OCR
Oxford Cambridge and RSA

GCE

Chemistry A

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

Advanced Subsidiary GCE

Mark Scheme for June 2016

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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.

Annotations

Annotation	Meaning
BP	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.
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	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

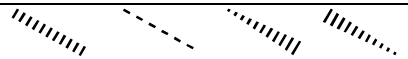
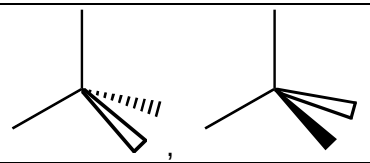
ORGANIC STRUCTURES
For a 'structure' or 'structural formula',
ALLOW correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,
ALLOW bond drawn to C or H,
e.g. **ALLOW** CH_3–,CH_2–, C_3H_7–, 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, **ALLOW**:	
• **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)

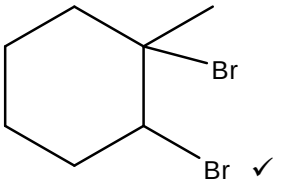
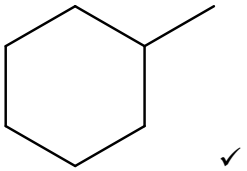
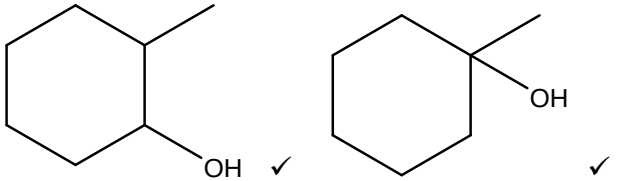
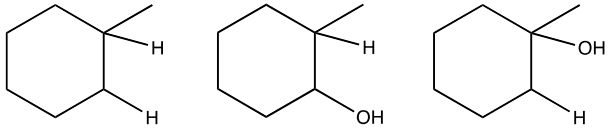
Hyphens separate name from numbers:
ALLOW absence of hyphens, e.g. propane 1,2 diol

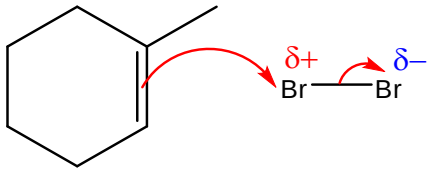
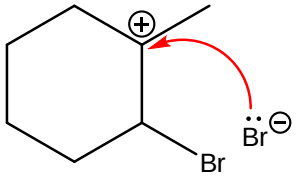
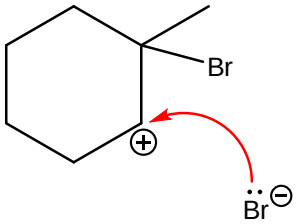
Multiple locant numbers must be clearly separated:
ALLOW full stops: e.g. 1.2 OR spaces: 1 2
DO NOT ALLOW e.g. 12

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)

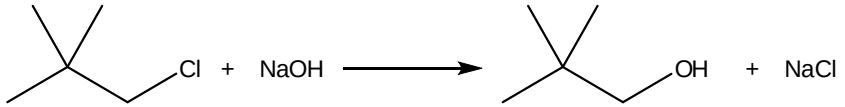
Question			Answer	Marks	Guidance
1	(a)		C_7H_{12} ✓	1	
1	(b)	(i)	**Product from Br_2**  ✓ **Product from H_2/Ni**  ✓ **Mixture of isomers from H_2O**  ✓ ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** names **WATCH** for missed methyl stick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

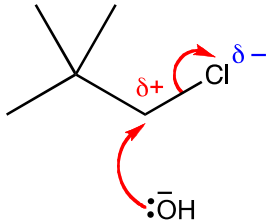
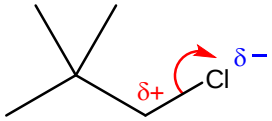
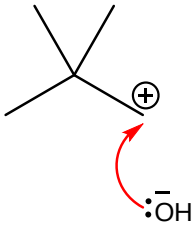
Question			Answer	Marks	Guidance
1	(b)	(iii)	Curly arrow from double bond to Br of Br–Br ✓ Correct dipole shown on Br–Br **AND** curly arrow showing breaking of Br–Br bond ✓  --- Correct carbocation with + charge on C **AND** curly arrow from Br^- to C^+ of carbocation ✓  **OR**  **Note:** '+' and '–' are fine for charge (circles used for clarity)	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curly arrow **must** start from bond and go to correct atom **DO NOT ALLOW** any other partial charges e.g. shown on C=C bond **DO NOT ALLOW** δ+ on C of carbocation. **IF** C atoms are displayed **IGNORE** missing bonds to H atoms 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)
1	(b)	(iv)	electrophilic addition ✓	1	
			Total	11	

Question			Answer	Marks	Guidance
2	(a)		(series of compounds with the) same functional group **OR** same/similar chemical properties/reactions ✓ each **successive/subsequent** member differs by CH_2 ✓	2	**IGNORE** reference to physical properties **IGNORE** same general formula Differs by CH_2 is **not** sufficient (*no successive*) **DO NOT ALLOW** same empirical **OR** molecular formula
2	(b)		$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ warm **OR** stated temperature between 20 ºC and 45 ºC **AND** anaerobic **OR** absence of air/oxygen ✓	2	**ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** state symbols **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 *(in question)*

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

Question			Answer	Marks	Guidance
2	(e)	(ii)	**IF answer = 14.0 OR 14.1 g award 3 marks** --- **actual** $n(C_5H_8)$ produced = $\frac{5.00}{68.0}$ = 0.0735 (mol) ✓ **theoretical** $n(C_5H_9OH) = n(C_5H_8) = 0.0735 \times \frac{100}{45.0}$ = 0.163 (mol) ✓ Mass of C_5H_9OH = 0.163 × 86.0 = 14.0 (g) **OR** 14 g **OR** 14.1 g ✓ (*use of unrounded values in calculator throughout)*	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW ECF** at each stage **ALLOW 3 SF** up to calculator value correctly rounded for intermediate values **ALLOW** expected mass $C_5H_8 = 5.00 \times \frac{100}{45.0}$ = 11.111 (g) **ALLOW** Mass C_5H_9OH reacted = 0.0735 × 86.0 = 6.321 (g) **ALLOW** Mass of C_5H_9OH used = $6.321 \times \frac{100}{45.0}$ = 14.0 **OR** 14 (g) **ALLOW 2 SF** up to calculator value correctly rounded for mass of C_5H_9OH **Note:** 2.84 **OR** 2.85 g would get 2 marks *(use of 45.0/100 instead of 100/45.0)* 13.76 **OR** 13.8 would get 2 marks *(use of 0.16 for moles C_5H_9OH)*

Question			Answer	Marks	Guidance
2	(f)	(i)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** equation with OH^- as reactant and Cl^- product e.g $(CH_3)_3CCH_2Cl + OH^- \rightarrow (CH_3)_3CCH_2OH + Cl^-$ **IGNORE** equations with KOH/H_2O as reactant *(question states sodium hydroxide)* **IGNORE** molecular formulae *(question requires structures)*

Question			Answer	Marks	Guidance
2	(f)	(ii)	 curly arrow from HO^- to carbon atom of C−Cl bond ✓ Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C−Cl bond to Cl atom ✓	**2**	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) **NOTE:** **ALLOW** mechanism involving **ANY** halogenoalkane as structures have been assessed in **2(f)(i)** --- **ALLOW** S_N1 mechanism: **First mark** Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C−Cl bond to Cl atom ✓  **Second mark** Correct carbocation **AND** curly arrow from HO^- to carbocation  **Note:** '+' is fine for charge (circle used for clarity) 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) ✓ ---
			Total	**15**	

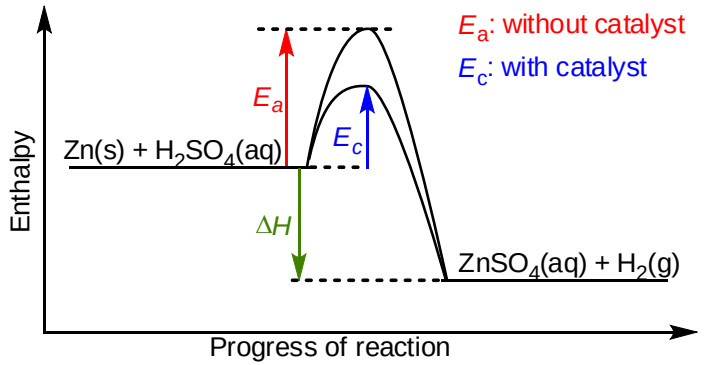
Question			Answer	Marks	Guidance
3	(a)	(i)	**IF ΔH_r = –347 (kJ mol^{-1}) award 4 marks** **IF ΔH_r = (+)347 (kJ mol^{-1}) award 3 marks (incorrect sign)** --- **Moles** Amount, $n(CuSO_4)$, calculated correctly = 0.0125 (mol) ✓ **Energy** q calculated correctly = 4336.75 (J) **OR** 4.33675 (kJ) ✓ **Calculating ΔH** correctly calculates ΔH in kJ mol^{-1} to 3 or more sig figs ✓ **Rounding and Sign** calculated value of ΔH rounded to 3 sig. fig. with minus sign ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Note:** q = 25.0 × 4.18 × 41.5 **ALLOW** 3 SF up to calculator value of 4336.75 J **IGNORE** sign **IGNORE** working **Note:** from 4336.75 J and 0.0125 mol ΔH = (-)346.940 kJ mol^{-1} **IGNORE** sign at this intermediate stage **ALLOW ECF** from $n(CuSO_4)$ and/or energy released Final answer must have **correct sign** and **three sig figs** Answer is still –347 from rounding of q to 4340 J
3	(a)	(ii)	Minimum mass = 0.0125 × 24.3 × 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)**

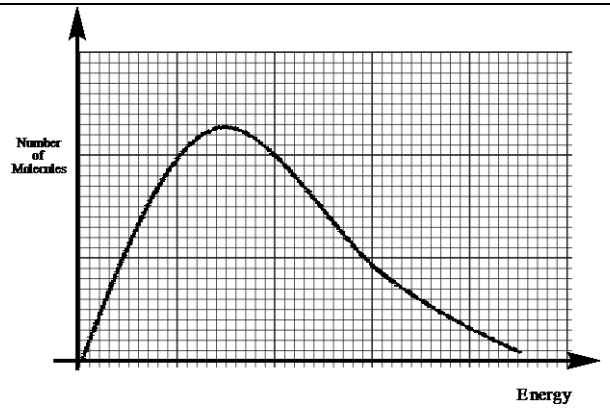
Question			Answer	Marks	Guidance
3	(b)	(i)	(enthalpy change that occurs) when one mole of a substance ✓ completely combusts **OR** reacts fully with oxygen ✓ 298 K / 25 °C **AND** 1 atm / 100 kPa / 101 kPa / 10^5 Pa / 1 bar ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** one mole of a 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)	**IF answer = (+)1062 (kJ mol^{-1}), award 3 marks** **IF answer = –1062 (kJ mol^{-1}), award 2 marks** --- (ΔH for bonds broken =) 2580 (kJ mol^{-1}) **OR** 1652 **AND** 928 (kJ mol^{-1}) ✓ (ΔH for bonds formed =) 1308 (kJ mol^{-1}) ✓ (bond enthalpy CO = 2580 – 1308 – 210) = (+)1062 (kJ mol^{-1}) ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** sign **IGNORE** sign **ALLOW ECF** **IGNORE** rounding of 1062 to 1060 and credit 1062 from working **Award 2 marks for** ±1272 (from ±(2580 – 1308)) ±1482 (from ±(2580 – 1308 + 210))
			Total	**15**	

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

Question			Answer	Marks	Guidance
4	(b)		**Addition of acid** $[H^+]$ **OR** H^+ increases **AND** equilibrium (position) shifts to right ✓ **Addition of alkali** Alkali reacts with H^+ **OR** alkali removes H^+ **AND** equilibrium (position) shifts to left ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** amount of acid increases *(in question)* **ALLOW** (added) acid reacts with CrO_4^{2-} **Note: ALLOW** suitable alternatives for 'to right', e.g.: towards products **OR** towards $Cr_2O_7^{2-}$ / H_2O **OR** in forward direction **OR** favours the right **ALLOW** $H^+ + OH^- \rightarrow H_2O$ **ALLOW** alkali reacts with (added) acid **Note: ALLOW** suitable alternatives for 'to left', e.g.: towards reactants **OR** towards CrO_4^{2-} / H^+ **OR** in reverse direction **OR** favours the left **IGNORE** just H^+ concentration decreases *(needs role of alkali)* **IGNORE** concentration of water increases *(needs role of alkali)*

Question			Answer	Marks	Guidance
4	(c)	(i)	 Zn and H_2SO_4 on LHS **AND** $ZnSO_4$ + H_2 on RHS✓ ΔH labelled with product below reactant **AND** arrow downwards ✓ E_a **AND** E_c correctly labelled with E_c below E_a ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** state symbols. ΔH**:** **DO NOT ALLOW** $-\Delta H$ **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 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

Question			Answer	Marks	Guidance
4	(c)	(ii)	 Correct drawing of a Boltzmann distribution curve ✓ Axes labelled y axis: (number of) molecules **AND** x axis: (kinetic) energy ✓ Catalyst lowers the activation energy (by providing an alternative route) ✓ **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 ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curve must start at origin. The limit of acceptability is that the curve must start within the first small square nearest the origin. Curve must not touch the x-axis at higher energy **IGNORE** a slight inflexion on the curve **DO NOT ALLOW** two curves **DO NOT ALLOW** a curve that bends up at the end by more than one small square **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) **ALLOW** annotations on Boltzmann distribution diagram **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 **IGNORE** (more) successful collisions

Question			Answer	Marks	Guidance
4	(d)	(i)	Catalyst (name or correct formula) **AND** balanced equation for the reaction catalysed ✓	1	Many possible responses but in practice it is likely that examples will be few, e.g. Fe **AND** $N_2 + 3H_2 \rightarrow 2NH_3$ V_2O_5/Pt **AND** $2SO_2 + O_2 \rightarrow 2SO_3$ H_2SO_4/H_3PO_4 **AND** $C_2H_4 + H_2O \rightarrow C_2H_5OH$ Hydrogenation of an alkene: e.g. Ni **AND** $C_2H_4 + H_2 \rightarrow C_2H_6$ Esterification: e.g. H_2SO_4 **AND** $CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$ **ALLOW** multiples for equation **Note:** the reaction chosen must be a feasible industrial reaction. If you see an alternative from the list above please contact your TL
4	(d)	(ii)	**Any two from:** lower temperatures/lower pressures (can be used) ✓ lower energy demand **OR** uses less fuel **OR** reduces CO_2 emissions ✓ (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 ✓ (catalysts are often enzymes) generating specific products ✓	2	**IGNORE** catalyst not used up in reaction **IGNORE** catalyst can be re-used **IGNORE** lower activation energy **IGNORE** cheaper **IGNORE** less greenhouse gases **OR** reduces global warming **ALLOW** increases atom economy **ALLOW** reduce use of hazardous/toxic/harmful/poisonous chemicals

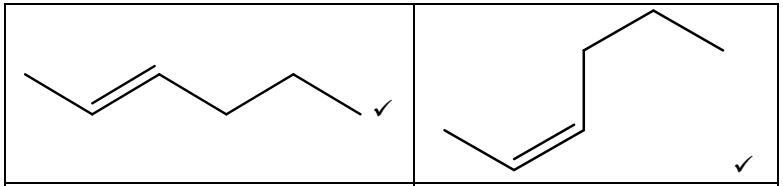
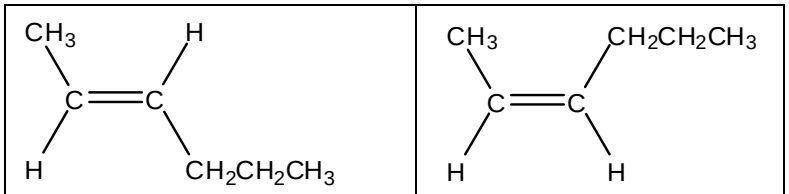
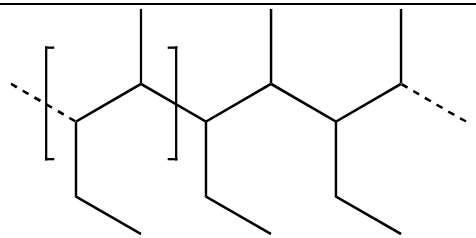
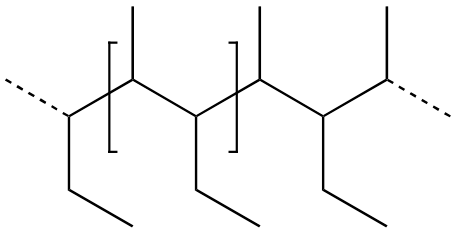
Question			Answer	Marks	Guidance
4	(e)	(i)	Thunderstorms/lightning **AND** aircraft ✓	1	**IGNORE** car engines
4	(e)	(ii)	$NO + O_3 \rightarrow NO_2 + O_2$ ✓ $NO_2 + O \rightarrow NO + O_2$ ✓	2	 **ALLOW** $NO_2 + O_3 \rightarrow NO + 2O_2$ **IGNORE** dots **IGNORE** $O + O_3 \rightarrow 2O_2$ **IGNORE** $2O_3 \rightarrow 3O_2$
			Total	19	

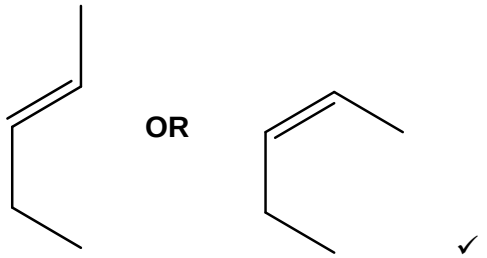
Question			Answer	Marks	Guidance
5	(a)		C_nH_{2n+2} ✓	1	
5	(b)		***Formation of NO and CO 2 marks*** $N_2 + O_2 \rightarrow 2NO$ **AND** $C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ ✓ (N_2 and O_2 react in) hot conditions (to form NO) **OR** incomplete combustion (of C_8H_{18} produces CO) ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** state symbols **ALLOW** multiples, e.g. $½N_2 + ½O_2 \rightarrow NO$ $2C_8H_{18} + 17O_2 \rightarrow 16CO + 18H_2O$ **ALLOW** equations for incomplete combustion that give CO with CO_2 and/or C e.g. $C_8H_{18} + 10½O_2 \rightarrow 4CO + 4CO_2 + 9H_2O$ **ALLOW** $C_8H_{18} + N_2 + 9½O_2 \rightarrow 8CO + 9H_2O + 2NO$ **IGNORE** NO/CO form in engine *(in question)*
			Reducing NO and CO by catalytic converter 4 marks CO and NO/reactants are adsorbed (onto surface) ✓ Bonds in reactants weaken **OR** activation energy decreases ✓ Reaction: $2CO + 2NO \longrightarrow 2CO_2 + N_2$ ✓ CO_2 and N_2 desorb (from surface) **OR** products desorb (from surface)✓		**ALLOW** CO and NO /reactants bond to surface (of catalyst) **DO NOT ALLOW** absorbed **ALLOW** bonds weaken in CO **OR** bonds weaken in NO **IGNORE** state symbols **ALLOW** multiples, e.g. $CO + NO \rightarrow CO_2 + ½N_2$ **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

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)		**IF answer = 259 (litres), award 4 marks** --- ($n(CO_2)$ decrease = $5.6 \times 10^5/44.0$) = 12727.27273 (mol) ✓ ($n(C_8H_{16})$ decrease = 12727 ÷ 8) = 1590.909091 (mol) ✓ (mass of C_8H_{18} decrease) = 1591 × 114 = 181363.6364 (g) ✓ (C_8H_{18} decrease) = 181363.6364 ÷ 700 g = 259 (litres) ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW 3 SF** up to calculator value correctly rounded throughout. **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. **ALLOW ECF** throughout for approaches that use moles CO_2/C_8H_{18} **IGNORE** rounding of 259 to 260 and credit 259 from working **ALLOW** the following alternate method --- (n C_8H_{18} in a litre = 700 ÷ 114) = 6.140350877 (mol) ✓ ($n(CO_2)$ produced per litre = 6.14 × 8) = 49.12280702 (mol) ✓ (mass CO_2 produced per litre = 49.12 × 44) = 2161.403509 (g) ✓ (annual reduction = $5.6 \times 10^5/2161$) = 259.0909091 (litres) ✓ ---
			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 × 12) + (12 × 1) = 84 *(use of empirical formula required)*
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** + change anywhere in structures **OR** outside brackets

Question			Answer	Marks	Guidance
6	(b)	(i)	 ✓ ✓ *E*-hex-2-ene | *Z*-hex-2-ene	2	**ALLOW** 1 mark if skeletal formulae of both *E* and *Z* hex-2-ene are shown but in the incorrect columns **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  *E*-hex-2-ene | *Z*-hex-2-ene **IF** the skeletal formula of *E* hex-3-ene is shown in the first box **ALLOW** 1 mark for the skeletal formula of *Z* hex-3-ene as **ECF**
6	(b)	(ii)	(carbon-carbon) double bond does not rotate **OR** has restricted rotation ✓ Each carbon atom of the double bond attached to (two) different groups/atoms ✓	2	
6	(c)	(i)	 One repeat unit shown ✓ *(could be any of the three repeat units shown)*	1	**ALLOW** repeat unit at any point along the section provided that it works, e.g. 

Question			Answer	Marks	Guidance
6	(c)	(ii)	Structure of pent-2-ene:  **OR** ✓	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)		***Empirical/molecular formula*** ***3 marks*** Mole ratio C : H : Br is 2.44 : 5.70 : 0.814 ✓ (Empirical formula) = C_3H_7Br ✓ **QWC** (Molecular formula) = C_3H_7Br **AND** relative mass linked to 150 evidence ✓ ***Structural isomers*** ***2 marks*** $CH_3CH_2CH_2Br$ ✓ $CH_3CHBrCH_3$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** $\frac{29.29}{12.0} : \frac{5.70}{1.0} : \frac{65.01}{79.9}$ Evidence could include a calculation of the relative mass of C_3H_7Br as 122.9 linking to M_r being less than 150 **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structure **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

Question			Answer	Marks	Guidance
7	(b)	(i)	***Infrared for G*** ***2 marks*** 1700 cm^{-1} **AND** C=O/carbonyl group ✓ (broad) 2300–3600 cm^{-1} **AND** O–H in carboxylic acid ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **LOOK ON THE SPECTRUM** for labelled peaks which can be given credit **ALLOW** ranges from *Data Sheet*: C=O within range 1640–1750 cm^{-1}; (broad) O–H within range 2500–3300 cm^{-1}
			Structures ***3 marks*** $CH_3CH_2CH_2OH$ ✓ $CH_3CHOHCH_3$ ✓ CH_3CH_2COOH ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $CH_3CH_2CO_2H$ for carboxylic acid **IGNORE** names **IGNORE** labels **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structures
			Equation for formation of G ***1 mark*** $C_3H_8O + 2[O] \rightarrow C_3H_6O_2 + H_2O$ ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above in equation

Question			Answer	Marks	Guidance
7	(b)	(ii)	2 marks for correct ester. $CH_3CH_2COOCH(CH_3)_2$ ✓✓ Award 1 mark for: $CH_3CH_2COOCH_2CH_2CH_3$ **OR** Ambiguous ester: $CH_3CH_2COOC_3H_7$ ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $C_2H_5CO_2CH(CH_3)_2$ **IF** there is one bond and its H missing from the correct ester award 1 mark
			Total	13	

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