OCR
Oxford Cambridge and RSA

GCE

Chemistry A

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

Advanced Subsidiary GCE

Mark Scheme for June 2017

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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.

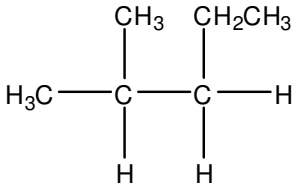
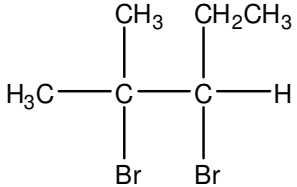
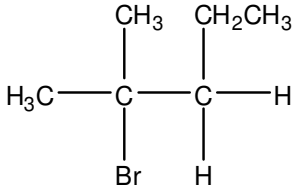
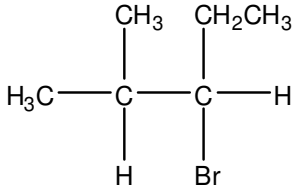
Annotations available in RM Assessor

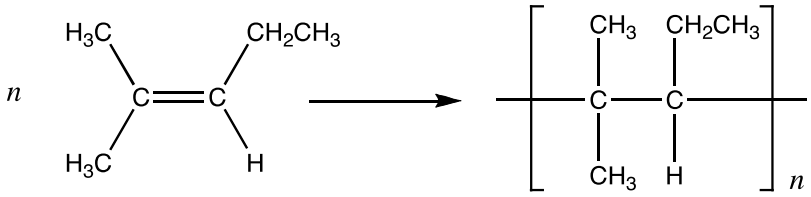
Annotation	Meaning
BP	Blank Page – this annotation must be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
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

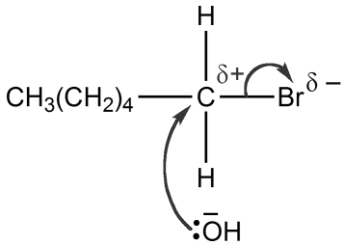
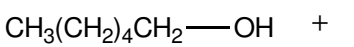
Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

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

Question			Answer	Marks	Guidance
1	(a)		C_5H_{10} ✓	1	
1	(b)		**A** and **E** ✓	1	
1	(c)		**C** ✓	1	
1	(d)		**B**, **C** and **F** ✓	1	
1	(e)		**A**, **B**, **C** and **F** ✓	1	
1	(f)		**C** and **F** ✓	1	
1	(g)		2,3-dimethylpent-2-ene ✓	1	**ALLOW** absence of hyphens or extra hyphen or space, e.g. 2,3-dimethyl pent-2-ene **ALLOW** full stops or spaces between numbers e.g. 2.3 dimethylpent-2-ene
			Total	7	

Question			Answer	Marks	Guidance
2	(a)		**Product from H_2/Ni**  ✓ **Product from Br_2**  ✓ **Product from HBr**  ✓  ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal **OR** mixture of the above **ALLOW** in either order
2	(b)	(i)	Addition ✓	1	

Question			Answer	Marks	Guidance
2	(b)	(ii)	 Correct repeat unit of polymer with side links ✓ Balanced equation for formation of correct polymer - correct use of *n* in the equation and brackets ✓	2	**For monomer, ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **For repeat unit, DO NOT ALLOW** correct molecular formula *(question requires structure)* *n* on LHS can be at any height to the left of formula **AND** *n* on the RHS must be a subscript (essentially below the side link)
2	(b)	(iii)	Combustion for energy production ✓ cracking **OR** organic feedstock **OR** production of plastics/other chemicals ✓	2	Combustion alone is **not** sufficient Used as a fuel is **not** sufficient
			Total	9	

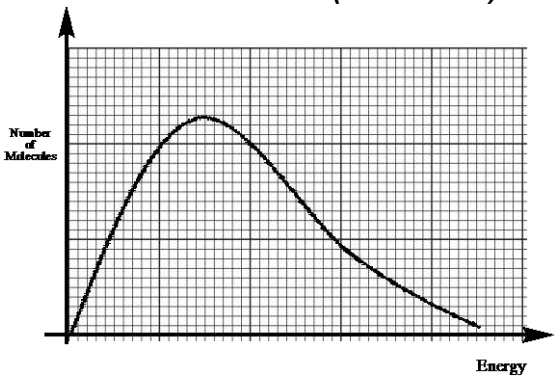
Question			Answer	Marks	Guidance
3	(a)	(i)	 curly arrow from HO^- to carbon atom of C–Br bond ✓ Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom ✓ ---  correct organic product **AND** Br^- ✓	3	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on HO^- ion (No need to show lone pair if curly arrow came from negative charge) **For organic product, ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) --- **ALLOW** S_N1 mechanism: Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C–Br bond to Br atom ✓ Correct carbocation **AND** curly arrow from HO^- to carbocation Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on HO^- ion (No need to show lone pair if curly arrow came from negative charge) ✓ correct organic product **AND** Br^- ✓
3	(a)	(ii)	nucleophilic substitution ✓	1	

3	(a)	(iii)	heterolytic ✓	1	**ALLOW** 'heterolysis'
3	(a)	(iv)	**Correct explanation of rate of hydrolysis for any two halogenoalkanes** e.g. 1-iodohexane is faster (that 1-bromohexane) **AND** C–I bond has a lower bond enthalpy/is weaker/easier to break (than C–Br) ✓ **Correct rate order of all three halogenoalkanes** 1-iodohexane > 1-bromohexane > 1-chlorohexane **OR** **Correct order of C–X bond enthalpy/bond strength/ease of breaking of all three halogenoalkanes** C–Cl > C–Br > C–I ✓	2	**IGNORE** references to bond length, polarity and electronegativity **ALLOW** iodo > bromo > chloro etc.
3	(b)	(i)	(Atom economy = $\frac{164.9}{245.8} \times 100$ =) 67.1 (%) ✓	1	Answer required to **one** decimal place

3	(b)	(ii)	(Initiation) $Br_2 \rightarrow 2Br$ **AND** UV/ultraviolet ✓ (Propagation) $C_6H_{14} + Br \rightarrow C_6H_{13} + HBr$ ✓ $C_6H_{13} + Br_2 \rightarrow C_6H_{13}Br + Br$ ✓ (Termination) Two from the three termination equations below ✓ $2Br \rightarrow Br_2$ $C_6H_{13} + Br \rightarrow C_6H_{13}Br$ $2C_6H_{13} \rightarrow C_{12}H_{26}$ Homolytic fission ✓ **QWC**: names of initiation, propagation and termination linked to at least one correct equation for each step ✓	6	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **THROUGHOUT, ALLOW** correct molecular formulae **OR** structural **OR** displayed **OR** skeletal **OR** mixture of structures **IGNORE** dots **IGNORE** state symbols **NOTE:** If mechanism uses Cl_2 instead of Br_2, **DO NOT ALLOW** initiation equation **BUT** all other marks available by **ECF**

3	(b)	(iii)	**IF answer = 9.34 OR 9.33 % award 3 marks** --- **actual** $n(C_6H_{13}Br)$ produced = $\frac{2.31}{164.9}$ = 0.0140 (mol) ✓ **theoretical** $n(C_6H_{13}Br) = n(C_6H_{14}) = \frac{12.90}{86.0}$ = 0.15(0) (mol) ✓ % yield = $\frac{0.014008}{0.150}$ × 100 = 9.34 (%) ✓ *use of unrounded values in calculator throughout* **OR** % yield = $\frac{0.0140}{0.150}$ × 100 = 9.33 (%) *use of 0.0140*	3	**ALLOW ECF** at each stage **ALLOW 3 SF** up to calculator value of 0.01400848999 **ALLOW** use of 165 (gives exactly 0.0140) **ALLOW approach via mass for 2nd and 3rd marks** Theoretical mass $C_6H_{13}Br$ = 0.15 × 164.9 = 24.735 (g) ✓ % yield = $\frac{2.31}{24.735}$ × 100 = 9.34 (%) ✓

3	(b)	(iv)	***formula of H*** ***2 marks*** Mole ratio C : H : Br is 3.64 : 7.88 : 0.607 ✓ Empirical formula = $C_6H_{13}Br$ ✓ ***Structure of H and explanation*** ***2 marks*** any structural isomer of 1-bromohexane, e.g. $CH_3CH_2CH_2CH_2CHBrCH_3$ ✓ Formed by substitution (of H) at different positions along chain ✓ ***Structure of I and explanation*** ***2 marks***: Any structural isomer of dibromohexane, e.g. $CH_3CH_2CH_2CH_2CH_2CHBr_2$ ✓ Formed by further substitution ✓	6	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **ALLOW** $\frac{43.66}{12.0} : \frac{7.88}{1.0} : \frac{48.46}{79.9}$ **IGNORE** names **ALLOW** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)
			Total	**23**	

Question	Answer	Marks	Guidance
4	***Boltzmann distribution (Seen once)***  Curve starts within one small square of the origin **AND** curve does not touch the x axis at high energy ✓ ***Temperature*** Two Boltzmann distributions at different temperatures **AND** higher and lower *T* clearly identified ✓ ***Catalyst*** Two activation energies labelled with catalyst energy less ✓ ***Effect on rate*** Rate increases with catalyst ✓ Rate increases with increased *T* ✓ ***Explanation*** *(seen in context of catalyst* ***OR*** *temperature)* more molecules have energy above activation energy **OR** more molecules have energy equal to the activation energy **OR** greater area under curve above the activation energy ✓	6	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **Note:**: Look for marking criteria within annotations on Boltzmann distribution diagrams **IGNORE** a slight inflexion on the curve **IGNORE** a 2nd curve that does not meet the drawing criteria **DO NOT ALLOW** a curve that bends up at the end by more than one small square **DO NOT ALLOW** two curves for effect of catalyst Maximum of curve for higher *T* to right **AND** lower than maximum of lower *T* curve **AND** above lower *T* line at higher energy **AND** higher *T* line intersect lower *T* line **only once** **IGNORE** more molecules have enough energy to react mark *(as not linked to E_a)* **IGNORE** (more) successful collisions
	Total	**6**	

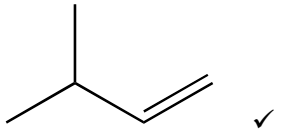
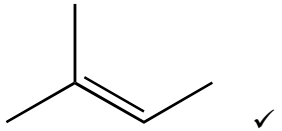
Question			Answer	Marks	Guidance
5	(a)		N_2: air **AND** H_2: water/H_2O **OR** natural gas/CH_4 **OR** oil ✓	1	
5	(b)		**Pressure**: Right-hand side has fewer (gaseous) moles/molecules **OR** left-hand side has more (gaseous) moles/molecules ✓ **Temperature**: Statement that (Forward) reaction is exothermic **OR** (forward) reaction gives out heat **OR** reverse reaction is endothermic **OR** reverse reaction takes in heat ✓ **Conditions AND equilibrium shift** Low temperature **AND** high pressure **AND** equilibrium (position) shifts to the right ✓	3	**ORA** throughout **Note:** Look for marking criteria within explanations for *p* and *T* **IGNORE** responses in terms of rate **IGNORE** comments about the 'exothermic side' or 'endothermic side' **ALLOW** suitable alternatives for 'to right', e.g.: towards products **OR** towards NH_3 **OR** in forward direction **OR** increases yield of NH_3/products **OR** favours the right
5	(c)		Low temperature gives a slow rate **OR** high temperatures needed to increase rate ✓ High pressure is expensive (to generate) **OR** high pressure provides a safety risk ✓	2	 **IGNORE** high pressure is dangerous **IGNORE** high pressure is explosive

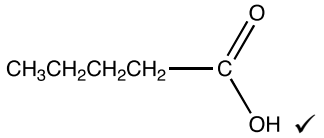
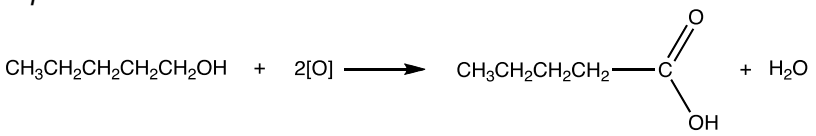
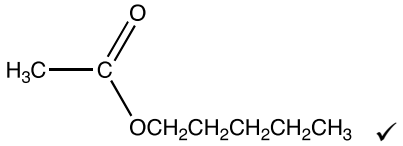
5	(d)		**Any two from**: lower temperatures/lower pressures (can be used) **OR** lower energy demand ✓ uses less fuel **OR** reduces CO_2 emissions ✓ (different reactions can be used with) greater atom economy **OR** less waste **OR** reduce use of hazardous/toxic/harmful/poisonous chemicals ✓	2	**IGNORE** catalyst not used up in reaction **IGNORE** catalyst can be re-used **IGNORE** enzymes (*question is about iron as a catalyst*) **IGNORE** lower activation energy **IGNORE** cheaper **IGNORE** less greenhouse gases **OR** reduces global warming **ALLOW** increases atom economy
5	(e)	(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
5	(e)	(ii)	**IF enthalpy change = –1272 (kJ mol^{-1}) award 3 marks** **IF enthalpy change = +1272 (kJ mol^{-1}) award 2 marks** (Energy for bonds broken = 12 × 391 + 3 × 498) = 6186 (kJ) ✓ (Energy for bonds made = 2 × 945 + 12 × 464) = 7458 (kJ) ✓ ΔH_r = –1272 (kJ mol^{-1}) ✓	3	 **IGNORE** sign **IGNORE** sign Correct sign required **ALLOW ECF** for bonds broken – bonds made **IF** at least one molar ratio is used e.g. 3 × O=O

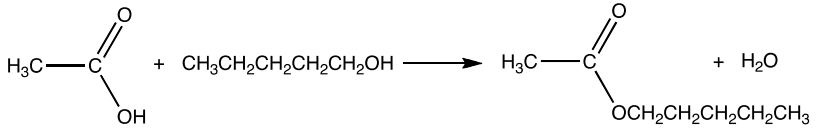
5	**(e)**	**(iii)**	**IF ΔH_c^{-o-} = –384 (kJ mol^{-1}) award 2 marks** **IF ΔH_c^{-o-} = –1536 (kJ mol^{-1}) award 1 marks** (ΔH) = –1272 – (6 × 44) = –1536 (kJ mol^{-1}) ✓ ΔH_c^{-o-} = –1536 ÷ 4 = –384 (kJ mol^{-1}) ✓	**2**	**ALLOW ECF** from incorrect answer from **(e)(ii)** *i.e.* answer to **(ii)** – (6 x 44) = ……. (kJ mol^{-1}) **ALLOW 1 mark for** (+)384 *(wrong sign for final answer)* *–252 (wrong sign for 44)* –329 *(no × 6)* (+)252 *(wrong sign for –1272 i.e. answer to **(e)(ii)**)* Any other number **CHECK** for **ECF** from first marking point expression with **ONE** error **ONLY**
			Total	**15**	

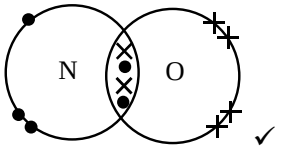
Question			Answer	Marks	Guidance
6	(a)		**IF ΔH_c = –1070 (kJ mol^{-1}) award 4 marks** **IF ΔH_c = (+)1070 (kJ mol^{-1}) award 3 marks (incorrect sign)** **IF ΔH_c = (±)1073 (kJ mol^{-1}) award 3 marks (not 3 sig fig)** **Moles** Amount, n, C_3H_7OH calculated correctly = 0.0302 (mol) ✓ **Energy** q calculated correctly = 32395 (J) **OR** 32.395 (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	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **Note:** q = 125 × 4.18 × 62 **ALLOW** 3 SF up to calculator value of 32395 J **IGNORE** sign **IGNORE** working **Note:** from 32395 J and 0.0302 mol ΔH = (-)1072.682119 kJ mol^{-1} **IGNORE** sign at this intermediate stage **ALLOW** ECF from $n(C_3H_7OH)$ and/or energy released Final answer must have **correct sign** and **three sig figs** Answer is still –1070 from rounding of q to 32400 J
6	(b)	(i)	(Enthalpy change) when one mole of a compound ✓ is formed from its elements ✓ 298 K / 25 °C **AND** 1 atm / 100 kPa / 101 kPa / 1 bar ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** one mole of substance **OR** one mole of product **DO NOT ALLOW** one mole of element **IGNORE** reference to concentration
6	(b)	(ii)	$6C(s) + 7H_2(g) + ½O_2(g) \rightarrow CH_3(CH_2)_5OH(l)$ correct species, state symbols **and** balancing ✓	1	**ALLOW** $C_6H_{13}OH(l)$ **OR** $C_6H_{14}O(l)$ **DO NOT ALLOW** multiples of this equation

6	(b)	(iii)	**IF answer = –3988 (kJ mol^{-1}), award 3 marks** **IF answer = (+)3988 (kJ mol^{-1}), award 2 marks** 6 × –394 + 7 × –286 shown/calculated/–4366 kJ ✓ –378 and –4366 added/subtracted ✓ correct answer = (–4366) – (–378) = –3988 kJ mol^{-1} ✓	3	**IF there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW** 1st mark for using 6 × (–)394 **AND** 7 × (–)286 **OR** (–)2364 **AND** (–)2002 **OR** (–)4366 **ALLOW ECF** **Common incorrect answers are shown below** **Award 2 marks for** –2018 **OR** –2272 **OR** –302 **OR** –4744 **Award 1 mark for** 2018 **OR** 2272 **OR** 302
			Total	**11**	

Question			Answer	Marks	Guidance
7	(a)		**Fermentation** $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ yeast/zymase **AND** warm **OR** stated temperature between 20ºC and 45ºC **AND** anaerobic/absence of air ✓ **Hydration of ethene** $C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓ steam **OR** H_2O at ≥ 100ºC **AND** acid (catalyst) ✓	4	**ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** state symbols in equations **ALLOW** conditions shown in the equation **IGNORE** pressure A limited supply of oxygen/lack of oxygen is **NOT** sufficient **DO NOT ALLOW** acidic or alkaline conditions **IGNORE** pressure **ALLOW** H^+ / named mineral acid / H_2SO_4 / H_3PO_4 **DO NOT ALLOW** 'weak acid' e.g. ethanoic acid
7	(b)	(i)	acid ✓	1	**ALLOW** H^+ / named mineral acid / H_2SO_4 / H_3PO_4
7	(b)	(ii)	H_2O ✓	1	
7	(b)	(iii)	 ✓  ✓	2	**CARE** with orientation which could be rotated. **IF** correct unambiguous structural **OR** displayed **OR** mixture of formulae shown **ALLOW** one mark if both correct products are shown.
7	(b)	(iv)	Monitor absorption of alcohol O–H/3200–3550 cm^{-1} ✓ All alcohol has reacted when O–H peak has disappeared ✓	2	**ALLOW** monitor absorption of C–O/1000-1300 cm^{-1} **Note:** 'alcohol peak' is **not** sufficient. The peak must be identified by wavenumber range **OR** bond

7	(c)		**pentan-1-ol into a carboxylic acid** *Reagents and conditions (QWC):* Acid/H^+ and (potassium or sodium) dichromate/$Cr_2O_7^{2-}$ **AND** reflux ✓ *Structure*  OH ✓ *Equation*  ✓ **pentan-1-ol into an ester** *Reagents and conditions (QWC):* carboxylic acid identified by structure or name **AND** acid catalyst/H_2SO_4 ✓ *Structure*  e.g. ✓ *Equation*	6	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **QWC** – the QWC mark is for linking the correct reagents and conditions to **one** of the reactions. **ALLOW** H_2SO_4 and $K_2Cr_2O_7$ **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) Bonds around C of carboxylic acid group **must** be displayed *(in* question) Structure can be awarded within equation **ALLOW** any carboxylic acid **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) Bonds around C=O of ester group **must** be displayed *(in* question) Structure can be awarded within equation

			 ✓		---------- **ALLOW** the following alternative approach to prepare the ester from pentanoic acid (formed in the first reaction) **First mark** any alcohol and acid catalyst/H^+ **Second mark** Correct structure with bonds around C of C=O ester group displayed **Third mark** Correct equation ----------
			Total	**16**	

Question			Answer	Marks	Guidance
8	(a)	(i)	A species with an unpaired electron ✓	1	**ALLOW** atom **OR** molecule for 'species'
8	(a)	(ii)	 ✓	1	Circles **not** required
8	(a)	(iii)	Cl from action of UV on CFCs ✓ NO from aircraft **OR** lightning/thunderstorms ✓	2	UV **AND** CFCs required. **IGNORE** car engines
8	(a)	(iv)	$Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O \rightarrow Cl + O_2$ ✓	2	**IGNORE** dots **ALLOW** $ClO + O_3 \rightarrow Cl + 2O_2$ **IGNORE** $O + O_3 \rightarrow 2O_2$ **IGNORE** $2O_3 \rightarrow 3O_2$
8	(b)		toxicity **OR** low level ozone/photochemical smog ✓	1	**ALLOW** causes acid rain **OR** can result in respiratory irritation **IGNORE** greenhouse gas

8	(c)	(i)	**IR spectrum** 1700 cm^{-1} **AND** C=O/carbonyl group ✓ **Mass spectrum** (molecular ion) peak at (*m*/*z* =) 58 gives molecular mass ✓ Molecular formula = C_3H_6O ✓ (Fragment ion) peak at (*m*/z =) 29 suggests CH_3CH_2 **OR** C_2H_5 **OR** CHO ✓ Compound is CH_3CH_2CHO **OR** C_2H_5CHO ✓	**5**	***FULL ANNOTATIONS MUST BE USED THROUGHOUT*** **LOOK ON THE SPECTRUM** for labelled peak which can be given credit **ALLOW** range from the *Data Sheet* C=O within range 1640–1750 cm^{-1}; **IGNORE** names **IGNORE** absence of + charge for fragment ion **ALLOW** CH_3COCH_3 *The fragment ion is the evidence that differentiates between CH_3CH_2CHO and CH_3COCH_3*
8	(c)	(ii)	Compare spectrum with spectral database/spectra of known compounds ✓	**1**	
			Total	**13**	

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