



## 4: Organic chemistry 1 – Topic questions

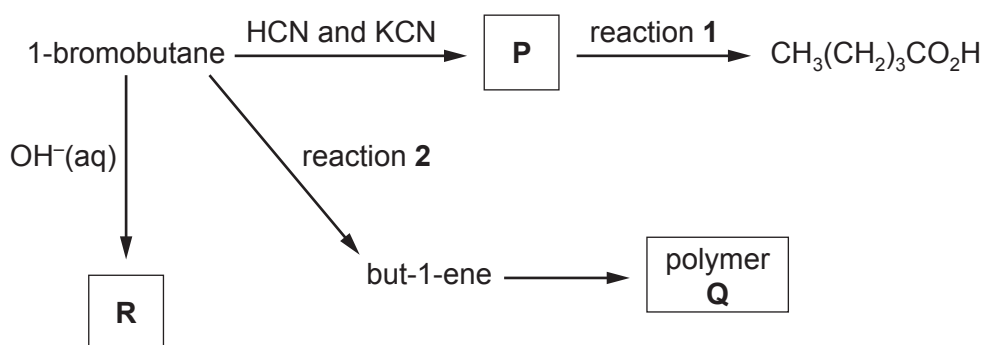
The questions in this document have been compiled from a number of past papers, as indicated in the table below.

Use these questions to formatively assess your learners' understanding of this topic.

Question	Year	Series	Paper number
3	2017	March	22
4	2017	June	21
4	2017	June	22

The mark scheme for each question is provided at the end of the document.

3 (a) A series of reactions starting from 1-bromobutane is shown.



(i) Draw the **displayed** formula of compound **P**.

[1]

(ii) Identify the reagent(s) and conditions for reactions 1 and 2.

reaction 1 .....

reaction 2 .....

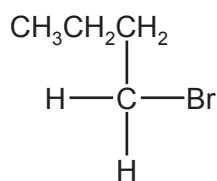
[2]

(iii) Draw the structure of the repeat unit of polymer **Q**.

[2]

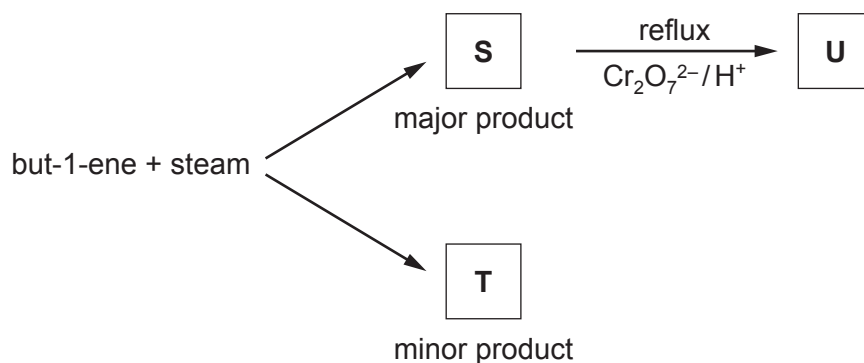
- (b) Complete the reaction scheme to show the mechanism of the reaction of 1-bromobutane with  $\text{OH}^-(\text{aq})$  to produce **R**.

Include all necessary charges, dipoles, lone pairs and curly arrows and the structure of **R**.



[3]

- (c) But-1-ene reacts with steam as shown to form a mixture of two structural isomers, **S** and **T**.



**S** can be oxidised with acidified potassium dichromate(VI) to form compound **U**.  
**S** and **U** both react with alkaline aqueous iodine.

- (i) Identify the *type of reaction* that occurs when but-1-ene reacts with steam.

..... [1]

- (ii) State what can be deduced about the structure of **S** from its reaction with alkaline aqueous iodine.

..... [1]

(iii) Explain why **S** is the major product of the reaction of but-1-ene with steam.

.....

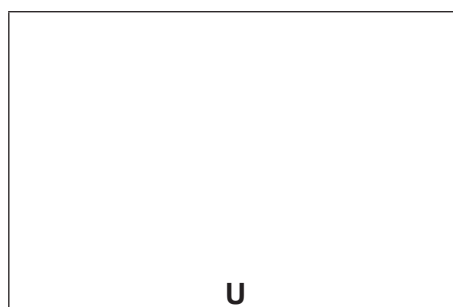
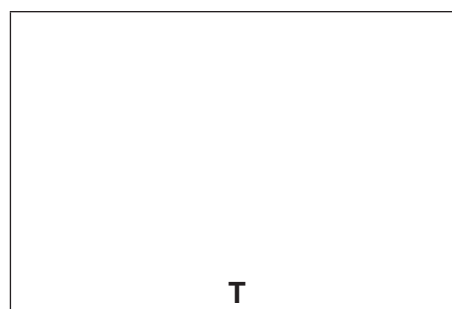
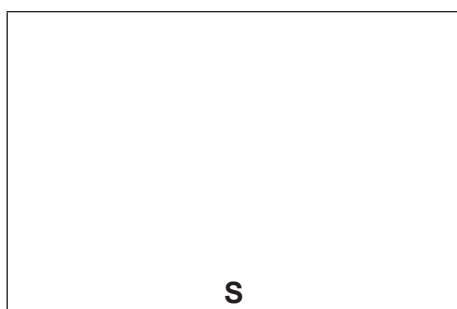
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.....

.....

..... [2]

(iv) Draw the **skeletal** formulae of **S**, **T** and **U**.



[3]

(v) Write an equation to represent the oxidation of **S** to **U** by acidified potassium dichromate(VI).  
You should use [O] to represent the oxidising agent.

..... [1]

(d)  $\text{CH}_3(\text{CH}_2)_3\text{CO}_2\text{H}$  is a colourless liquid with an unpleasant odour.

It reacts with methanol in the presence of an acid catalyst to produce an organic product **V**, which has a pleasant fruity smell.

(i) Name **V**.

..... [1]

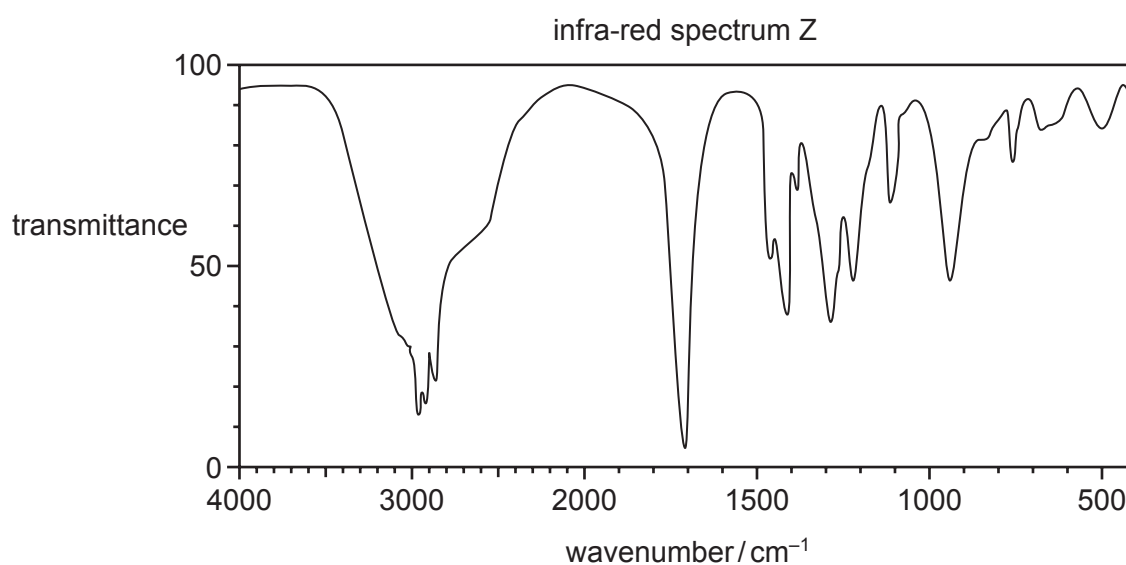
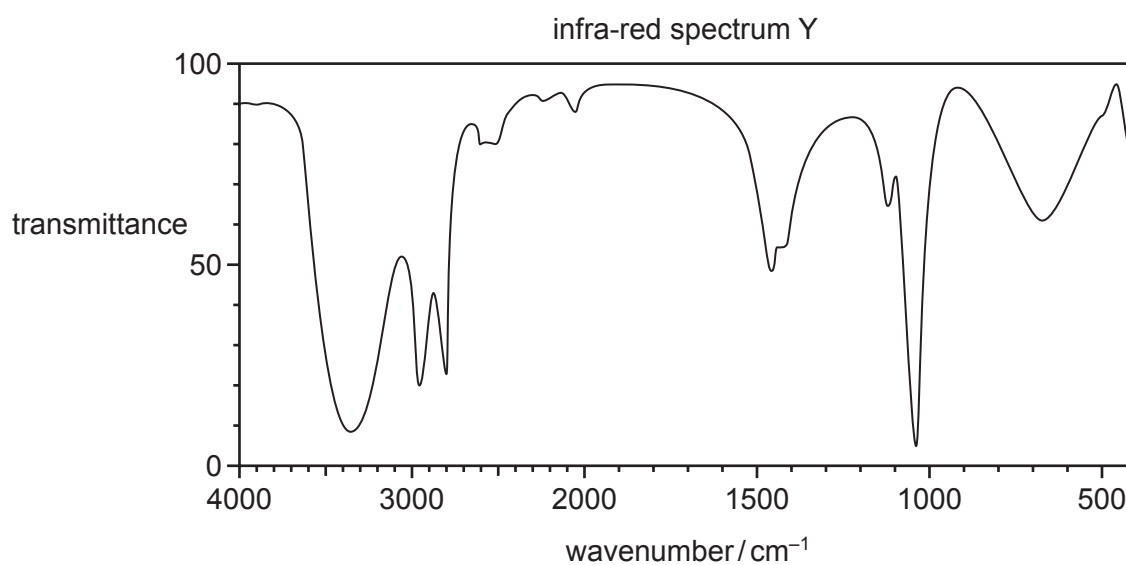
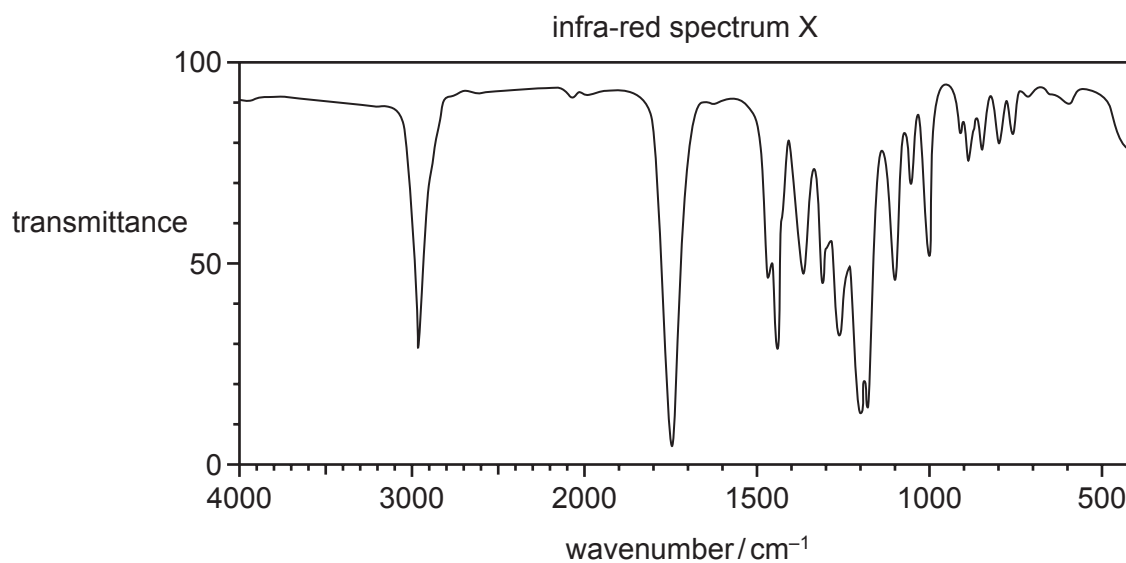
(ii) A student analysed  $\text{CH}_3(\text{CH}_2)_3\text{CO}_2\text{H}$ , methanol and **V** using infra-red spectroscopy. The spectra were returned to the student without labels.

Identify which of the infra-red spectra, X, Y or Z, corresponds to **V**.

compound	$\text{CH}_3(\text{CH}_2)_3\text{CO}_2\text{H}$	methanol	<b>V</b>
spectrum			

Explain your answer with reference to relevant features of the **three** spectra in the region above  $1500\text{ cm}^{-1}$ .

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.....  
.....  
.....  
.....  
..... [4]



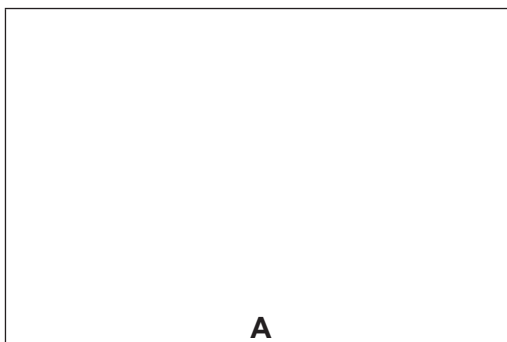
[Total: 21]

- 4 (a) The hydrocarbons **A**,  $C_4H_{10}$ , and **B**,  $C_4H_8$ , are both unbranched.

**A** does **not** decolourise bromine.

**B** decolourises bromine and shows geometrical isomerism.

- (i) Draw the skeletal formula of **A**.



[1]

- (ii) The hydrocarbon **A**,  $C_4H_{10}$ , has a branched isomer.

Suggest why unbranched **A** has a higher boiling point than its branched isomer.

.....

.....

.....

.....

..... [2]

- (iii) Give the structural formula of **B**.

..... [1]

- (iv) Explain why **B** shows geometrical isomerism.

.....

.....

.....

..... [2]

- (v) Draw the mechanism of the reaction of **B** with bromine, Br<sub>2</sub>.  
Include all necessary charges, dipoles, lone pairs and curly arrows.

[4]

- (vi) Explain the origin of the dipole on Br<sub>2</sub> in this mechanism.

.....  
.....  
..... [1]

- (b) The alcohols **C** and **D** are isomers of each other with molecular formula C<sub>4</sub>H<sub>10</sub>O. Both isomers are branched.

When **C** is heated under reflux with acidified potassium dichromate(VI) no colour change is observed.

When **D** is heated under reflux with acidified potassium dichromate(VI) the colour of the mixture changes from orange to green and **E**, C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>, is produced.

**E** reacts with aqueous sodium carbonate to form carbon dioxide gas.

- (i) Identify **C**, **D** and **E**.

<b>C</b>	<b>D</b>	<b>E</b>
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[3]

- (ii) Write the equation for the reaction between **E** and aqueous sodium carbonate.

..... [1]



(c) The isomers **F** and **G**,  $C_5H_{10}O$ , both form an orange precipitate when reacted with 2,4-DNPH.

**F** is unbranched and reacts with alkaline aqueous iodine to produce a yellow precipitate.

**G** does not react with alkaline aqueous iodine. It contains a chiral centre and produces a silver mirror when warmed with Tollens' reagent.

(i) Name the yellow precipitate produced by the reaction between **F** and alkaline aqueous iodine.

..... [1]

(ii) Give the structural formula of **F** and of **G**.

**F** .....

**G** .....

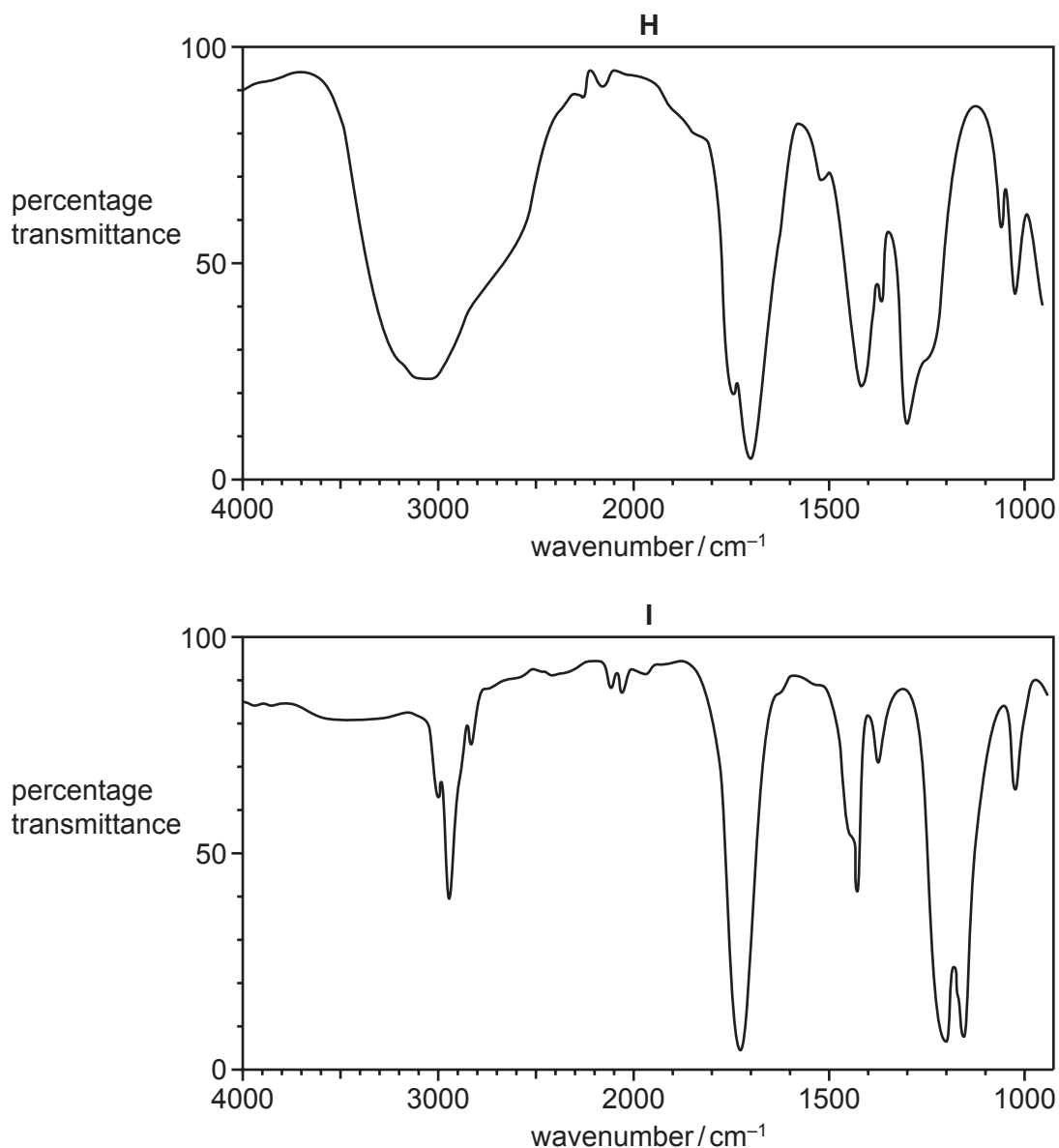
[2]

(iii) Explain the meaning of the term *chiral centre*.

.....

..... [1]

(d) **H** and **I** are isomers with molecular formula  $C_2H_4O_2$ . The infra-red spectra of isomers **H** and **I** are shown.



(i) Identify the bonds responsible for the principal peaks above  $1500\text{ cm}^{-1}$  in each spectrum.

spectrum of **H** .....

.....

spectrum of **I** .....

.....

[2]

(ii) Name **H** and **I**.

**H** .....

**I** .....

[2]

[Total: 23]

4 **P**, **Q** and **R** all have the molecular formula  $C_3H_6O$ . They are all structural isomers of each other.

**P** and **Q** each contain an oxygen atom bonded directly to a carbon atom that is  $sp^2$  hybridised.  
**R** contains an oxygen atom bonded directly to a carbon atom that is  $sp^3$  hybridised.

(a) (i) Explain the meaning of the term *structural isomers*.

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.....  
.....  
..... [2]

(ii) Explain how  $sp^2$  and  $sp^3$  hybridisation can occur in carbon atoms.

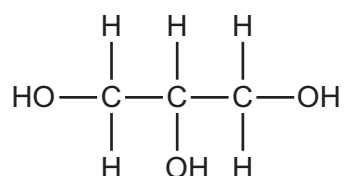
$sp^2$  hybridisation .....  
.....  
 $sp^3$  hybridisation .....  
..... [2]

(iii) State the bond angles normally associated with each type of hybridisation in carbon atoms.

$sp^2$  .....  
 $sp^3$  ..... [2]

(b) **R** contains two different functional groups, one of which is an alkene group.

**R** reacts with cold, dilute, acidified manganate(VII) ions to form propane-1,2,3-triol.



propane-1,2,3-triol

(i) Give the displayed formula of **R**.

[1]

(ii) State the type of reaction and what you would observe when **R** reacts with bromine water.

.....  
..... [2]

(iii) Draw the structure of the product formed when **R** reacts with bromine water.

[1]

(iv) Identify the gaseous product formed when **R** reacts with hot, concentrated, acidified manganate(VII) ions.

..... [1]

(c) **P** and **Q** ( $C_3H_6O$ ) both form an orange precipitate when reacted with 2,4-DNPH. Only **Q** produces a yellow precipitate when reacted with alkaline aqueous iodine.

(i) Name **P** and **Q**.

**P** .....

**Q** .....

[2]

(ii) Identify the yellow precipitate formed by the reaction of **Q** with alkaline aqueous iodine.

..... [1]

(d) **P** and **Q** each react with hydrogen cyanide to form a single product.

The product formed from **P** exists as a pair of optical isomers.

The product formed from **Q** does not exhibit optical isomerism.

(i) Explain the meaning of the term *optical isomers*.

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.....  
..... [2]

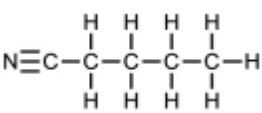
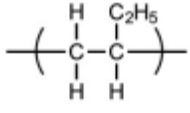
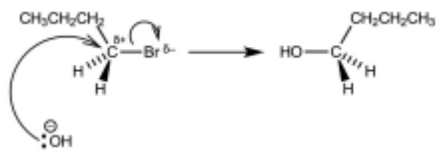
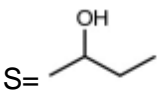
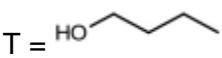
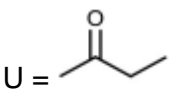
- (ii) Ethanal,  $\text{CH}_3\text{CHO}$ , also reacts with hydrogen cyanide. The product of this reaction is  $\text{CH}_3\text{CH}(\text{OH})\text{CN}$ .


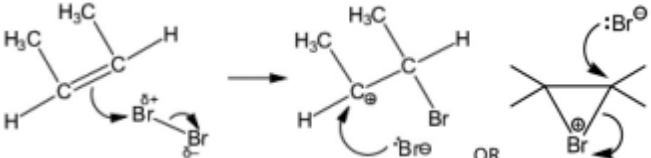
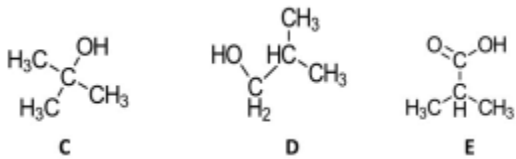
Draw the mechanism of this reaction.

Include all necessary charges, dipoles, lone pairs and curly arrows.

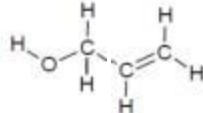
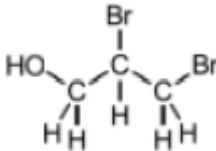
[3]

[Total: 19]

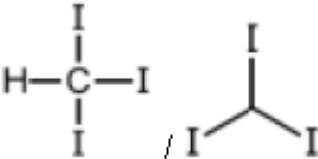
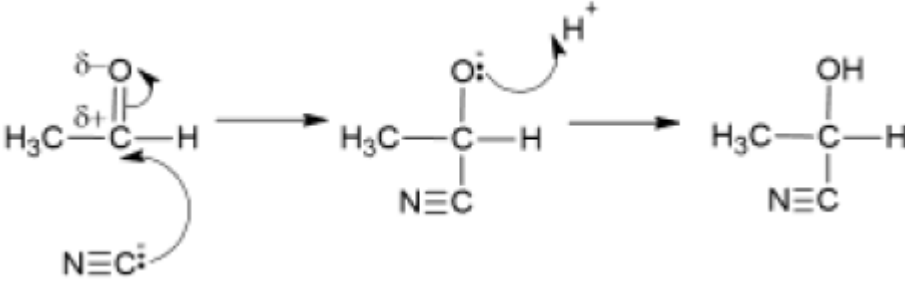
Question	Answer	Marks
3 (a) (i)		1
3 (a) (ii)	reaction 1 = $\text{HCl (aq)}$	1
	reaction 2 = (conc.) $\text{NaOH / KOH AND ethanol}$	1
3 (a) (iii)		
	C–C backbone with dangling bonds	1
	rest of structure	1
3 (b)		
	lone pair on O <b>AND</b> curly arrow from O to C of C–Br	1
	dipole on C–Br <b>AND</b> curly arrow from C–Br to Br	1
	product (butan-1-ol)	1
3 (c) (i)	(electrophilic) addition	1
3 (c) (ii)	<b>S</b> has $\text{CH}_3\text{CHOH}$ <b>OR</b> methyl / $\text{CH}_3$ group next to $\text{CHOH}$	1
3 (c) (iii)	positive inductive effect of more alkyl groups / more alkyl groups donate electron density	1
	secondary carbocation / secondary intermediate is more stable (than primary)	1
3 (c) (iv)	<b>S</b> = 	1
	<b>T</b> = 	1
	<b>U</b> = 	1
3 (c) (v)	$\text{CH}_3\text{CHOHCH}_2\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}_2\text{CH}_3 + \text{H}_2\text{O}$	1
3 (d) (i)	methyl pentanoate	1
3 (d) (ii)	(compound <b>V</b> is) spectrum X	1
	spectra X and Z show a $\text{C}=\text{O}$ (stretch) at $1730\text{ (cm}^{-1}\text{)}$	1
	spectra Y and Z show $\text{O}-\text{H}$ (stretches) above $2500\text{ (cm}^{-1}\text{)}$	1
	<b>V</b> has a $\text{C}=\text{O}$ (bond) and no $\text{O}-\text{H}$ (bond)	1
		Total: 21

Question	Answer	Marks
4 (a) (i)	(A = ) 	1
4 (a) (ii)	(A / straight chain) has strong(er) (temporary dipole-) induced dipole (attractions) <i>ora</i>	1
	(because A / straight chain has) bigger (surface) area / more (points of) contact (in unbranched isomer) <i>ora</i> OR (so) more energy required to break the intermolecular forces <i>ora</i>	1
4 (a) (iii)	CH <sub>3</sub> CHCHCH <sub>3</sub> OR CH <sub>3</sub> CH=CHCH <sub>3</sub>	1
4 (a) (iv)	No rotation / restricted / limited rotation of C=C / (carbon) double bond	1
	One (of the two) methyl groups / one (of the two) H (atoms) is on each C (of C=C)	1
4 (a) (v)	 arrow from the C=C double bond drawn to the bromine	1
	dipole on Br <sub>2</sub> in correct orientation AND arrow from the Br-Br bond to the Br <sup>δ-</sup>	1
	correct carbocation / bromonium ion from the structure with C=C drawn	1
	Br <sup>-</sup> with lone pair, negative charge AND arrow from lone pair to the carbon atom of intermediate OR using both arrows shown (in alternative diagram)	1
4 (a) (vi)	electrons in pi bond induce it (the dipole) OR (high) electron density in pi bond / double bond / C=C repels electrons (away from nearest Br) OR polarised by (high) electron density in pi bond / double bond / C=C	1
4 (b) (i)	<b>C</b> = (2-)methylpropan-2-ol / (CH <sub>3</sub> ) <sub>3</sub> COH / any unambiguous structure	1
	<b>D</b> = (2-)methylpropan-1-ol / (CH <sub>3</sub> ) <sub>2</sub> CHCH <sub>2</sub> OH / any unambiguous structure	1
	<b>E</b> = (2-)methylpropanoic acid / (CH <sub>3</sub> ) <sub>2</sub> CHCO <sub>2</sub> H / any unambiguous structure	1
	 <b>C</b> <b>D</b> <b>E</b>	
4 (b) (i)	2C <sub>4</sub> H <sub>8</sub> O <sub>2</sub> + Na <sub>2</sub> CO <sub>3</sub> → 2C <sub>4</sub> H <sub>7</sub> O <sub>2</sub> Na + H <sub>2</sub> O + CO <sub>2</sub>	1
4 (c) (i)	triiodomethane	1

Question	Answer	Marks
4 (c) (ii)	<b>F</b> = $\text{CH}_3\text{CH}_2\text{CH}_2\text{COCH}_3$	<b>1</b>
	<b>G</b> = $\text{C}_2\text{H}_5\text{CH}(\text{CH}_3)\text{CHO}$	<b>1</b>
4 (c) (iii)	a (tetrahedral) atom with four different groups / atoms / substituents attached OR a carbon (atom) with four different groups / atoms / substituents attached	<b>1</b>
4 (d) (i)	<b>H</b> $\text{C}=\text{O}$ (group / bond) AND $\text{O}-\text{H}$ (group / bond)	<b>1</b>
	<b>I</b> $\text{C}=\text{O}$ (group / bond) AND $\text{C}-\text{H}$ (group / bond)	<b>1</b>
Total: 21		

Question	Answer	Marks
4 (a) (i)	(molecules / isomers with) the same molecular formula / same number of atoms of each element	<b>1</b>
	different structural / displayed formulae / arrangement of bonds	<b>1</b>
4 (a) (ii)	$\text{sp}^2$ overlap of (2)s with (2)p (atomic) orbitals	<b>1</b>
	$\text{sp}^3$ overlap of (2)s with all three (2)p (atomic) orbitals	<b>1</b>
4 (a) (iii)	$\text{sp}^2 = 116^\circ - 124^\circ$	<b>1</b>
	$\text{sp}^3 = 106^\circ - 112^\circ$	<b>1</b>
4 (b) (i)		<b>1</b>
4 (b) (ii)	(electrophilic) addition	<b>1</b>
	bromine decolourises / turns colourless / fades (from orange / brown)	<b>1</b>
4 (b) (iii)	 $\text{HOCH}_2\text{CHBrCH}_2\text{Br}$ OR	<b>1</b>
4 (b) (iv)	$\text{CO}_2$ / carbon dioxide	<b>1</b>
4 (c) (i)	<b>P</b> = propanal	<b>1</b>
	<b>Q</b> = propanone	<b>1</b>



Question	Answer	Marks
4 (c) (ii)	 tr(i)iodomethane / $\text{CHI}_3$	1
4 (d) (i)	(molecules / isomers with) the same (molecular and) structural formula	1
	Any two of: <ul style="list-style-type: none"> <li>• Chiral centre / C attached to four different groups / atoms</li> <li>• Non-super(im)posable mirror images</li> <li>• Different spatial / 3D arrangement of atoms (owtte)</li> <li>• Different rotation of plane-polarised light</li> </ul>	1
4 (d) (ii)		1
	curly arrow from lone pair on $\text{:C}\equiv\text{N}$ to $\text{C}^{(\delta+)}$	1
	correct dipole on carbonyl $\delta^+\text{C}=\text{O}^{\delta-}$ AND curly arrow from bond to $\text{O}^{(\delta-)}$	1
	correct intermediate, including $\text{C}-\text{O}^-$ AND curly arrow from lone pair to $\text{H}^+$	1
Total: 19		

Notes about the mark scheme are available separately.