K (Range 301K -303K)<br/>TE from incorrect <math>1/T</math> read from graph<br/>Ignore SF</p> | (2)  |

(Total for Question 16 = 19 marks)

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Additional Guidance                                                                                                                                                                                   | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 17(a)(i)        | <p>An answer that makes reference to six of the following points:<br/>Clockwise from enthalpy change A</p> <ul style="list-style-type: none"> <li>Mg(g) + Cl<sub>2</sub>(g) (1)</li> <li>B / (+)738 (1)</li> <li>Mg<sup>+</sup>(g) + Cl<sub>2</sub>(g) + e<sup>-</sup> (1)</li> <li>C/ (+)1451 (1)</li> <li>2D / (+)244 (1)</li> <li>E / (-)2526 (1)</li> </ul> <p>All 6 points correct three marks<br/>4/5 points correct two marks<br/>2/3 points correct one mark</p> | <p>Allow any unambiguous labels for the arrows including words or values<br/>If the value is given correctly ignore an incorrect letter.<br/>Penalise missing or incorrect state symbol once only</p> | (3)  |

| Question Number | Answer                                                                                                                                                                            | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark |
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| 17(a)(ii)       | <ul style="list-style-type: none"> <li>correct expression (1)</li> <li>correct rearrangement <b>and</b> evaluation of 1<sup>st</sup> electron affinity of chlorine (1)</li> </ul> | <u>Example of calculation</u><br>$-641 = 148 + 738 + 1451 + (2 \times 122) + 2EACl_2 - 2526$ $2EACl_2 = -641 - (148 + 738 + 1451 + (2 \times 122)) + 2526$ $= -696$ $\Delta H(EA_{\text{chlorine}}) = -696 \div 2 = -348 \text{ (kJ mol}^{-1}\text{)}$ <p>Correct answer with no working scores 2<br/>         No TE on incorrect expression except<br/>         Failure to multiply atomisation energy by 2 i.e.<br/> <math>2EACl_2 = -574 \text{ (kJ mol}^{-1}\text{)}</math> and then <math>\Delta H(EA_{\text{chlorine}}) = -574 \div 2 = -287 \text{ (kJ mol}^{-1}\text{)}</math> for 1 mark</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                    | Additional Guidance                                                                                                                                                                                                        | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 17(a)(iii)      | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>the third ionisation energy for magnesium is very high (because the third electron is being removed from the 2p orbital / an inner shell) (1)</li> <li>which would not be compensated for by the lattice energy (1)</li> </ul> | <p>Allow the enthalpy of formation of <math>MgCl_3</math> would be (highly) endothermic/the energy released when <math>MgCl_3</math> is formed would need to be more than that released when <math>MgCl_2</math> forms</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                 | Additional Guidance                                                                                                                                                                                       | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 17(a)(iv)       | <ul style="list-style-type: none"> <li>calculation of the combined hydration enthalpies of the gaseous ions (1)</li> <li>subtraction of the lattice energy of the solid (1)</li> </ul> | <u>Example of calculation</u><br>$-1920 - 2(364) = -2648 \text{ (kJ mol}^{-1}\text{)}$<br>$-2648 - -2526 = -122 \text{ (kJ mol}^{-1}\text{)}$<br>Correct answer scores 2<br>Sign reversed (+)122 scores 1 | (2)  |

| Question Number                                                                                                        | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Additional Guidance                                | Mark                                                  |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |
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| *17(b)                                                                                                                 | <p>This question assesses the 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 of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent 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 of answer and sustained lines of reasoning | Answer shows a coherent 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>Guidance on how the mark scheme should be applied.</p> <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, a response 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 were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p> <p>In general it would be expected that<br/>5 or 6 indicative points would get 2 reasoning marks<br/>3 or 4 indicative points would get 1 reasoning mark<br/>0, 1 or 2 indicative points would get zero reasoning marks</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><b>Comment:</b> 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 of answer and sustained lines of reasoning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |     |
| Answer shows a coherent 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><b>Indicative content</b></p> <p><b>IP1</b> The magnesium (ion) has larger charge/smaller <b>ionic</b> radius than the sodium (ion)</p> <p><b>IP2</b> The attraction between the ions/ionic bond is stronger in magnesium fluoride (so lattice energies of sodium fluoride are less exothermic)</p> <p><b>IP3</b> The magnesium ion is more polarising than the sodium ion</p> <p><b>IP4</b> The chloride ion is larger/ more polarisable than the fluoride ion</p> <p><b>IP5</b> The difference between theoretical and experimental values is greatest for magnesium chloride / the difference between theoretical and experimental values is least for sodium fluoride</p> <p><b>IP6</b> Magnesium chloride has the greatest degree of covalent character/Sodium fluoride has the greatest degree of ionic character</p> | <p>Allow reverse arguments throughout</p> <p>Allow sodium ion has 1+ charge and magnesium ion has 2+charge/sodium has smaller charge density than magnesium</p> <p>Cannot get this mark just for comparing values in table</p> <p>Magnesium ion causes more distortion of anion than sodium ion</p> <p>Accept the electronegativity <b>difference</b> between sodium and fluorine is greater than that between magnesium and chlorine</p> <p>Allow <math>\text{MgCl}_2</math> has more covalent character than <math>\text{NaF}</math><br/>Allow <math>\text{NaF}</math> is 100% ionic and <math>\text{MgCl}_2</math> is partially covalent</p> <p>Ignore references to the number of bonds<br/>mention of intermolecular forces loses 1 reasoning mark</p> |  |
|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|

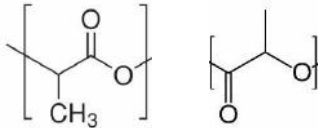
(Total for Question 17 = 15 marks)

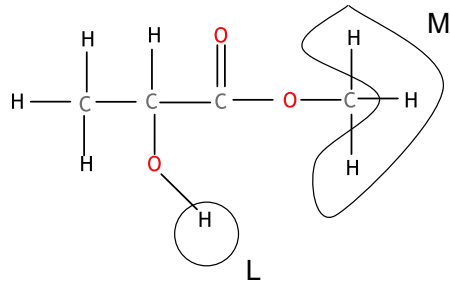
| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                              | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 18(a)           | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>Step 1<br/>Hydrogen cyanide and potassium/sodium cyanide<br/>HCN and KCN / KCN and <math>\text{H}^+</math> / HCN and a trace of base (1)</li> <li>Step 2<br/>(dil) hydrochloric acid /HCl/ sulfuric acid / <math>\text{H}_2\text{SO}_4</math> (and water) (1)</li> </ul> | <p>If names and formulae are given both must be correct</p> <p>Allow named strong acids<br/>Accept HCN/hydrogen cyanide<br/>Do not award just cyanide ions</p> <p>If HCN used accept trace of base/NaOH//at pH5-8</p> <p>Accept NaOH/sodium hydroxide/KOH/potassium hydroxide <b>then</b> hydrochloric/sulfuric acid to produce free carboxylic acid<br/>Do not award just concentrated acid<br/>Do not award <math>\text{H}^+</math> or <math>\text{H}^+</math> and water</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Additional Guidance                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 18(b)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• lone pair on carbon of <math>\text{CN}^-</math></li> <li>• dipole shown on <math>\text{C}=\text{O}</math></li> <li>• arrow from lone pair on <math>\text{CN}^-</math> to carbonyl C</li> <li>• arrow from <math>\text{C}=\text{O}</math> double bond to O or just beyond</li> <li>• correct formula and charge on intermediate</li> <li>• lone pair on O of intermediate</li> <li>• arrow from <math>(\text{:})\text{O}^-</math> to H of <math>\text{HCN}/\text{H}^+</math></li> </ul> <p>7 points correct scores 4 marks</p> <p>5/6 points correct scores 3 marks</p> <p>3/4 points correct scores 2 marks</p> <p>1/2 points correct scores 1 mark</p> | <p>Accept arrow from C if no lone pair shown</p> <p>Ignore vertical connectivity<br/>Penalise missing H atoms</p> <p>Allow to <math>\text{H}^+</math><br/>Ignore any dipole on <math>\text{HCN}</math> and curly arrow from <math>\text{H}-\text{C}</math> bond to C</p> <p>Example of mechanism</p> <div data-bbox="1205 1078 1946 1291"> </div> | (4)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                       | Additional Guidance                                                                                                                                                                     | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 18(b)(ii)       | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>a racemic mixture is formed / two enantiomers are formed (1)</li> <li>because the (molecule is planar around the carbon of the) aldehyde group/(H)C=O/carbonyl is (trigonal) planar (1)</li> <li>the nucleophile/<math>\text{CN}^-</math> is equally likely to attack the C of C=O from above or below (the plane) (1)</li> </ul> | <p>Allow reaction site is planar<br/>Do not award carbocation/molecule/ethanal is planar</p> <p>Do not award <math>\text{S}_{\text{N}}1</math> or <math>\text{S}_{\text{N}}2</math></p> | (3)  |

| Question Number | Answer                                                                                                                         | Additional Guidance | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------|---------------------|------|
| 18(c)(i)        | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>esterification</li> </ul> | Allow condensation  | (1)  |

| Question Number | Answer                                                                                                                                                        | Additional Guidance                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 18(c)(ii)       | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>correct formula including extension bonds (1)</li> </ul> | <p>Examples of correct formulae:</p>  <p>— [ <math>\text{OCH}(\text{CH}_3)\text{CO}</math> ] —</p> <p>— [ <math>\text{CH}(\text{CH}_3)\text{COO}</math> ] —</p> <p>Ignore absence of square brackets and/or n<br/>Accept two correct repeat units</p> | (1)  |

| Question Number | Answer                                                                                                                                                                  | Additional Guidance                                                                                                                                                                                                                                              | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 18(d)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>L on —OH proton</li> <li>M on all methyl ester protons</li> </ul> | <p>(1)<br/>(1)</p>  <p>Allow inclusion of C in CH<sub>3</sub> and O in OH<br/>Ignore labels J and K<br/>If no labels, but both protons are clearly correct allow one mark</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                   | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark               |         |                          |                   |   |     |   |         |   |     |   |                    |   |     |   |         |   |     |   |         |     |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|---------|--------------------------|-------------------|---|-----|---|---------|---|-----|---|--------------------|---|-----|---|---------|---|-----|---|---------|-----|
| 18(d)(ii)       | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>Any two correctly filled boxes</li> <li>All four correctly filled boxes</li> </ul> | <p>(1)<br/>(1)</p> <table border="1"> <thead> <tr> <th>Peak</th><th>δ / ppm</th><th>Number of hydrogen atoms</th><th>Splitting pattern</th></tr> </thead> <tbody> <tr> <td>J</td><td>1.3</td><td>3</td><td>doublet</td></tr> <tr> <td>K</td><td>4.1</td><td>1</td><td>quartet/quadruplet</td></tr> <tr> <td>L</td><td>3.6</td><td>1</td><td>singlet</td></tr> <tr> <td>M</td><td>3.7</td><td>3</td><td>singlet</td></tr> </tbody> </table> | Peak               | δ / ppm | Number of hydrogen atoms | Splitting pattern | J | 1.3 | 3 | doublet | K | 4.1 | 1 | quartet/quadruplet | L | 3.6 | 1 | singlet | M | 3.7 | 3 | singlet | (2) |
| Peak            | δ / ppm                                                                                                                                                                                  | Number of hydrogen atoms                                                                                                                                                                                                                                                                                                                                                                                                                   | Splitting pattern  |         |                          |                   |   |     |   |         |   |     |   |                    |   |     |   |         |   |     |   |         |     |
| J               | 1.3                                                                                                                                                                                      | 3                                                                                                                                                                                                                                                                                                                                                                                                                                          | doublet            |         |                          |                   |   |     |   |         |   |     |   |                    |   |     |   |         |   |     |   |         |     |
| K               | 4.1                                                                                                                                                                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                          | quartet/quadruplet |         |                          |                   |   |     |   |         |   |     |   |                    |   |     |   |         |   |     |   |         |     |
| L               | 3.6                                                                                                                                                                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                          | singlet            |         |                          |                   |   |     |   |         |   |     |   |                    |   |     |   |         |   |     |   |         |     |
| M               | 3.7                                                                                                                                                                                      | 3                                                                                                                                                                                                                                                                                                                                                                                                                                          | singlet            |         |                          |                   |   |     |   |         |   |     |   |                    |   |     |   |         |   |     |   |         |     |

(Total for Question 18 = 15 marks)  
TOTAL FOR SECTION B = 49 MARKS

### Section C

| Question Number | Answer                                                                                                                                                                                                                                                                                | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(a)(i)        | <ul style="list-style-type: none"> <li>expression for <math>K_c</math></li> <li>calculation of equilibrium quantities of reactants</li> <li>calculation of equilibrium concentrations of products<br/><b>and</b><br/>use of volume</li> <li>evaluation of <math>K_c</math></li> </ul> | <p><u>Example of calculation:</u></p> <p>(1) <math>K_c = \frac{[\text{CH}_3\text{CH}_2\text{COOH}] [\text{CH}_3\text{CH}_2\text{OH}]}{[\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3] [\text{H}_2\text{O}]}</math><br/>           Ignore state symbols<br/>           Brackets must be square brackets</p> <p>(1) <math>\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3</math><br/> <math>= (0.100 - 0.0440) = 0.056(0) \text{ (mol)}</math><br/> <math>\text{H}_2\text{O} = (0.2 - 0.0440) = 0.156 \text{ (mol)}</math></p> <p>(1) <math>[\text{CH}_3\text{CH}_2\text{COOH}] = 0.044(0) / V \text{ (mol dm}^{-3}\text{)}</math><br/> <math>[\text{CH}_3\text{CH}_2\text{OH}] = 0.044(0) / V \text{ (mol dm}^{-3}\text{)}</math><br/>           Allow volumes cancel</p> <p>(1) <math>K_c = \frac{0.044 \times 0.044}{0.056 \times 0.156} = 0.22161 = 0.222 / 0.22</math><br/>           TE on incorrect moles<br/>           Answer to 2/3 SF and no units</p> | (4)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                       | Additional Guidance                                                                                                             | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|------|
| 19(a)(ii)       | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>Same number and type of bonds are being broken (in reactants) and made (in products) (1)</li> <li>but the bonds are in different molecules/ environments (so not exactly the same) (1)</li> </ul> | <p>Allow similar bonds are being broken (in reactants) and made (in products).<br/>Do not award: incorrect bonds identified</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Additional Guidance                                                                                                                                                                                                                     | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(a)(iii)      | <p>An explanation that makes reference to three of the following points</p> <ul style="list-style-type: none"> <li><math>\Delta S_{\text{surroundings}} = \frac{-\Delta H}{T}</math> (1)</li> <li>(since <math>\Delta H</math> is close to zero) then <math>\Delta S_{\text{surroundings}} / \Delta S_{\text{total}}</math> does not change / only changes by a small amount (with a change in temperature) (1)</li> <li><math>\Delta S_{\text{total}} = R \ln K</math> so <math>K_c</math> does not change (much) (with a change in temperature) (1)</li> </ul> | <p>Ignore references to Le Chatelier's principle and predictions based on position of equilibrium</p> <p>Allow expression for <math>\Delta S_{\text{surroundings}}</math> in an expression for <math>\Delta S_{\text{total}}</math></p> | (3)  |

| Question Number | Answer                                                                                                                                                              | Additional Guidance                                                                     | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|------|
| 19(b)(i)        | <ul style="list-style-type: none"> <li>a weak acid is dissociated (into its ions) to a small extent and a strong acid is (almost) completely dissociated</li> </ul> | <p>Allow propanoic acid is partially ionised and hydrochloric acid is fully ionised</p> | (1)  |

| Question Number | Answer                                                              | Additional Guidance                                                         | Mark |
|-----------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------|------|
| 19(b)(ii)       | <ul style="list-style-type: none"> <li>calculation of pH</li> </ul> | $\text{pH} = -\log_{10}(0.500) = 0.30103 / 0.301 / 0.30 / 0.3$<br>Ignore SF | (1)  |

| Question Number | Answer                                                                                                                                                                   | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(b)(iii)      | <ul style="list-style-type: none"> <li>expression for acid dissociation constant</li> <li>calculation of hydrogen ion concentration</li> <li>evaluation of pH</li> </ul> | <p>Example of calculation:</p> <p>(1) <math>K_a = \frac{[\text{CH}_3\text{CH}_2\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{CH}_2\text{COOH}]}</math></p> <p>Allow <math>K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}</math></p> <p>Allow <math>K_a = \frac{[\text{H}^+][\text{salt}]}{[\text{acid}]}</math></p> <p>Allow <math>1.3 \times 10^{-5} = \frac{[\text{H}^+]^2}{0.5}</math></p> <p>(1) <math>[\text{H}^+] = 2.5495 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}</math><br/>           If M2 is scored assume M1 is correct even if not shown</p> <p>(1) <math>\text{pH} = -\log_{10} [\text{H}^+] = 2.59 / 2.6</math><br/>           Correct answer with some working scores 3<br/>           Ignore SF except 1SF</p> | (3)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                  | Additional Guidance                                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(c)(i)        | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(when half the acid has been neutralised )<br/> <math>[\text{CH}_3\text{CH}_2\text{COOH}] = [\text{CH}_3\text{CH}_2\text{COO}^-]</math></li> <li>evaluation of pH</li> </ul> | <p>(1) Allow in words<br/> Allow pH at half neutralisation = <math>\text{p}K_a</math> propanoic acid<br/> Allow <math>[\text{H}^+]</math> at half neutralisation = <math>K_a</math> propanoic acid</p> <p>(1) <math>\text{pH} = -\log_{10} 1.30 \times 10^{-5}</math><br/> <math>= 4.8861 = 4.89/4.9</math></p> <p>Ignore SF except 1SF<br/> Correct answer scores 2</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                          | Additional Guidance                                       | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|------|
| 19(c)(ii)       | <p>An answer that makes reference to three of the following points:</p> <ul style="list-style-type: none"> <li>start pH between 2 and 4 <b>and</b> finish at 12-14</li> <li>vertical section of at least 3 pH units starting at or above 6 and finishing at or below 11.</li> <li>S-shaped curve with equivalence( vertical section) at <math>25 \text{ cm}^3</math></li> </ul> | <p>Example of sketch</p> <p>(1)</p> <p>(1)</p> <p>(1)</p> | (3)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                          | Additional Guidance                                                                                                                      | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(c)(iii)      | <p>An answer that makes reference to two of the following points:</p> <ul style="list-style-type: none"> <li>phenolphthalein/ bromothymol blue / phenol red (1)</li> <li>because the indicator pH range / <math>pK_{ind} \pm 1</math> lies (completely) within the vertical section of the graph (1)</li> </ul> | <p>TE from incorrect vertical section provided indicator chosen from Data Booklet</p> <p>Allow a pH range for their vertical section</p> | (2)  |

(Total for Question 19 = 21 marks)  
**TOTAL FOR SECTION C = 21 MARKS**  
**TOTAL FOR PAPER =90 MARKS**