

GCE

Chemistry A

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

Advanced Subsidiary GCE

Mark Scheme for June 2016

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





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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Annotations

Annotation	Meaning
	Blank Page – this annotation must be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
	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).

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

The following questions should be marked using **ALL** appropriate annotations to show where marks have been awarded in the body of the text:

1(b)(iii),
 2(c), 2(d), 2e(ii),
 3(a)(i), 3(b)(ii), 3(c)(ii),
 4(b), 4(c)(i), 4(c)(ii)
 5(b), 5(e)
 7(a), 7b(i), 7b(ii)

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 24 one of the Additional Pages.
If the page is blank then, using the marking mode, annotate the page with the BP annotation
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** CH₃–, CH₂–, C₃H₇–, 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,

<ul style="list-style-type: none"> For bond in the plane of paper, a solid line is expected: 	
<ul style="list-style-type: none"> For bond out of plane of paper, a solid wedge is expected: 	
<ul style="list-style-type: none"> For bond into plane of paper, ALLOW: 	
<ul style="list-style-type: none"> ALLOW a hollow wedge for 'in bond' OR 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

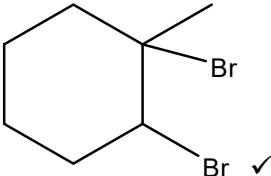
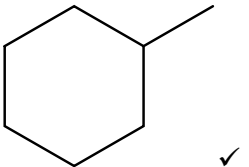
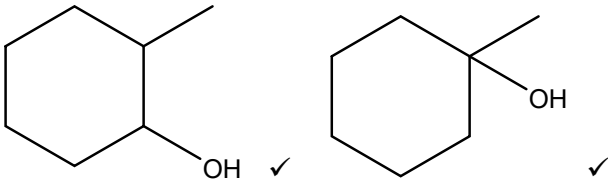
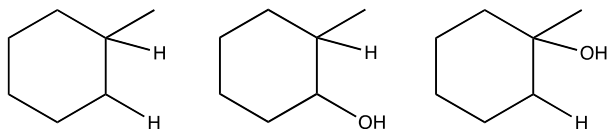
Order of substituents should be alphabetical:

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)

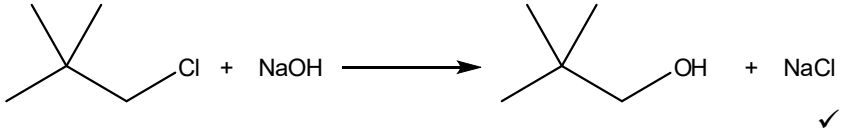
Question		Answer	Marks	Guidance
1	(a)	C_7H_{12} ✓	1	
1	(b) (i)	<p>Product from Br_2</p>  <p>Product from H_2/Ni</p>  <p>Mixture of isomers from H_2O</p> 	4	<p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above</p> <p>IGNORE names</p> <p>WATCH for missed methyl stick</p> <p>ALLOW added H shown, i.e.</p>  <p>ALLOW in either order</p>
1	(b) (ii)	<p>Steam OR temperature $\geq 100\text{ }^\circ\text{C}$ ✓</p> <p>acid (catalyst) ✓</p>	2	<p>ALLOW $H_2O(g)$</p> <p>IGNORE pressure</p> <p>IGNORE High temperature / reflux</p> <p>ALLOW H^+ / named mineral acid / H_2SO_4 / H_3PO_4</p> <p>DO NOT ALLOW 'weak acid' e.g. ethanoic acid</p>

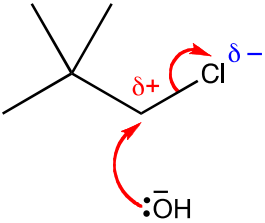
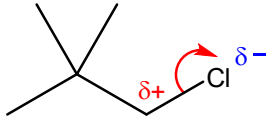
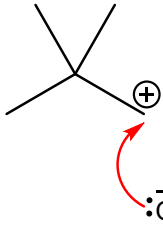
Question			Answer	Marks	Guidance
1	(b)	(iii)	<p>Curly arrow from double bond to Br of Br–Br ✓</p> <p>Correct dipole shown on Br–Br AND curly arrow showing breaking of Br–Br bond ✓</p> <p>-----</p> <p>Correct carbocation with + charge on C AND curly arrow from Br⁻ to C⁺ of carbocation ✓</p> <p>Note: '+' and '-' are fine for charge (circles used for clarity)</p>	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>Curly arrow must start from bond and go to correct atom</p> <p>DO NOT ALLOW any other partial charges e.g. shown on C=C bond</p> <p>DO NOT ALLOW $\delta+$ on C of carbocation.</p> <p>IF C atoms are displayed IGNORE missing bonds to H atoms</p> <p>Curly arrow must come from a lone pair on Br⁻ OR from the negative sign of Br⁻ ion (then lone pair on Br⁻ ion does not need to be shown)</p>
1	(b)	(iv)	electrophilic addition ✓	1	
Total				11	

Question		Answer	Marks	Guidance
2	(a)	<p>(series of compounds with the) same functional group OR same/similar chemical properties/reactions ✓</p> <p>each successive/subsequent member differs by CH₂ ✓</p>	2	<p>IGNORE reference to physical properties IGNORE same general formula</p> <p>Differs by CH₂ is not sufficient (<i>no successive</i>)</p> <p>DO NOT ALLOW same empirical OR molecular formula</p>
2	(b)	<p>$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓</p> <p>warm OR stated temperature between 20 °C and 45 °C AND anaerobic OR absence of air/oxygen ✓</p>	2	<p>ALLOW correct molecular OR structural OR displayed OR skeletal formula OR mixture of the above IGNORE state symbols</p> <p>DO NOT ALLOW acidic or alkaline conditions ALLOW conditions shown in the equation A limited supply of oxygen is NOT sufficient IGNORE pressure IGNORE yeast (<i>in question</i>)</p>

Question		Answer	Marks	Guidance
2	(c)	<p>Alcohols have hydrogen bonds (and van der Waals' forces) ✓</p> <p>Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓</p>	2	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW reference to specific compounds e.g. comparing methane and methanol</p> <p>Second marking point requires BOTH types of intermolecular forces in response i.e comparison of hydrogen bonds AND van der Waals is essential</p> <p>DO NOT ALLOW the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water</p> <p>ALLOW more energy required to break hydrogen bonds than van der Waals' forces</p> <p>ALLOW it is harder to overcome the hydrogen bonds than van der Waals' forces</p> <p>IGNORE more energy is needed to break bonds</p>
2	(d)	<p>2-methylpropan-1-ol has less surface (area of) contact OR fewer points of contact ✓</p> <p>2-methylpropan-1-ol has fewer/weaker van der Waals' forces OR less energy required to break van der Waals' forces in 2-methylpropan-1-ol ✓</p>	2	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>Both answers need to be comparisons</p> <p>ALLOW ORA throughout</p> <p>Reference to just surface area / closeness of molecules is not sufficient</p> <p>IGNORE reference to H bonds</p> <p>IGNORE less energy is needed to break bonds</p>
2	(e) (i)	Elimination OR dehydration ✓	1	

Question		Answer	Marks	Guidance
2	(e) (ii)	<p>IF answer = 14.0 OR 14.1 g award 3 marks</p> <p>-----</p> <p>actual</p> $n(\text{C}_5\text{H}_8) \text{ produced} = \frac{5.00}{68.0} = 0.0735 \text{ (mol)} \checkmark$ <p>theoretical</p> $n(\text{C}_5\text{H}_9\text{OH}) = n(\text{C}_5\text{H}_8) = 0.0735 \times \frac{100}{45.0} = 0.163 \text{ (mol)} \checkmark$ <p>Mass of $\text{C}_5\text{H}_9\text{OH} = 0.163 \times 86.0 = 14.0 \text{ (g)}$ OR 14 g OR 14.1 g \checkmark (<i>use of unrounded values in calculator throughout</i>)</p>	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW ECF at each stage</p> <p>ALLOW 3 SF up to calculator value correctly rounded for intermediate values</p> <p>ALLOW expected mass $\text{C}_5\text{H}_8 = 5.00 \times \frac{100}{45.0} = 11.111 \text{ (g)}$</p> <p>ALLOW Mass $\text{C}_5\text{H}_9\text{OH}$ reacted = $0.0735 \times 86.0 = 6.321 \text{ (g)}$</p> <p>ALLOW Mass of $\text{C}_5\text{H}_9\text{OH}$ used = $6.321 \times \frac{100}{45.0} = 14.0$ OR 14 (g)</p> <p>ALLOW 2 SF up to calculator value correctly rounded for mass of $\text{C}_5\text{H}_9\text{OH}$</p> <p>Note: 2.84 OR 2.85 g would get 2 marks <i>(use of 45.0/100 instead of 100/45.0)</i> 13.76 OR 13.8 would get 2 marks <i>(use of 0.16 for moles $\text{C}_5\text{H}_9\text{OH}$)</i></p>

Question			Answer	Marks	Guidance
2	(f)	(i)		1	<p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above</p> <p>ALLOW equation with OH⁻ as reactant and Cl⁻ product e.g (CH₃)₃CCH₂Cl + OH⁻ → (CH₃)₃CCH₂OH + Cl⁻</p> <p>IGNORE equations with KOH/H₂O as reactant (<i>question states sodium hydroxide</i>)</p> <p>IGNORE molecular formulae (<i>question requires structures</i>)</p>

Question	Answer	Marks	Guidance
2 (f) (ii)	 <p>curly arrow from HO⁻ to carbon atom of C–Cl bond ✓</p> <p>Dipole shown on C–Cl bond, C^{δ+} and Cl^{δ-} AND curly arrow from C–Cl bond to Cl atom ✓</p>	2	<p>Curly arrow must come from lone pair on O of HO⁻ OR OH⁻ OR from minus sign on O of HO⁻ ion (No need to show lone pair if curly arrow came from negative charge)</p> <p>NOTE: ALLOW mechanism involving ANY halogenoalkane as structures have been assessed in 2(f)(i)</p> <hr/> <p>ALLOW S_N1 mechanism:</p> <p>First mark Dipole shown on C–Cl bond, C^{δ+} and Cl^{δ-} AND curly arrow from C–Cl bond to Cl atom ✓</p>  <p>Second mark Correct carbocation AND curly arrow from HO⁻ to carbocation</p>  <p>Note: '+' is fine for charge (circle used for clarity)</p> <p>Curly arrow must come from lone pair on O of HO⁻ OR OH⁻ OR from minus sign on O of HO⁻ ion (No need to show lone pair if curly arrow came from negative charge) ✓</p> <hr/>
	Total	15	

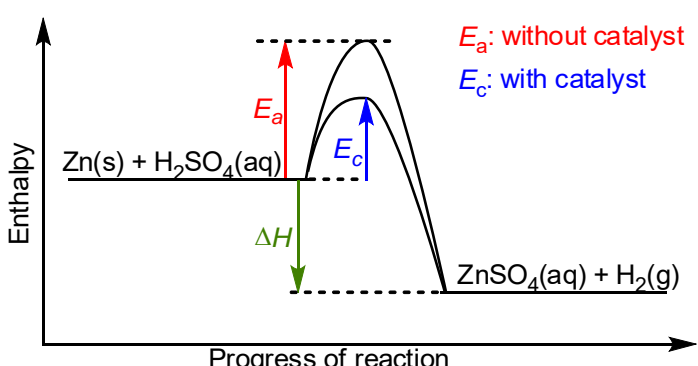
Question			Answer	Marks	Guidance
3	(a)	(i)	<p>IF $\Delta H_r = -347$ (kJ mol⁻¹) award 4 marks IF $\Delta H_r = (+)347$ (kJ mol⁻¹) award 3 marks (incorrect sign)</p> <hr/> <p>Moles Amount, $n(\text{CuSO}_4)$, calculated correctly = 0.0125 (mol) ✓</p> <p>Energy q calculated correctly = 4336.75 (J) OR 4.33675 (kJ) ✓</p> <p>Calculating ΔH correctly calculates ΔH in kJ mol⁻¹ to 3 or more sig figs ✓</p> <p>Rounding and Sign calculated value of ΔH rounded to 3 sig. fig. with minus sign ✓</p>	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>Note: $q = 25.0 \times 4.18 \times 41.5$</p> <p>ALLOW 3 SF up to calculator value of 4336.75 J IGNORE sign IGNORE working</p> <p>Note: from 4336.75 J and 0.0125 mol $\Delta H = (-)346.940$ kJ mol⁻¹ IGNORE sign at this intermediate stage ALLOW ECF from $n(\text{CuSO}_4)$ and/or energy released</p> <p>Final answer must have correct sign and three sig figs</p> <p>Answer is still -347 from rounding of q to 4340 J</p>
3	(a)	(ii)	Minimum mass = $0.0125 \times 24.3 \times 1.25 = 0.38(0)$ g ✓	1	ALLOW ECF for mass correctly rounded to 2 dp from incorrect moles of CuSO_4 in 3(a)(i)

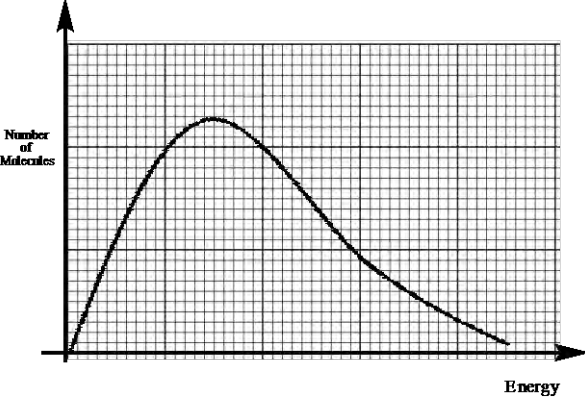
Question			Answer	Marks	Guidance
3	(b)	(i)	(enthalpy change that occurs) when one mole of a substance ✓ completely combusts OR reacts fully with oxygen ✓ 298 K / 25 °C AND 1 atm / 100 kPa / 101 kPa / 10 ⁵ Pa / 1 bar ✓	3	ALLOW energy required OR energy released ALLOW one mole of a compound OR one mole of an element ALLOW combusts in excess oxygen ALLOW burns in excess oxygen Combusts in excess air is not sufficient IGNORE reference to concentration
3	(b)	(ii)	IF answer = -281 (kJ mol⁻¹), award 2 marks IF answer = (+)281 (kJ mol⁻¹), award 1 mark ----- Working for C AND H ₂ seen anywhere 9 × (-)394 AND 10 × (-)286 OR (-)3546 AND (-)2860 OR (-)6406 ✓ Calculates ΔH _c correctly -6406 – -6125 = -281 kJ mol ⁻¹ ✓	2	ANNOTATE ANSWER WITH TICKS AND CROSSES IF there is an alternative answer, check to see if there is any ECF credit possible Common incorrect answers are shown below Award 1 mark for 5445 (not used × 9 and × 10) 2871 (not used × 9) 2293 (not used × 10)
3	(c)	(i)	(Average enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	IGNORE energy required OR energy released DO NOT ALLOW bonds formed IGNORE heterolytic/homolytic

Question			Answer	Marks	Guidance
3	(c)	(ii)	<p>IF answer = (+)1062 (kJ mol⁻¹), award 3 marks IF answer = -1062 (kJ mol⁻¹), award 2 marks</p> <p>-----</p> <p>(ΔH for bonds broken =) 2580 (kJ mol⁻¹) OR 1652 AND 928 (kJ mol⁻¹) ✓</p> <p>(ΔH for bonds formed =) 1308 (kJ mol⁻¹) ✓</p> <p>(bond enthalpy CO = 2580 – 1308 – 210) = (+)1062 (kJ mol⁻¹) ✓</p>	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>IGNORE sign</p> <p>IGNORE sign</p> <p>ALLOW ECF</p> <p>IGNORE rounding of 1062 to 1060 and credit 1062 from working</p> <p>Award 2 marks for ±1272 (from ±(2580 – 1308)) ±1482 (from ±(2580 – 1308 + 210))</p>
			Total	15	

Question			Answer	Marks	Guidance
4	(a)	(i)	<p>Equilibrium (position) shifts to right AND turns paler (brown) ✓</p> <p>Right-hand side has fewer (gaseous) moles/molecules OR left-hand side has more (gaseous) moles/molecules ✓</p>	2	<p>ALLOW turns colourless</p> <p>IGNORE initially goes darker (brown)</p> <p>Note: ALLOW suitable alternatives for 'to right', e.g.: towards products OR towards N_2O_4 OR in forward direction OR favours the right</p> <p>IGNORE responses in terms of rate</p>
4	(a)	(ii)	<p>Equilibrium (position) shifts to left AND turns darker/deeper (brown) ✓</p> <p>(Forward) reaction is exothermic OR (forward) reaction gives out heat OR reverse reaction is endothermic OR reverse reaction takes in heat ✓</p>	2	<p>ALLOW turns brown</p> <p>Note: ALLOW suitable alternatives for 'to left', e.g.: towards reactants OR towards NO_2 OR in reverse direction OR favours the left</p> <p>IGNORE comments about the 'exothermic side' or 'endothermic side'</p> <p>ALLOW 'equilibrium (position) shifts left AND in the endothermic direction' for second marking point</p> <p>IGNORE responses in terms of rate</p>

Question		Answer	Marks	Guidance
4	(b)	<p>Addition of acid</p> <p>[H⁺] OR H⁺ increases AND equilibrium (position) shifts to right ✓</p> <p>Addition of alkali</p> <p>Alkali reacts with H⁺ OR alkali removes H⁺ AND equilibrium (position) shifts to left ✓</p>	2	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>IGNORE amount of acid increases (<i>in question</i>) ALLOW (added) acid reacts with CrO₄²⁻</p> <p>Note: ALLOW suitable alternatives for 'to right', e.g.: towards products OR towards Cr₂O₇²⁻ / H₂O OR in forward direction OR favours the right</p> <p>ALLOW H⁺ + OH⁻ → H₂O ALLOW alkali reacts with (added) acid</p> <p>Note: ALLOW suitable alternatives for 'to left', e.g.: towards reactants OR towards CrO₄²⁻ / H⁺ OR in reverse direction OR favours the left</p> <p>IGNORE just H⁺ concentration decreases (<i>needs role of alkali</i>) IGNORE concentration of water increases (<i>needs role of alkali</i>)</p>

Question			Answer	Marks	Guidance
4	(c)	(i)	 <p>Zn and H₂SO₄ on LHS AND ZnSO₄ + H₂ on RHS ✓</p> <p>ΔH labelled with product below reactant AND arrow downwards ✓</p> <p>E_a AND E_c correctly labelled with E_c below E_a ✓</p>	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>IGNORE state symbols.</p> <p>ΔH: DO NOT ALLOW -ΔH ALLOW this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line</p> <p>E_a: ALLOW no arrowhead or arrowheads at both ends of activation energy line The E_a line must point to maximum (or near to the maximum) on the curve OR span approximately 80% of the distance between reactants and maximum regardless of position ALLOW AE or A_E for E_a</p>

Question	Answer	Marks	Guidance
4 (c) (ii)	 <p>Correct drawing of a Boltzmann distribution curve ✓</p> <p>Axes labelled y axis: (number of) molecules AND x axis: (kinetic) energy ✓</p> <p>Catalyst lowers the activation energy (by providing an alternative route) ✓</p> <p>QWC – (With a catalyst a) greater proportion of molecules with energy greater than activation energy OR (With a catalyst a) greater proportion of molecules with energy equal to the activation energy OR (With a catalyst there is a) greater area under curve above the activation energy ✓</p>	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</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>IGNORE a slight inflexion on the curve</p> <p>DO NOT ALLOW two curves DO NOT ALLOW a curve that bends up at the end by more than one small square</p> <p>ALLOW particles instead of molecules on y axis DO NOT ALLOW enthalpy for x-axis label DO NOT ALLOW atoms instead of particles or molecules ALLOW ECF for the subsequent use of atoms (instead of molecules or particles)</p> <p>ALLOW annotations on Boltzmann distribution diagram</p> <p>QWC requires more molecules have/exceed activation energy/E_a. IGNORE more molecules have enough energy to react for the QWC mark (as not linked to E_a) ORA if states the effect with no catalyst</p> <p>IGNORE (more) successful collisions</p>

Question			Answer	Marks	Guidance
4	(d)	(i)	Catalyst (name or correct formula) AND balanced equation for the reaction catalysed ✓	1	<p>Many possible responses but in practice it is likely that examples will be few, e.g. Fe AND $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ V₂O₅/Pt AND $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$ H₂SO₄/H₃PO₄ AND $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$ Hydrogenation of an alkene: e.g. Ni AND $\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$ Esterification: e.g. H₂SO₄ AND $\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightarrow \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$ ALLOW multiples for equation</p> <p>Note: the reaction chosen must be a feasible industrial reaction. If you see an alternative from the list above please contact your TL</p>
4	(d)	(ii)	<p>Any two from:</p> <p>lower temperatures/lower pressures (can be used) ✓</p> <p>lower energy demand OR uses less fuel OR reduces CO₂ emissions ✓</p> <p>(different reactions can be used with) greater atom economy OR less waste OR can reduce use of toxic solvents OR can reduce use of toxic reactants ✓</p> <p>(catalysts are often enzymes) generating specific products ✓</p>	2	<p>IGNORE catalyst not used up in reaction IGNORE catalyst can be re-used</p> <p>IGNORE lower activation energy IGNORE cheaper IGNORE less greenhouse gases OR reduces global warming</p> <p>ALLOW increases atom economy</p> <p>ALLOW reduce use of hazardous/toxic/harmful/poisonous chemicals</p>

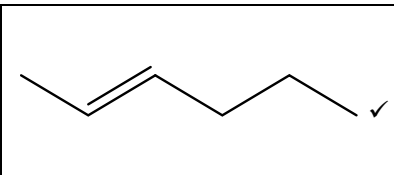
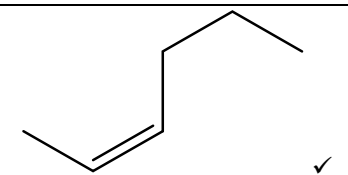
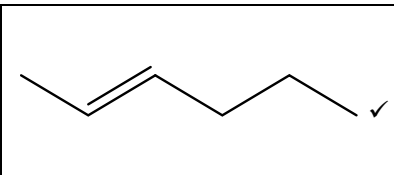
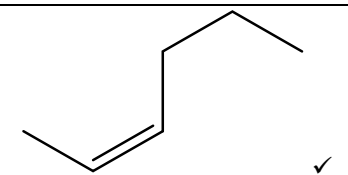
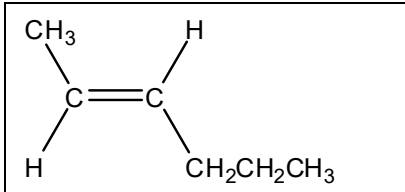
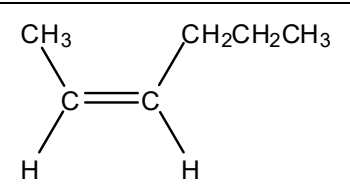
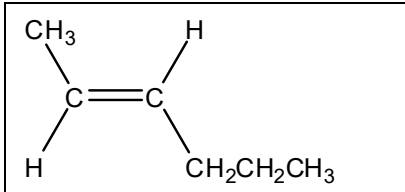
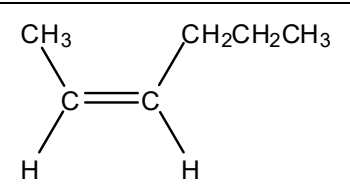
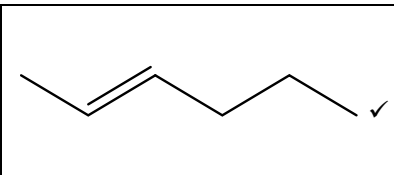
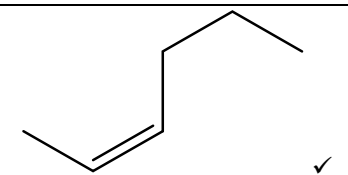
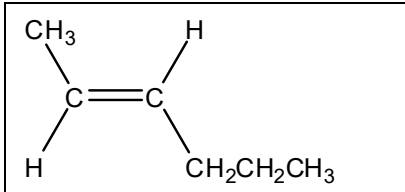
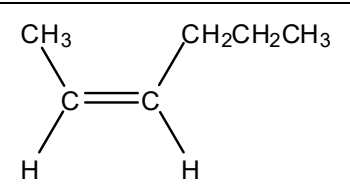
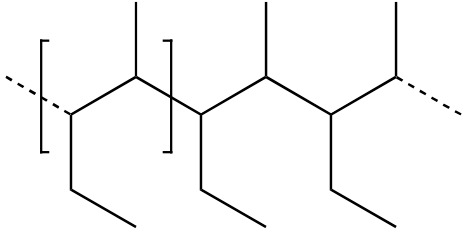
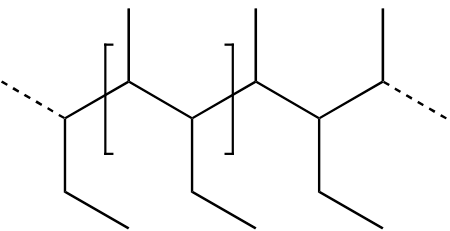
Question			Answer	Marks	Guidance
4	(e)	(i)	Thunderstorms/lightning AND aircraft ✓	1	IGNORE car engines
4	(e)	(ii)	$\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$ ✓ $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2$ ✓	2	ALLOW $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO} + 2\text{O}_2$ IGNORE dots IGNORE $\text{O} + \text{O}_3 \rightarrow 2\text{O}_2$ IGNORE $2\text{O}_3 \rightarrow 3\text{O}_2$
			Total	19	

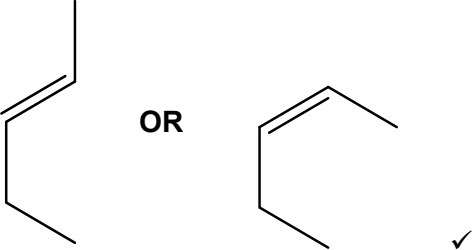
Question		Answer	Marks	Guidance
5	(a)	C_nH_{2n+2} ✓	1	
5	(b)	<p>Formation of NO and CO 2 marks</p> <p>$N_2 + O_2 \rightarrow 2NO$ AND $C_8H_{18} + 8\frac{1}{2}O_2 \rightarrow 8CO + 9H_2O$ ✓</p> <p>(N_2 and O_2 react in) hot conditions (to form NO) OR incomplete combustion (of C_8H_{18} produces CO) ✓</p>	6	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>IGNORE state symbols ALLOW multiples, e.g. $\frac{1}{2}N_2 + \frac{1}{2}O_2 \rightarrow NO$ $2C_8H_{18} + 17O_2 \rightarrow 16CO + 18H_2O$</p> <p>ALLOW equations for incomplete combustion that give CO with CO_2 and/or C e.g. $C_8H_{18} + 10\frac{1}{2}O_2 \rightarrow 4CO + 4CO_2 + 9H_2O$</p> <p>ALLOW $C_8H_{18} + N_2 + 9\frac{1}{2}O_2 \rightarrow 8CO + 9H_2O + 2NO$</p> <p>IGNORE NO/CO form in engine (<i>in question</i>)</p>
		<p>Reducing NO and CO by catalytic converter 4 marks</p> <p>CO and NO/reactants are adsorbed (onto surface) ✓</p> <p>Bonds in reactants weaken OR activation energy decreases ✓</p> <p>Reaction: $2CO + 2NO \longrightarrow 2CO_2 + N_2$ ✓</p> <p>CO_2 and N_2 desorb (from surface) OR products desorb (from surface) ✓</p>		<p>ALLOW CO and NO /reactants bond to surface (of catalyst) DO NOT ALLOW absorbed</p> <p>ALLOW bonds weaken in CO OR bonds weaken in NO</p> <p>IGNORE state symbols ALLOW multiples, e.g. $CO + NO \rightarrow CO_2 + \frac{1}{2}N_2$</p> <p>ALLOW products leave the surface/catalyst OR CO_2 and N_2 no longer bonded to surface/catalyst ALLOW deadsorption ALLOW diffuse away for desorption</p>

Question		Answer	Marks	Guidance
5	(c)	structure of a branched saturated hydrocarbon with 8 C atoms ✓ structure of a cyclic saturated hydrocarbon with 8 C atoms ✓ Correct name for BOTH structures given ✓	3	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above DO NOT ALLOW names for hydrocarbons that do not have 8 C atoms
5	(d)	ANY TWO from abundance (in atmosphere) OR amount (in atmosphere) OR (atmospheric) concentration OR percentage (in air) ✓ OR ability to absorb infrared/IR (radiation)✓ OR residence time ✓	2	ALLOW absorption of infrared/IR

Question		Answer	Marks	Guidance
5	(e)	<p>IF answer = 259 (litres), award 4 marks</p> <p>-----</p> <p>$(n(\text{CO}_2) \text{ decrease} = 5.6 \times 10^5 / 44.0) = 12727.27273 \text{ (mol)} \checkmark$</p> <p>$(n(\text{C}_8\text{H}_{16}) \text{ decrease} = 12727 \div 8) = 1590.909091 \text{ (mol)} \checkmark$</p> <p>$(\text{mass of C}_8\text{H}_{18} \text{ decrease}) = 1591 \times 114 = 181363.6364 \text{ (g)} \checkmark$</p> <p>$(\text{C}_8\text{H}_{18} \text{ decrease}) = 181363.6364 \div 700 \text{ g} = 259 \text{ (litres)} \checkmark$</p>	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW 3 SF up to calculator value correctly rounded throughout.</p> <p>NOTE: Be generous for values. Depending on any intermediate rounding, you may see a range of values for each stage. For guidance, the expected answers give unrounded values throughout.</p> <p>ALLOW ECF throughout for approaches that use moles $\text{CO}_2/\text{C}_8\text{H}_{18}$</p> <p>IGNORE rounding of 259 to 260 and credit 259 from working</p> <p>ALLOW the following alternate method</p> <p>-----</p> <p>$(n \text{ C}_8\text{H}_{18} \text{ in a litre} = 700 \div 114) = 6.140350877 \text{ (mol)} \checkmark$</p> <p>$(n(\text{CO}_2) \text{ produced per litre} = 6.14 \times 8) = 49.12280702 \text{ (mol)} \checkmark$</p> <p>$(\text{mass CO}_2 \text{ produced per litre} = 49.12 \times 44) = 2161.403509 \text{ (g)} \checkmark$</p> <p>$(\text{annual reduction} = 5.6 \times 10^5 / 2161) = 259.0909091 \text{ (litres)} \checkmark$</p> <p>-----</p>
		Total	16	

Question			Answer	Marks	Guidance
6	(a)	(i)	Evidence that 84 (M^+ peak) = 6×14 (mass of CH_2) ✓ e.g. $\frac{84}{14} = 6$	1	IGNORE use of molecular formula e.g. $(6 \times 12) + (12 \times 1) = 84$ (<i>use of empirical formula required</i>)
6	(a)	(ii)	Structures of species 2 marks peak I $CH_3CH=CH$ ✓ peak II $CH_3CH=CHCH_2CH_2$ OR $CH=CHCH_2CH_2CH_3$ ✓ + charge on BOTH CORRECT species 1 mark $CH_3CH=CH^+$ AND $CH_3CH=CHCH_2CH_2^+$ ✓ peak I peak II	3	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above ALLOW 1 mark if both correct structures are shown but in the incorrect columns ALLOW 1 mark for both correct structures if one or both have an 'end bond' ALLOW 1 mark for BOTH molecular formulae correct C_3H_5 AND C_5H_9 peak I peak II ALLOW 'charge mark' for + charge on BOTH fragments with correct molecular formulae ALLOW 'charge mark' for + charge on BOTH CORRECT molecular formulae ALLOW + charge anywhere in structures OR outside brackets

Question			Answer	Marks	Guidance								
6	(b)	(i)	<table border="1" style="width: 100%; text-align: center;"> <tr> <td></td> <td></td> </tr> <tr> <td><i>E</i>-hex-2-ene</td> <td><i>Z</i>-hex-2-ene</td> </tr> </table>			<i>E</i> -hex-2-ene	<i>Z</i> -hex-2-ene	2	<p>ALLOW 1 mark if skeletal formulae of both <i>E</i> and <i>Z</i> hex-2-ene are shown but in the incorrect columns</p> <p>IF correct unambiguous structural OR displayed OR mixture of formulae are shown ALLOW 1 mark if both stereoisomers are in the correct columns e.g the following scores 1 mark</p> <table border="1" style="width: 100%; text-align: center;"> <tr> <td>  </td> <td>  </td> </tr> <tr> <td><i>E</i>-hex-2-ene</td> <td><i>Z</i>-hex-2-ene</td> </tr> </table> <p>IF the skeletal formula of <i>E</i> hex-3-ene is shown in the first box ALLOW 1 mark for the skeletal formula of <i>Z</i> hex-3-ene as ECF</p>			<i>E</i> -hex-2-ene	<i>Z</i> -hex-2-ene
													
<i>E</i> -hex-2-ene	<i>Z</i> -hex-2-ene												
													
<i>E</i> -hex-2-ene	<i>Z</i> -hex-2-ene												
6	(b)	(ii)	<p>(carbon-carbon) double bond does not rotate OR has restricted rotation ✓</p> <p>Each carbon atom of the double bond attached to (two) different groups/atoms ✓</p>	2									
6	(c)	(i)	 <p>One repeat unit shown ✓ (could be any of the three repeat units shown)</p>	1	<p>ALLOW repeat unit at any point along the section provided that it works, e.g.</p> 								

Question			Answer	Marks	Guidance
6	(c)	(ii)	Structure of pent-2-ene: 	1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)
6	(c)	(iii)	(50,000/70 =) 714 OR 715 ✓	1	MUST be a whole number
			Total	11	

Question		Answer	Marks	Guidance
7	(a)	<p>Empirical/molecular formula 3 marks Mole ratio C : H : Br is 2.44 : 5.70 : 0.814 ✓ (Empirical formula) = C₃H₇Br ✓</p> <p>QWC (Molecular formula) = C₃H₇Br AND relative mass linked to 150 evidence ✓</p> <p>Structural isomers 2 marks CH₃CH₂CH₂Br ✓ CH₃CHBrCH₃ ✓</p>	5	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW $\frac{29.29}{12.0} : \frac{5.70}{1.0} : \frac{65.01}{79.9}$</p> <p>Evidence could include a calculation of the relative mass of C₃H₇Br as 122.9 linking to <i>M_r</i> being less than 150</p> <p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>DO NOT ALLOW missing H atom(s) in a displayed formula for one structure but ALLOW missing H atoms in subsequent structure</p> <p>Note: structures from an incorrect molecular formula will be credited on their merits. Please consult TL for advice on how to mark the subsequent parts of this question</p>

Question			Answer	Marks	Guidance
7	(b)	(i)	<p>Infrared for G 2 marks</p> <p>1700 cm⁻¹ AND C=O/carbonyl group ✓</p> <p>(broad) 2300–3600 cm⁻¹ AND O–H in carboxylic acid ✓</p>	6	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>LOOK ON THE SPECTRUM for labelled peaks which can be given credit</p> <p>ALLOW ranges from <i>Data Sheet</i>: C=O within range 1640–1750 cm⁻¹; (broad) O–H within range 2500–3300 cm⁻¹</p>
			<p>Structures 3 marks</p> <p>CH₃CH₂CH₂OH ✓</p> <p>CH₃CHOHCH₃ ✓</p> <p>CH₃CH₂COOH ✓</p>		<p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>ALLOW CH₃CH₂CO₂H for carboxylic acid</p> <p>IGNORE names</p> <p>IGNORE labels</p> <p>DO NOT ALLOW missing H atom(s) in a displayed formula for one structure but ALLOW missing H atoms in subsequent structures</p>
			<p>Equation for formation of G 1 mark</p> <p>C₃H₈O + 2[O] → C₃H₆O₂ + H₂O ✓</p>		<p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above in equation</p>

Question			Answer	Marks	Guidance
7	(b)	(ii)	<p>2 marks for correct ester.</p> $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)_2 \checkmark\checkmark$ <p>Award 1 mark for:</p> $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3$ <p>OR</p> <p>Ambiguous ester: $\text{CH}_3\text{CH}_2\text{COOC}_3\text{H}_7 \checkmark$</p>	2	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>ALLOW $\text{C}_2\text{H}_5\text{CO}_2\text{CH}(\text{CH}_3)_2$</p> <p>IF there is one bond and its H missing from the correct ester award 1 mark</p>
			Total	13	

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

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