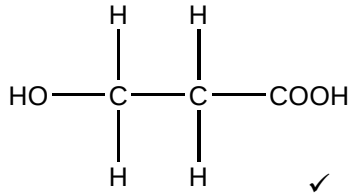
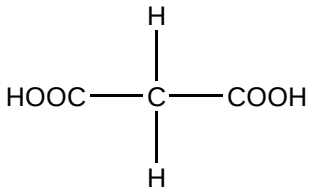
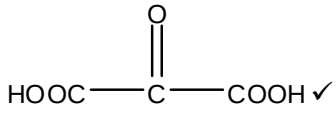
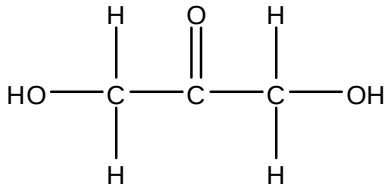
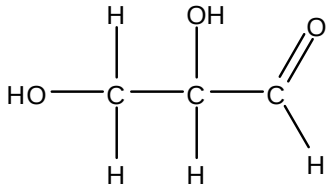
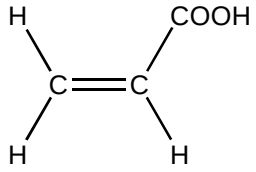
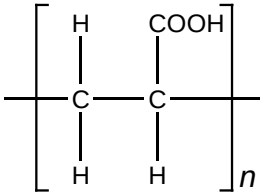
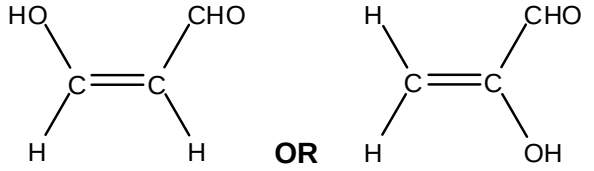
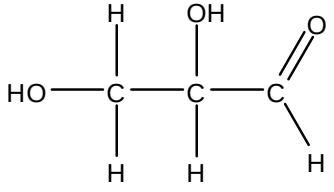
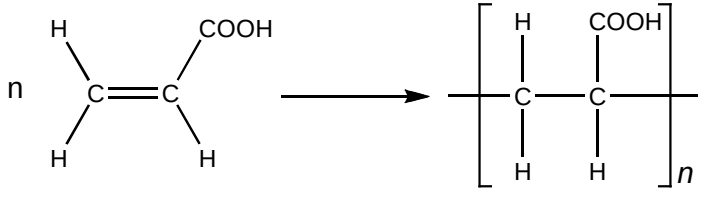
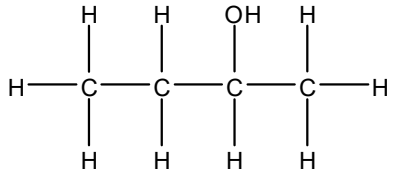
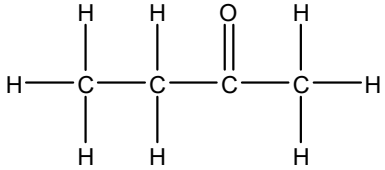
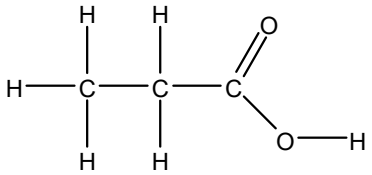
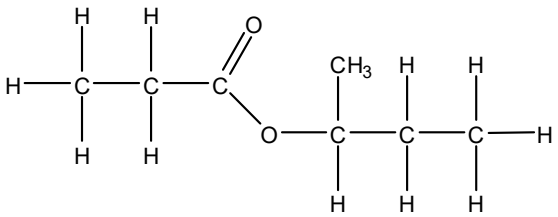
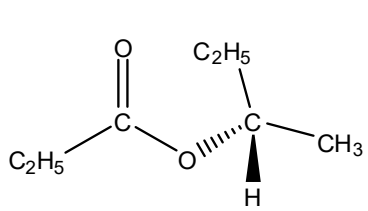
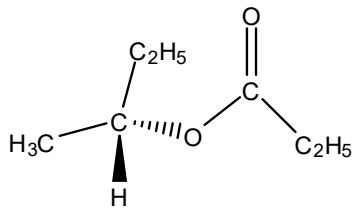
Question			Answer	Mark	Guidance
1	(a)		Mole ratio C : H : O is 3.33 : 6.67 : 3.33 ✓ Empirical formula is CH_2O ✓ Molecular formula is $C_3H_6O_3$ **AND** use of 90 **OR** 3 × 30 ✓	3	**ALLOW** $\frac{40.00}{12.0}:\frac{6.67}{1.0}:\frac{53.33}{16.0}$ **ALLOW** mass of C = 0.400 x 90 **or** 36 **AND** mass of H = 0.06677 x 90 **or** 6 **AND** mass of O = 0.5333 x 90 **or** 48

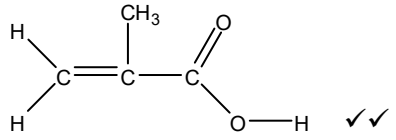
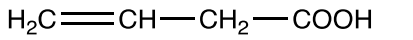
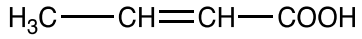
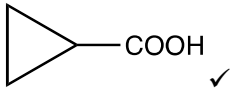
Question	Answer	Mark	Guidance
(b)	**Evidence of carboxylic acid (1 mark)** **IR:** 1550–1800 cm^{-1} **AND** C=O/carbonyl **AND** 2300–3700 cm^{-1} **AND** O–H in carboxylic acid ✓ **Evidence of alcohol (1 mark)** (broad) 3200–3700 cm^{-1} linked to O–H in alcohol **OR** (is a primary) alcohol as oxidised (to a COOH) **OR** is an alcohol as it forms a carboxylic acid **OR** is an alcohol as water is eliminated. ✓ **Identifications (2 marks)** **L**:  ✓ **M**:  ✓ **Equation (1 mark)** $C_3H_6O_3 + 2[O] \longrightarrow C_3H_4O_4 + H_2O$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **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} (broad) O–H within range 3200–3550 cm^{-1} **For ALL structures:** **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above **IGNORE** names --- **FOR M: ALLOW 1 mark for**  ✓ **AS ECF from L as either**  **OR**  **Equation:** $C_3H_6O_3 + 4[O] \longrightarrow C_3H_2O_5 + 2H_2O$ ✓ --- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above in equation

Question	Answer	Mark	Guidance
(c)	**Monomer N: (1 mark)**  ✓ **Polymer P: (1 mark)** Section showing at least one repeat unit of a polymer formed from **N** with side links ✓ e.g. 	4	**For ALL structures:** **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above **IGNORE** names **ALLOW 1 mark for either**  **AS ECF** from **L:**  --- **For P: ALLOW ECF** from an alkene with molecular formula $C_3H_4O_2$ **ALLOW** one or more repeat units but has to have a whole number of repeat units **ALLOW** repeat unit with no brackets and absence of *n*

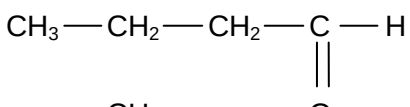
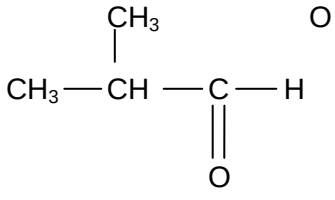
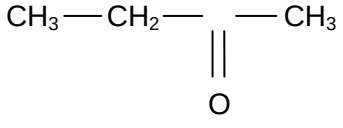
Question			Answer	Mark	Guidance
			Repeat units (1 mark) n = 10000/72 = 139 ✓		**MUST** be a whole number. **ALLOW** 138 **OR**140
			Equation (1 mark) Balanced equation for formation of P from N✓ **e.**  		**For equation, ALLOW** molecular **OR** structural **OR** skeletal **OR** displayed formulae **OR** mixture of the above e.g. **ALLOW** $nC_3H_4O_2 \longrightarrow (C_3H_4O_2)_n$ 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 if displayed/skeletal formula is used) **ALLOW** use of calculated value for n in equation e.g. $139C_3H_4O_2 \longrightarrow (C_3H_4O_2)_{139}$
			Total	**12**	

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 $C_3H_5^+$ ✓		+ harge required for each response **ALLOW** one mark if both formulae are correct but with no charge/incorrect charge
	Peak **Y or peak 45** indicates $COOH^+$ ✓		**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 $C_4H_6O_2$:  **OR**  **OR**  ✓		**ALLOW** structural, skeletal or displayed formula. **DO NOT ALLOW ECF** from incorrect molecular formula
			Total	**13**	

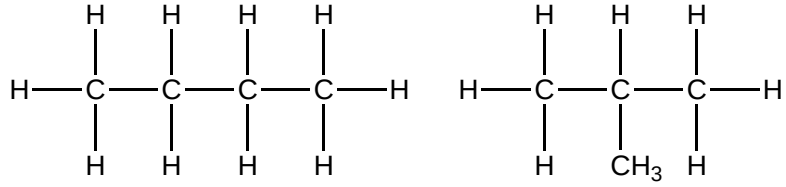
Question			Answer	Marks	Guidance
3	(a)	(i)	256 ✓	1	
		(ii)	S_8 ✓	1	**ALLOW** $^{32}S_8$ **OR** $^{32}_{16}S_8$ **DO NOT ALLOW** $^{33}S_8$ **OR** $^{30}_{16}S_8$ etc
		(iii)	S_4^+ ✓	1	Positive ion must be present **ALLOW** $^{32}S_4^+$ **OR** $^{32}_{16}S_4^+$ **DO NOT ALLOW** $^{33}S_4^+$ **OR** $^{30}_{16}S_4^+$ etc
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 195.2, award **2 marks.** **IF** answer = 195.16 award **1 marks.** $= \frac{(194\times33)+(195\times34)+(196\times25)+(198\times8)}{100}$ ✓ 195.2 ✓	2	195 on its own with no working scores 0 marks
	(c)		Monitor **air** pollution **OR** breathalysers ✓	1	**ALLOW** measure the concentration or abundance of atmospheric pollutants **ALLOW** measure concentration of named atmospheric pollutant **ALLOW** monitoring of gases in car exhaust fumes **ALLOW** drug detection or drug identification **IGNORE** night vision goggles, identifying gases on distant planets / ice samples

Question			Answer	Marks	Guidance
	(d)		mole ratio C : H : O $\frac{66.7}{12.0} : \frac{11.1}{1.0} : \frac{22.2}{16.0}$ **OR** 5.56 :11.1 : 1.39 ✓ 4 : 8 : 1 **OR** C_4H_8O ✓ contains a C=O or carbonyl because of absorbance at about 1710 cm^{-1} ✓ ***Any two from:***    ✓✓	5	**PLEASE LOOK AT THE SPECTRA AND ABOVE THE SPECTRA FOR POSSIBLE ANSWERS** **ALLOW** two marks for 72 x 66.7/100 = 48/12 = 4 (C) 72 x 11.1/100 = 8 = 8 (H) 72 x 22.2/100 = 16 = 1 (O) **ALLOW** C=O or carbonyl since has absorbance within the range 1640 to 1750 cm^{-1} **ALLOW** ketone **OR** aldehyde linked to correct absorbance **ALLOW** 'could be aldehyde, ketone, carboxylic acid, ester (or amide) because of absorbance between range 1640 to 1750 cm^{-1}' (ie direct quote from the data book) **DO NOT ALLOW** reference to **M** being a carboxylic acid, ester or amide **unless** they are included in a list with aldehyde/ketone in which case **IGNORE** carboxylic acid/ester/amide **IGNORE** reference to C—O / absence of O—H **DO NOT ALLOW** has O—H **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **eg** $CH_3CH_2CH_2CHO$, $CH_3COCH_2CH_3$ **OR** $(CH_3)_2CHCHO$ **DO NOT ALLOW** C_3H_7CHO **IGNORE** incorrect name correct name on its own is **not** sufficient
			Total	**11**	

Question			Answer	Mark	Guidance
4				7	**ANNOTATE ANSWER WITH TICKS AND CROSSES** PLEASE ENSURE YOU LOOK AT THE DATA AND SPECTRA ON PAGE 20 IN CASE THEY INCLUDE COMMENTS THAT ARE WORTHY OF CREDIT. MARK THIS PAGE WITH AN OMISSION MARK, ^ , IF BLANK QWC: mark is integrated into the chemistry marks. These marks need to link evidence with an explanation
			ANY SEVEN FROM: **Compound X** QWC: **X** contains C=O because of absorption at 1720 cm^{-1} **AND** contains O–H because of (broad) absorption between 2500 to 3300 cm^{-1} ✓ So **X** is a carboxylic acid ✓ Molar ratio (C:H:O) of **X** is 4.05 : 8.1 : 2.7 **OR** $\frac{48.65}{12.0} : \frac{8.11}{1.0} : \frac{43.24}{16.0}$ ✓ (Empirical formula) is $C_3H_6O_2$ ✓ M_r is 74.0 so **X** is $C_3H_6O_2$ ✓		**ALLOW X** contains C=O and O–H because of absorptions at 1720 cm^{-1} and 2500 to 3300 cm^{-1} **ALLOW X** contains carboxylic acid/COOH because of absorption at 1720 cm^{-1} and (broad) absorption between 2500 to 3300 cm^{-1} ✓✓ **ALLOW** alternative approach to molecular formula M_r is 74.0 ✓ 74 x $\frac{48.65}{100}$: 74 x $\frac{8.11}{100}$: 74 x $\frac{43.24}{100}$ = 36 : 6 : 32 ✓ $C_3H_6O_2$ ✓ This mark is for some evidence of using M_r to deduce the molecular or structural formula **ALLOW** M_r is 74.0 so **X** is CH_3CH_2COOH ✓ **DO NOT ALLOW** ECF from the empirical formula with the wrong molar ratio

Question	Answer	Mark	Guidance
	Compound Y QWC **Y** contains O–H because of absorption between 3100 and 3500 cm^{-1} ✓ QWC Mass spec of **Y** has molecular ion, *m*/*z* = 46 so M_r is 46 ✓ Correct identification of one fragment from a *m*/*z* value e.g. *m/z* = 31 is CH_2OH^+; *m/z* = 29 is $C_2H_5^+$; *m/z* = 15 is CH_3^+ ✓		**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW Y** is an alcohol (or phenol) because of absorption between 3200 and 3550 cm^{-1} **ALLOW Y** contains C–O, C–H and O–H bonds because of absorptions at approximately 1030, 2950 and 3350 cm^{-1} **ALLOW** *m/z* = 46 so M_r is 46 **OR** mass spectrum has a peak at 46 which is the M_r **OR** M_r is 46 because of *m/z* peak shown on the actual spectra M_r = 46 on its own is **not** sufficient *m*/*z* = 46 on its own is not sufficient **ALLOW** *m/z* = 31 shows CH_2OH (fragment); *m/z* = 29 shows C_2H_5 (fragment); *m/z* = 15 is CH_3 (fragment)
	Identification of compounds So **X** must be CH_3CH_2COOH **OR** propanoic acid ✓ So **Y** is ethanol **OR** C_2H_5OH **OR** CH_3CH_2OH ✓ **Z** is $CH_3CH_2COOC_2H_5$ **OR** ethyl propanoate ✓	**3**	**Note**: an incorrect name CONs a correct structure **ALLOW** skeletal **OR** displayed formula throughout **DO NOT ALLOW** propanoic acid with wrong structure or incorrect molecular formula **DO NOT ALLOW** ethanol with wrong structure or incorrect molecular formula **DO NOT ALLOW** ethyl propanoate with wrong structure or incorrect molecular formula **ALLOW** ECF for identification of **Z** from incorrect **X** and **Y**. **DO NOT ALLOW** this ECF if name and structures of **X** or **Y** do **not** match
	Total	**10**	

Question			Expected Answers	Marks	Additional Guidance
5	a	i	**Any two from:** Any value between 1000–1300 ✓ Any value between 2850–3100 ✓ Any value between 3200–3550 ✓	2	
		ii	Orange to green or blue ✓	1	
		iii	$CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$ **OR** $CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$ Correct organic product ✓ Balanced equation ✓	2	**IGNORE** any state symbols **ALLOW** CH_3COH in equation but not for the structure **ALLOW** equations with molecular formulae but not the product mark
	b	i	Absorption around 2850–3100 (cm^{-1}) so contains C—H bonds ✓ No other **important** absorptions present / no other **characteristic** absorptions ✓	2	Answer must have a reference to infrared spectrum i.e. use of cm^{-1} or data from the infrared spectrum 'Has no other peaks so no functional groups present' is **not** sufficient **BUT** There are no peaks due to functional groups is sufficient **ALLOW** peaks instead of absorption **ALLOW** no absorption due to C=O and O–H / no absorption due to carbonyl and hydroxyl
		ii	Peak furthest to right hand side is 58 / molecular ion peak is 58 / peak at highest mass ✓	1	**ALLOW** peak at *m*/*z* 58 marked on the mass spectrum / M peak is 58 / peak at 58 linked to the molecular mass **DO NOT ALLOW** highest peak but **ALLOW** 58 is the highest peak

Question			Expected Answers	Marks	Additional Guidance
	b	**iii**	 **BOTH** isomers correct ✓	1	If three structures are drawn then do not award mark **ALLOW** skeletal formulae / structural formulae **IGNORE** incorrect names
		iv	CH_3^+ ✓ $C_2H_5^+$ ✓ $C_3H_7^+$ / $CH_3CH_2CH_2^+$ / $(CH_3)_2CH^+$ ✓	3	Essentially marks are allocated as positive ions ✓ Formula of two fragments correct (ignore charge) ✓ **BUT** formulae of all three fragments correct (ignore charge) ✓✓
		v	$CH_3CH_2CH_2CH_3$ because there is a peak at *m*/*z* = 29 ✓	1	**ALLOW** name, displayed or skeletal structure **ALLOW** butane because there is a C_2H_5 fragment **ALLOW** butane because it gives all three fragments listed in **(iv)**
			Total	**13**	