

**GCE**

**Chemistry A**

Unit **F322**: Chains, Energy and Resources

Advanced Subsidiary GCE

**Mark Scheme for June 2015**

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.













All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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## 1. Annotations

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Ignore
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

<b>Annotation</b>	<b>Meaning</b>
<b>DO NOT ALLOW</b>	Answers which are not worthy of credit
<b>IGNORE</b>	Statements which are irrelevant
<b>ALLOW</b>	Answers that can be accepted
( )	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
<b>ECF</b>	Error carried forward
<b>AW</b>	Alternative wording
<b>ORA</b>	Or reverse argument

## 12 Subject-specific Marking Instructions

The following questions should be annotated with ticks and crosses to show how marks have been awarded in the body of the text:

**3(c)(i), 3(d), 4(c)(ii) 5(d)(i), 5(e)(i), 5(f)(ii), 6(a)(i), 6(b)(ii), 6(c) and 7(b)**

**All questions where an ECF has been applied.**

### Checking additional pages

**All** the Additional Pages in the examination script must be checked to see if any candidates include any answers.

- When you open question **1(a)** you will see a view of page 22 one of the Additional Pages.
- If the page is blank then, using the marking mode, annotate the page with an omission mark, ^, or the BP annotation
- Scroll down to page 24 and annotate with a ^ if the page is blank.
- If pages 22, 23 or 24 are not blank then use the paper clip icon to link the pages to the correct questions.
- You may need to contact your Team Leader if you do not know how to do this.

## Generic comments

**ORGANIC STRUCTURES**

For a 'structure' or 'structural formula',

- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,

- **ALLOW** bond drawn to C or H,  
e.g. **ALLOW** CH<sub>3</sub>–, CH<sub>2</sub>–, C<sub>3</sub>H<sub>7</sub>–, etc
- **ALLOW** vertical 'bond' to any part of an alkyl group





For an OH group shown within a structure,

- **DO NOT ALLOW** formula with horizontal —HO **OR** OH –
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,

- **DO NOT ALLOW** COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, <b>ALLOW</b> :	
• <b>ALLOW</b> a hollow wedge for 'in bond' <b>OR</b> an 'out bond', provided it is different from the other in or out wedge e.g.:	

**NAMES**

Names including alkyl groups:

- **ALLOW** alkanyl, e.g. ethanyl (i.e. **IGNORE** 'an')
- **DO NOT ALLOW** alkol, e.g. ethol (ie 'an' is essential)

Names of esters:

- Two words are expected, e.g. ethyl ethanoate
- **ALLOW** one word, e.g. ethylethanoate

Names with multiple numbers and hyphens:

Use of 'e'

- **ALLOW** superfluous 'e', e.g. propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', e.g. propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:

- **ALLOW** absence of hyphens, e.g. propane 1,2 diol

Multiple locant numbers must be clearly separated:

- **ALLOW** full stops: e.g. 1.2 OR spaces: 1 2
- **DO NOT ALLOW** e.g. 12

Locant numbers in formula must be correct

- **DO NOT ALLOW** propan-3-ol

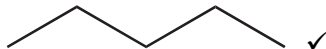
Order of substituents should be alphabetical:

- **ALLOW** any order (as long as unambiguous), e.g. 2-chloro-3-bromobutane

**ABBREVIATIONS**

van der Waal's forces

**ALLOW** vdw forces **OR** VDW forces (and any combination of upper and lower cases)

Question			Answer	Mark	Guidance
1	(a)	(i)	(compounds or molecules having the) same molecular formula but different structural formulae ✓	1	<b>ALLOW</b> different structure <b>OR</b> different displayed formula <b>OR</b> different skeletal formula for structure  <b>DO NOT ALLOW</b> any reference to spatial/space  Same formula is <b>not</b> sufficient ( <i>no reference to molecular</i> ) Different arrangement of atoms is <b>not</b> sufficient ( <i>no reference to structure/structural</i> )
		(ii)	2,2,3-trimethylbutane ✓	1	<b>ALLOW</b> trimethylbutane as the <b>ONLY</b> alternative response
	(b)		 ✓	1	<b>DO NOT ALLOW</b> molecular formulae <b>OR</b> structural formula <b>OR</b> displayed formula <b>OR</b> mixture of the above
	(c)		C <sub>12</sub> H <sub>25</sub> ✓	1	<b>IGNORE</b> C <sub>24</sub> H <sub>50</sub>
	(d)	(i)	C <sub>8</sub> H <sub>18</sub> + 12½O <sub>2</sub> → 8CO <sub>2</sub> + 9H <sub>2</sub> O ✓	1	<b>ALLOW</b> multiples e.g. 2C <sub>8</sub> H <sub>18</sub> + 25O <sub>2</sub> → 16CO <sub>2</sub> + 18H <sub>2</sub> O  <b>IGNORE</b> state symbols

Question	Answer	Mark	Guidance
(ii)	$(n(\text{C}_8\text{H}_{18}) \text{ burned}) = 0.32 \text{ (mol)} \checkmark$  $(n(\text{CO}_2) \text{ from complete combustion}) = 2.56 \text{ or } 2.6 \text{ mol}$ <b>OR</b> $(\text{ratio } n\text{CO}_2/n\text{C}_8\text{H}_{18} ) = 7.8(125)$ <b>OR</b> $(n \text{ C}_8\text{H}_{18} \text{ produce } 2.5 \text{ mol CO}_2) = 0.31(25) \checkmark$	2	<p><b>DO NOT ALLOW ECF</b> from an incorrect moles of octane</p> <p><b>DO NOT ALLOW ECF</b> from incorrect ratio from equation in (i)</p> <p><b>ALLOW</b> the following alternate methods</p> <p>-----</p> <p><b>Method 1</b></p> <p><math>(\text{mass CO}_2 \text{ produced}) = 110 \text{ g} \checkmark</math></p> <p><math>(\text{mass CO}_2 \text{ from complete combustion})</math>  <math>= 8 \times 0.32 \times 44 = 112.64 \text{ or } 112.6 \text{ or } 113 \text{ g} \checkmark</math></p> <p>-----</p> <p><b>Method 2</b></p> <p><math>(n \text{ C}_8\text{H}_{18} \text{ to produce } 2.5 \text{ mol CO}_2) = 0.31(25) \checkmark</math></p> <p><math>(\text{mass of octane required to produce } 2.50 \text{ mol CO}_2)</math>  <math>= 35.6 \text{ OR } 35.63 \text{ OR } 35.625 \text{ g} \checkmark</math></p>



Question		Answer	Mark	Guidance	
	(e)	(i)	Fractional distillation <b>AND</b> cracking ✓	1	<b>ALLOW</b> either order
		(ii)	Correct equation showing cracking of an alkane to form ethene ✓	1	<p><b>ALLOW</b> any correct equation with correct formulae to show cracking forming C<sub>2</sub>H<sub>4</sub> of the type:            alkane → shorter alkane(s) + alkene,            e.g. C<sub>10</sub>H<sub>22</sub> → C<sub>8</sub>H<sub>18</sub> + C<sub>2</sub>H<sub>4</sub>                  C<sub>10</sub>H<sub>22</sub> → C<sub>6</sub>H<sub>14</sub> + 2C<sub>2</sub>H<sub>4</sub></p> <p><sup>C</sup><b>ALLOW</b> C<sub>2</sub>H<sub>6</sub> → C<sub>2</sub>H<sub>4</sub> + H<sub>2</sub></p> <p><b>ALLOW</b> correct molecular formulae <b>OR</b> structural <b>OR</b> displayed <b>OR</b> skeletal <b>OR</b> mixture of the above.</p> <p><b>IGNORE</b> state symbols</p>
			<b>Total</b>	<b>9</b>	

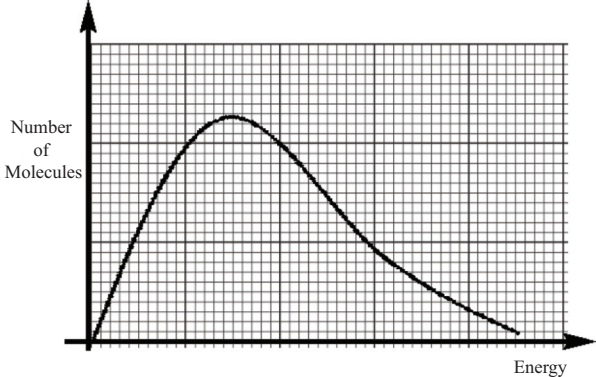
Question		Answer	Mark	Guidance
2	(a)	<p>Method 1: 100% <b>OR</b> (only) one product <b>OR</b> no waste product <b>OR</b> addition (reaction) ✓</p> <p>Method 2: &lt; 100%  <b>AND</b>  two products  <b>OR</b> (also) produces NaBr  <b>OR</b> (There is a) waste product  <b>OR</b> substitution (reaction) ✓</p>	2	<p><b>ALLOW</b> co-product or by-product for waste product</p> <p>For '&lt; 100%' <b>ALLOW</b> not 100% <b>OR</b> method 2 has a low(er) atom economy (compared to method 1)</p> <p><b>IGNORE</b> produces Br<sup>-</sup>/ Na<sup>+</sup>  <b>DO NOT ALLOW</b> incorrect waste products e.g. Br<sub>2</sub>, HBr, Br, Na</p> <p><b>ALLOW</b> correctly calculated value of 42 or 41.8 up to calculator value of 41.83154324 correctly rounded for second mark</p> <p><b>DO NOT ALLOW</b> incorrect values for the atom economy of method 2.</p> <p><b>ALLOW ONLY</b> 1 mark for a statement that both methods have 100% atom economy.</p>
	(b)	Acid ✓	1	<p><b>ALLOW</b> H<sup>+</sup> / named mineral acid / H<sub>2</sub>SO<sub>4</sub> / H<sub>3</sub>PO<sub>4</sub></p> <p><b>DO NOT ALLOW</b> 'weak acid' e.g. ethanoic acid</p> <p><b>IGNORE</b> pressure  <b>IGNORE</b> temperature</p>

Question		Answer	Mark	Guidance
(c)	(i)	(Average enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	<b>IGNORE</b> energy required <b>OR</b> energy released <b>DO NOT ALLOW</b> bonds formed
	(ii)	<b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b> <b>IF enthalpy change = <math>-42 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks</b> <b>IF enthalpy change = <math>+42 \text{ (kJ mol}^{-1}\text{)}</math> award 2 marks</b>  (Energy for bonds broken) = 5538 (kJ) ✓ (Energy for bonds made) = 5580 (kJ) ✓  $\Delta H_f = -42 \text{ (kJ mol}^{-1}\text{)}$ ✓	3	<b>IF there is an alternative answer, check to see if there is any ECF credit possible.</b>  two common incorrect answers are: $-970 \text{ (kJ mol}^{-1}\text{)}$ award 2 marks $+970 \text{ (kJ mol}^{-1}\text{)}$ award 1 mark  <b>IGNORE</b> signs <b>ALLOW</b> 1076 (bonds broken); 1118 (bonds made)  Correct sign required  <b>ALLOW ECF</b> for bonds broken – bonds made <b>IF</b> at least one molar ratio is used e.g. 8 x C–H

Question	Answer	Mark	Guidance
(d)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE IF mass = 8.21 (g) award 3 marks</b></p> <p><b>Actual</b></p> $n(\text{C}_4\text{H}_9\text{OH}) \text{ produced} = \frac{3.552}{74} = 0.048 \text{ (mol)} \checkmark$ <p><b>theoretical</b></p> $n(\text{C}_4\text{H}_9\text{OH}) = n(\text{C}_4\text{H}_9\text{Br}) = 0.048 \times \frac{100}{80} = 0.06 \text{ (mol)} \checkmark$ <p>Mass of <math>\text{C}_4\text{H}_9\text{Br} = 0.06 \times 136.9 = 8.21 \text{ (g)} \checkmark</math>  <b>3 SF required</b></p>	3	<p><b>ALLOW ECF</b> at each stage</p> <p><b>ALLOW</b> expected mass <math>\text{C}_4\text{H}_9\text{OH} = 3.552 \times \frac{100}{80} = 4.44 \text{ (g)}</math></p> <p><b>ALLOW</b> Mass <math>\text{C}_4\text{H}_9\text{Br}</math> reacted = <math>0.048 \times 136.9 = 6.5712 \text{ (g)}</math></p> <p><b>ALLOW</b> Mass of <math>\text{C}_4\text{H}_9\text{Br}</math> used = <math>6.5712 \times \frac{100}{80} = 8.21 \text{ (g)}</math></p> <p><b>DO NOT ALLOW</b> 8.22 (from use of 137 as <math>M_r</math> of <math>\text{C}_4\text{H}_9\text{Br}</math>)</p>
	<b>Total</b>	<b>11</b>	

Question		Answer	Mark	Guidance
3	(a)	<p>Increased rate  <b>AND</b>            greater concentration of molecules / more molecules per (unit) volume ✓</p> <p>More collisions per second / more frequent collisions ✓</p>	2	<p><b>ALLOW</b> particles for molecules  <b>IGNORE</b> atoms</p> <p><b>Response must imply a volume and not area</b>  <b>ALLOW</b> more molecules in the <b>same space</b>  <b>OR</b> more molecules in the <b>same volume</b>  <b>OR</b> same number of molecules in a <b>smaller volume</b></p> <p><b>IGNORE</b> molecules are closer together (<i>no idea of volume</i>)</p> <p><b>ALLOW</b> collisions more often  <b>OR</b> increased rate of collision  <b>IGNORE</b> more chance of collisions</p> <p>'more collisions' alone is <b>not</b> sufficient (<i>no rate</i>)  <b>IGNORE</b> 'successful'</p>
3	(b)	The (position of a dynamic) equilibrium shifts to minimise (the effect of) any change ✓	1	<p><b>ALLOW</b> suitable alternatives for 'shifts' and 'minimises'</p> <p><b>IGNORE</b> 'reaction shifts'</p>

Question		Answer	Mark	Guidance
(c)	(i)	<p><b>Pressure:</b> Right-hand side has fewer (gaseous) moles/molecules <b>OR</b> left-hand side has more (gaseous) moles/molecules ✓</p> <p><b>Temperature:</b> Statement that: (Forward) reaction is exothermic <b>OR</b> (forward) reaction gives out heat <b>OR</b> reverse reaction is endothermic <b>OR</b> reverse reaction takes in heat ✓</p> <p><b>Equilibrium</b> Lower temperature/cooling <b>AND</b> increasing pressure shifts (equilibrium position) to the right ✓</p>	3	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>DO NOT ALLOW</b> fewer atoms on right-hand side <b>OR</b> more atoms on left-hand side.</p> <p><b>IGNORE</b> comments about the 'exothermic side' or 'endothermic side'</p> <p><b>Equilibrium mark</b> is for stating that <b>BOTH</b> low temperature and high pressure shift equilibrium to the right (Could be separate statements)</p> <p><b>Note: ALLOW</b> suitable alternatives for 'to right', e.g.: towards products <b>OR</b> towards CH<sub>3</sub>OH / H<sub>2</sub>O <b>OR</b> in forward direction <b>OR</b> favours the right</p> <p><b>IGNORE</b> Increases yield of CH<sub>3</sub>OH/products (<i>in question</i>)</p> <p><b>IGNORE</b> responses in terms of rate</p>
	(ii)	<p>Low temperature gives a slow rate <b>OR</b> high temperatures needed to increase rate ✓</p> <p>High pressure is expensive (to generate) <b>OR</b> high pressure provides a safety risk ✓</p>	2	<p><b>ALLOW</b> high pressure is dangerous <b>IGNORE</b> high pressure is explosive</p>

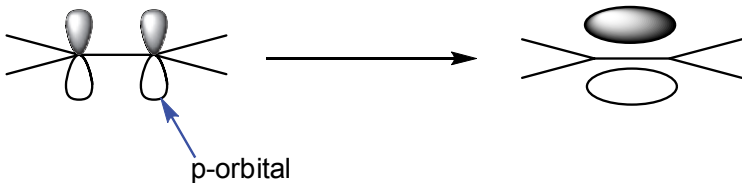
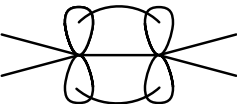
Question	Answer	Mark	Guidance
(d)	 <p>Correct drawing of Boltzmann distribution curve ✓</p> <p>Axes labelled: y axis: (number of) molecules <b>AND</b> x axis: energy ✓</p> <p>Catalyst lowers the activation energy (by providing an alternative route) ✓</p> <p>(With a catalyst a) greater proportion of molecules with energy greater than activation energy <b>OR</b> (With a catalyst a) greater proportion of molecules with energy equal to the activation energy ✓</p>	4	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p>Curve must start at origin. The limit of acceptability is that the curve must start within the first small square nearest the origin.</p> <p>Curve must not touch the x-axis at higher energy</p> <p><b>IGNORE</b> a slight inflexion on the curve</p> <p><b>DO NOT ALLOW</b> two curves <b>DO NOT ALLOW</b> a curve that bends up at the end by more than one small square</p> <p><b>ALLOW</b> particles instead of molecules on y axis <b>DO NOT ALLOW</b> enthalpy for x-axis label <b>DO NOT ALLOW</b> atoms instead of particles or molecules <b>ALLOW ECF</b> for the subsequent use of atoms (instead of molecules or particles)</p> <p><b>ALLOW</b> annotations on Boltzmann distribution diagram</p> <p><b>ALLOW</b> (with a catalyst) more molecules have sufficient energy to react</p> <p><b>IGNORE</b> (more) successful collisions</p>
(e)	Allows reactions to take place at lower temperatures ✓	1	<p><b>ALLOW</b> less heat (required) <b>IGNORE</b> references to pressure <b>IGNORE</b> references to less energy (<i>in question</i>) e.g. lowers <math>E_a</math></p>
<b>Total</b>		<b>13</b>	

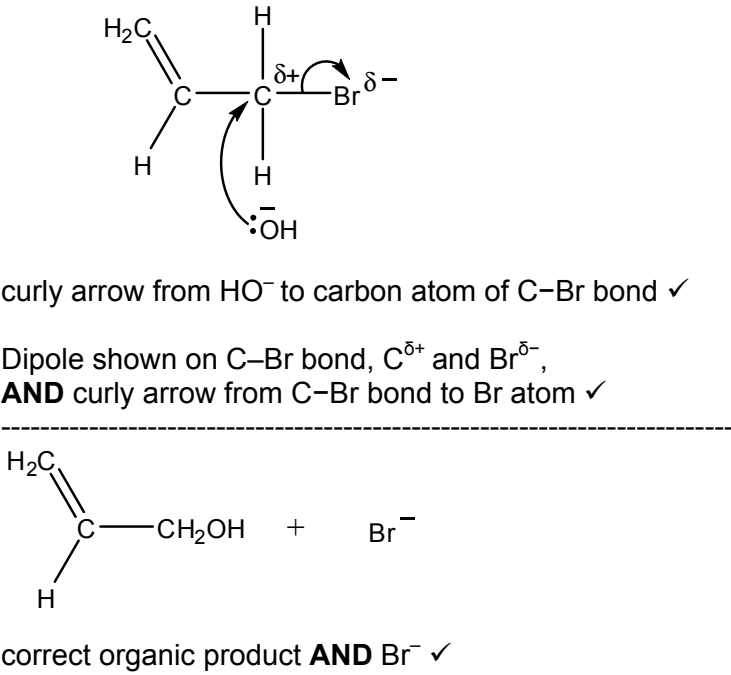
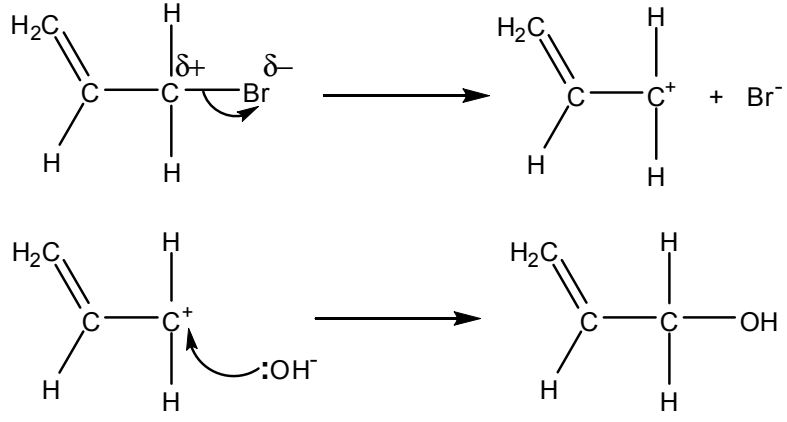
Question		Answer	Mark	Guidance
4	(a)	B ✓	1	<b>ALLOW</b> CF <sub>2</sub> CF <sub>2</sub> <b>OR</b> C <sub>2</sub> F <sub>4</sub> <b>OR</b> tetrafluoroethene
	(b)	(i) <div style="text-align: center;"> </div>	1	<b>ALLOW</b> correct structural <b>OR</b> displayed <b>OR</b> skeletal <b>OR</b> mixture of the above  <b>ALLOW</b> <i>E</i> isomer  <div style="text-align: center;"> </div>
		(ii) HCl ✓	1	<b>DO NOT ALLOW</b> Cl <sub>2</sub> <b>IGNORE</b> names <b>IGNORE</b> nitrogen oxides / NO <sub>x</sub>
	(c)	(i) <b>ANY TWO FROM THE FOLLOWING</b> ✓  Low reactivity <b>OR</b> will not burn/non-flammable  Volatile <b>OR</b> low boiling point  non-poisonous <b>OR</b> non-toxic	1	<b>ALLOW</b> inert <b>OR</b> stable <b>DO NOT ALLOW</b> inflammable  <b>ALLOW</b> it is a gas <b>IGNORE</b> easily compressed  <b>IGNORE</b> not harmful  <b>IGNORE</b> references to solubility

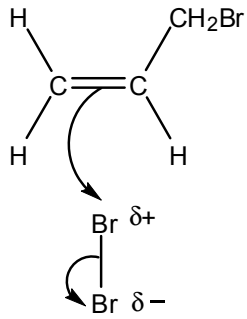
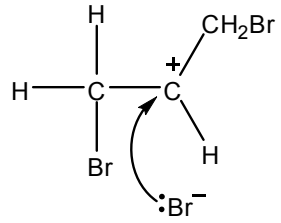
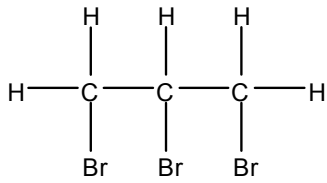
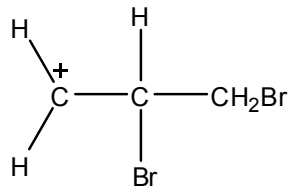


Question	Answer	Mark	Guidance
(ii)	<p><i>Benefit of ozone layer to life (1 mark)</i></p> <p>Ozone absorbs <b>UV</b> (radiation)</p> <p><b>UV</b> at Earth's surface is reduced ✓</p> <p><b>OR</b>-----</p> <p><i>Maintenance of O<sub>3</sub> concentration (1 mark)</i></p> $O_3 \rightleftharpoons O_2 + O \checkmark$ <p>O</p> <p>-----</p> <p><i>Production of radicals from G (1 mark)</i></p> $2C l_2 \longrightarrow C l + C F_2 C l \checkmark$ <p>-----</p> <p>CF</p> <p><i>Breakdown of O<sub>3</sub> (2 marks)</i></p> $C l + O_3 \longrightarrow C l O + O_2 \checkmark$ $C l O + O \longrightarrow C l + O_2$ <p><b>OR</b></p> $C l O + O_3 \longrightarrow C l + 2O_2 \checkmark$ <p>C</p>	5	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p>For all equations, <b>IGNORE</b> dots on radicals</p> <p>-----</p> <p>Essential idea for first mark is that <b>UV</b> is removed in some way.</p> <p><b>ALLOW</b> Prevents <b>UV</b> damaging life or stated type of damage, e.g. cataracts, skin cancer, mutation, crop damage</p> <p><b>DO NOT ALLOW</b> ozone absorbs IR</p> <p>-----</p> <p><b>ALLOW</b></p> $O_3 \longrightarrow O_2 + O$ $O_2 + O \longrightarrow O_3$ <p><b>AND</b></p> <p><b>DO NOT ALLOW</b> <math>2O_3 \rightleftharpoons 3O_2</math></p> <p><b>OR</b> <math>O_3 + O \longrightarrow 2O_2</math> for this mark</p> <p>-----</p> <p><b>DO NOT ALLOW</b> equations with other CFCs</p> <p><b>DO NOT ALLOW</b> <math>CF_2C l_2 \longrightarrow 2C l + CF_2</math></p> <p>-----</p> <p>These are the only acceptable equations</p> <p><b>IGNORE</b> overall equation (<i>does not show role of catalyst</i>) e.g. <math>O_3 + O \longrightarrow 2O_2</math></p>

Question		Answer	Mark	Guidance
	(iii)	D ✓	1	<b>ALLOW</b> CHF <sub>2</sub> Cl <b>ALLOW B OR</b> C <sub>2</sub> F <sub>4</sub> <b>OR</b> CF <sub>2</sub> CF <sub>2</sub>
(d)	(i)	<b>bond</b> vibrates (more) <b>OR bond</b> bends (more) <b>OR bond</b> stretches (more) ✓	1	<b>BOND essential</b>  <b>IGNORE</b> molecule vibrates/rotates Assume "It" refers to the molecule and is insufficient <b>DO NOT ALLOW</b> any reference to bond breaking  <b>DO NOT ALLOW</b> a stated bond if <b>not</b> present in <b>C</b> and <b>F</b> e.g. C–O, C–H not present
	(ii)	Cl <sub>3</sub> C <sup>+</sup> ✓ CF <sub>2</sub> Cl <sup>+</sup> ✓	2	<b>ALLOW</b> 1 mark for Cl <sub>3</sub> C <b>AND</b> CF <sub>2</sub> Cl <i>i.e. no + charge used</i>  <b>ALLOW</b> 1 mark for Cl <sub>3</sub> C <sup>-</sup> <b>AND</b> CF <sub>2</sub> Cl <sup>-</sup> <i>i.e. – charge used on both</i>
<b>Total</b>			<b>13</b>	

		Answer	Mark	Guidance	
5	(a)	 <p><b>First mark</b>            diagram on left with p-orbitals labelled  <b>OR</b> unlabelled diagram <b>AND</b> the statement: (sideways) overlap of p orbitals ✓</p> <p><b>Second mark</b>            (labelled) diagram on right showing <math>\pi</math>-bond ✓</p>	2	<p><b>Note:</b> A diagram is required for <b>each</b> mark</p> <p><b>DO NOT ALLOW</b> C=C in one diagram but <b>ALLOW ECF</b> for subsequent use in another diagram.</p> <p>The bonds shown in the diagram are <b>required</b>  <b>ALLOW ECF</b> for missing bonds in second diagram  <b>IGNORE</b> any atoms joined to the bonds</p> <p><b>ALLOW</b> a diagram where the p-orbitals are linked for second mark.</p> <p>e.g. </p>	
	(b)	(i)	<p>(series of compounds with the) same functional group  <b>OR</b> same/similar chemical properties  <b>OR</b> same/similar chemical reactions ✓</p> <p>each <b>successive/subsequent</b> member differing by <math>\text{CH}_2</math> ✓</p>	2	<p><b>IGNORE</b> reference to physical properties</p> <p><b>IGNORE</b> same general formula (<i>in question</i>)</p> <p>Differs by <math>\text{CH}_2</math> is <b>not</b> sufficient (<i>no successive</i>)</p> <p><b>DO NOT ALLOW</b> same empirical <b>OR</b> have the same molecular formula</p>
		(ii)	$\text{C}_n\text{H}_{2n-1}\text{Br}$ ✓	1	<b>ALLOW</b> $\text{C}_n\text{H}_{2n-1}\text{X}$ <b>ONLY</b> if X is specified as Br ( <i>question asks for bromide</i> )
		(iii)	3-bromoprop(-1-)ene ✓	1	<b>ALLOW</b> 1-bromoprop-2-ene
	(c)	(i)	Movement of an electron pair ✓	1	<b>ALLOW</b> movement of a lone pair <b>OR</b> movement of a bond
		(ii)	Electron pair donor ✓	1	<b>ALLOW</b> can donate a lone pair

		Answer	Mark	Guidance
(d)	(i)	 <p>curly arrow from HO<sup>-</sup> to carbon atom of C-Br bond ✓</p> <p>Dipole shown on C-Br bond, C<sup>δ+</sup> and Br<sup>δ-</sup>,  <b>AND</b> curly arrow from C-Br bond to Br atom ✓</p> <hr/> <p>correct organic product <b>AND</b> Br<sup>-</sup> ✓</p>	3	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p>Curly arrow must come from lone pair on O of HO<sup>-</sup> <b>OR</b> OH<sup>-</sup>  <b>OR</b> from minus sign on HO<sup>-</sup> ion (No need to show lone pair if curly arrow came from negative charge on O)</p> <hr/> <p><b>ALLOW</b> S<sub>N</sub>1 mechanism:</p> <p>Dipole shown on C-Br bond, C<sup>δ+</sup> and Br<sup>δ-</sup>,  <b>AND</b> curly arrow from C-Br bond to Br atom ✓</p> <p>Correct carbocation <b>AND</b> curly arrow from HO<sup>-</sup> to carbocation  Curly arrow must come from lone pair on O of HO<sup>-</sup> <b>OR</b> OH<sup>-</sup>  <b>OR</b> from minus sign on HO<sup>-</sup> ion (No need to show lone pair if curly arrow came from negative charge on O) ✓</p> <p>correct organic product <b>AND</b> Br<sup>-</sup> ✓</p> 
	(ii)	Nucleophilic substitution ✓	1	

	Answer	Mark	Guidance
(e)	<p>(i)</p> <p>Curly arrow from double bond to Br of Br–Br ✓</p> <p>Correct dipole shown on Br–Br  <b>AND</b> curly arrow showing breaking of Br–Br bond ✓</p>  <p>-----</p> <p>Correct carbocation with + charge on C with 3 bonds  <b>AND</b> curly arrow from Br<sup>-</sup> to C<sup>+</sup> of carbocation ✓</p>  <p>-----</p> <p>Correct product: ✓</p> 	4	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p>Curly arrow <b>must</b> start from bond and go to correct atom</p> <p><b>DO NOT ALLOW</b> any other partial charges  e.g. shown on double bond</p> <p><b>ALLOW</b> carbocation on terminal CH<sub>2</sub></p>  <p><b>DO NOT ALLOW</b> δ+ on C of carbocation.</p> <p>Curly arrow must come from a lone pair on Br<sup>-</sup>  <b>OR</b> from the negative sign of Br<sup>-</sup> ion (then lone pair on Br<sup>-</sup> ion does not need to be shown)</p>
(ii)	Electrophilic addition ✓	1	

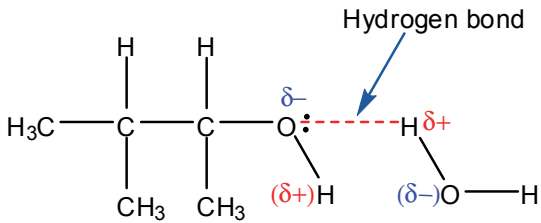
		Answer	Mark	Guidance
	(f)	(i) H <sub>2</sub> <b>AND</b> Ni (catalyst) ✓	1	<b>ALLOW</b> name or formula for each <b>IGNORE</b> any stated temperature and pressure
		(ii) (Initiation) Cl <sub>2</sub> → 2Cl ✓ <b>AND</b> UV ✓  (Propagation) C <sub>3</sub> H <sub>7</sub> Br + Cl → C <sub>3</sub> H <sub>6</sub> Br + HCl ✓  C <sub>3</sub> H <sub>6</sub> Br + Cl <sub>2</sub> → C <sub>3</sub> H <sub>6</sub> BrCl + Cl ✓  (Termination) Two from the three termination equations below ✓ 2Cl → Cl <sub>2</sub>  C <sub>3</sub> H <sub>6</sub> Br + Cl → C <sub>3</sub> H <sub>6</sub> BrCl  2C <sub>3</sub> H <sub>6</sub> Br → C <sub>6</sub> H <sub>12</sub> Br <sub>2</sub>  names of steps initiation, propagation and termination linked to one correct equation for each step in this mechanism ✓	5	<b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b>  <b>DO NOT ALLOW</b> any ECF in this question  <b>IGNORE</b> references to temperature  <b>THROUGHOUT, ALLOW</b> correct molecular formulae <b>OR</b> structural <b>OR</b> displayed <b>OR</b> skeletal <b>OR</b> mixture of the above  <b>IGNORE</b> dots <b>IGNORE</b> state symbols  <b>IGNORE</b> one incorrect termination equation
		(iii) further substitution <b>OR</b> produces different termination products <b>OR</b> More than one termination step ✓  substitution at different positions along chain ✓	2	<b>IGNORE</b> mixture of organic products ( <i>in question</i> )  <b>ALLOW</b> dichloro/multichloro/dibromo/multibromo compounds formed <b>OR</b> an example of a further substitution product <b>OR</b> an example of a different termination product <b>ALLOW</b> more than one hydrogen (atom) can be replaced <b>ALLOW</b> radicals react with each other to form other products  <b>ALLOW</b> forms different structural isomers <b>ALLOW</b> a hydrogen (atom) on a different carbon (atom) can be replaced
<b>Total</b>			<b>25</b>	

Question	Answer	Mark	Guidance
6 (a) (i)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF <math>\Delta H_c = -2260</math> (kJ mol<sup>-1</sup>) award 4 marks</b>  <b>IF <math>\Delta H_c = (+)2260</math> (kJ mol<sup>-1</sup>) award 3 marks (incorrect sign)</b>  <b>IF <math>\Delta H_c = (\pm)2257(.2)</math> (kJ mol<sup>-1</sup>) award 3 marks (not 3 sf)</b></p> <p><b>Moles</b>  Amount, <math>n</math>, C<sub>5</sub>H<sub>12</sub>O calculated correctly = 0.0175 (mol) ✓</p> <p><b>Energy</b>  <math>q</math> calculated correctly = 39501 (J) <b>OR</b> 39.5(01) (kJ) ✓</p> <p><b>Calculating <math>\Delta H</math></b>  correctly calculates <math>\Delta H</math> in kJ mol<sup>-1</sup> to 3 or more sig figs ✓</p> <p><b>Rounding and Sign</b>  calculated value of <math>\Delta H</math> rounded to 3 sig. fig. with minus sign ✓</p>	4	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>Note:</b> <math>q = 180 \times 4.18 \times 52.5</math>  <b>ALLOW</b> 39501 <b>OR</b> correctly rounded to 3 sig. fig. (J)  <b>IGNORE</b> sign  <b>IGNORE</b> working</p> <p><b>Note:</b> from 39501 J and 0.0175 mol <math>\Delta H = (-)2257.2</math> kJ mol<sup>-1</sup></p> <p><b>IGNORE</b> sign at this intermediate stage  <b>ALLOW</b> ECF from incorrect <math>q</math> and/or incorrect <math>n</math></p> <p>Final answer must have <b>correct sign</b> and <b>three sig figs</b></p>
	<p>(ii) <b>ANY TWO FROM THE FOLLOWING</b> ✓✓</p> <p>incomplete combustion</p> <p>non-standard conditions</p> <p>evaporation of alcohol/water</p> <p>specific heat capacity of beaker/apparatus</p>	2	<p><b>IGNORE</b> heat loss (<i>in question</i>)</p> <p><b>ALLOW</b> burns incompletely  <b>IGNORE</b> incomplete reaction</p>

Question	Answer	Mark	Guidance
(b) (i)	$5\text{C(s)} + 6\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \longrightarrow \text{C}_5\text{H}_{12}\text{O(l)} \checkmark$	1	Balancing numbers <b>AND</b> species <b>AND</b> states all required <b>DO NOT ALLOW</b> multiples of this equation
	<p>(ii) <b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF enthalpy change = <math>-3320 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks</b>  <b>IF enthalpy change = <math>(+3320 \text{ (kJ mol}^{-1}\text{)})</math> award 2 marks</b>            -----            Working for <math>\text{CO}_2</math> <b>AND</b> <math>\text{H}_2\text{O}</math> seen anywhere</p> <p><math>5 \times (-)394</math> <b>AND</b> <math>6 \times (-)286</math>  <b>OR</b> <math>(-)1970</math> <b>AND</b>  <b>OR</b> <math>(-)3686 \checkmark</math> <math>(-)1716</math></p> <p>Calculates <math>\Delta H_c</math></p> <p><b>A further 2 marks</b> for correct answer <b>AND</b> correct sign  <math>= 5 \times -394 + 6 \times -286 - -366</math>  <math>= -3320 \text{ (kJ mol}^{-1}\text{)} \checkmark\checkmark</math></p> <p><b>A further 1 mark</b> for correct answer <b>AND</b> incorrect or no sign  <math>= (+)3320 \text{ (kJ mol}^{-1}\text{)} \checkmark</math>  <i>Cycle wrong way around:</i>  <math>-366 - (5 \times -394 + 6 \times -286)</math></p>	3	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>IF there is an alternative answer, check to see if there is any ECF credit possible</b></p> <p><b>Common incorrect answers are shown below</b>  <b>Award 2 marks for</b>  <math>-1744</math> <b>OR</b> <math>-1890</math> <b>OR</b> <math>-314</math> <b>OR</b> <math>-4052</math>  <b>Award 1 mark for</b>  <math>1744</math> <b>OR</b> <math>1890</math> <b>OR</b> <math>314</math> <b>OR</b> <math>4052</math></p>

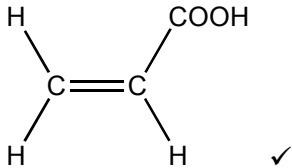
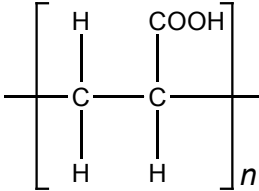
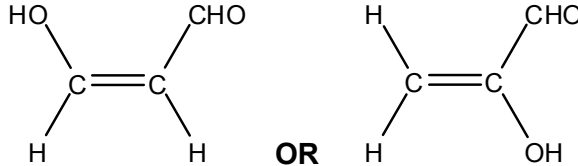
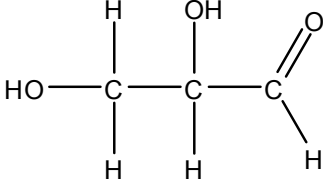


Question	Answer	Mark	Guidance
(c)	<p><b>QWC:</b> Evidence of the <b>IR</b> absorption at 1720 (<math>\text{cm}^{-1}</math>) for presence of C=O/carbonyl group ✓</p> <p><b>QWC:</b> No carboxylic acid OH absorption in IR <b>OR</b> no peak between 2500–3300 <math>\text{cm}^{-1}</math>  <b>AND</b>  so <b>J</b> is a secondary alcohol <b>OR</b> so <b>K</b> is a ketone ✓</p> <p><b>Alcohol J</b></p> $\begin{array}{c} \text{OH} \quad \text{H} \\   \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \quad   \\ \text{H} \quad \text{CH}_3 \end{array}$ <p style="text-align: right;">✓✓</p> <p><b>Compound K</b>  Structure of a carbonyl compound that could be obtained from alcohol <b>J</b> ✓</p> <p><b>Equation</b>  Balanced equation for conversion of <b>J</b> to <b>K</b> ✓  e.g.  <math>\text{CH}_3\text{CHOHCH}(\text{CH}_3)_2 + [\text{O}] \longrightarrow \text{CH}_3\text{COCH}(\text{CH}_3)_2 + \text{H}_2\text{O}</math></p>	6	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>LOOK ON THE SPECTRUM</b> for labelled peaks which can be given credit  <b>BOTH IR</b> at <math>\sim 1720</math> (<math>\text{cm}^{-1}</math>) <b>AND</b> C=O required  <b>ALLOW</b> ranges from <i>Data Sheet</i>,  i.e. C=O within range 1640–1750 <math>\text{cm}^{-1}</math>;</p> <p><b>IGNORE</b> any reference to C-O absorption  For structures of <b>J</b> and <b>K</b>,  <b>ALLOW</b> correct structural <b>OR</b> displayed <b>OR</b> skeletal formula <b>OR</b> mixture of the above  <b>IGNORE</b> any names given for <b>J</b> and <b>K</b></p> <p><b>ALLOW</b> 1 mark for the structure of an alcohol with the molecular formula <math>\text{C}_5\text{H}_{12}\text{O}</math>  <b>DO NOT ALLOW</b> pentan-1-ol (<i>primary and unbranched</i>) or 2-methylbutan-2-ol (<i>branched but tertiary</i>)</p> <p><b>DO NOT ALLOW</b> any marks for <b>J</b> and <b>K</b> if more than one structure is given for <b>J</b></p> <p><b>Note:</b> 'sticks' in either <b>J</b> and/or <b>K</b> will lose only 1 mark</p> <p><b>ALLOW</b> 1 mark for:</p> $\begin{array}{c} \text{O} \quad \text{H} \\    \quad   \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\   \\ \text{CH}_3 \end{array}$ <p style="text-align: right;"><b>IF</b> a structure is not given for <b>J</b></p> <p><b>NOTE:</b> structures for <b>J</b> and <b>K</b> could be awarded from the equation, even if not labelled.</p> <p><b>ALLOW</b> molecular formulae in equation  i.e. <math>\text{C}_5\text{H}_{12}\text{O} + [\text{O}] \longrightarrow \text{C}_5\text{H}_{10}\text{O} + \text{H}_2\text{O}</math>  <b>DO NOT ALLOW</b> equations that form a carboxylic acid</p>

Question	Answer	Mark	Guidance
(d)	<p><b>Labelled</b> diagram showing at least one H-bond between alcohol molecule and water ✓</p> <p>e.g.</p> 	1	<p><b>IF</b> diagram is not labelled <b>ALLOW</b> Hydrogen bonds / H bonds from text</p> <p>Diagram should include role of an O lone pair and dipole charges on each end of H bond.</p> <p><b>IGNORE</b> alcohol R group, even if wrong</p> <p><b>ALLOW</b> structural <b>OR</b> displayed <b>OR</b> skeletal formula <b>OR</b> mixture of the above</p>
	<b>Total</b>	<b>17</b>	

Question		Answer	Mark	Guidance
7	(a)	Mole ratio C : H : O is 3.33 : 6.67 : 3.33 ✓ Empirical formula is CH <sub>2</sub> O ✓ Molecular formula is C <sub>3</sub> H <sub>6</sub> O <sub>3</sub> <b>AND</b> use of 90 <b>OR</b> 3 × 30 ✓	3	<b>ALLOW</b> $\frac{40.00}{12.0}, \frac{6.67}{1.0}, \frac{53.33}{16.0}$ <b>ALLOW</b> mass of C = 0.400 x 90 <b>or</b> 36 <b>AND</b> mass of H = 0.06677 x 90 <b>or</b> 6 <b>AND</b> mass of O = 0.5333 x 90 <b>or</b> 48

Question	Answer	Mark	Guidance
(b)	<p><b>Evidence of carboxylic acid (1 mark)</b>  <b>IR:</b> 1550–1800 cm<sup>-1</sup> <b>AND</b> C=O/carbonyl  <b>AND</b> 2300–3700 cm<sup>-1</sup>  <b>AND</b> O–H in carboxylic acid ✓</p> <p><b>Evidence of alcohol (1 mark)</b></p> <p>(broad) 3200–3700 cm<sup>-1</sup> linked to O–H in alcohol  <b>OR</b> (is a primary) alcohol as oxidised (to a COOH)  <b>OR</b> is an alcohol as it forms a carboxylic acid  <b>OR</b> is an alcohol as water is eliminated. ✓</p> <p><b>Identifications (2 marks)</b></p> <p><b>L:</b></p> $\begin{array}{c} \text{H} \quad \text{H} \\   \quad   \\ \text{HO}-\text{C}-\text{C}-\text{COOH} \\   \quad   \\ \text{H} \quad \text{H} \end{array} \quad \checkmark$ <p><b>M:</b></p> $\begin{array}{c} \text{H} \\   \\ \text{HOOC}-\text{C}-\text{COOH} \\   \\ \text{H} \end{array} \quad \checkmark$ <p><b>Equation (1 mark)</b></p> $\text{C}_3\text{H}_6\text{O}_3 + 2[\text{O}] \longrightarrow \text{C}_3\text{H}_4\text{O}_4 + \text{H}_2\text{O} \quad \checkmark$	5	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>LOOK ON THE SPECTRUM</b> for labelled peaks which can be given credit</p> <p><b>ALLOW</b> ranges from <i>Data Sheet</i>:  C=O within range 1640–1750 cm<sup>-1</sup>;  (broad) O–H within range 2500–3300 cm<sup>-1</sup>  (broad) O–H within range 3200–3550 cm<sup>-1</sup></p> <p><b>For ALL structures:</b>  <b>ALLOW</b> correct structural <b>OR</b> skeletal <b>OR</b> displayed formula <b>OR</b> mixture of the above</p> <p><b>IGNORE</b> names</p> <hr/> <p><b>FOR M: ALLOW 1 mark for</b> <math>\text{HOOC}-\overset{\text{O}}{\parallel}{\text{C}}-\text{COOH} \quad \checkmark</math></p> <p><b>AS ECF from L as either</b></p> $\begin{array}{c} \text{H} \quad \text{O} \quad \text{H} \\   \quad    \quad   \\ \text{HO}-\text{C}-\text{C}-\text{C}-\text{OH} \\   \quad   \\ \text{H} \quad \text{H} \end{array} \quad \text{OR} \quad \begin{array}{c} \text{H} \quad \text{OH} \\   \quad   \\ \text{HO}-\text{C}-\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H} \\   \quad   \\ \text{H} \quad \text{H} \end{array}$ <p><b>Equation:</b> <math>\text{C}_3\text{H}_6\text{O}_3 + 4[\text{O}] \longrightarrow \text{C}_3\text{H}_2\text{O}_5 + 2\text{H}_2\text{O} \quad \checkmark</math></p> <hr/> <p><b>ALLOW</b> correct structural <b>OR</b> displayed <b>OR</b> skeletal formula <b>OR</b> mixture of the above in equation</p>

Question	Answer	Mark	Guidance
(c)	<p><b>Monomer N:</b> _____ (1 mark)</p>  <p><b>Polymer P:</b> _____ (1 mark)</p> <p>Section showing at least one repeat unit of a polymer formed from <b>N</b> with side links ✓</p> <p>e.g.</p> 	4	<p><b>For ALL structures:</b>  <b>ALLOW</b> correct structural <b>OR</b> skeletal <b>OR</b> displayed formula <b>OR</b> mixture of the above</p> <p><b>IGNORE</b> names</p> <p><b>ALLOW 1 mark for either</b></p>  <p><b>AS ECF from L:</b></p>  <hr style="border-top: 1px dashed black;"/> <p><b>For P: ALLOW ECF</b> from an alkene with molecular formula <math>C_3H_4O_2</math></p> <p><b>ALLOW</b> one or more repeat units but has to have a whole number of repeat units</p> <p><b>ALLOW</b> repeat unit with no brackets and absence of <math>n</math></p>

Question	Answer	Mark	Guidance
	<p><b>Repeat units</b> (1 mark)</p> <p><math>n = 10000/72 = 139 \checkmark</math></p> <p><b>Equation</b> (1 mark)</p> <p>Balanced equation for formation of P from N ✓ e.g.</p> $n \begin{array}{c} \text{H} & & \text{COOH} \\ & \diagdown & / \\ & \text{C} = \text{C} & \\ & / & \diagdown \\ \text{H} & & \text{H} \end{array} \longrightarrow \left[ \begin{array}{c} \text{H} & \text{COOH} \\   &   \\ -\text{C} & - & \text{C}- \\   &   \\ \text{H} & \text{H} \end{array} \right]_n$		<p><b>MUST</b> be a whole number. <b>ALLOW</b> 138 <b>OR</b> 140</p> <hr/> <p><b>For equation, ALLOW</b> molecular <b>OR</b> structural <b>OR</b> skeletal <b>OR</b> displayed formulae <b>OR</b> mixture of the above e.g. <b>ALLOW</b> <math>n\text{C}_3\text{H}_4\text{O}_2 \longrightarrow (\text{C}_3\text{H}_4\text{O}_2)_n</math></p> <p><math>n</math> on LHS can be at any height to the left of formula <b>AND</b> <math>n</math> on the RHS must be a subscript (essentially below the side link if displayed/skeletal formula is used)</p> <p><b>ALLOW</b> use of calculated value for <math>n</math> in equation e.g. <math>139\text{C}_3\text{H}_4\text{O}_2 \longrightarrow (\text{C}_3\text{H}_4\text{O}_2)_{139}</math></p>
	<b>Total</b>	<b>12</b>	

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