



## Mark Scheme (Results)

January 2023

Pearson Edexcel International Advanced  
Subsidiary Level in Chemistry (WCH12)  
Paper 01 Energetics, Group Chemistry,  
Halogenoalkanes and Alcohols

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## 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.

## Section A

| Question Number | Answer                                                                                                                                                                                                                                                                                                                   | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(a)            | <p><b>The only correct answer is C (6.3 %)</b></p> <p><i>A is not correct because the uncertainty has been halved rather than doubled</i></p> <p><i>B is not correct because this is the uncertainty for a single measurement only</i></p> <p><i>D is not correct because the uncertainty has been doubled twice</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(b)            | <p><b>The only correct answer is C (16.0 °C)</b></p> <p><i>A is not correct because this is being calculated by using times 2/3 of the mass of methanol rather than times 3/2</i></p> <p><i>B is not correct because this would be the expected temperature change had the mass of methanol burned remained at 0.20 g</i></p> <p><i>D is not correct because this is being calculated by using times 3/2 of the volume of water rather than times 2/3</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1(c)            | <p><b>The only correct answer is D (use of the molar mass of ethanol, C<sub>2</sub>H<sub>5</sub>OH, in the calculation)</b></p> <p><i>A is not correct because this would produce a smaller temperature change and result in a less exothermic value for the combustion enthalpy</i></p> <p><i>B is not correct because this would produce a smaller temperature change and result in a less exothermic value for the combustion enthalpy</i></p> <p><i>C is not correct because this would result in a larger apparent mass of methanol burned and a less exothermic value for the combustion enthalpy</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2               | <p><b>The only correct answer is A</b> (<math>\frac{1}{2}\text{Br}_2(\text{l}) \rightarrow \text{Br}(\text{g})</math>)</p> <p><i>B is not correct because bromine is a liquid in its standard state</i></p> <p><i>C is not correct because this shows the formation of two moles of gaseous bromine atoms</i></p> <p><i>D is not correct because bromine is a liquid in its standard state and this shows the formation of two moles of gaseous bromine atoms</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 3               | <p><b>The only correct answer is A</b> (<math>((0.5 \times 436 + 0.5 \times 242) - 431)</math>)</p> <p><i>B is not correct because the bond enthalpies of the reactants have been subtracted from the bond enthalpy of the product and this is for the formation of two moles of HCl</i></p> <p><i>C is not correct because the bond enthalpies of the reactants have been subtracted from the bond enthalpy of the product</i></p> <p><i>D is not correct because this is for the formation of two moles of HCl</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 4               | <p><b>The only correct answer is D</b> (<math>\text{CF}_4</math>)</p> <p><i>A is not correct because HF also has hydrogen bonds and permanent dipole-permanent dipole interactions</i></p> <p><i>B is not correct because OF<sub>2</sub> also has permanent dipole-permanent dipole interactions</i></p> <p><i>C is not correct because PF<sub>3</sub> also has permanent dipole-permanent dipole interactions</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 5               | <p><b>The only correct answer is C ((CH<sub>3</sub>)<sub>3</sub>COH)</b></p> <p><i>A is not correct because the electronegative nitrogen is not bonded directly to a hydrogen</i></p> <p><i>B is not correct because the electronegative fluorine is not bonded directly to a hydrogen</i></p> <p><i>D is not correct because the electronegative oxygen is not bonded directly to a hydrogen</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 6               | <p><b>The only correct answer is B (HF &gt; HI &gt; HBr &gt; HCl)</b></p> <p><i>A is not correct because the trend in boiling temperature of the hydrogen halides depends on the strength of the London forces as well as polarity</i></p> <p><i>C is not correct because HF has hydrogen bonding and a higher boiling temperature than HI</i></p> <p><i>D is not correct because HF has hydrogen bonding and the highest boiling temperature</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                     | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 7               | <p><b>The only correct answer is A (VO<sup>2+</sup>)</b></p> <p><i>B is not correct because the oxidation number of vanadium is +5 in this ion</i></p> <p><i>C is not correct because the oxidation number of vanadium is +5 in this ion</i></p> <p><i>D is not correct because the oxidation number of vanadium is +5 in this ion</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                  | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 8               | <p><b>The only correct answer is B (<math>K_2MnO_4</math>)</b></p> <p><i>A is not correct because the oxidation number of manganese is +7 in this compound</i></p> <p><i>C is not correct because the oxidation number of manganese is +5 in this compound</i></p> <p><i>D is not correct because there are two atoms of manganese and the oxidation number of manganese is +3 in this compound</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 9               | <p><b>The only correct answer is C (<math>Sr(NO_3)_2</math>)</b></p> <p><i>A is not correct because <math>LiCl</math> would not form a precipitate when mixed with a solution of potassium sulfate</i></p> <p><i>B is not correct because <math>NaNO_3</math> produces a yellow flame colour and would not form a precipitate when mixed with a solution of potassium sulfate</i></p> <p><i>D is not correct because <math>BaCl_2</math> produces a green flame colour</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                         | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 10              | <p><b>The only correct answer is C (<math>Sr + H_2O \rightarrow</math>)</b></p> <p><i>A is not correct because <math>MgO</math> is the only product of this reaction</i></p> <p><i>B is not correct because <math>CaCl_2</math> is the only product of this reaction</i></p> <p><i>D is not correct because <math>Ba(OH)_2</math> is the only product of this reaction</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 11              | <p><b>The only correct answer is D</b> (<math>2\text{F}^-(\text{aq}) + \text{At}_2(\text{aq}) \rightarrow 2\text{At}^-(\text{aq}) + \text{F}_2(\text{aq})</math>)</p> <p><i>A is not correct because iodine is more reactive than astatine</i></p> <p><i>B is not correct because chlorine is more reactive than bromine</i></p> <p><i>C is not correct because chlorine is more reactive than iodine</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 12              | <p><b>The only correct answer is D</b> (<math>8\text{KI}(\text{s}) + 9\text{H}_2\text{SO}_4(\text{aq}) \rightarrow 8\text{KHSO}_4(\text{aq}) + 4\text{I}_2(\text{s}) + \text{H}_2\text{S}(\text{g}) + 4\text{H}_2\text{O}(\text{l})</math>)</p> <p><i>A is not correct because this is not a redox reaction</i></p> <p><i>B is not correct because this is not a redox reaction</i></p> <p><i>C is not correct because one mole of <math>\text{H}_2\text{SO}_4</math> oxidises only <math>\frac{2}{3}</math> moles of bromide ions</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 13              | <p><b>The only correct answer is A</b> (<math>(\text{CH}_3)_3\text{CI}</math>)</p> <p><i>B is not correct because iodoalkanes have higher rates of hydrolysis than chloroalkanes</i></p> <p><i>C is not correct because tertiary halogenoalkanes have higher rates of hydrolysis than primary halogenoalkanes</i></p> <p><i>D is not correct because iodoalkanes have higher rates of hydrolysis than chloroalkanes and tertiary halogenoalkanes have higher rates of hydrolysis than primary halogenoalkanes</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 14              | <p><b>The only correct answer is D</b> (four)</p> <p><i>A is not correct because E and Z isomers of both hex-2-ene and hex-3-ene are possible</i></p> <p><i>B is not correct because E and Z isomers of both hex-2-ene and hex-3-ene are possible</i></p> <p><i>C is not correct because E and Z isomers of both hex-2-ene and hex-3-ene are possible</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 15              | <p><b>The only correct answer is B</b> (<math>\text{CH}_3\text{CH}_2\text{NHCH}_3</math>)</p> <p><i>A is not correct because this molecule has a prominent peak at <math>m/z = 43</math> in its mass spectrum (due to <math>\text{CH}_3\text{CO}^+</math>)</i></p> <p><i>C is not correct because this molecule has a prominent peak at <math>m/z = 43</math> in its mass spectrum (due to <math>(\text{CH}_3)_2\text{CH}^+</math>)</i></p> <p><i>D is not correct because this molecule has a prominent peak at <math>m/z = 43</math> in its mass spectrum (due to <math>\text{CH}_3\text{CH}_2\text{CH}_2^+</math>)</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 16              | <p><b>The only correct answer is A</b> (<math>\text{H}_2\text{NCH}_2\text{CH}_2\text{C}\equiv\text{N}</math>)</p> <p><i>B is not correct because this molecule does not have a triple bond so no peak at <math>2250\text{ cm}^{-1}</math></i></p> <p><i>C is not correct because this molecule does not have an O-H or N-H bond so no peak at <math>3415\text{ cm}^{-1}</math></i></p> <p><i>D is not correct because this molecule does not have a triple bond so no peak at <math>2250\text{ cm}^{-1}</math></i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                       | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 17(a)           | <p><b>The only correct answer is B</b> (all molecules possess some energy)</p> <p><i>A is not correct because all molecules possess some energy</i></p> <p><i>C is not correct because the temperature cannot be 0 K</i></p> <p><i>D is not correct because this relates to the activation energy, and rate, for a chemical reaction</i></p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 17(b)           | <p><b>The only correct answer is B</b> (decreases, shifts to the left)</p> <p><i>A is not correct because the area under the curve decreases (as there are fewer molecules)</i></p> <p><i>C is not correct because the area under the curve decreases (as there are fewer molecules) and the peak shifts to the left (as the molecules have less energy)</i></p> <p><i>D is not correct because the peak shifts to the left (as the molecules have less energy)</i></p> | (1)  |

(Total for Section A = 20 marks)

## Section B

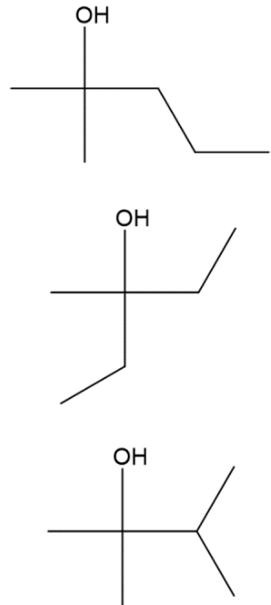
| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark       |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>18(a)</b>    | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>disproportionation (of chlorine) <b>(1)</b></li> <li>(oxidation numbers of chlorine)<br/>0 (in <math>\text{Cl}_2</math>)<br/><b>and</b><br/>(+)1 in <math>\text{Ca}(\text{ClO})_2</math><br/><b>and</b><br/>-1 in <math>\text{CaCl}_2</math> <b>(1)</b></li> <li>oxidised from 0 to +1<br/><b>and</b><br/>reduced from 0 to -1 <b>(1)</b></li> </ul> | <p>Ignore redox<br/>Do not award disproportionation of calcium/oxygen/hydrogen</p> <p>Allow annotations on the equation</p> <p>Allow 1–<br/>Do not award if any other element is also changing oxidation number</p> <p>Allow oxidation is increase in oxidation number<br/><b>and</b><br/>reduction is decrease in oxidation number</p> <p>TE on oxidation numbers given in M2, even for Ca/O/H</p> <p>Ignore any reference to oxidising agents / reducing agents<br/>Ignore any reference to electron transfer</p> | <b>(3)</b> |

| Question Number | Answer                                                                                                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark       |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>18(b)</b>    | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li><math>M_r</math> of <math>\text{Ca}(\text{ClO})_2</math> <b>(1)</b></li> <li>percentage atom economy (by mass) <b>(1)</b></li> </ul> | <p>Examples of calculation:</p> <p><math>M_r = 40.1 + 2 \times 16.0 + 2 \times 35.5 = 143.1</math><br/>Allow 143.0 / 143</p> <p><math>\frac{143.1}{(143.1 + 111.1 + 2 \times 18.0)} \times 100 = 49.311(\%)</math></p> <p>Allow use of 143 for <math>M_r</math> of <math>\text{Ca}(\text{ClO})_2</math> and 111 for <math>M_r</math> of <math>\text{CaCl}_2</math> giving 49.310(%)</p> <p>OR</p> <p><math>\frac{143.1}{(2 \times 74.1 + 2 \times 71.0)} \times 100 = 49.311(\%)</math></p> <p>Allow use 143 for <math>M_r</math> of <math>\text{Ca}(\text{ClO})_2</math> and 74 for <math>M_r</math> of <math>\text{Ca}(\text{OH})_2</math> giving 49.310(%)</p> <p>TE on <math>M_r</math> of <math>\text{Ca}(\text{ClO})_2</math></p> <p>Ignore SF except 1SF</p> <p>Correct answer with some working scores (2)</p> | <b>(2)</b> |

| Question Number | Answer                                                                                                                                                                                                                                                          | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 18(c)(i)        | <ul style="list-style-type: none"> <li>• volume of swimming pool water (1)</li> <li>• mass of <math>\text{Ca}(\text{ClO})_2 = \text{concentration} \times \text{volume}</math> (1)</li> <li>• mass of <math>\text{Ca}(\text{ClO})_2</math> in kg (1)</li> </ul> | <p>Example of calculation:</p> <p><b>In M1 and M2, Allow expression and/or evaluation</b></p> <p>volume = <math>50 \times 25 \times 2.0 = 2500 \text{ (m}^3\text{)}</math></p> <p>Ignore units, even if incorrect</p> <p>mass = <math>2500 (\times 10^3) \times 4.2 (\times 10^{-3}) = 10500 \text{ (g)}</math></p> <p>Ignore units, even if incorrect</p> <p>Do not award multiplication by 143.1 / 143 / molar mass</p> <p>10.5 (kg)</p> <p>TE only if <math>10500 \times 143.1</math> (or 143) in M2, giving 1502.55 (or 1501.5) (kg)</p> <p>Ignore SF except 1 SF</p> <p>Correct answer with some working scores (3)</p> | (3)  |

| Question Number  | Answer                                                                                                                                                                                                                                                                                                                                                                                                                             | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Mark       |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>18(c)(ii)</b> | <ul style="list-style-type: none"> <li>moles <math>\text{Ca}(\text{ClO})_2</math> (1)</li> <li>moles <math>\text{Cl}_2</math> (1)</li> <li>           volume <math>\text{Cl}_2</math> in <math>\text{dm}^3</math><br/>           OR<br/>           volume <math>\text{Cl}_2</math> in <math>\text{cm}^3</math><br/>           OR<br/>           volume <math>\text{Cl}_2</math> in <math>\text{m}^3</math> (1)         </li> </ul> | <p>Example of calculation:</p> <p>moles = <math>10500 \div 143.1 = 73.375</math><br/>           TE on mass <math>\text{Ca}(\text{ClO})_2</math> from (c)(i)<br/>           TE on <math>M(\text{Ca}(\text{ClO})_2)</math> from (b)<br/>           Allow 73.427 from <math>M(\text{Ca}(\text{ClO})_2) = 143</math></p> <p>moles = <math>73.375 \times 2 = 146.75</math><br/>           TE on moles <math>\text{Ca}(\text{ClO})_2</math><br/>           Allow 146.85 from <math>M(\text{Ca}(\text{ClO})_2) = 143</math></p> <p>volume = <math>146.75 \times 24</math><br/>           = 3522.0/3522/3520/3500 (<math>\text{dm}^3</math>)<br/>           volume = <math>146.75 \times 24000</math><br/>           = 3.5220/3.522/3.52/3.5 <math>\times 10^6</math> (<math>\text{cm}^3</math>)<br/>           volume = <math>146.75 \times 0.024</math><br/>           = 3.5220/3.522/3.52/3.5 (<math>\text{m}^3</math>)</p> <p>TE on moles <math>\text{Cl}_2</math></p> <p>Allow omission of units<br/>           Do not award incorrect units</p> <p>Ignore SF except 1 SF</p> <p>Correct answer with some working scores (3)</p> | <b>(3)</b> |

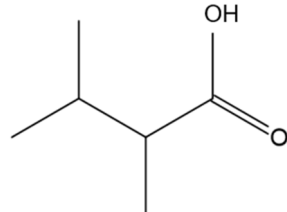
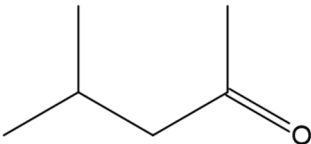
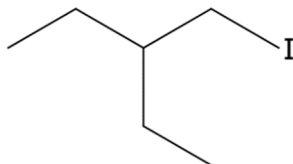
(Total for Question 18 = 11 marks)

| Question Number | Answer                                                                                                                                                                                                                                                                    | Additional Guidance                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(a)           | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>skeletal formula of 2-methylpentan-2-ol (1)</li> <li>skeletal formula of 3-methylpentan-3-ol (1)</li> <li>skeletal formula of 2,3-dimethylbutan-2-ol (1)</li> </ul> | <p>Example of correct skeletal formulae in any order:</p> <p><b>Penalise non-skeletal formulae once only</b><br/>           Ignore bond lengths and bond angles<br/>           Ignore names, even if incorrect<br/>           Ignore connectivity</p>  | (3)  |

| Question Number | Answer                                                                                                                                  | Additional Guidance                                                                                                                   | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(b)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>3,3-dimethylbutan-1-ol</li> </ul> | <p>Accept 3,3-dimethyl-1-butanol<br/>           Do not award 3,3-dimethylbutanol<br/>           Do not award 3-dimethylbutan-1-ol</p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                        | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 19(b)(ii)       | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(alcohol B has) stronger London forces</li> <li>(as) greater (contact) surface area (between molecules)</li> </ul> | <p><b>M1 and M2 independent marks</b></p> <p>Accept reverse argument</p> <p>Ignore any reference to hydrogen bonding / permanent dipole-permanent dipole forces</p> <p>Accept stronger dispersion / instantaneous-induced dipole / temporary-induced dipole forces</p> <p>Allow stronger van der Waals' forces</p> <p>Allow "more" / "greater" for "stronger"</p> <p>Ignore just stronger intermolecular forces</p> <p>Allow more points of contact</p> <p>Allow less branched / fewer side chains / fewer methyl groups</p> <p>Allow longer carbon chain</p> <p>Ignore straight-chained</p> <p>Ignore pack more closely</p> <p>Do not award more electrons</p> <p>Do not award more/stronger covalent bonds</p> | (2)  |

| Question Number   | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Mark       |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>19(b)(iii)</b> | <p>An explanation that makes reference to the following points:</p> <p><b>M1 – London forces</b></p> <ul style="list-style-type: none"> <li>London forces between B and ethanol (aiding complete solubility) <b>(1)</b></li> </ul> <p><b>M2 – hydrogen bonds</b></p> <ul style="list-style-type: none"> <li>hydrogen bonds between B and water (aiding slight solubility) <b>(1)</b></li> </ul> <p><b>M3 – comparison of intermolecular forces formed and broken</b></p> <ul style="list-style-type: none"> <li>intermolecular forces (formed) between B and ethanol are stronger than / similar in strength to those in B and/or in ethanol<br/>OR<br/>intermolecular forces (formed) between B and water are weaker than those in B and/or in water <b>(1)</b></li> </ul> | <p>Accept dispersion / instantaneous-induced dipole / temporary-induced dipole for London<br/>Allow just London forces in B (limit solubility in water)<br/>Ignore just London forces in ethanol</p> <p>Accept H-bond for hydrogen bond<br/>Ignore just B, ethanol and water all have hydrogen bonding<br/>Ignore any reference to strength / number of hydrogen bonds</p> <p><b>Accept reverse arguments in M3</b></p> <p>London forces between B and ethanol are stronger than / similar to those in B scores (2) for M1 and M3</p> <p>Hydrogen bonds between B and water are weaker than hydrogen bonds in water scores (2) for M2 and M3</p> <p>Hydrogen bonds between B and water are weaker than London forces in B scores (3)</p> | <b>(3)</b> |

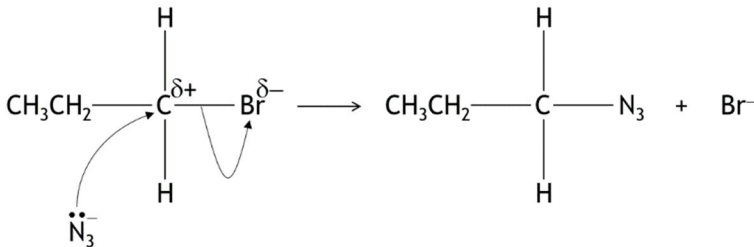
| Question Number | Answer                                                                                                                                                                                                                                                              | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark       |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>19(c)</b>    | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• structure of product from Reaction 1 (1)</li> <li>• structure of product from Reaction 2 (1)</li> <li>• structure of product from Reaction 3 (1)</li> </ul> | <p><b>Mark independently</b><br/> Example of correct structures:</p> <p>Accept any type of structure<br/> Ignore connectivity<br/> Ignore bond lengths and bond angles<br/> Ignore names, even if incorrect<br/> Ignore inorganic products even if incorrect<br/> Do not award additional incorrect organic products in each reaction (but ignore aldehyde in M1)<br/> Penalise incorrect carbon chains once only</p> <div style="text-align: center;">  <br/>  <br/>  </div> | <b>(3)</b> |

(Total for Question 19 = 12 marks)

| Question Number | Answer                                                                                                                                                          | Additional Guidance                                                                                                                     | Mark       |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>20(a)</b>    | An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>hydrogen chloride / <math>\text{HCl}(\text{g})</math></li> </ul> | Allow hydrochloric acid / $\text{HCl}(\text{aq})$<br><br>Ignore any reference to conditions<br><br>Do not award any additional reagents | <b>(1)</b> |

| Question Number | Answer                                                                                                                                                                                              | Additional Guidance                                                                                                                                                                                                                     | Mark       |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>20(b)</b>    | An answer that makes reference to the following points: <ul style="list-style-type: none"> <li><math>\text{CH}_3\text{CH}_2\text{CN}</math> / <math>\text{C}_2\text{H}_5\text{CN}</math></li> </ul> | Accept displayed or skeletal formula<br><br>Ignore any inorganic products, even if incorrect<br>Ignore any reagents / conditions<br><br>Do not award any additional organic products<br><br>Do not award $\text{C}_3\text{H}_5\text{N}$ | <b>(1)</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                            | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 20(c)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>8 electrons surrounding central N atom<br/><b>or</b><br/>8 electrons surrounding <b>both</b> terminal N atoms (1)</li> <li>8 electrons surrounding <b>all</b> N atoms<br/><b>and</b><br/>a total of 16 outer shell electrons (1)</li> </ul> | <p><b>Mark independently</b><br/>Examples of correct diagram:</p> $\left( \begin{array}{ccc} \times & \times & \times \\ \times & \text{N} & \times \\ \times & \times & \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \right)^{-}$ $\left( \begin{array}{ccc} \times & \times & \times \\ \times & \text{N} & \times \\ \times & \times & \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \right)^{-}$ <p>Do not award incorrect charge</p> <p>Allow any symbols to represent outer shell electrons and allow any combination, eg</p> $\left( \begin{array}{ccc} \times & \bullet & \triangle \\ \times & \text{N} & \times \\ \times & \times & \times \end{array} \quad \begin{array}{c} \bullet \\ \bullet \\ \bullet \end{array} \quad \begin{array}{c} \bullet \\ \bullet \\ \bullet \end{array} \quad \begin{array}{c} \triangle \\ \triangle \\ \triangle \end{array} \quad \begin{array}{c} \triangle \\ \triangle \\ \triangle \end{array} \right)^{-}$ <p>Allow bonded electrons to be shown as pairs, eg</p> $\left( \begin{array}{ccc} \times & \times & \times \\ \times & \text{N} & \times \\ \times & \times & \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \quad \begin{array}{c} \times \\ \times \\ \times \end{array} \right)^{-}$ <p>Allow circles to indicate outer shells<br/>Ignore inner shell electrons<br/>Ignore lines representing bonds<br/>Ignore displayed diagrams</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                     | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 20(c)(ii)       | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• lone pair on N of <math>\text{N}_3^-</math><br/><b>and</b><br/>curly arrow from lone pair to C of C–Br (1)</li> <li>• dipole shown on C–Br<br/><b>and</b><br/>curly arrow from C–Br bond to (<math>\delta^-</math>)Br (1)</li> <li>• organic product<br/><b>and</b><br/>bromide ion (1)</li> </ul> | <p>Example of correct mechanism:</p>  <p>Penalise half-headed arrows once in M1 and M2</p> <p>Do not award curly arrow from negative charge on <math>\text{N}_3^-</math></p> <p>Allow <math>\text{CH}_3\text{CH}_2\text{CH}_2\text{N}_3</math> for organic product<br/>Allow <math>\text{C}_3\text{H}_7\text{N}_3</math> for organic product<br/>Ignore structure of <math>\text{N}_3</math> group if displayed<br/>Do not award charged organic product<br/>Allow <math>\text{K}^{(+)}\text{Br}^{(-)}</math><br/>Ignore <math>\text{K}^+</math> spectator ion<br/>Do not award K–Br<br/>Do not award Br atom<br/>Do not award any additional inorganic product</p> | (3)  |

| Question Number | Answer                                                                                                                                                                                      | Additional Guidance                                                                                                                                                                                                                         | Mark       |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>20(d)(i)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• alcohol (solvent) <b>(1)</b></li> <li>• under (high) pressure <b>(1)</b></li> </ul> | <p>Accept ethanol<br/>Allow aqueous ethanol</p> <p>Ignore concentrated/excess <math>\text{NH}_3</math></p> <p>Do not award KOH/NaOH/alkaline</p> <p>Allow any stated pressure above 100 kPa / 1 atm</p> <p>Ignore any reference to heat</p> | <b>(2)</b> |

| Question Number  | Answer                                                                                                                                                                                            | Additional Guidance                                                                                                                                                                                                                                                                                                                                | Mark       |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>20(d)(ii)</b> | <p>An answer that makes reference to one of the following points:</p> <ul style="list-style-type: none"> <li>• secondary amine / tertiary amine / quarternary (ammonium) salt may form</li> </ul> | <p>Allow further <b>substitution</b> may occur<br/>Allow product may react with 1-bromopropane<br/>Allow 1-bromopropane/haloalkane in excess<br/>Allow <math>\text{NH}_3</math>/ammonia not in excess</p> <p>Ignore just amine reacts further<br/>Ignore just side products / side reactions</p> <p>Do not award any reference to atom economy</p> | <b>(1)</b> |

(Total for Question 20 = 10 marks)

| Question Number                                                                                                             | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Additional Guidance                                | Mark                                                  |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-------------------------------------------------------|---|---|-----|---|-----|---|---|---|---|---|--|------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|---|---------------------------------------------------------------------------|---|------------------------------------------------------------|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 21                                                                                                                          | <p>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> <table><tr><th></th><th>Number of marks awarded for structure and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr></table> | Number of indicative marking points seen in answer | Number of marks awarded for indicative marking points | 6 | 4 | 5-4 | 3 | 3-2 | 2 | 1 | 1 | 0 | 0 |  | Number of marks awarded for structure and sustained lines of reasoning | Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. | 2 | Answer is partially structured with some linkages and lines of reasoning. | 1 | Answer has no linkages between points and is unstructured. | 0 | <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded, do not deduct mark(s).</p> <p>Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.</p> | (6) |
| Number of indicative marking points seen in answer                                                                          | Number of marks awarded for indicative marking points                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| 6                                                                                                                           | 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| 5-4                                                                                                                         | 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| 3-2                                                                                                                         | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| 1                                                                                                                           | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| 0                                                                                                                           | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
|                                                                                                                             | Number of marks awarded for structure and sustained lines of reasoning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout. | 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| Answer is partially structured with some linkages and lines of reasoning.                                                   | 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |
| Answer has no linkages between points and is unstructured.                                                                  | 0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                    |                                                       |   |   |     |   |     |   |   |   |   |   |  |                                                                        |                                                                                                                             |   |                                                                           |   |                                                            |   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |     |

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|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
|  | <p>Indicative points:</p> <ul style="list-style-type: none"> <li>• <b>IP1:</b> thermal stability increases down Group (2)</li> <li>• <b>IP2:</b> ionic radius / size of ions increases (down groups)<br/>and<br/>polarising power (of cations) decreases / charge remains the same/2+</li> <li>• <b>IP3:</b> N–O breaks less easily / requires more energy to break (down groups)</li> <li>• <b>IP4:</b> LiNO<sub>3</sub> decomposes like Group 2 nitrates<br/>OR<br/>Group 1 nitrates other than lithium form (metal) nitrite/<br/>nitrate(III)/MNO<sub>2</sub></li> <li>• <b>IP5:</b> equation for thermal decomposition of NaNO<sub>3</sub></li> <li>• <b>IP6:</b> equation for thermal decomposition of Mg(NO<sub>3</sub>)<sub>2</sub></li> </ul> | <p><b>Accept reverse arguments</b></p> <p>Allow decompose less easily<br/>Ignore any stated trend for Group 1</p> <p>Accept charge density of (cat)ions<br/>decreases (down groups)<br/>Ignore atomic radius</p> <p>Allow anion/nitrate (ion) for N–O<br/>Allow less polarised / less distorted for<br/>breaks less easily<br/>Do not award nitrate molecule<br/>Do not award ionic bonds break less easily</p> <p>Allow LiNO<sub>3</sub> decomposes to form lithium<br/>oxide and/or nitrogen dioxide<br/>Allow partial/unbalanced equation, eg<br/>LiNO<sub>3</sub> → Li<sub>2</sub>O + NO<sub>2</sub><br/>Ignore just brown fumes</p> <p>2NaNO<sub>3</sub> → 2NaNO<sub>2</sub> + O<sub>2</sub><br/>Allow multiples<br/>Allow equation for any Group 1 nitrate<br/>except LiNO<sub>3</sub></p> <p>2Mg(NO<sub>3</sub>)<sub>2</sub> → 2MgO + 4NO<sub>2</sub> + O<sub>2</sub><br/>Allow multiples<br/>Allow equation for any Group 2 nitrate<br/>Ignore state symbols</p> |  |
|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|

(Total for Question 21 = 6 marks)  
(Total for Section B = 39 marks)

## Section C

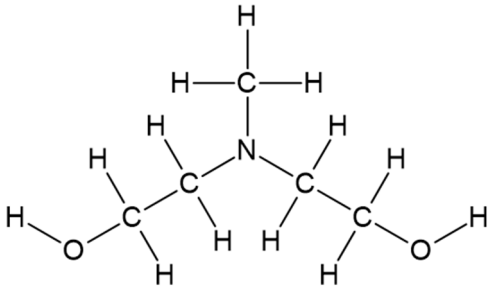
| Question Number | Answer                                                                                                                                                                                                                                    | Additional Guidance                                                                                                                                                                                                                                                                                                                                            | Mark |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(a)(i)        | <p>An answer that makes reference to one of the following points:</p> <ul style="list-style-type: none"> <li>shifts position of equilibrium to the right</li> </ul> <p>OR</p> <p>increases the (equilibrium) yield (of H<sub>2</sub>)</p> | <p>Ignore to increase rate (of forward reaction)</p> <p>Ignore cheaper to have steam in excess</p> <p>Ignore to react with most of the CH<sub>4</sub></p> <p>Allow to increase yield (of CO / products)</p> <p>Do not award so all of the CH<sub>4</sub> reacts / so reaction goes to completion</p> <p>Do not award to increase the moles of gas/pressure</p> | (1)  |

| Question Number | Answer                                                                                                                                                                                        | Additional Guidance                                                                                                                                                                                                                                                                                                                                      | Mark |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(a)(ii)       | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>T<sub>1</sub> (is higher)<br/><b>and</b><br/>(first reaction is) endothermic</li> </ul> | <p><b>Accept reverse argument</b></p> <p>Allow positive enthalpy change for endothermic</p> <p>Allow (first reaction) absorbs (heat) energy for endothermic</p> <p>Ignore just +206 for endothermic</p> <p>Ignore correct reference to effect of temperature on equilibrium yields</p> <p>Do not award absorbs more energy to break (reactant) bonds</p> | (1)  |

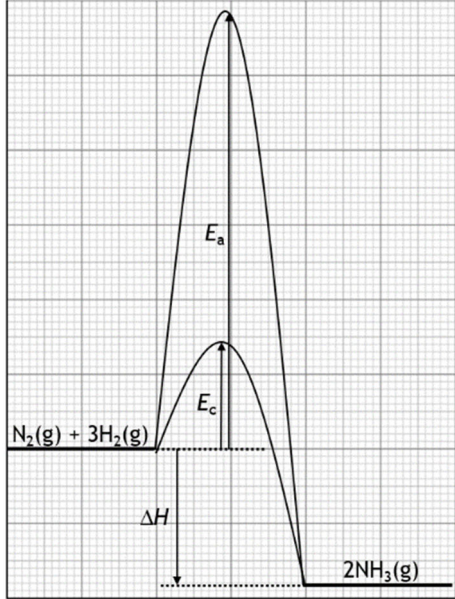
| Question Number   | Answer                                                                                                                                       | Additional Guidance                                                                                                                                                                                                                                                                                            | Mark       |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>22(a)(iii)</b> | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>overall equation for Stage 1</li> </ul> | <p>Example of correct equation:</p> $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow 4\text{H}_2 + \text{CO}_2$ <p>Allow <math>\rightleftharpoons</math> for <math>\rightarrow</math><br/>Allow multiples</p> <p>Ignore state symbols even if incorrect<br/>Ignore working</p> <p>Do not award uncanceled CO</p> | <b>(1)</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                            | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark       |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>22(b)(i)</b> | <p>An answer that makes reference to one of the following points:</p> <ul style="list-style-type: none"> <li>to reduce greenhouse gas emissions</li> </ul> <p>OR</p> <p>to sell (to increase profit)</p> <p>OR</p> <p>to prevent poisoning of the catalyst(s) in later stages</p> | <p>Ignore any reference to position of equilibrium in Stage 1 reactions</p> <p>Allow <math>\text{CO}_2</math> / it is a greenhouse gas<br/>Allow <math>\text{CO}_2</math> / it causes global warming / climate change</p> <p>Ignore (to make the process more) carbon neutral / to reduce carbon footprint<br/>Ignore <math>\text{CO}_2</math> is harmful to the environment<br/>Ignore just to reduce air pollution</p> <p>Do not award reference to ozone layer</p> | <b>(1)</b> |

| Question Number  | Answer                                                                                                                         | Additional Guidance                                                                                                                                     | Mark       |
|------------------|--------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>22(b)(ii)</b> | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>neutralisation</li> </ul> | <p>Accept acid-base</p> <p>Ignore addition</p> <p>Ignore reversible</p> <p>Ignore formation</p> <p>Do not award hydration</p> <p>Do not award redox</p> | <b>(1)</b> |

| Question Number   | Answer                                                                                                                                                       | Additional Guidance                                                                                                                                                                                                                | Mark       |
|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>22(b)(iii)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>displayed formula of N-methyldiethanolamine</li> </ul> | <p>Example of displayed formula:</p>  <p>Allow OH for O–H</p> <p>Ignore bond angles and bond lengths</p> <p>Do not award C–HO connectivity</p> | <b>(1)</b> |

| Question Number | Answer                                                                                                                                                                                             | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(c)           | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• advantage of using high pressure</li> <li>• disadvantage of using high pressure</li> </ul> | <p>(1) Examples of advantage:<br/>shifts position of equilibrium to right / products<br/>OR<br/>increases (equilibrium) yield (of <math>\text{NH}_3</math>)<br/>OR<br/>increases rate<br/>OR<br/>increases occupation of catalyst active sites</p> <p>Ignore any reference to collisions</p> <p>(1) Examples of disadvantage:<br/>requires more energy<br/>OR<br/>costs more for energy/fuel<br/>OR<br/>requires expensive/specialist equipment (to withstand pressure)</p> <p>Ignore just expensive / costs more</p> <p>Ignore dangerous / risk of explosion</p> | (2)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                               | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(d)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li><math>\Delta H</math> labelled<br/><b>and</b><br/>arrow pointing downwards</li> <li><b>labelled</b> reaction profiles for uncatalysed <b>and</b> catalysed reactions</li> <li>correct scale for activation energies</li> </ul> | <p>Example of labelled reaction profile:</p>  <p>Allow arrows to start/end within one small square of correct placement and penalise incorrect placement once only</p> <p>Allow <math>-92</math> / 'enthalpy change' for <math>\Delta H</math></p> <p>Do not award double headed arrow</p> <p>Allow any form of unambiguous labelling, eg values<br/>Allow double headed arrows<br/>Do not award downward arrows<br/>Do not award <math>E_{\text{cat}} &gt; E_{\text{a}}</math></p> <p>Accept accuracy of <math>\pm</math> one small square<br/>Ignore scale shown on y-axis</p> | (3)  |

| Question Number | Answer                                                                                                                                                                                                              | Additional Guidance                                                                                                                  | Mark |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(d)(ii)       | <p>An answer that makes reference to one of the following points:</p> <ul style="list-style-type: none"> <li>less energy (needed) / (works at a) lower temperature</li> </ul> <p>OR</p> <p>less fuel (required)</p> | <p>Ignore lowers <math>E_a</math></p> <p>Ignore catalyst can be reused</p> <p>Ignore reduces carbon footprint / carbon emissions</p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                               | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Mark |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(e)(i)        | <p>An answer that makes reference to one of the following points:</p> <ul style="list-style-type: none"> <li>increase rate</li> </ul> <p>OR</p> <p>rate is slow at low temperature</p> <p>OR</p> <p>catalyst does not work at low temperature</p> <p>OR</p> <p>so more reactants/collisions have <math>E \geq E_a</math></p> <p>OR</p> <p>to break O=O/N-H bonds</p> | <p>Do not award to increase yield</p> <p>Do not award to shift position of equilibrium (to left / right)</p> <p>Do not award reverse reaction is endothermic</p> <p>Allow to increase the number of successful collisions</p> <p>Ignore to increase collision frequency</p> <p>Allow catalyst more efficient at high temperature</p> <p>Allow to activate the catalyst</p> <p>Accept (to reach) high activation energy</p> <p>Allow to break bonds in oxygen/ammonia/reactants</p> | (1)  |

| Question Number  | Answer                                                                                                                                                                                                                         | Additional Guidance                                                                                                                                                                        | Mark       |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>22(e)(ii)</b> | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(forward reaction is highly) exothermic</li> </ul> <p>OR</p> <p>(forward reaction) releases (a lot of) heat (energy)</p> | <p>Ignore any reference to catalysis</p> <p>Allow thermal energy for heat</p> <p>Do not award <math>\text{NH}_3</math> from Stage 2 is hot</p> <p>Do not award 1100 K is not very high</p> | <b>(1)</b> |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                 | Additional Guidance                                                                                                                                                                                                                                                                                                       | Mark       |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <b>22(f)</b>    | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li><math>\text{NO}_2</math> removed (in second reaction)</li> </ul> <p>shifting position of equilibrium (in first reaction) to right<br/><b>and</b><br/>increasing the yield (of <math>\text{NO}_2</math>)</p> | <p>Allow (as) NO formed (in second reaction)</p> <p>Ignore <math>\text{HNO}_3</math> is formed (in second reaction)</p> <p>Ignore reaction is irreversible</p> <p>Ignore <math>\text{NO}_2</math> dissolves</p> <p>Allow shifting reaction to right<br/><b>and</b><br/>increasing yield (of <math>\text{NO}_2</math>)</p> | <b>(2)</b> |

| Question Number | Answer                                                                                                                                                                                               | Additional Guidance                                                                                                                                                                                                              | Mark |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(g)(i)        | <p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>left hand side of enthalpy cycle (1)</li> <li>right hand side of enthalpy cycle (1)</li> </ul> | <p>Example of completed enthalpy cycle:</p> <p>Do not award omission/incorrect state symbols<br/>Do not award multiples</p> <p>Do not award numbers in opposite order<br/>Do not award -25.6<br/>Do not award +365.6 / 365.6</p> | (2)  |

| Question Number | Answer                                                                                                                                                 | Additional Guidance                                                                                                                                                                                    | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(g)(ii)       | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>calculation of <math>\Delta_r H</math></li> </ul> | <p>Example of calculation:</p> $\Delta_r H = -(-32.6) - (-220.2) + (-365.6) + 25.6$ $= -87.2 / -87 \text{ (kJ mol}^{-1}\text{)}$ <p>Allow omission of units<br/>Allow kJ<br/>TE on cycle in (g)(i)</p> | (1)  |

| Question Number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Additional Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 22(h)           | <p>An answer that makes reference to two of the following points:</p> <ul style="list-style-type: none"> <li>• cheaper to produce <math>\text{H}_2/\text{NH}_3/\text{NO}/\text{HNO}_3</math> than to purchase (from other suppliers) (1)<br/>OR</li> <li>• (better) knowledge of chemical purity / chemical quality (1)<br/>OR</li> <li>• lower transportation / travel costs (between sites) (1)<br/>OR</li> <li>• prevents (more) chemical waste through transfer losses (1)<br/>OR</li> <li>• energy produced in exothermic reactions can be used (in endothermic processes) (1)<br/>OR</li> <li>• smaller workforce required (1)<br/>OR</li> <li>• less land required (1)<br/>OR</li> <li>• saves time so cheaper operational costs (1)</li> </ul> | <p><b>Ignore just cheaper (operational costs)</b><br/> <b>Ignore just less energy required</b><br/> <b>Ignore just saves time / makes product faster</b></p> <p>Ignore just chemicals need transporting<br/> Ignore just chemical lost through transportation<br/> Ignore just higher yield<br/> Do not award higher atom economy<br/> Allow lower energy costs<br/> Allow reduces carbon footprint</p> <p>Allow lower workforce costs</p> <p>Allow saves building / maintenance costs</p> | (2)  |

(Total for Question 22 = 21 marks)

(Total for Section C = 21 marks)

(Total for Paper = 80 marks)

