



# Mark Scheme (Results)

Summer 2022

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

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## General Marking Guidance

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

## Using the Mark Scheme

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

The mark scheme gives examiners:

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

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

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

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

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

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

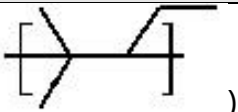
### Quality of Written Communication

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

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

Full marks will be awarded if the candidate has demonstrated the above abilities.

Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)	<p data-bbox="376 411 1093 451">The only correct answer is A (  )</p> <p data-bbox="376 499 1189 539"><b>B</b> is not correct because there is no C=C in the repeat unit</p> <p data-bbox="376 587 1794 667"><b>C</b> is not correct because the extension bonds are not from the correct carbon atoms of the chain and there should not be a C=C in the repeat unit</p> <p data-bbox="376 715 1733 754"><b>D</b> is not correct because the extension bonds are not from the correct carbon atoms of the chain</p>	(1)

Question Number	Answer	Mark
1(b)	<p data-bbox="376 944 1429 984">The only correct answer is <b>B</b> (generation of biodegradable materials)</p> <p data-bbox="376 1032 1559 1072"><b>A</b> is not correct because some poly(alkenes) may be used as a feedstock for cracking</p> <p data-bbox="376 1120 1581 1160"><b>C</b> is not correct because some poly(alkenes) may be used for energy from incineration</p> <p data-bbox="376 1208 1686 1248"><b>D</b> is not correct because some poly(alkenes) may be used for recycling to make new materials</p>	(1)

Question Number	Answer	Mark
1(c)	<p>The only correct answer is B ( <math>\left[ \text{-O-(CH}_2\text{)}_2\text{-O-C(=O)-(CH}_2\text{)}_2\text{-C(=O)-} \right]</math> )</p> <p><i>A is not correct because there is an additional oxygen atom in the repeat unit</i></p> <p><i>C is not correct because there is an incorrect number of CH<sub>2</sub> groups in one of the monomers and there is an additional oxygen atom in the repeat unit</i></p> <p><i>D is not correct because there is an incorrect number of CH<sub>2</sub> groups in one of the monomers</i></p>	(1)

Question Number	Answer	Mark
1(d)	<p>The only correct answer is D (use a higher temperature for a faster reaction rate)</p> <p><i>A is not correct because efficient use of energy does contribute to sustainability</i></p> <p><i>B is not correct because efficient use of resources does contribute to sustainability</i></p> <p><i>C is not correct because use of catalysts do contribute to sustainability</i></p>	(1)

(Total Question 1 = 4 marks)

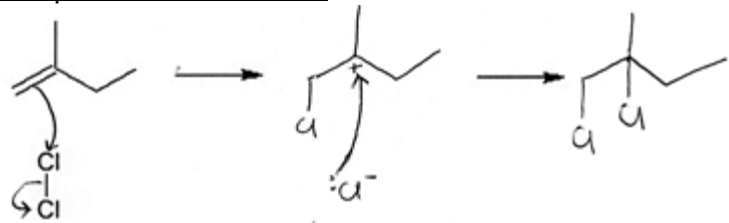
Question Number	Answer	Additional Guidance	Mark
2(a)	<p>An answer which makes reference to:</p> <ul style="list-style-type: none"> <li>a compound of hydrogen and carbon only</li> </ul>	<p>Allow absence of 'only'  Allow  substance/molecule/chain/species  for compound</p> <p>Do not award reference to a  carbon and/or a hydrogen  Do not award 'an element made  of carbon and hydrogen'  Do not award a mixture of carbon  and hydrogen  Do not award contains carbon  and hydrogen molecules</p>	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)	<p>An explanation which makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• branching results in fewer/weaker London forces (1)</li> <li>• due to less surface area/points of contact (1)</li> </ul>	<p>Accept reverse argument</p> <p>Allow van der Waals / instantaneous dipole-induced dipole / dispersion forces Ignore just intermolecular forces</p> <p>Do not award 'fewer electrons' Do not award if <b>covalent</b> bonds broken</p> <p>Allow reference to less close packing of molecules together</p>	(2)

Question Number	Answer	Mark
2(c)	<p><b>The only correct answer is D</b> (ions)</p> <p><i>A is not correct because both anions and cations are produced</i></p> <p><i>B is not correct because homolytic fission produces free radicals</i></p> <p><i>C is not correct because homolytic fission produces free radicals and heterolytic fission also produces anions</i></p>	(1)

(Total Question 2 = 4 marks)



Question Number	Answer	Additional Guidance	Mark
3(a)(i)	<ul style="list-style-type: none"> <li>curly arrow from C=C to chlorine <b>and</b> curly arrow from Cl-Cl to 'bottom' chlorine atom <b>(1)</b></li> <li>structure of carbocation intermediate <b>and</b> structure of final product <b>(1)</b></li> <li>chloride ion with lone pair <b>and</b> curly arrow from lone pair to C<sup>+</sup> of carbocation <b>(1)</b></li> </ul>	<p>Example of mechanism:</p>  <p>Ignore dipoles even if incorrect</p> <p>Allow correct structural/displayed formulae for intermediate and/or product</p> <p>Allow TE on incorrect primary carbocation</p>	<b>(3)</b>

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	<ul style="list-style-type: none"> <li>1,2-dichloro-2-methylbutane</li> </ul>	<p>Allow name shown on mechanism Ignore missing hyphens and commas</p> <p>Do not allow 2-methyl-1,2-dichlorobutane</p> <p>TE on structure in (a)(i) Allow correct name even if incorrect structure in (i)</p>	<b>(1)</b>

Question Number	Answer	Mark
3(b)	<p><b>The only correct answer is A</b> (primary)</p> <p><i>B is not correct because there is no chlorine atom bonded to a carbon atom which is bonded to two other carbon atoms</i></p> <p><i>C is not correct because there is no chlorine atom bonded to a carbon atom which is bonded to three other carbon atoms</i></p> <p><i>D is not correct because both chlorine atoms are bonded to carbon atoms which are bonded to only one carbon atom</i></p>	(1)

(Total Question 3 = 5 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)(i)	<ul style="list-style-type: none"> <li>• evaluation of number of moles of nitrogen <span style="float: right;"><b>(1)</b></span></li> <li>• conversion of pressure and temperature to correct units <span style="float: right;"><b>(1)</b></span></li> <li>• rearrangement of ideal gas equation so <math>V = nRT \div P</math> and evaluation of volume <span style="float: right;"><b>(1)</b></span></li> <li>• answer converted into <math>\text{cm}^3</math> <span style="float: right;"><b>(1)</b></span></li> </ul>	<p><u>Example of calculation:</u></p> <p><math>n = 0.42 \div 28 = 0.015 \text{ (mol)}</math></p> <p><math>120 \text{ kPa} = 120\,000 \text{ Pa}</math>  <math>20^\circ\text{C} = 293 \text{ K}</math></p> <p><math>V = \frac{0.015 \times 8.31 \times 293}{120\,000}</math>  <math>= 3.0435 \times 10^{-4} \text{ (m}^3\text{)}</math></p> <p><math>= 3.0435 \times 10^{-4} \times 10^6</math>  <math>= 304 \text{ (cm}^3\text{)}</math></p> <p>Ignore SF except 1SF  TE throughout</p> <p>Correct answer without working scores (4)</p>	<b>(4)</b>

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	<p>An answer that makes reference to</p> <ul style="list-style-type: none"> <li>• prevents oxidation (of the crisps)</li> </ul>	<p>Allow answers such as  'keep the crisps fresh' or 'prevents the crisps from going off/stale'  Allow reference to 'crisps not reacting with nitrogen but will with air'</p> <p>Ignore reference to gas prevents crisps from getting squashed/broken</p> <p>Ignore nitrogen is less reactive than air/oxygen or nitrogen is inert</p> <p>Ignore reference to effects of moisture</p>	<b>(1)</b>

Question Number	Answer	Additional Guidance	Mark
4(b)	<ul style="list-style-type: none"> <li data-bbox="427 357 1128 392">• dot-and-cross diagram of nitrogen gas (1)</li> <li data-bbox="427 485 1128 520">• dot-and-cross diagram of nitride ion (1)</li> </ul>	<p data-bbox="1167 268 1697 303"><u>Example of dot-and-cross diagrams</u></p> <div data-bbox="1167 363 1659 576" style="text-align: center;"> </div> <p data-bbox="1182 600 1592 632">Nitrogen molecule    Nitride ion</p> <p data-bbox="1167 651 1962 820"> Allow electrons to be paired horizontally  Allow the crosses to be paired in any way  Allow representation of inner shell with two electrons  Allow any pairing of dots and crosses </p> <p data-bbox="1167 871 1951 1040"> Ignore lines representing covalent bonds  Ignore missing circles  Ignore absence of brackets and charge on nitride ion  Ignore any diagram of the sodium ion </p>	(2)

Question Number	Answer	Additional Guidance	Mark
4(c)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• the lone pair (of electrons) in ammonia repels more than the bonded pairs (of electrons) <b>(1)</b></li> </ul> <p>The further three marks are scored as follows: Six of the following scores (3) four or five scores (2) and two or three scores (1)</p> <ul style="list-style-type: none"> <li>• the ammonia molecule has three bond pairs and one lone pair</li> <li>• the ammonium ion has four bond pairs</li> <li>• the ammonia molecule is (trigonal) pyramidal</li> <li>• ammonium ion is tetrahedral</li> <li>• the bond angle in ammonia is 107(°)</li> <li>• the bond angle in the ammonium ion is 109.5(°)</li> </ul>	<p>Standalone mark</p> <p>Accept points made on labelled diagrams</p>	<b>(4)</b>

Question Number	Answer	Additional Guidance	Mark
4(d)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• nucleophiles are electron <b>pair</b> donors / attack areas of low electron density / the nitrogen donates its lone <b>pair</b> of electrons <b>(1)</b></li> <li>• so the amine group attacks as a (nucleophile) by attacking the C<sup>δ+</sup> of the acyl chloride <b>(1)</b></li> <li>• which produces hydrogen chloride <b>(1)</b></li> <li>• it's a base because amine group reacts with the acid / protons (to produce the salt / C<sub>4</sub>H<sub>9</sub>NH<sub>3</sub>Cl) <b>(1)</b></li> </ul>	<p>Allow the N/ butylamine for 'the amine group'  Allow shown in a mechanism  Do not award attacks carbocation</p> <p>Allow hydrochloric acid</p> <p>Allow the N/ butylamine for 'the amine group'</p> <p>Allow base is a proton acceptor  Do not award just 'hydrogen' for proton  Do not award reference to ethanoyl chloride as an acid/donating a proton</p>	<b>(4)</b>

**(Total Question 4 = 15 marks)**

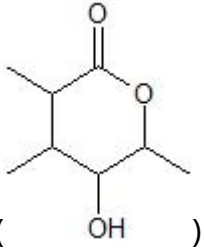

Question Number	Answer	Additional Guidance	Mark
5(a)	<p>An answer which makes reference to the following points:</p> <ul style="list-style-type: none"> <li data-bbox="427 312 1263 347">• density between 0.92 and 1.00 (g cm<sup>-3</sup>) (1)</li> <li data-bbox="427 488 1263 608">• because water is the bottom layer so more dense <b>and</b> ice floats on oil so is less dense (1)</li> </ul>	<p>Accept any value or range between 0.92 – 1.00 Ignore units even if incorrect</p> <p>Accept reverse arguments Reference to the layers is required</p>	(2)





Question Number	Answer	Additional Guidance	Mark
5(b)	<p>An answer that give evidence of the following:</p> <ul style="list-style-type: none"> <li>• use of <b>both</b> densities to get two masses <b>and</b> division by 18 to give moles <b>(1)</b></li> <li>• subtraction to give either mass or moles or number of molecules <b>(1)</b></li> <li>• multiplication by Avogadro constant to give number of molecules <b>(1)</b></li> </ul>	<p>Multiple correct methods are possible which process the data in different sequences. The correct final answer is <math>1.34 \times 10^{22}</math> / <math>1.338 \times 10^{22}</math> which can be awarded (3) regardless of working</p> <p>If this answer is not given then look for evidence of each of the given mathematical processes and give one mark for each</p> <p>The use of both densities must be carried out <b>first</b> Note that the use of 5 for the mass of water implies the use of a density of <math>1.00 \text{ g cm}^{-3}</math></p> <p>Depending on the method used this can be done at the beginning, the middle or at the end of the calculation but <b>must</b> be of (water – ice)</p> <p>This must be evidenced <b>after</b> moles have been calculated</p> <p>Allow TE throughout Ignore SF except 1SF for the final answer Allow use of <math>6 \times 10^{23}</math> which gives <math>1.33 \times 10^{22}</math> for (3) Correct answer without working scores (3) Do not allow a number of molecules &lt;1</p>	<b>(3)</b>

	<p><b>Marking points</b></p> <p>Subtraction (1)</p> <p>Use of both densities and division by 18 to give moles (1)</p> <p>Multiplication by Avogadro constant (1)</p> <p><b>or</b></p> <p>Multiplication by Avogadro constant (1)</p> <p>Use of both densities and division by 18 to give moles (1)</p> <p>Subtraction (1)</p> <p><b>or</b></p> <p>Use of both densities and division by 18 to give moles (1)</p> <p>Subtraction (1)</p> <p>Multiplication by Avogadro constant (1)</p>	<p><u>Example of calculation vs1</u></p> <p><math>m(\text{water}) = (5 \times 1.00) - (5 \times 0.92) = 0.40 \text{ (g)}</math></p> <p><math>n(\text{H}_2\text{O}) = (0.40 \div 18)</math>  <math>= 0.022222 / 2.2222 \times 10^{-2} \text{ (mol)}</math></p> <p><math>N = (2.2222 \times 10^{-2} \times 6.02 \times 10^{23})</math>  <math>= 1.34 \times 10^{22} / 1.338 \times 10^{22}</math></p> <p><u>Example of calculation vs2</u></p> <p><math>N(\text{water molecules}) = ((5 \times 1) \div 18) \times 6.02 \times 10^{23}</math>  <math>= 1.667 \times 10^{23}</math></p> <p><math>N(\text{ice molecules}) = ((5 \times 0.92) \div 18) \times 6.02 \times 10^{23}</math>  <math>= 1.533 \times 10^{23}</math></p> <p><math>N(\text{Extra}) = 1.667 \times 10^{23} - 1.533 \times 10^{23} = 1.34 \times 10^{22}</math></p> <p><u>Example of calculation vs3</u></p> <p><math>n(\text{water}) = ((1.00 \times 5.00) \div 18) = 0.27778 \text{ (mol)}</math>  <math>n(\text{ice}) = ((0.92 \times 5.00) \div 18) = 0.25556 \text{ (mol)}</math></p> <p>Difference in mol = <math>(0.27778 - 0.25556) = 0.022222 \text{ (mol)}</math></p> <p>Extra molecules = <math>0.022222 \times 6.02 \times 10^{23} = 1.34 \times 10^{22}</math></p>	
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**(Total Question 5 = 5 marks)**

Question Number	Answer	Mark
6(a)	<div style="text-align: center;">  </div> <p>The only correct answer is D (  )</p> <p><i>A is not correct because there is a ketone group present</i></p> <p><i>B is not correct because there is a ketone group present</i></p> <p><i>C is not correct because there is a ketone group present</i></p>	(1)

Question Number	Answer	Mark
6(b)	<div style="text-align: center;">  </div> <p>The only correct answer is C (  )</p> <p><i>A is not correct because there are two ketone groups but no aldehyde group</i></p> <p><i>B is not correct because there are two ketone groups but no aldehyde group</i></p> <p><i>D is not correct because there are two aldehyde groups but no ketone group</i></p>	(1)

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	<p>An explanation that makes reference to</p> <ul style="list-style-type: none"> <li>propanal is condensed back (to the pear-shaped flask) <b>(1)</b></li> <li>so propanal is (further) oxidised (to propanoic acid) or propanal is more readily oxidised than propan-1-ol <b>(1)</b></li> </ul>	<p>Allow aldehyde for propanal</p> <p>Allow 'apparatus is reflux'</p> <p>Allow propanal is not being removed /distilled off (from the oxidising agent)</p> <p>Ignore just 'reacts further'</p> <p>Do not award reference to propanal being completely oxidised</p>	<b>(2)</b>

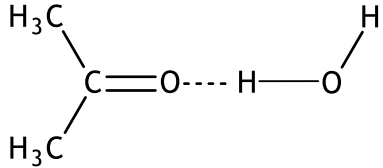
Question Number	Answer	Additional Guidance	Mark
6(c)(ii)	<ul style="list-style-type: none"> <li>(+)VI</li> </ul>	<p>Allow (+) six / (+)6 / six (+) / 6(+)</p>	<b>(1)</b>

Question Number	Answer	Additional Guidance	Mark
6(c)(iii)	<ul style="list-style-type: none"> <li>balanced equation</li> </ul>	<p><u>Example of equation</u></p> $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{CHO} + 2\text{H}^+ + 2\text{e}^-$	<b>(1)</b>

Question Number	Answer	Additional Guidance	Mark
6(c)(iv)	<ul style="list-style-type: none"><li>provides a surface for bubbles to form / enables smaller bubbles to form / provides nucleation sites for bubbles</li></ul> or to prevent large bubbles forming	Allow distribution of heat more evenly / to prevent superheating  Ignore mixing / to stop bumping / spitting / explosion / liquid splashing out / vigorous reaction / loss of reactants  Do not award reference to large gas molecules	(1)

Question Number	Answer	Additional Guidance	Mark
6(c)(v)	<ul style="list-style-type: none"> <li>• (M1) evaluation of number of moles of propan-1-ol (1)</li> </ul> <p>Method one using masses for percentage calculation</p> <ul style="list-style-type: none"> <li>• (M2) evaluation of maximum mass of propanal (1)</li> <li>• (M3) percentage yield (1)</li> </ul> <p>or</p> <p>Method two using moles for percentage calculation</p> <ul style="list-style-type: none"> <li>• (M2) evaluation of actual moles of propanal (1)</li> <li>• (M3) percentage yield (1)</li> </ul>	<p><u>Example of calculation</u></p> <p><math>n(\text{propan-1-ol}) = (1.50 \div 60) = 0.025 \text{ (mol)}</math></p> <p><math>n(\text{propan-1-ol}) = n(\text{propanal})</math>  <math>\text{max } m(\text{propanal}) = (0.025 \times 58)</math>  <math>= 1.45 \text{ (g)}</math></p> <p><math>\% \text{Yield} = ((0.609 \div 1.45) \times 100) = 42 \%</math></p> <p><math>n(\text{propanal}) = (0.609 \div 58) = 0.0105 \text{ (mol)}</math></p> <p><math>\% \text{Yield} = ((0.0105 \div 0.025) \times 100) = 42 \%</math></p> <p>Allow TE at each stage  Ignore SF except 1SF  Penalise incorrect <math>M_r</math> values once only  Correct answer without working scores (3)</p>	(3)

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• similar molar masses so the number of electrons is similar/same resulting in similar London forces <b>(1)</b></li> <li>• propanone (and ethanoic acid) form permanent dipole(-dipole) forces <b>(1)</b></li> <li>• (only) ethanoic acid forms (intermolecular) hydrogen bonding <b>(1)</b></li> <li>• which is stronger so requires more <b>energy</b> to break (giving a higher boiling temperature) <b>(1)</b></li> </ul>	<p>Allow van der Waals' forces / dispersion forces / instantaneous dipole-induced dipole forces</p> <p>Ignore reference to ethanoic acid having greater London forces</p> <p>Ignore reference to hydrogen bonding to water by propanone Penalise abbreviation pd-d once only</p> <p>Ignore references to ethanoic acid dimerization</p> <p>Reference to energy must be linked to the breaking of hydrogen bonds</p>	<b>(4)</b>

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>forms hydrogen bonds with water</li> <li>diagram of hydrogen bond</li> </ul>	<p>(1) Allow H bonds for hydrogen bonds</p> <p>(1)</p>  <p>Ignore bond angle and missing dipoles and missing lone pair</p> <p>Do not award incorrect dipoles Do not award incorrect propanone and/or water structure Do not award if second hydrogen bond drawn to the hydrogen of the CH<sub>3</sub></p>	(2)

(Total Question 6 = 16 marks)



**Allow annotated equations to score these marks in both (i) and (ii)**  
**Allow any unambiguous formulae for the organic molecules in both (i) and (ii) such as C<sub>2</sub>H<sub>5</sub>CN for CH<sub>3</sub>CH<sub>2</sub>CN**

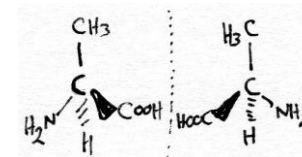
Question Number	Answer	Additional Guidance	Mark
<b>7(a)(i)</b>	<p>A description which includes</p> <ul style="list-style-type: none"> <li>• equation <span style="float: right;"><b>(1)</b></span></li> <li>• LiAlH<sub>4</sub> in (dry) ether (followed by dilute acid) or H<sub>2</sub> with Ni / Pt / Pd <span style="float: right;"><b>(1)</b></span></li> </ul>	<p><u>Example of equation</u></p> <p>CH<sub>3</sub>CH<sub>2</sub>CN + 4[H] → CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub>            CH<sub>3</sub>CH<sub>2</sub>CN + 2H<sub>2</sub> → CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub></p> <p>Allow names or formulae but both must be correct if given together            Allow Lithal            Allow hydrogen to be given in the equation or written over the arrow</p> <p>Ignore references to heat or a temperature</p>	<b>(2)</b>
Question Number	Answer	Additional Guidance	Mark
<b>7(a)(ii)</b>	<p>A description which includes</p> <ul style="list-style-type: none"> <li>• equation from any halogenoalkane <span style="float: right;"><b>(1)</b></span></li> <li>• ethanolic/alcoholic ammonia <span style="float: right;"><b>(1)</b></span></li> <li>• heat <b>and</b> under pressure <span style="float: right;"><b>(1)</b></span></li> </ul>	<p><u>Example of equation</u></p> <p>CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>Br + NH<sub>3</sub> → CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub> + HBr            or            CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>Br + 2NH<sub>3</sub> → CH<sub>3</sub>CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub> + NH<sub>4</sub>Br</p> <p>Allow use of state symbol (alc)/(EtOH)/(eth) with NH<sub>3</sub>            Allow ammonia to be given in equation or written over the arrow</p> <p>Accept heat <b>and</b> in a sealed tube            Ignore mechanisms            If a contradictory chemical is stated then penalise once against M2 or M3</p>	<b>(3)</b>

Question Number	Answer	Mark
7(b)	<p><b>The only correct answer is A</b> (an amide)</p> <p><i>B is not correct because the amine range does not include 3220 cm<sup>-1</sup></i></p> <p><i>C is not correct because the amine range does not include 3220 cm<sup>-1</sup></i></p> <p><i>D is not correct because the amide range does include 3220 cm<sup>-1</sup></i></p>	(1)

Question Number	Answer	Additional Guidance	Mark												
7(c)	<p>This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1" data-bbox="383 715 1137 1074"> <thead> <tr> <th data-bbox="383 715 759 847">Number of indicative marking points seen in answer</th> <th data-bbox="759 715 1137 847">Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td data-bbox="383 847 759 895">6</td> <td data-bbox="759 847 1137 895">4</td> </tr> <tr> <td data-bbox="383 895 759 943">5-4</td> <td data-bbox="759 895 1137 943">3</td> </tr> <tr> <td data-bbox="383 943 759 991">3-2</td> <td data-bbox="759 943 1137 991">2</td> </tr> <tr> <td data-bbox="383 991 759 1038">1</td> <td data-bbox="759 991 1137 1038">1</td> </tr> <tr> <td data-bbox="383 1038 759 1074">0</td> <td data-bbox="759 1038 1137 1074">0</td> </tr> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning</p>	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	<p>Guidance on how the mark scheme should be applied:</p> <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).</p>	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5-4	3														
3-2	2														
1	1														
0	0														

	Number of marks awarded for structure of answer and sustained lines of reasoning		<p>More than one indicative marking point may be made within the same comment or explanation</p> <p>Accept annotated diagrams to illustrate the indicative points</p> <p>Ignore reference to other amino acid properties</p>			
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2			<p>More than one indicative marking point may be made within the same comment or explanation</p> <p>Accept annotated diagrams to illustrate the indicative points</p> <p>Ignore reference to other amino acid properties</p>		
Answer is partially structured with some linkages and lines of reasoning	1				<p>More than one indicative marking point may be made within the same comment or explanation</p> <p>Accept annotated diagrams to illustrate the indicative points</p> <p>Ignore reference to other amino acid properties</p>	
Answer has no linkages between points and is unstructured	0					<p>More than one indicative marking point may be made within the same comment or explanation</p> <p>Accept annotated diagrams to illustrate the indicative points</p> <p>Ignore reference to other amino acid properties</p>
			<p>More than one indicative marking point may be made within the same comment or explanation</p> <p>Accept annotated diagrams to illustrate the indicative points</p> <p>Ignore reference to other amino acid properties</p>			

	<p>Indicative content</p> <p>IP1 (Similarity)</p> <ul style="list-style-type: none"> <li>• they are <b>both</b> 2-amino acids / alpha amino acids / naturally occurring/ zwitterions</li> </ul> <p>IP2</p> <ul style="list-style-type: none"> <li>• equation for the reaction with an acid</li> </ul> <p>IP3</p> <ul style="list-style-type: none"> <li>• equation for the reaction with a base</li> </ul> <p>IP4</p> <ul style="list-style-type: none"> <li>• alanine has a chiral centre/ asymmetric carbon atom/ non-superimposable mirror images <b>and</b> glycine does not</li> </ul> <p>IP5</p> <ul style="list-style-type: none"> <li>• (an aqueous solution of) alanine rotates the plane (of polarisation) of plane-polarised (monochromatic) light but glycine does not</li> </ul> <p>IP6</p> <ul style="list-style-type: none"> <li>• diagram to show enantiomers of alanine</li> </ul>	<p>The zwitterions can be evidenced from each amino acid zwitterion in an equation e.g. <math>\text{NH}_3^+\text{CH}(\text{CH}_3)\text{COO}^- / \text{NH}_3^+\text{CH}_2\text{COO}^-</math></p> <p>e.g. <math>\text{H}^+ + \text{NH}_3^+\text{CH}_2\text{COO}^- \rightarrow \text{NH}_3^+\text{CH}_2\text{COOH}</math> or <math>\text{H}^+ + \text{NH}_3^+\text{CH}(\text{CH}_3)\text{COO}^- \rightarrow \text{H}_3\text{N}^+\text{CH}(\text{CH}_3)\text{COOH}</math></p> <p><math>\text{OH}^- + \text{NH}_3^+\text{CH}_2\text{COO}^- \rightarrow \text{NH}_2\text{CH}_2\text{COO}^- + \text{H}_2\text{O}</math> or <math>\text{OH}^- + \text{NH}_3^+\text{CH}(\text{CH}_3)\text{COO}^- \rightarrow \text{NH}_2\text{CH}(\text{CH}_3)\text{COO}^- + \text{H}_2\text{O}</math> Allow use of un-ionised amino acid structures</p> <p>If IP2 and 3 not scored then allow 1IP for a suitable description of acid and base behaviour</p> <p>Allow reference to four different atoms/groups bonded to central carbon for chiral centre</p> <p>'Plane' must be stated at least once</p> <p>Wedges must be drawn e.g. Ignore angles and connectivity</p>	
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Question Number	Answer	Additional Guidance	Mark
7(d)	<p>An explanation which includes</p> <ul style="list-style-type: none"> <li>• lysine requires twice (the volume of HCl) <b>(1)</b></li> <li>• (because) lysine has two (basic) amine/NH<sub>2</sub> groups whereas serine has one <b>(1)</b></li> </ul>	<p>Allow lysine requires 20.0 cm<sup>3</sup> and serine requires 10 cm<sup>3</sup></p> <p>Allow lysine has one more (basic) / another amine/ NH<sub>2</sub> group</p> <p>Allow lysine can accept two protons whereas serine can only accept one</p>	<b>(2)</b>

**(Total Question 7 = 14 marks)**

Question Number	Answer	Mark
8(a)	<p><b>The only correct answer is C</b> (6 ..... 7)</p> <p><i>A is not correct because there are six non-equivalent carbons in isoamyl acetate and seven in amyl acetate</i></p> <p><i>B is not correct because all carbons of amyl acetate generate their own peak in the spectrum</i></p> <p><i>D is not correct because the two methyl groups on the branched chain are equivalent</i></p>	(1)

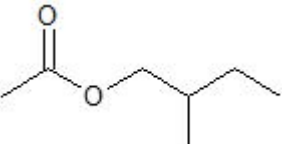
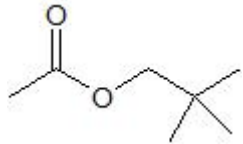
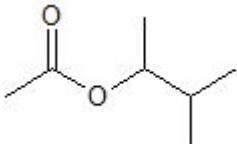
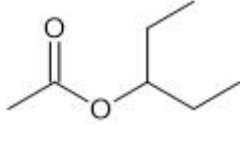
Question Number	Answer	Additional Guidance	Mark
8(b)	<ul style="list-style-type: none"> <li>• C<sub>7</sub>H<sub>14</sub>O<sub>2</sub></li> </ul>	Accept atoms in any order	(1)


Question Number	Answer	Additional Guidance	Mark
8(c)	<ul style="list-style-type: none"> <li>• CH<sub>3</sub>COOH</li> </ul>	Allow displayed, skeletal or combination of Do not award molecular formula	(1)

Question Number	Answer	Additional Guidance	Mark
8(d)	<ul style="list-style-type: none"> <li>• 3-methylbutan-1-ol</li> </ul>	Allow 'methly' for methyl Allow name with missing hypkens Allow 3-methylbutane-1-ol Allow 3-methylbut-1-anol Allow 1-hydroxy-3-methylbutane  Do not allow 3-methylbut-1-ol  Ignore formulae even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
8(e)	<ul style="list-style-type: none"> <li>• pentyl ethanoate</li> </ul>	Allow pentanyl ethanoate	(1)



Question Number	Answer	Additional Guidance	Mark
8(f)(i)	<p data-bbox="376 308 996 347">Any three of the following four structures</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p data-bbox="479 507 524 544">(1)</p> </div> <div style="text-align: center;">  <p data-bbox="792 507 837 544">(1)</p> </div> <div style="text-align: center;">  <p data-bbox="1077 507 1122 544">(1)</p> </div> <div style="text-align: center;">  <p data-bbox="1352 523 1397 560">(1)</p> </div> </div>	<p data-bbox="1523 355 1870 432">Accept formulae in any order</p> <p data-bbox="1523 488 1839 608">Award (2) if 3 correct displayed/structural formulae given</p> <p data-bbox="1523 663 1839 783">Award (1) if 2 correct displayed/structural formulae given</p>	(3)

Question Number	Answer	Additional Guidance	Mark
8(f)(ii)	<p>An equation that has</p> <ul style="list-style-type: none"> <li>• ethanoyl chloride (1)</li> <li>• alcohol and ester+ HCl product (1)</li> </ul>	<p><u>Example of equation</u></p>  <p>Allow structural, displayed formulae in any combination  Ignore connectivity to OH except horizontal  Ignore state symbols even if incorrect  If molecular formulae used then allow (1) for correct equation</p> <p>Allow (1) for a correct equation to form ester A from ethanoic acid  e.g.  <math>\text{CH}_3\text{COOH} + \text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3 \rightleftharpoons \text{CH}_3\text{COOCH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}</math></p>	(2)

Question Number	Answer	Additional Guidance	Mark
8(g)	<p>An answer that makes reference to the following points:</p> <p>(similarity)</p> <ul style="list-style-type: none"> <li>• both make the (same) alcohol / pentan-1-ol <b>(1)</b></li> </ul> <p>(differences)</p> <ul style="list-style-type: none"> <li>• acid hydrolysis is reversible, alkaline hydrolysis is irreversible <b>(1)</b></li> <li>• acid hydrolysis produces the carboxylic acid/ ethanoic acid <b>and</b> alkaline hydrolysis produces the carboxylate / ethanoate (ion) <b>(1)</b></li> <li>• the acid is a catalyst and the alkali is a reactant <b>(1)</b></li> </ul>	<p>Points can be made in equations</p> <p>Accept acid hydrolysis is an equilibrium and alkaline hydrolysis goes to completion</p> <p>Allow just acid for carboxylic acid</p> <p>Allow salt for carboxylate</p> <p>Allow the acid will be regenerated /not used up but the alkali will be used up</p> <p>Ignore references to rate differences</p> <p>Ignore references to a need for the product of alkaline hydrolysis to be acidified which is different to acid hydrolysis</p>	<b>(4)</b>

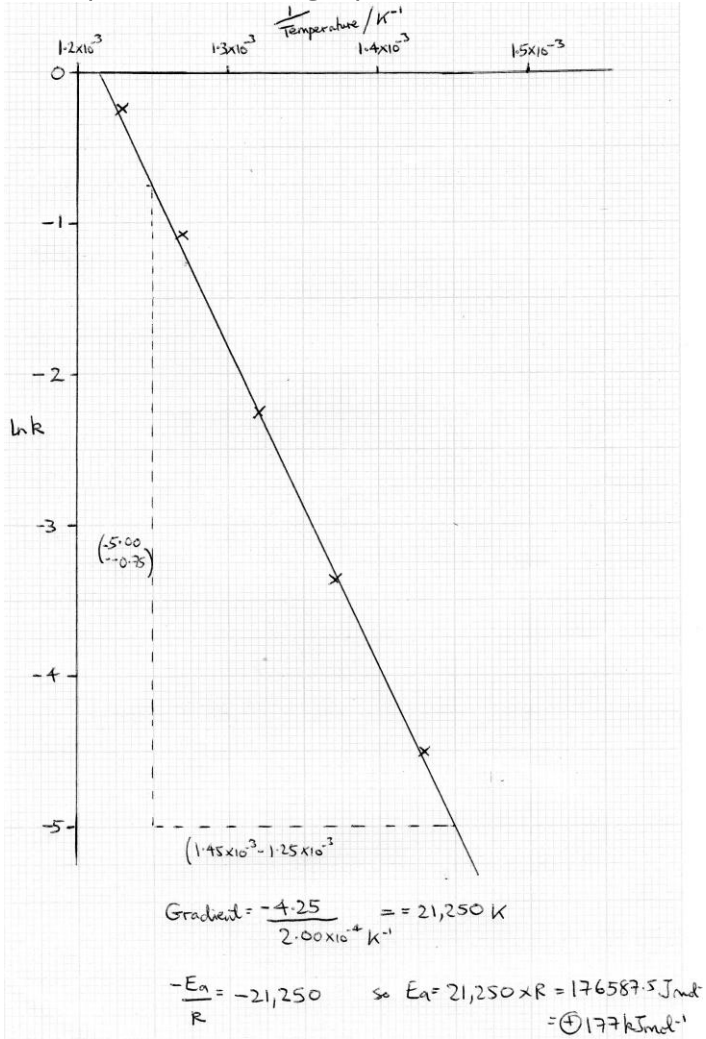
**(Total Question 8 = 14 marks)**

Question Number	Answer	Additional Guidance	Mark
9(a)	<ul style="list-style-type: none"> <li>rate equation</li> </ul>	<p>Rate = <math>k[\text{CH}_3\text{CHO}]^2</math></p> <p>Allow K for <math>k</math>  Allow r or R for Rate  Allow displayed, semi-structural or skeletal formula for ethanal</p> <p>Do not allow rounded brackets  Do not allow missing rate  Do not allow "rate equation = "</p>	(1)

Question Number	Answer	Additional Guidance	Mark
9(b)	<ul style="list-style-type: none"> <li>rate constant units</li> </ul>	<p><math>\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}</math></p> <p>Allow units in any order  Do not penalise use of <math>\text{mol}^{-1} / \text{s}^{-1}</math></p> <p>No TE on incorrect equation in (a)</p>	(1)

Question Number	Answer	Additional Guidance	Mark
9(c)	<ul style="list-style-type: none"> <li data-bbox="409 395 1167 480">• calculation of average rate between 0 – 420 s to 1/2 SF <b>(1)</b></li> <li data-bbox="409 528 1167 612">• calculation of average rate between 420 – 1260 s to 1/2 SF <b>(1)</b></li> </ul>	<p data-bbox="1218 355 1559 387"><u>Example of calculation</u></p> <p data-bbox="1218 395 1906 480">Rate = <math>((0.72 - 0.36) \div (420 - 0)) = 8.5714 \times 10^{-4}</math>  <math>= 9 \times 10^{-4} / 8.6 \times 10^{-4} \text{ (mol dm}^{-3} \text{ s}^{-1}\text{)}</math></p> <p data-bbox="1218 528 1962 612">Rate = <math>((0.36 - 0.18) \div (1260 - 420)) = 2.1429 \times 10^{-4}</math>  <math>= 2 \times 10^{-4} / 2.1 \times 10^{-4} \text{ (mol dm}^{-3} \text{ s}^{-1}\text{)}</math></p> <p data-bbox="1218 660 1704 692">Penalise lack of 1/2 SF once only</p> <p data-bbox="1218 748 1653 780">Ignore units even if incorrect</p> <p data-bbox="1218 788 1749 820">Ignore negative sign in front of rate</p>	<b>(2)</b>

Question Number	Answer	Additional Guidance	Mark
9(d)	<p>An explanation that makes reference to</p> <ul style="list-style-type: none"> <li>• not zero order because the rate is not constant <b>(1)</b></li> <li>• not first order because the time taken for the concentration to halve is not equal/ half lives are not constant or not first order because the rate change is not (directly) proportional to the concentration change <b>(1)</b></li> </ul>	<p>Allow the rates calculated in (c) are not the same</p> <p>Allow different times are taken for the concentration to halve</p> <p>Allow the concentration is halved but the rate decreases by a quarter</p> <p>If no other mark awarded allow (1) for reference to justification of second order due to concentration decreasing by <math>\frac{1}{2}</math> but rate decreasing by <math>\frac{1}{4}</math> or due to rate change proportional to concentration squared/ exponential change</p>	<b>(2)</b>

Question Number	Answer	Additional Guidance	Mark
9(e)		<p>Example of suitable graph:</p>  <p> <math>\text{Gradient} = \frac{-4.25}{2.00 \times 10^{-4} \text{ K}^{-1}} = 21,250 \text{ K}</math>  <math>\frac{-E_a}{R} = -21,250 \quad \text{so} \quad E_a = 21,250 \times R = 176587.5 \text{ J mol}^{-1}</math>  <math>= \oplus 177 \text{ kJ mol}^{-1}</math> </p>	(7)

	<ul style="list-style-type: none"> <li>• calculation of <math>1/T</math> value (1)</li> <li>• calculation of <math>\ln k</math> value (1)</li> <li>• axes: correct way round and in the correct direction, labelled with units, suitable scale (1)</li> <li>• all points plotted correctly, with best-fit straight line (1)</li> <li>• calculation of gradient (1)</li> <li>• sign <b>and</b> units of gradient (1)</li> <li>• use of gradient to calculate activation energy (1)</li> </ul>	<p><math>1.27 \times 10^{-3}</math></p> <p>-1.07 Penalise values not to 3 SF once only in M1 and M2</p> <p>Accept use of <math>1 \times 10^3</math> or <math>1 \times 10^{-3}</math> on x axis Do not award <math>1/t</math> for <math>1/T</math> Plotted points must cover at least <math>\frac{1}{2}</math> the graph paper on each axis</p> <p>Allow <math>\pm 1</math> square</p> <p>Gradient = (-) 21250 Allow <math>\pm 900</math></p> <p>- and K</p> <p><math>E_a = -(-21250 \times 8.31) / 1000</math> = (+) 177 (kJ mol<sup>-1</sup>) Allow <math>\pm 7</math></p> <p>Allow 177000 J mol<sup>-1</sup> <math>\pm 7000</math> Ignore SF except 1 SF Do not penalise mol<sup>-1</sup> TE on numerical value of gradient Final answer must be positive</p>	
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(Total Question 9 = 13 marks)



