



# Mark Scheme (Results)

Summer 2024

Pearson Edexcel GCE  
In Chemistry (9CH0)  
Paper 02: Advanced Organic and Physical  
Chemistry

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## General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

## Using the Mark scheme

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

The Mark scheme gives examiners:

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

/ means that the responses are alternatives and either answer should receive full credit. ( ) means that a phrase/word is not essential for the award of the Mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer. ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

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

## Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:

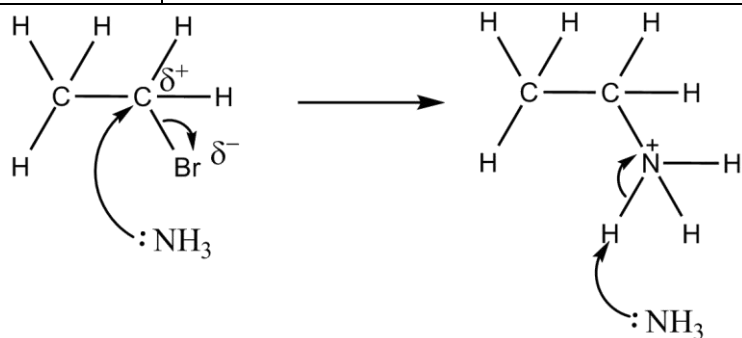
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full Marks will be awarded if the candidate has demonstrated the above abilities. Questions where QWC is likely to be particularly important are indicated (QWC) in the Mark scheme, but this does not preclude others.

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(a)            | <p><b>The only correct answer is D (2-bromo-2-methylpropane)</b></p> <p><i>A is not correct because 1-bromobutane is a primary halogenoalkane so hydrolyses more slowly than the tertiary halogenoalkane</i></p> <p><i>B is not correct because 2-bromobutane is a secondary halogenoalkane so hydrolyses more slowly than the tertiary halogenoalkane</i></p> <p><i>C is not correct because 1-bromo-2-methylpropane is a primary halogenoalkane so hydrolyses more slowly than the tertiary halogenoalkane</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                              | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(b)            | <p><b>The only correct answer is C (CH<sub>3</sub>COCl and CH<sub>3</sub>NH<sub>2</sub>)</b></p> <p><i>A is not correct because the reactants will form a primary amide</i></p> <p><i>B is not correct because the reactants will not form an N-substituted amide as there is no reaction</i></p> <p><i>D is not correct because the reactants will not form an N-substituted amide as there is no reaction</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(c)(i)         | <p>An explanation that makes reference to three of the following points:</p> <ul style="list-style-type: none"> <li>one (molecule of) ammonia acts as a nucleophile (1)</li> <li>to attack the carbon with a (partial) positive charge (1)</li> <li>a (second) molecule (of ammonia) acts as a base (1)</li> <li>to remove a <math>\text{H}^+</math> / H ion / proton from the intermediate (1)</li> </ul> | <p>Correctly drawn mechanism with no reference to nucleophile and base scores 2 max (see diagram)</p> <p>Allow 'ammonia donates its lone pair' / 'ammonia reacts in a nucleophilic substitution reaction'</p> <p>Allow 'attacks the carbocation'</p> <p>Do not award <math>\text{NH}_3</math> acting as a base in an incorrect context (e.g. with <math>\text{Br}^-</math>)</p> <p>If intermediate drawn then this must be correct</p> <p>Allow ammonia gains a <math>\text{H}^+</math> (ion) / proton from the intermediate</p> <p>Ignore comments related to oxidation and reduction</p> | (3)  |



1 mark for left hand side, including dipole, curly arrow from lone pair on N and arrow from bond to Br

1 mark for right hand side including structure of intermediate with charge, arrow from lone pair on  $\text{NH}_3$  to H, and arrow from bond to  $\text{N}^+$

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                   | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(c)(ii)        | <p>The only correct answer is A (heat in a sealed tube, ethanol)</p> <p><i>B is not correct as the reaction is carried out in a closed system</i></p> <p><i>C is not correct as the bromoethane is not soluble in water</i></p> <p><i>D is not correct as the reaction is carried out in a closed system and bromoethane is not soluble in water</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                   | Additional Guidance                                                                                                                                                                                                                                                                                                                           | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(d)            | <ul style="list-style-type: none"> <li>calculation of total relative mass of all reactants<br/>or<br/>calculation of total relative mass of all products (1)</li> <li>calculation of atom economy to 1 dp (1)</li> </ul> | <p><u>Example of calculation</u></p> <p><math>74 + 102.9 + 98.1 / = 275</math><br/>or<br/><math>136.9 + 120.1 + 18 / = 275</math></p> <p><math>(136.9 \div 275) \times 100 = 49.782 (\%) = 49.8 (\%)</math></p> <p>Correct answer with no working scores 2<br/>TE from M1 to M2<br/>Incorrect rounding for final answer does not score M2</p> | (2)  |

(Total for Question 1 = 8 marks)

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(a)            | <p><b>The only correct answer is B (ether)</b></p> <p><i>A is not correct because cyclohexane is not a good solvent for Grignard reagents as it is not polar</i></p> <p><i>C is not correct because ethyl ethanoate would react with Grignard reagents</i></p> <p><i>D is not correct because hexane is not a good solvent for Grignard reagents as it is not polar</i></p> | (1)  |

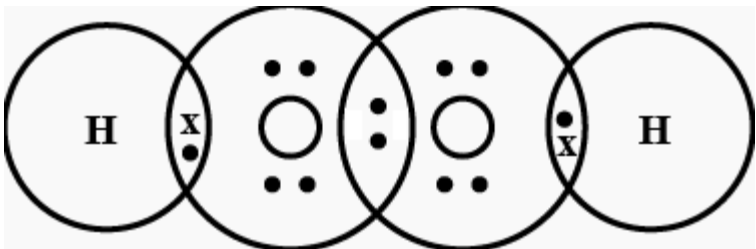
| Question Number | Answer                                                                                                                                                                                                           | Additional Guidance                                                                                                                                                                                                                                        | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(b)            | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>to increase the length of a <b>carbon</b> chain (in a molecule) / extend the <b>carbon</b> chain</li> </ul> | <p>Accept to form a (new) carbon- carbon (single) bond</p> <p>Allow to increase the number of <b>carbon(s)</b> (atoms) (in the starting material) /</p> <p>Ignore to increase chain length / add to the carbon chain</p> <p>Ignore adding alkyl groups</p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(c)            | <p><b>The only correct answer is C (a nucleophile)</b></p> <p><i>A is not correct because the reactive carbon has a partial negative charge</i></p> <p><i>B is not correct because the reactive carbon has a partial negative charge</i></p> <p><i>D is not correct because the reactive carbon has a partial negative charge</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                         | Additional Guidance                                                                                                                                                                                                                        | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(d)            | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>ethane</li> <li>(partially) negative carbon (in Grignard reagents) is attracted to / reacts with the (partially) positive hydrogen (in water)</li> </ul> | <p>Accept <math>\text{CH}_3\text{CH}_3</math> / <math>\text{C}_2\text{H}_6</math></p> <p>Allow use of symbols e.g. <math>\delta^- \text{C}</math>, <math>\delta^+ \text{H}</math></p> <p>Allow use of full negative charges on C and H</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2(e)            | <p><b>The only correct answer is D (<math>\text{CH}_3\text{COCH}_3</math>)</b></p> <p><i>A is not correct because <math>\text{CO}_2</math> would form a carboxylic acid with a Grignard reagent</i></p> <p><i>B is not correct because <math>\text{HCHO}</math> would form a primary alcohol with a Grignard reagent</i></p> <p><i>C is not correct because <math>\text{CH}_3\text{CHO}</math> would form a secondary alcohol with a Grignard reagent</i></p> | (1)  |

(Total for Question 2 = 6 marks)

| Question Number | Answer                                                                             | Additional Guidance                                                                                                                                        | Mark |
|-----------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(a)            |  | <p>Ignore omission of circles</p> <p>Ignore line to show covalent bonds</p> <p>Allow reversal of dots and crosses</p> <p>Allow all dots or all crosses</p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(b)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>oxidation number of oxygen has changed from <math>-1</math> (in <math>\text{H}_2\text{O}_2</math>)</li> <li>to <math>-2</math> in water, so reduced</li> <li>and <math>0</math> in (elemental) oxygen, so is oxidised</li> </ul> | <p><b>Oxidation numbers may be shown above / below species in equation</b></p> <p>Allow Roman numerals to show oxidation numbers</p> <p>Allow 1 rescue mark for correct oxidation numbers of oxygen in both products if references to oxidation and reduction incorrect or omitted or not linked to a specific reaction in M2 and M3</p> <p>Allow 1 rescue mark for correct oxidation numbers and references to oxidation and reduction if products omitted in M2 and M3</p> | (3)  |

| Question Number | Answer                                                                                                                                                                                                                                  | Additional Guidance | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|------|
| 3(c)(i)         | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(order with respect to hydrogen peroxide =) 1 / first (1)</li> <li>(order with respect to iodide ions =) 1 / first (1)</li> </ul> |                     | (2)  |

| Question Number | Answer                                                                                                                                                                      | Additional Guidance                                                                                                                                                                             | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(c)(ii)        | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>rate / r = <math>k[\text{H}_2\text{O}_2][\text{I}^-]</math></li> </ul> | <p>Rate equation must be consistent on orders from (i)</p> <p>Allow use of correct names<br/> Allow TE from 3(c)(i)<br/> Do not award round brackets<br/> Do not award omission of rate / r</p> | (1)  |

| Question Number | Answer                                                                                                           | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(c)(iii)       | <ul style="list-style-type: none"> <li>calculation of <math>k</math></li> <li>units of <math>k</math></li> </ul> | <p><u>Example of calculation</u><br/>Calculation must be consistent on rate equation from (ii)</p> <p>(1) <math>k = \text{rate} \div [\text{H}_2\text{O}_2][\text{I}^-]</math></p> <p><math>3.56 \times 10^{-6} \div (0.200 \times 0.100) = 1.78 \times 10^{-4}</math></p> <p>(1) <math>\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}</math></p> <p>Allow <math>\text{dm}^3/\text{mol/s}</math></p> <p>Allow <math>\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}</math></p> <p>Allow units in any order<br/>Ignore SF except 1 SF</p> <p>Allow TE from incorrect rate equation in 3(c)(ii)<br/>Allow calculation based on data from experiments 1 or 2<br/>NOTE – with TE on incorrect order, calculation and units require checking as different experiments give different values</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                         | Additional Guidance                                                                                                                            | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(d)(i)         | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>put glowing splint (into bubbles of gas / presence of gas)<br/><b>and</b><br/>splint relights</li> </ul> | <p>Ignore ‘a splint that has (just) been blown out relights’</p> <p>Do not award ‘relights a burnt splint’</p> <p>Do not award squeaky pop</p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(d)(ii)        | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(colour caused by aqueous solution of) iodine (1)</li> <li>(formed as excess hydrogen) peroxide oxidises iodide (ions) / converts iodide (ions) / reacts with iodide (ions) (1)</li> </ul> | <p>Accept (colour caused by) aqueous (solution of) I<sub>3</sub><sup>-</sup></p> <p>Ignore iodide ions are yellow in solution</p> <p>Do not award iodine ions</p> <p>Allow oxygen oxidises / converts / reacts with the iodide (ions) / iodide reduces (hydrogen) peroxide</p> <p>Allow correct equation</p> $2\text{H}^+ + \text{H}_2\text{O}_2 + 2\text{I}^- \rightarrow \text{I}_2 + 2\text{H}_2\text{O}$ <p>Ignore incomplete equations (as considered part of the working out process)</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                    | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(e)(i)         | <ul style="list-style-type: none"> <li>triangle or similar shown on graph to indicate changes in <math>x</math> and <math>y</math></li> <li>calculation of gradient</li> <li>units of gradient</li> </ul> | <p><u>Example of calculation</u></p> <p>Allow circling of points / marking of points on line<br/>For example</p> $-11 - -6 = -5$ $0.003588 - 0.003038 = 0.00055$ $-5 \div 0.00055 = -9090.9$ <p>Allow gradient in range <math>-8500</math> to <math>-9500</math>, consistent with correctly determined <math>y</math> and <math>x</math> values, though gradient must be checked for calculator errors</p> <p>Allow TE on incorrectly determined <math>y</math> and <math>x</math> values from M1</p> <p>Allow negative gradient even if values used in <math>\Delta y / \Delta x</math> would give a positive value</p> <p>Ignore SF</p> <p>Ignore rounding errors in final value of gradient</p> <p>K</p> <p>No TE for units based on inverted axes</p> | (3)  |

| Question Number | Answer                                                                            | Additional Guidance                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(e)(ii)        | <ul style="list-style-type: none"> <li>calculation of <math>E_a</math></li> </ul> | <p><u>Example of calculation</u></p> $-9090.9 \times 8.31 = -E_a$ $E_a = (+) 75.545 \text{ (kJ mol}^{-1}\text{)}$ <p>Allow (+) 75545 J mol<sup>-1</sup></p> <p>Ignore SF except 1 SF<br/>Allow TE from (e)(i)<br/>Do not award negative activation energies.<br/>Note : if answer is in J mol<sup>-1</sup> units must be given</p> | (1)  |

| Question Number | Answer                                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3(f)            | <ul style="list-style-type: none"> <li>expression for, using numbers, or calculation of <math>e^{-E_a/RT}</math> (1)</li> <li>calculation of <math>A</math> (1)</li> </ul> | <p><u>Example of calculation</u></p> $e^{-50200 \div (8.31 \times 370)} / 8.1164 \times 10^{-8}$ $1.60 \times 10^{-3} \div 8.1164 \times 10^{-8} = 1.9713 \times 10^4$ <p>Ignore SF<br/>Ignore units<br/>TE from M1 to M2<br/>Correct answer with no working scores 2<br/>Note – use of rounded values of <math>e^{-E_a/RT}</math> is acceptable and final answer may need checking as it will make a difference to the numerical value<br/>M1 can be subsumed in M2</p> | (2)  |

(Total for Question 3 = 18 marks)

| Question Number                                                                                                        | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Additional Guidance                                | Mark                                                  |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |
|------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------------------|---|---|-----|---|-----|---|---|---|---|---|--|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|---|--------------------------------------------------------------------------|---|-----------------------------------------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| *4                                                                                                                     | <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.</p> <p>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 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</p> <p>Comment: Look for the indicative marking points first, then consider the mark for the structure of the Answer and sustained line of reasoning.</p> | (6) |
| Number of indicative marking points seen in answer                                                                     | Number of marks awarded for indicative marking points                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |
| 6                                                                                                                      | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |
| 5-4                                                                                                                    | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |
| 3-2                                                                                                                    | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |
| 1                                                                                                                      | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |
| 0                                                                                                                      | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |
|                                                                                                                        | Number of marks awarded for structure 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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                                  |                                                                                                                        |   |                                                                          |   |                                                           |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |     |

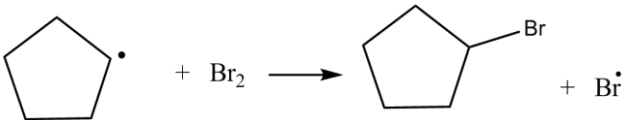
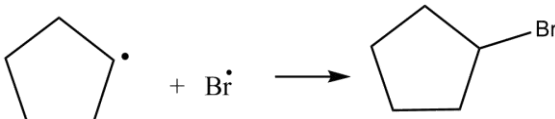
|  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
|  | <p><b>Indicative content</b></p> <p><b>Treatment of waste polymers</b></p> <p>IP1 (waste) polymers can be (sorted and) recycled</p> <p>IP2 (waste) polymers can be incinerated to release energy / generate electricity</p> <p>IP3 (waste) polymers can be cracked / thermally decomposed (to (re)form monomers)</p> <p><b>Limiting problems caused by disposal</b></p> <p>IP4 (chemists) develop / invent (new) biodegradable polymers</p> <p>IP5 (chemists can help develop techniques to) minimise emission of harmful / toxic / acidic gases from incineration (of waste polymers)</p> <p>IP6 by neutralising HCl / SO<sub>2</sub> / NO<sub>x</sub></p> | <p>Allow re-use / repurpose (objects made from) polymers</p> <p>Allow polymers can be incinerated to release heat / used as a fuel</p> <p>Allow polymers can be used as a feedstock/raw material for cracking</p> <p>Allow polymers can converted into smaller / more useful molecules (to be used as a feedstock)</p> <p>Allow use /develop / invent (new) polymers that decompose</p> <p>Ignore use of alternative non-synthetic materials</p> <p>Ignore biofuels</p> <p>Allow minimise emissions of named pollutants from incineration e.g. HCl / SO<sub>2</sub> / NO<sub>x</sub> / CO<sub>2</sub> / CO / dioxins</p> <p>Ignore comments on greenhouse gases / global warming</p> <p>Allow by carbon capture of CO<sub>2</sub></p> <p>Allow by ensuring complete combustion to minimise CO / by converting CO to CO<sub>2</sub></p> |  |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|

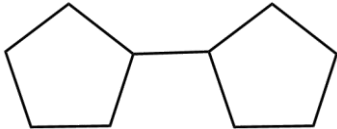
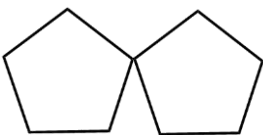
(Total for Question 4 = 6 marks)

| Question Number | Answer                                                                                                                         | Additional Guidance                                                                                        | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|------|
| 5(a)            | An answer that makes reference to the following point: <ul style="list-style-type: none"> <li>reforming/reformation</li> </ul> | Allow dehydrogenation / cyclisation<br>Ignore oxidation / catalytic<br>Do not award cracking / dehydration | (1)  |

| Question Number | Answer                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5(b)            | <ul style="list-style-type: none"> <li>calculate volume of cyclopentane</li> <li>calculate energy density of cyclopentane and appropriate units</li> </ul> | <p><u>Example of calculation</u></p> <p>(1) Volume = <math>30.0 \div 0.751 / 39.947 \text{ (cm}^3\text{)}</math><br/>Ignore units in M1</p> <p>(1) <math>1.41 \div (39.947 \div 1000) = 35.297 \text{ MJ dm}^{-3}</math></p> <p>Ignore SF except 1 SF<br/>           Allow TE from M1<br/>           Allow <math>3.5297 \times 10^4 \text{ kJ dm}^{-3}</math> or <math>3.5297 \times 10^7 \text{ J dm}^{-3}</math><br/> <math>3.5297 \times 10^4 \text{ J cm}^{-3}</math></p> | (2)  |

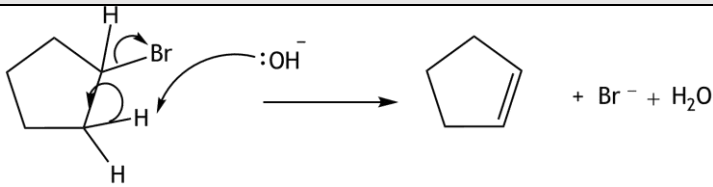
| Question Number | Answer                                                                                                                                    | Additional Guidance                                                                                 | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|------|
| 5(c)(i)         | An answer that makes reference to the following point: <ul style="list-style-type: none"> <li>UV (light) / ultraviolet (light)</li> </ul> | Allow sun(light) / temperature over 250°C<br>Ignore heat under reflux<br>Do not award high pressure | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Additional Guidance                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5(c)(ii)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>Initiation <math>\text{Br}_2 \rightarrow 2\text{Br}^\bullet</math> (1)</li> <li>Propagation           <div style="display: flex; align-items: center; justify-content: center;">  <div style="margin-left: 10px;">(1)</div> </div> </li> <li>Termination           <div style="display: flex; align-items: center; justify-content: center;">  <div style="margin-left: 10px;">(1)</div> </div> </li> </ul> | <p>NOTE – penalise use of hexagons once only in 5(c)(ii) and 5(c)(iii)</p> <p>Penalise omission of unpaired electrons once only</p> <p>Curly-half arrows if shown must be in correct direction</p> <p>Do not award double-headed arrow(s) in M1</p> <p>Penalise use of chlorine once only</p> <p>Ignore position of bromine relative to dot on free radical</p> | (3)  |

| Question Number | Answer                                                                                                                                  | Additional Guidance                                                                                                                       | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5(c)(iii)       | <ul style="list-style-type: none"> <li>  </li> </ul> | <p>Allow displayed formulae</p> <p>Do not award</p>  | (1)  |

| Question Number | Answer                                                                                                                                                                                                                               | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5(d)(i)         | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>to dry the ethanol / solvent</li> <li>as (presence of) water would result in formation of (some) cyclopentanol</li> </ul> | <p>(1) Allow remove water from the ethanol / solvent<br/>Allow to react with the ethanol to remove the water<br/>Allow to ensure the reaction conditions are not aqueous<br/>Ignore just 'it's a drying agent'<br/>Ignore to dry the reactants / removes water that forms in the reaction<br/>Do not allow 'to dehydrate'</p> <p>(1) Allow alcohol / hydroxycyclopentane for cyclopentanol<br/>Allow as (presence of) water would result in (some) (nucleophilic) substitution (by the hydroxide ion)<br/>Ignore hydrolysis</p> | (2)  |

| Question Number | Answer                                                                                                                      | Additional Guidance                                                                                                                             | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5(d)(ii)        | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>elimination</li> </ul> | <p>Comment: Allow dehydrohalogenation<br/>Do not award nucleophilic / electrophilic / free-radical<br/>Ignore oxidation / reduction / basic</p> | (1)  |

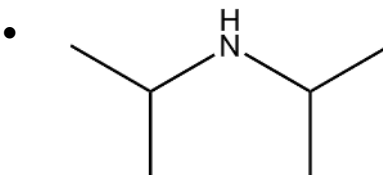
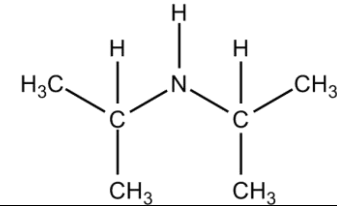
| Question Number | Answer                                                                                                                                                      | Additional Guidance                                                                                                                | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|------|
| 5(d)(iii)       | <ul style="list-style-type: none"> <li>double-headed arrow from C-H bond to <b>C-C bond</b><br/>and<br/>double-headed arrow from C-Br bond to Br</li> </ul> |  <p>Ignore any dipoles, even if incorrect</p> | (1)  |

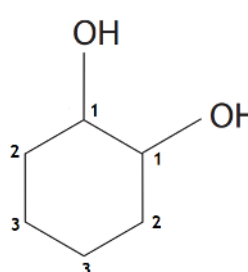
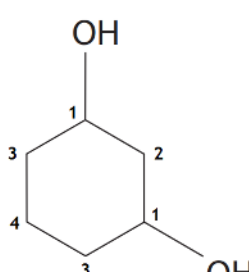
(Total for Question 5 = 12 marks)

| Question Number | Answer                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(a)            | <p><b>The only correct answer is B</b> (radio waves)</p> <p><i>A is not correct because IR interacts with bonds</i></p> <p><i>C is not correct because UV interacts with electrons</i></p> <p><i>D is not correct because X-rays are diffracted by crystals in the solid state</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                       | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(b)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>TMS acts as a standard / reference (at 0 ppm)</li> <li>as it has (12 equivalent) hydrogens that produce a single / strong peak</li> </ul> <p><b>or</b></p> <ul style="list-style-type: none"> <li>as it has (4 equivalent) carbons that produce a single / strong peak</li> </ul> | <p>(1) Allow acts as a control / comparison point / baseline / to calibrate / to mark 0 ppm</p> <p>(1) Ignore just ‘has a shift at 0 ppm’<br/> Allow produces a peak (well) away from those caused by other hydrogens / carbons<br/> Allow (most organic) compounds result in shift values (much) greater than TMS<br/> Allow easy to separate from sample (after spectrum is obtained)<br/> Allow unreactive (so will not react with sample)</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                   | Additional Guidance                                                                                                                                                                      | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(c)(i)         | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>the nitrogen (in the amine group) is attached to two carbon atoms / the nitrogen (in the amine group) is attached to two carbons (atoms)</li> </ul> | <p>Allow contains an NH group / two alkyl groups attached to the N / two R groups attached to the N / N is adjacent to two carbons<br/>Ignore amine group is attached to two carbons</p> | (1)  |

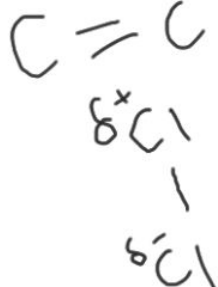
| Question Number | Answer                                                                                                                                | Additional Guidance                                                                                                                                                                                                    | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(c)(ii)        | <ul style="list-style-type: none"> <li>  </li> </ul> | <p>Note – take care to check H is present on N in skeletal formula</p> <p>Allow structural, displayed or hybrid formulae, e.g.</p>  | (1)  |

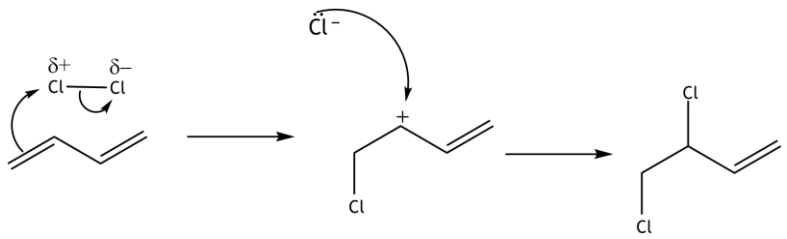
| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                       | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6(d)            | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>cyclohexane-1,2-diol has <b>3 peaks</b> (in its <math>^{13}\text{C}</math> spectra) <b>(1)</b><br/> <b>and</b><br/> 3 environments shown on diagram <b>(1)</b></li> <li>cyclohexane-1,3-diol has <b>4 peaks</b> (in its <math>^{13}\text{C}</math> spectra) <b>(1)</b><br/> <b>and</b><br/> 4 environments shown on diagram</li> </ul> | <p>If no marks scored allow 1 mark for idea that the spectrum of cyclohexane-1,2-diol has fewer peaks / fewer environments than cyclohexane-1,3-diol (even if any numbers quoted are incorrect)</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">  <p>cyclohexane-1,2-diol</p> </div> <div style="text-align: center;">  <p>cyclohexane-1,3-diol</p> </div> </div> <p>Allow alternative labelling systems on diagrams e.g. use of letter<br/> Ignore comments related to size of peaks / position of shift values / splitting</p> | (2)  |

(Total for Question 6 = 7 marks)

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                              | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7(a)            | <p><b>The only correct answer is D</b> (2-chlorobuta-1,3-diene)</p> <p><i>A is not correct as the position of chlorine is incorrectly numbered</i></p> <p><i>B is not correct as the position of double bonds are incorrectly numbered</i></p> <p><i>C is not correct as the position of double bonds and chlorine are incorrectly numbered</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                              | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7(b)            | <ul style="list-style-type: none"> <li>calculation of <math>M_r</math> of chloroprene (1)</li> <li>calculation of amount of chloroprene in mol (1)</li> <li>conversion of °C to K and kPa to Pa (1)</li> <li>re-arrangement of <math>pV = nRT</math> and calculation of <math>V</math> (1)</li> <li>conversion to <math>\text{cm}^3</math> and rounding to 2 or 3 SF (1)</li> </ul> | <p><u>Example of calculation</u></p> <p>88.5</p> <p><math>10.0 \div 88.5 = 0.11299</math> (mol)</p> <p>353 (K) and <math>205 \times 10^3 / 205000</math> (Pa)<br/> M3 may be subsumed in M4<br/> Allow pressure in kPa if volume is clearly shown as <math>\text{dm}^3</math> in M4</p> <p><math>V = (nRT) \div p</math><br/> <math>= (0.11299 \times 8.31 \times 353) \div 205000 = 1.6169 \times 10^{-3} (\text{m}^3)</math><br/> M4 may be subsumed in M5<br/> Ignore units in M4</p> <p>1600 / 1620 (<math>\text{cm}^3</math>)</p> <p>1620 with no working scores 5</p> <p><b>Comments</b><br/> Allow use of correctly rounded values carried forward<br/> Take care with awarding 5 for 1600, as it may be the result of an incorrect value from M4, correctly rounded</p> | (5)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                              | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7(c)(i)         | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>chlorine (molecule) moves close to (electron rich) double bond / pi bond</li> <li>which induces partial positive charge on chlorine (atom) (nearest to double bond / pi bond)</li> </ul> | <p>(1)</p> <p>(1)</p> <p>M1 via diagram e.g</p> <p>Allow C=C bond has a high electron density</p> <p>Accept repulsion between the electrons of chlorine and the pi electrons results in partial positive charge on chlorine (atom)</p> <p>Allow polarises the chlorine forming a <math>\delta^+</math> Cl</p> <p>Note M2 must have idea that the partial charge is induced / brought about / produced so a diagram alone <b>does not score M2</b></p>  | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7(c)(ii)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>curly arrow from one double bond to chlorine or just beyond (1)</li> <li>correct dipole on chlorine molecule (1)</li> <li>curly arrow from Cl-Cl bond to Cl (1)</li> <li>carbocation intermediate (1)</li> <li>lone pair on chloride ion (1)</li> <li>curly arrow from chloride ion to carbocation and correct final product (1)</li> </ul> <p>6 bullet points scores 3 marks, 4/5 bullet points scores 2 marks, 2/3 bullet points scores 1 mark, 0/1 bullet points scores 0 marks</p> | <p>Do not award if arrow shown to partial negative / negative Cl</p> <p>Do not award primary carbocation</p> <p>Do not award Cl / Cl<sup>δ-</sup>, but allow TE into BP6</p> <p>If lone pair evident, curly arrow must originate from it</p>  <p>Note – correct dipole discussed in (c)(i) can be awarded as part of M1 if not shown on the diagram</p> | (3)  |

| Question Number | Answer                                                                                                                                    | Additional Guidance       | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|------|
| 7(c)(iii)       | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>addition (polymerisation)</li> </ul> | Do not award condensation | (1)  |

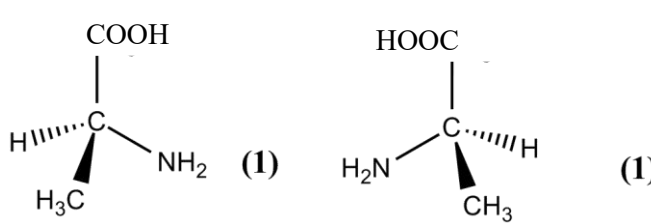
| Question Number | Answer                                                                                                                                                                                                                                                                                                                                 | Additional Guidance                                                                                                                                                                                                                                                                                           | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7(d)(i)         | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>both compounds have hydrogen bonds</li> <li>so the intermolecular forces / hydrogen bonds they form together will be similar in strength (to the intermolecular forces / hydrogen bonds they have before mixing)</li> </ul> | <p>(1) Allow can hydrogen bond to each other<br/>Allow H-bond for hydrogen bond<br/>Allow correct diagram for M1</p> <p>(1) Allow 'they break strong H bonds but then form strong H bonds together'<br/>Allow the new hydrogen bonds are stronger than the ones between water molecules / ethane-1-2-diol</p> | (2)  |

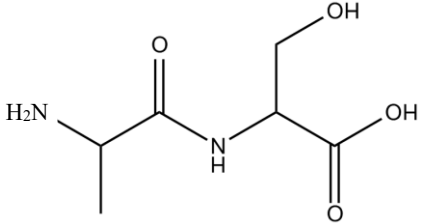
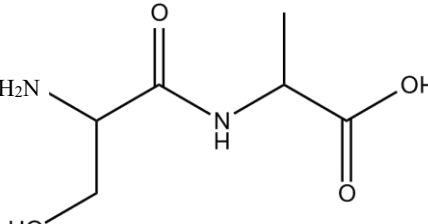
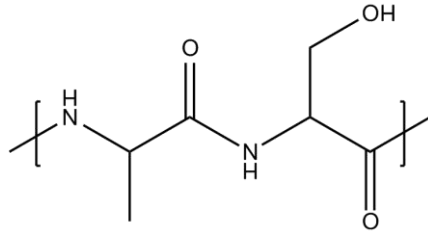
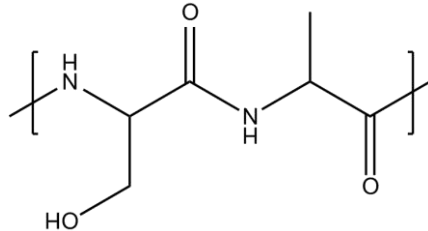
| Question Number | Answer                                                                                                                                                | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                            | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7(d)(ii)        | <ul style="list-style-type: none"> <li>calculation of mass and moles of polyester</li> <li>calculation of number of molecules of polyester</li> </ul> | <p><u>Example of calculation</u></p> <p><math>4.25 \times 10^{-3} \div 8400 = 5.0595 \times 10^{-7} \text{ (mol)}</math></p> <p><math>5.0595 \times 10^{-7} \times 6.02 \times 10^{23} = 3.0458 \times 10^{17} \text{ (molecules)}</math></p> <p>Ignore SF<br/>Allow TE from M1<br/>If incorrect units given in M1 and M2, penalise only once</p> <p>Correct answer with or without working scores 2 marks</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                     | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7(d)(iii)       | <p><b>The only correct answer is B</b> (hydrolysis)</p> <p><i>A is not correct as the reaction as dehydration is the removal of water</i></p> <p><i>C is not correct as the reaction as neutralisation is a reaction between an acid and a base</i></p> <p><i>D is not correct as the reaction as redox is oxidation and reduction</i></p> | (1)  |

**(Total for Question 7 = 17 marks)**

| Question Number | Answer                                                                                                                                                                               | Additional Guidance                                                                                                                                                                                                                                                | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(a)(i)         | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>a carbon atom with four different atoms / groups (of atoms) attached</li> </ul> | <p>Allow resulting molecule has non-superimposable mirror images</p> <p>Allow a carbon atom with four different functional groups attached</p> <p>Ignore a carbon atom with four different species attached</p> <p>Do not award 'molecules' for atoms / groups</p> | (1)  |

| Question Number | Answer                                                                                                                                  | Additional Guidance                                                                                                                                                                                                                                                               | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(a)(ii)        | <ul style="list-style-type: none"> <li>  </li> </ul> | <p>Allow 1 mark for 2 tetrahedral mirror images shown with only lines and no wedges / dashed lines</p> <p>Allow 1 mark for 2 tetrahedral mirror images shown with two similar wedges on each structure</p> <p>Accept dashed line for dashed wedges</p> <p>Ignore connectivity</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                             | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(b)            | <ul style="list-style-type: none"> <li>  </li> <li>  </li> </ul> | <p>Allow 1 mark for 2 correct structures shown as structural or displayed formulae</p> <p>Ignore displayed NH<sub>2</sub>, NH, or OH groups</p> <p>Penalise missing hydrogen atoms on amide group once only</p> <p>Penalise NH group shown as part of chain once only</p> <p>(1)</p> <p>Allow 1 if both dipeptides shown as correct polymer repeat units</p> <div style="text-align: center;">  <p>and</p>  </div> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                             | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(c)            | <p>The only correct answer is A</p> $\left( \begin{array}{c} \text{CH}_2\text{OH} \\   \\ \text{H}_3\text{N}^+ - \text{C} - \text{CO}_2^- \\   \\ \text{H} \end{array} \right)$ <p><i>B is not correct because the CO<sub>2</sub>H group has not lost a proton</i></p> <p><i>C is not correct because the NH<sub>2</sub> group has not gained a proton</i></p> <p><i>D is not correct because the CH<sub>2</sub>OH group has lost a proton</i></p> | (1)  |

| Question Number | Answer                                                              | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(d)(i)         | <ul style="list-style-type: none"> <li>balanced equation</li> </ul> | <p><u>Examples</u></p> $\text{C}_2\text{H}_5\text{OH} + \text{Na} \rightarrow \text{C}_2\text{H}_5\text{ONa} + \frac{1}{2}\text{H}_2$ $\text{C}_2\text{H}_5\text{OH} + \text{Na} \rightarrow \text{C}_2\text{H}_5\text{O}^-\text{Na}^+ + \frac{1}{2}\text{H}_2$ $\text{C}_2\text{H}_6\text{O} + \text{Na} \rightarrow \text{C}_2\text{H}_5\text{ONa} + \frac{1}{2}\text{H}_2$ $\text{C}_2\text{H}_6\text{O} + \text{Na} \rightarrow \text{C}_2\text{H}_5\text{O}^-\text{Na}^+ + \frac{1}{2}\text{H}_2$ <p>Allow multiples<br/> Allow displayed / skeletal / molecular formulae<br/> Ignore state symbols even if incorrect<br/> Do not award <math>\text{C}_2\text{H}_5\text{OH} + \text{Na} \rightarrow \text{C}_2\text{H}_5\text{O}^\delta-\text{Na}^{\delta+} + \frac{1}{2}\text{H}_2</math></p> | (1)  |

| Question Number | Answer                                                                                                                                                      | Additional Guidance                                                                                                                                                             | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(d)(ii)        | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>ester</li> <li>(<i>N</i>-substituted) amide</li> </ul> | <p>(1) If 3 answers given and 2 are correct, award 1 mark</p> <p>(1) If 4 or more answers given and 2 are correct award 0 marks</p> <p>Ignore structures, even if incorrect</p> | (2)  |

| Question Number | Answer                                                                                                                                                                    | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                          | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(d)(iii)       | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>hydrochloric acid / HCl(aq)</li> <li>(heat under) reflux</li> </ul> | <p>Ignore references to concentrated / dilute</p> <p>(1) Allow HCl<br/>Allow correct name or formulae of any strong acid e.g. HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>,<br/>Allow phosphoric acid / H<sub>3</sub>PO<sub>4</sub><br/>Allow NaOH followed by any identified strong acid<br/>Ignore H<sup>+</sup> / H<sub>3</sub>O<sup>+</sup> / catalyst</p> <p>(1) Mark independently</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(d)(iv)        | <ul style="list-style-type: none"> <li>calculation of moles of alanine</li> <li>scale to 100 %</li> <li>calculation of mass of compound X</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>scale mass of alanine to 100%</li> <li>calculation of moles of alanine</li> <li>calculation of mass of compound X</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>calculation of moles of alanine</li> <li>calculate mass of X</li> <li>scale to 100 %</li> </ul> | <p><u>Example of calculation</u></p> <p>(1) <math>15.0 \div 89.0 = 0.16854 \text{ (mol)}</math></p> <p>(1) <math>0.16854 \times (100 \div 55) = 0.30644 \text{ (mol)}</math></p> <p>(1) <math>0.30644 \times 217 = 66.496 = 66.5 \text{ g}</math></p><br><p>(1) <math>15.0 \times (100 \div 55) = 27.273 \text{ (g)}</math></p> <p>(1) <math>27.273 \div 89.0 = 0.30644 \text{ (mol)}</math></p> <p>(1) <math>0.30644 \times 217 = 66.496 = 66.5 \text{ g}</math></p><br><p>(1) <math>15.0 \div 89.0 = 0.16854 \text{ (mol)}</math></p> <p>(1) <math>0.16854 \times 217 = 36.573</math></p> <p>(1) <math>36.573 \times (100 \div 55) = 66.496 = 66.5 \text{ g}</math></p><br><p>Correct answer no working scores 3<br/>Ignore SF except 1 SF<br/>Allow TE throughout</p><br><p>If no mark scored allow 1 mark for 2 correct <math>M_r</math> values, 89 and 217</p> | (3)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                            | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8(e)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>would move towards the positive electrode / to the left<br/><b>and</b><br/>as it will form a negative ion (1)</li> <li>(as basic pH means) the acid groups will <b>both</b> lose a proton / has <b>two</b> COO<sup>-</sup> groups (1)</li> </ul> | <p>Note<br/>The negative charge on the ion and loss of both hydrogen ions from the COOH groups can both be awarded from a correct diagram of the ion</p> <p>Do not award zwitterion</p> <p>Allow the acid groups will <b>both</b> lose a hydrogen (ion)<br/>M2 can be awarded from diagram / amended structure in question</p> | (2)  |

(Total for Question 8 = 16 marks)

**TOTAL FOR PAPER = 90 MARKS**

