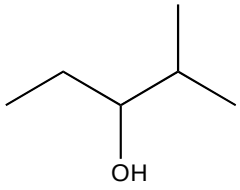
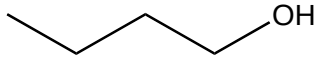
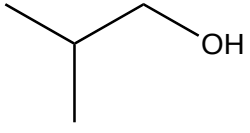
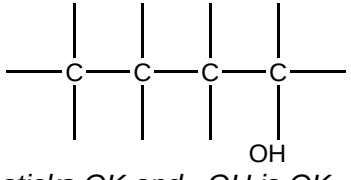
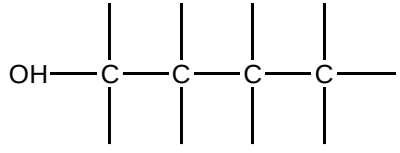
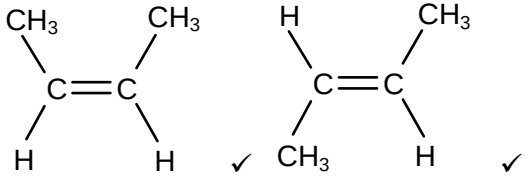
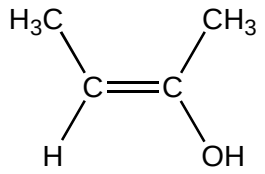
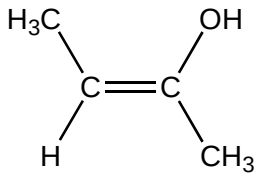
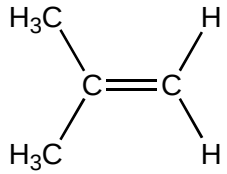
Question			Expected Answers	Marks	Additional Guidance
1	(a)	(i)	2-Methylpropan-2-ol ✓	1	**ALLOW** methylpropan-2-ol
	(b)		 ✓	1	Formula **must** be skeletal **AND** not include any symbol except for OH
	(c)	(i)	Same **molecular** formula but different structural formulae ✓	1	**ALLOW** Same molecular formula 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**	

Extra guidance for marking of Q6(g)

If **E** has **not** been identified **OR** if **F** has been identified as a **ketone or aldehyde**,
use the **left-hand** mark scheme

If **F** has been identified as a **carboxylic acid**,
use the **right-hand** mark scheme

Mass spec

These two marking points stand as **independent** marks whichever compounds have been identified.

The positive sign for fragment ions is not required. **IGNORE** negative charge.
The mass spec may well be on the actual spectrum.

IR mark

These stand as **independent** marks whichever compounds have been identified.
The IR analysis may well be on the actual spectrum.

Identification marks

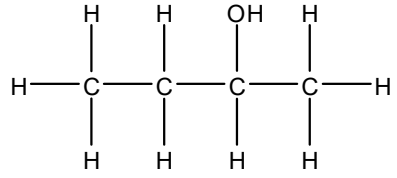
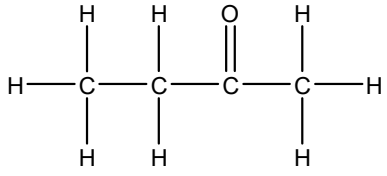
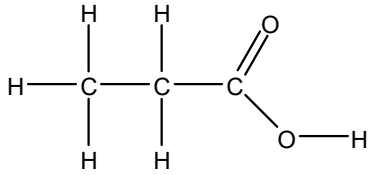
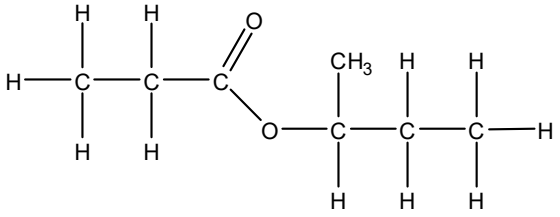
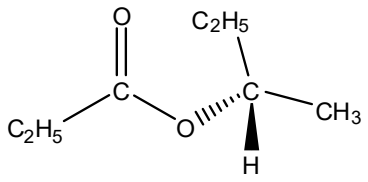
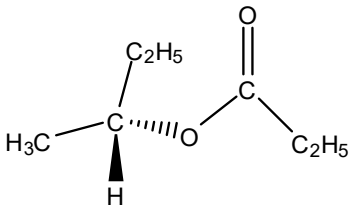
If both structure and name are given they must **both** be correct
but allow 'propanol' drawn with the correct structure because the position number of the –OH has been clearly identified

ALLOW ECF for identification of **F** e.g. if **E** is pentan-2-ol **×** then an answer of pentan-2-one for **F** will be given a mark ✓ as ECF

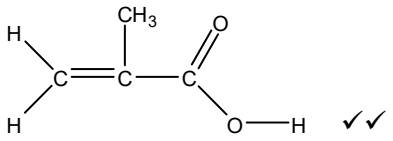
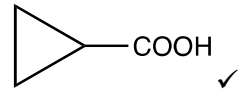
ALLOW identification marks for **E** and **F** from equation

Equation mark

ALLOW ECF for any correct equation showing the oxidation of **any** alcohol to the appropriate product.
ALLOW molecular formulae in equations,
i.e. $C_3H_7OH + [O] \rightarrow C_2H_5CHO + H_2O$ ✓ ; $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ ✓ ; $C_3H_7OH + [O] \rightarrow C_2H_5COH + H_2O$ ✓

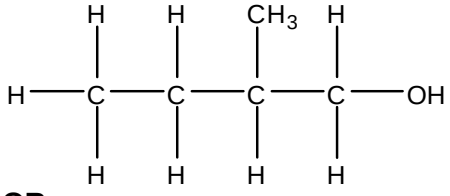
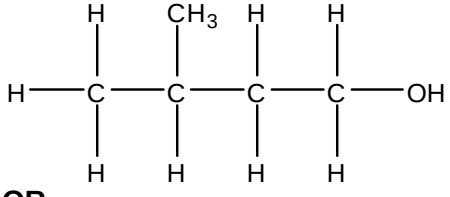
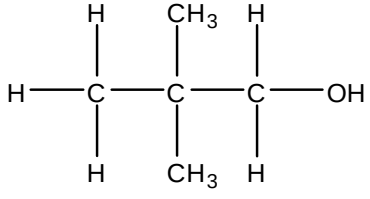
Question			Answer	Mark	Guidance
2	(a)		Molar mass of **B** = 74 ✓ **B-F** clearly identified **B/alcohol:**  ✓ **C/ketone:**  ✓ **D/carboxylic acid:**  ✓ **E and F:**  ✓ H_2O/water ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Check and annotate page 19 below this response** Molar mass = $\frac{2.59}{0.035}$ = 74 For structure of **B, C, D** or **E/F ALLOW** correct displayed **OR** correct structural formula **OR** correct 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 structures. **IGNORE** names of organic compounds **E** and **F** can be identified either way round **ALLOW** H_2O or displayed formula for mark For **E** and **F** – **ALLOW** the two optical isomers  

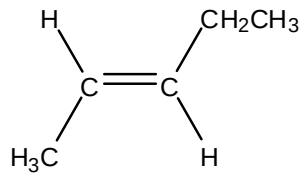
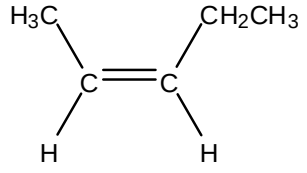
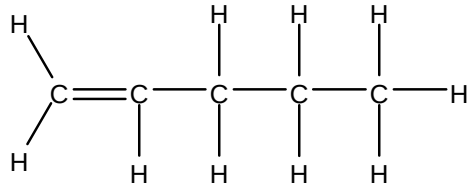
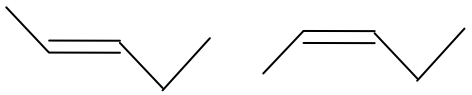
Question	Answer	Mark	Guidance
(b)	**7**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**	
	Molecular formula for G: 2 marks		
	Mole ratio C : H : O = $\frac{55.8}{12.0} : \frac{7.0}{1.0} : \frac{37.2}{16.0}$		
	OR 4.65 : 7.0 : 2.33/2.325 **OR** 2 : 3 : 1 **OR** C_2H_3O ✓		**ALLOW** mass of C = 0.558 x 86 **or** 48 **AND** mass of H = 0.07 x 86 **or** 6 **AND** mass of O = 0.372 x 86 = 32
	Molecular formula of **G** $C_4H_6O_2$ ✓		
	Mass spectrum for G: 2 marks		
	Peak **X or peak 41** indicates $C_3H_5^+$ ✓		
	Peak **Y or peak 45** indicates $COOH^+$ ✓		+ harge required for each response **ALLOW** one mark if both formulae are correct but with no charge/incorrect charge
			ALLOW any possible fragments that contain C, H and/or O that have the correct mass. E.g. Peak X indicates C_2OH^+, Peak **Y** indicates $C_2H_5O^+$ Unfeasible fragments are not allowed e.g. $C_3H_9^+$ (too many H atoms)
	Infrared for G: 1 mark		
	Peak at 1640–1750 cm^{-1} indicates presence of C=O **AND** Peak at 2500–3300 cm^{-1} (indicates the presence of) –OH group linked carboxylic acid/COOH **QWC** ✓		**LOOK ON THE SPECTRUM** for labelled absorbance which can be given credit Candidates must link absorbance to bond in order to gain the mark **ALLOW** 1700 cm^{-1} For 2500–3300 cm^{-1}, **ALLOW** 2900 cm^{-1} or any stated wavenumber with range 2500–3300 cm^{-1} **ALLOW** wavenumber range up to 2400–3500 cm^{-1}

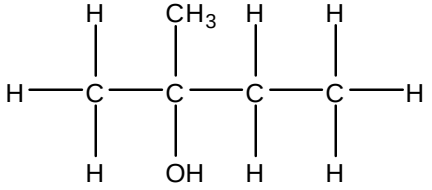
Question	Answer	Mark	Guidance
	Structure of G: 2 marks Correct structure:  ✓✓ 1 mark for one of the following structures of $C_4H_6O_2$: $H_2C{=}CH{-}CH_2{-}COOH$ **OR** $H_3C{-}CH{=}CH{-}COOH$ **OR**  ✓		**ALLOW** structural, skeletal or displayed formula. **DO NOT ALLOW ECF** from incorrect molecular formula
	Total	**13**	

Question			er	Marks	Guidance
3	(a)		Only one (desired) product formed ✓	1	**ALLOW** no waste products **OR** no co-product **OR** all atoms on left hand side are in the desired product **OR** sulfuric acid is the only product **IGNORE** it is an addition reaction
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 94% award 3 marks** Moles of sulfur reacted or theoretical moles of H_2SO_4 = 1.60×10^6 ✓ Actual moles of H_2SO_4 = 1.50×10^6 ✓ % yield = 94 ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** 1.6×10^6 to the calculator value 1.601246106×10^6 correctly rounded **ALLOW** 1.60 up to calculator value 1.601246106 correctly rounded **ALLOW** 1.5×10^6 to the calculator value 1.498470948×10^6 correctly rounded **ALLOW** 1.5 up to calculator value 1.498470948 correctly rounded **ALLOW** theoretical mass of H_2SO_4 = 157 (tonnes) up to the calculator value of 157.0822430 correctly rounded for two marks **ALLOW** ECF for a percentage yield from wrong moles above but answer must have two significant figures
	(c)	(i)	Position of equilibrium – unchanged ✓ Rate of backward reaction – decreases ✓	2	

Question			er	Marks	Guidance
	(c)	(i	(equilibrium position shifts) to the left **because** (forward) reaction is exothermic **OR** equilibrium position shifts) to the left **because reverse** reaction is endothermic ✓	1	Both position of equilibrium **AND** explanation needed for one mark **Note: ALLOW** suitable alternatives for 'to left', e.g. towards SO_2 or O_2 / towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of SO_3/products **ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **ALLOW** reaction gives out heat for exothermic **ALLOW** reaction takes in heat for endothermic **ALLOW** moves to the left in the endothermic direction **ALLOW ORA** if specified **IGNORE** responses in terms of rate
		(iii)	(equilibrium position shifts) to the left **because** there are more moles (of gas) on the reactant side **OR** (equilibrium position shifts) to the left because there are fewer moles (of gas) on product side ✓	1	Both position of equilibrium **AND** explanation needed for one mark **Note: ALLOW** suitable alternatives for 'to left', e.g.: towards SO_2 or O_2 / towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of SO_3/products **ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **ALLOW** correct reference to volume of gases e.g. shifts to the left because there is a smaller volume of gas on the product side **ALLOW ORA** if specified **IGNORE** responses in terms of rate

Question			er	Marks	Guidance
	(d)	(	Correct structure ✓  **OR**  **OR** 	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** bonds going to any part of the CH_3, CH_2 and CH bonds **ALLOW** vertical 'bond' to any part of the OH group **DO NOT ALLOW** horizontal –HO in the formula **ALLOW** as a slip one stick with no H on in a displayed formula **IGNORE** name

Question			er	Marks	Guidance
	(d)	(ii)	Correct structure for **L** ✓  Correct structure for **M** ✓  Correct structure for **N** ✓  	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) for **L**, **M** and **N** **e.g.**  **L or M** ***L or M*** **N –** $CH_2CHCH_2CH_2CH_3$ Answers to **L** and M are interchangeable **IGNORE** *cis*/*trans* **OR** *E*/*Z* labels **ALLOW** as a slip one stick with no H on in a displayed formula **ALLOW** 2 marks if three correct structures are drawn but some are in the wrong boxes **ALLOW** 1 mark if two correct structures are drawn but in the wrong boxes

Question			er	Marks	Guidance
	(d)	(ii	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** vertical 'bond' to any part of the OH group **DO NOT ALLOW** horizontal –HO in the formula **ALLOW** as a slip one stick with no H on in a displayed formula
			Total	**13**	