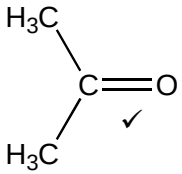
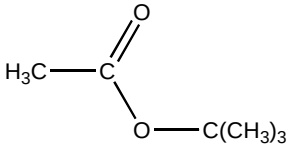
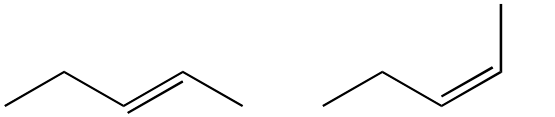
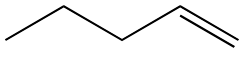
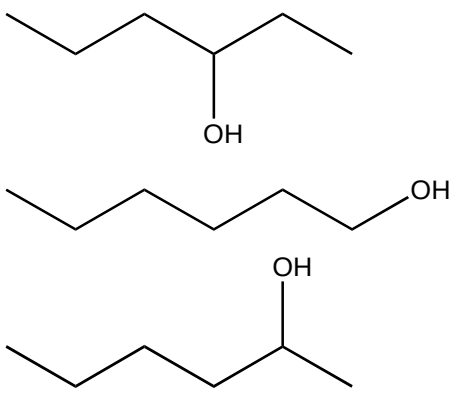
Question			Expected Answers	Marks	Additional Guidance
1	(a)		**method 1:** fermentation of sugars or carbohydrates **OR** reaction with yeast with sugar or carbohydrates ✓ $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ **method 2:** hydration of ethene OR reaction of ethene with water **OR** reaction of steam with ethene ✓ $C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓	**4**	**ALLOW** sugar from equation **ALLOW** C_2H_6O in equation **ALLOW** correct multiples **IGNORE** state symbols **ALLOW** ethene from the equation **IGNORE** mention of any catalyst **ALLOW** C_2H_6O in equation **OR** H_2O over the arrow **ALLOW** correct multiples **IGNORE** state symbols
	(b)	(i)	$(CH_3)_2CO$ **OR**  $(CH_3)_2CHOH + [O] \longrightarrow (CH_3)_2CO + H_2O$ ✓	**2**	If name and formula given both need to be correct **ALLOW** propanone **OR** acetone **IGNORE** propone **NOT** incorrect named compound **ALLOW** $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ **ALLOW** O instead of [O] **ALLOW** correct multiples **IGNORE** state symbols
		(ii)	CH_3CH_2COOH **OR** propanoic acid ✓ Any number or range of numbers between 1750–1640 (cm^{-1}) for C=O ✓ Any number or range of numbers between 2500–3300 (cm^{-1}) for O–H ✓	**3**	 **ALLOW** C=O and O—H marks independent of compound identified **i.e. stand alone marks** **ALLOW** correct bonds shown by the appropriate absorption on the IR spectrum **IGNORE** reference to C—O bond
	(c)	(i)	2-methylpropan-2-ol ✓	**1**	**ALLOW** methylpropan-2-ol **OR** tertiarybutanol

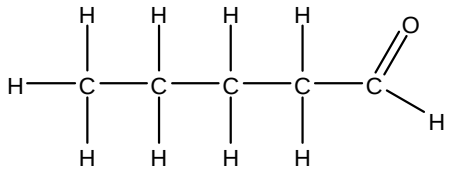
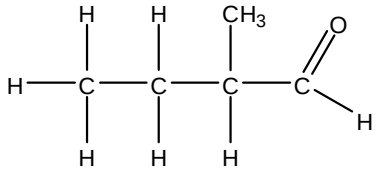
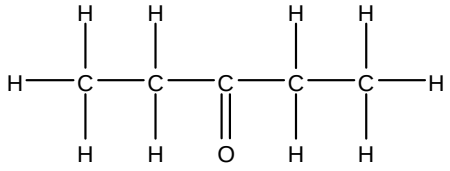
Question			Expected Answers	Marks	Additional Guidance
		(ii)	ester ✓	**1**	
		(iii)	$CH_3CO_2C(CH_3)_3$ **OR** $CH_3COOC(CH_3)_3$ **OR**  ester group shown ✓ rest of molecule ✓	**2**	**ALLOW** skeletal formula **OR** displayed formula **ALLOW** ester linkage even if rest of structure is wrong
			Total	**13**	

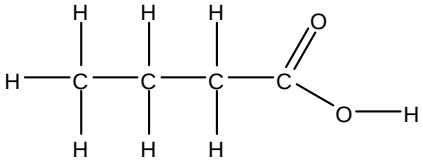
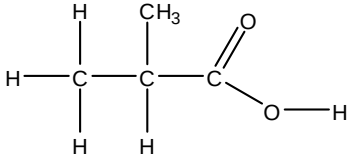
Question			Expected Answers	Marks	Additional Guidance
2	(a)		**Structural isomer** compounds with the same molecular formula ✓ but with different structural formulae ✓ **Stereoisomer** compounds with the same structural formula ✓ but with different arrangements in space ✓ **Evidence** of using M_r of 70 to **calculate** molecular formula of C_5H_{10} ✓ **F** and **G** are  o ✓ Correct identification of the *E* and *Z* isomers ✓ **H is**  ✓ ***E/Z* happens because** double bonds restricts rotation ✓ different groups on each carbon of the double bond ✓	**11**	**ALLOW** same molecular formula ✓ but different structures✓ Second marking point is **DEPENDENT** on first mark **ALLOW** compounds with the same structure Second marking point is **DEPENDENT** on first mark This is the QWC mark **IGNORE** wrong names of **F**, **G** and **H** **ALLOW** structural or displayed formulae for **F**, **G** and **H** e.g. **H is** $CH_3CH_2CH_2CHCH_2$ **ALLOW** identification using *trans* and *cis* and **ALLOW** this marking point as identification of another example of identifying *E/Z* or *cis* and *trans* if not done for **F** and **G** **ALLOW** one mark if no structures drawn but correct names given for **F**, **G** and **H** i.e *E*-pent-2-ene, *Z*-pent-2-ene and pent-1-ene **ALLOW** ecf on structures if wrong molecular formula used or consistent error or slip such as having just sticks

Question			Expected Answers	Marks	Additional Guidance
	(b)		from IR absorption, **J** contains O–H **OR** from IR **J** is an alcohol✓ C : H : O = $\frac{70.59}{12.0}$: $\frac{13.72}{1.0}$: $\frac{15.69}{16.0}$ **OR** 5.8825 : 13.72 : 0.9806 ✓ empirical formula = $C_6H_{14}O$ ✓ (from mass spectrum), M_r = 102 ✓ evidence that it has been shown that the empirical formula is the molecular formulae e.g. M_r of $C_6H_{14}O$ = 102 so empirical formula is molecular formula ✓  One mark for each correct structure ✓ ✓ ✓	**8**	This is a QWC mark **ALLOW two** marks for correct empirical formula with no working out This is a QWC mark **ALLOW** structural or displayed formulae **IGNORE** incorrect names **ALLOW** one minor slip in drawing structures e.g. one missing hydrogen but **ALLOW** ecf for bigger slips such as showing just sticks and no hydrogen atoms **ALLOW** bond to H in OH **ALLOW one** mark for three isomers of $C_6H_{13}OH$ whether branched or unbranched as a catch mark if no other mark has been awarded for the structures If more than three isomers of $C_6H_{13}OH$ drawn • 1 branched and 3 unbranched award **two** marks • any other combination award **one** mark **ALLOW** one mark for hexan-1-ol, hexan-2-ol and hexan-3-ol if structures not drawn
			Total	**19**	

Question			er	Marks	Guidance
3	(a)		***Any three from:***	3	Assume it refers to **Process 1**
			Process 1 has a high atom economy **OR** has 100% atom economy **OR** a greater atom economy **OR** makes only the desired product ✓		**ALLOW** process **1** has no waste **OR** process **1** has no co-products **OR** process **1** needs less separation **OR** process **1** has fewer other products **OR** gives only one product **ALLOW** ORA if process **2** is specified
			Process 1 has a very efficient conversion of reactants to products **OR** not much waste of **starting material** ✓		**ALLOW** ORA if process **2** is specified high percentage yield is **not** sufficient **DO NOT ALLOW** if percentage yield is explicitly linked to more waste (products) e.g. process **1** has a high percentage yield so makes little waste (product) scores **0 marks** but process **1** makes no waste (product) and it has a high percentage yield scores **1 mark**
			Process 1 uses a low**er** pressure ✓		**ALLOW** ORA if process **2** is specified
			Process 1 uses up **toxic** carbon monoxide ✓		
			Process 1 uses methanol which can be produced from biomass ✓		**IGNORE** process **2** comes from crude oil a non-renewable source **ALLOW** process **1** starts from a renewable source if the source is specified e.g. wood, municipal waste or sewage **IGNORE** reference to catalyst and rate of reaction

Question			er	Marks	Guidance
	(b)	(		5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			Contains C=O bond because of absorption between 1700 and 1740 cm^{-1} (from the spectrum) ✓		**ALLOW** contains a carbonyl group because of absorption within range 1640–1750 cm^{-1} **OR** contains an aldehyde, ketone or carboxylic acid because of absorption within range 1640–1750 cm^{-1} ✓ Mention of only an aldehyde or a ketone is not sufficient it needs reference to the wavenumber **LOOK FOR THIS MARK ON THE SPECTRUM**
			does not contain an O–H bond ✓		**ALLOW** not a carboxylic acid ✓ **ALLOW** does not have any other characteristic absorbance due to other functional groups
			(So was a) ketone **OR** aldehyde ✓		**ALLOW (**so was a) carbonyl compound **ALLOW** this mark if a structure of an aldehyde or a ketone is given even if the structure has an incorrect number of carbon atoms
			M_r = 86 ✓		
			Correct structure ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) LOOK FOR AN **ALDEHYDE** or **KETONE** with **FIVE** carbon atoms **OR** a **DIALDEHYDE**, **DIONE OR** an **OXOALDEHYDE** with **FOUR** carbon atoms – a comprehensive list of correct structures is shown on page 34 **IGNORE** incorrect name **DO NOT ALLOW** COH for an aldehyde

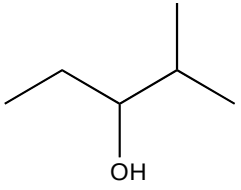
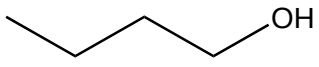
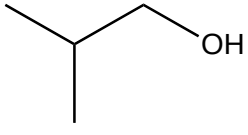
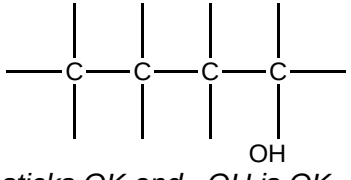
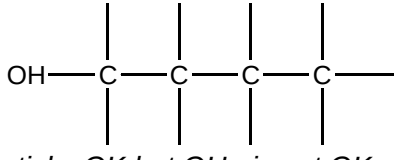
Question			er	Marks	Guidance
			 pentanal **OR**  2-methylbutanal **OR**  pentan-3-one		**ALLOW** as a slip one stick with no H on in a displayed formula

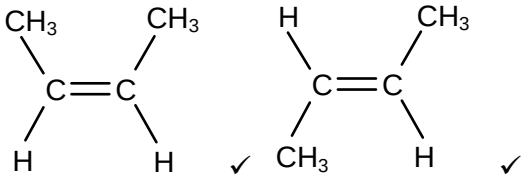
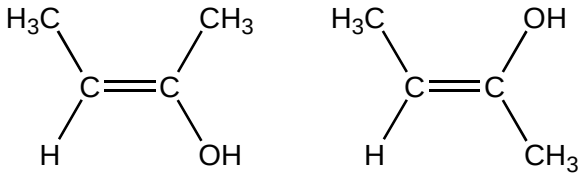
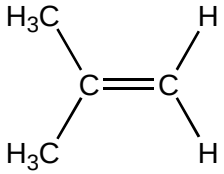
Question			er	Marks	Guidance
	(b)	(i	Correct structure ✓ Name of the structure drawn ✓  butanoic acid **OR**  2-methylpropanoic acid	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) All bonds and all hydrogen atoms must be shown in a displayed formula within this question Name must correspond to the correct structure for two marks **ALLOW** butanoic acid or 2-methylpropanoic acid if the structure drawn is incorrect There is **no** ECF in this question **ALLOW** $CH_3CH_2CH_2COOH$ **ALLOW** $(CH_3)_2CHCOOH$ **ALLOW** methylpropanoic acid

Question			er	Marks	Guidance
	(c)		Use of propan-1-ol ✓ $CH_3COOH + C_3H_7OH \rightarrow CH_3COOCH_2CH_2CH_3 + H_2O$ Correct formulae for the ester ✓ Correctly balanced equation ✓ Add H_2SO_4 **OR** acid catalyst **OR** H^+ ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** from the equation propanol **OR** C_3H_7OH is **not** sufficient **ALLOW** molecular formula **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** propan-2-ol in the equation **ALLOW** conditions mark over the arrow in the equation
			Total	**14**	

Question			er	Marks	Guidance
4	(a)		Shape – tetrahedral ✓ Bond angle 109.5^{o} ✓	2	 **ALLOW** 109–110^{o}
	(b)	(	Volatile **OR** non-toxic **OR** non-flammable **OR** easily vaporised ✓	1	**ALLOW** not carcinogenic / not an irritant / not harmful / not hazardous **IGNORE** cheap / not dangerous / gas / low boiling point **DO NOT ALLOW** inflammable
		(ii)	(C–F or C–C*l*) bonds need a large amount of energy to break ✓	1	**ALLOW (**the C–F or C–C*l*) bonds are strong / bonds have a large bond enthalpy **ALLOW** the molecule is not polar enough / non-polar molecule is **not** sufficient **ALLOW** the activation energy is too high **DO NOT ALLOW dissolves** **IGNORE** references to hydrogen bonding
	(c)		$CF_2Cl_2 \rightarrow CF_2Cl + Cl$ ✓ **AND ANY TWO FROM** C*l* catalyses the decomposition of ozone ✓ $Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O \rightarrow Cl + O_2$ ✓	3	**ALLOW** CF_2Cl_2 (breaks down to) produces **chlorine** atoms/radicals **ALLOW** equation with any CFC **ALLOW** $ClO + O_3 \rightarrow Cl + 2O_2$ **ALLOW** $O_3 + O \rightarrow 2O_2$ **OR** $3O_2 \rightarrow 2O_3$ for one mark if the two equations for the steps have not been given **IGNORE** other propagation equations

Question			Answer	Marks	Guidance
	(d)		Because (more) UV will reach the Earth's surface **and** risk of (skin) cancer increased/risk of cataracts/crop mutation increased ✓	1	**DO NOT ALLOW** global warming **ALLOW** protects from UV which causes skin cancer etc
	(e)		***Ideas related to uses*** CFCs are still entering the atmosphere (from disused items) **OR** CFCs are still used (for some purposes and by some countries) ✓ ***Ideas relating to lifetime within the atmosphere*** CFCs have a long lifetime in the atmosphere **OR** it takes a long time for CFCs to reach upper atmosphere **OR** CFCs are inert ✓	2	**ALLOW** 'stratosphere' for 'upper atmosphere' **ALLOW** CFCs are still entering the ozone layer
			Total	**10**	

Question			Expected Answers	Marks	Additional Guidance
5	(a)	(i)	2-Methylpropan-2-ol ✓	1	**ALLOW** methylpropan-2-ol
	(b)		 ✓	1	Formula **must** be skeletal **AND** not include any symbol except for OH
	(c)	(i)	Same **molecular** formula but different structural formulae ✓	1	**ALLOW** Same molecular formula but different arrangement of atoms **OR** Same molecular formula but different structures **OR** Same molecular formula but different displayed formulae **DO NOT ALLOW** Same molecular formula but different spatial arrangement of atoms
		(ii)	$CH_3CH_2CH_2CH_2OH$ **OR** $(CH_3)_2CHCH_2OH$ ✓ **ALLOW**  **OR** 	1	**ALLOW** displayed formula **ALLOW** sticks (i.e. no H shown bonded to C) **ALLOW**  *sticks OK and –OH is OK* **DO NOT ALLOW** OH shown as below  *sticks OK but OH– is not OK* **ALLOW** correct ethers

Question			Expected Answers	Marks	Additional Guidance
	(d)		Has O–H (bonds) **OR** has hydroxyl (groups) **OR** has hydroxy (groups) ✓ Forms hydrogen bonds with water (molecules) ✓	**2**	**ALLOW** marks from a diagram of hydrogen bonding **IGNORE** reference to alcohol functional group **DO NOT ALLOW** 'forms hydrogen bonds'
	(e)		$CH_3COOCH_2CH_2OOCCH_3$ 1 mark for each ester end of molecule ✓✓	**2**	**ALLOW** displayed formula **OR** skeletal formula **ALLOW** sticks $CH_3COOCH_2CH_2OH$ shows one of the two ester groups and scores one mark
	(f)	**(i)**	 ✓ ✓	**2**	**DO NOT ALLOW**  i.e. no E
		(ii)	*E/Z* ✓	**1**	**ALLOW** *cis-trans* **IGNORE** geometric
		(iii)	$CH_3CH_2CH=CH_2$ **OR** but-1-ene ✓	**1**	If but-1-ene given in part **(i)**, **ALLOW** but-2-ene **OR** $CH_3CH=CHCH_3$ i.e. ECF from **f(i)** **DO NOT ALLOW** methylpropene: 

Question	Expected Answers	Marks	Additional Guidance
From the evidence, candidates may have identified compound **F** as propanone, propanal or propanoic acid • The mark scheme for **F** = propanone and propanal is shown in the 'Expected Answers' column. • The mark scheme for **F** = propanoic acid is shown in the 'Additional Guidance' column. If **F** is propanone or propanoic acid, then maximum score = 7; **but** if **F** is propanal then maximum score = 6			
(g)	**Mark scheme for F = propanone and propanal**	**7**	**Mark scheme for F = propanoic acid**
	mass spec of E– Remember to check the spectrum **Quality of Written Communication –** mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**ALLOW** *m*/*e*) value is 60 ✓ *m*/*z* = 45 indicates loss of CH_3 **OR** *m*/*z* = 45 indicates presence of CH_3CHOH **OR** CH_2CH_2OH **OR** C_2H_5O ✓		**mass spec of E– Remember to check the spectrum** **QWC –** mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**OR** *m*/*e*) value is 60 ✓ *m*/*z* = 45 indicates loss of CH_3 **OR** *m*/*z* = 45 indicates presence of CH_3CHOH **OR** CH_2CH_2OH **OR** C_2H_5O ✓
	IR of F – Remember to check the spectrum IR shows no broad absorption between 2500 to 3300 cm^{-1} so no O—H bond **OR** no broad absorption between 2500 to 3300 cm^{-1} so not a carboxylic acid ✓ IR shows absorption at 1700 cm^{-1} due to a C=O bond **OR** absorption at 1700 cm^{-1} indicates a ketone **OR** aldehyde present ✓		**IR of F– Remember to check the spectrum** IR shows (broad) absorption somewhere between 3500 and 2500 cm^{-1} suggests carboxylic acid **OR** O–H bond ✓ IR shows absorption at 1700 cm^{-1} due to C=O **OR** absorption at 1700 cm^{-1} indicates a carboxylic acid ✓
	Identification and equation **F** is CH_3COCH_3 **OR** propanone ✓ **E** is $CH_3CHOHCH_3$ **OR** propan-2-ol ✓ $CH_3CHOHCH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$ ✓		**Identification and equation** **F** is CH_3CH_2COOH **OR** propanoic acid ✓ **E** is $CH_3CH_2CH_2OH$ **OR** propan-1-ol ✓ $CH_3CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2COOH + H_2O$ ✓
	If **F** has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2 **ALLOW E** is $CH_3CH_2CH_2OH$ ✓ **ALLOW**: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓		
	Total	**19**	