

1 This question is about the six alcohols below.

butan-2-ol
2-methylpentan-3-ol
propan-1-ol

ethane-1,2-diol
2-methylpropan-2-ol
propan-2-ol

(a) Which alcohol is an example of a tertiary alcohol?

..... [1]

(b) Draw the skeletal formula for 2-methylpentan-3-ol.

[1]

(c) Butan-2-ol and 2-methylpropan-2-ol are structural isomers.

(i) What is meant by the term *structural isomer*?

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

(ii) Draw another structural isomer of these two alcohols.

[1]

(d) Ethane-1,2-diol can be dissolved in water to act as an anti-freeze in car radiators.

Explain why ethane-1,2-diol is very soluble in water.

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.....
.....

..... [2]
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- (e) Ethane-1,2-diol is heated under reflux with ethanoic acid and a small amount of H_2SO_4 catalyst. Compound **A** is formed with molecular formula $\text{C}_6\text{H}_{10}\text{O}_4$.

Draw the structure of compound **A**.

[2]

- (f) Butan-2-ol is heated with H_2SO_4 catalyst.

- A mixture of **three** alkenes forms, **B**, **C** and **D**.
- The alkenes **B** and **C** are stereoisomers.

- (i) Draw the structures of the two stereoisomers **B** and **C**.

[2]

- (ii) What type of stereoisomerism is shown by **B** and **C**?

..... [1]

- (iii) Draw the structure of the other alkene, **D**, that is formed in this reaction.

[1]

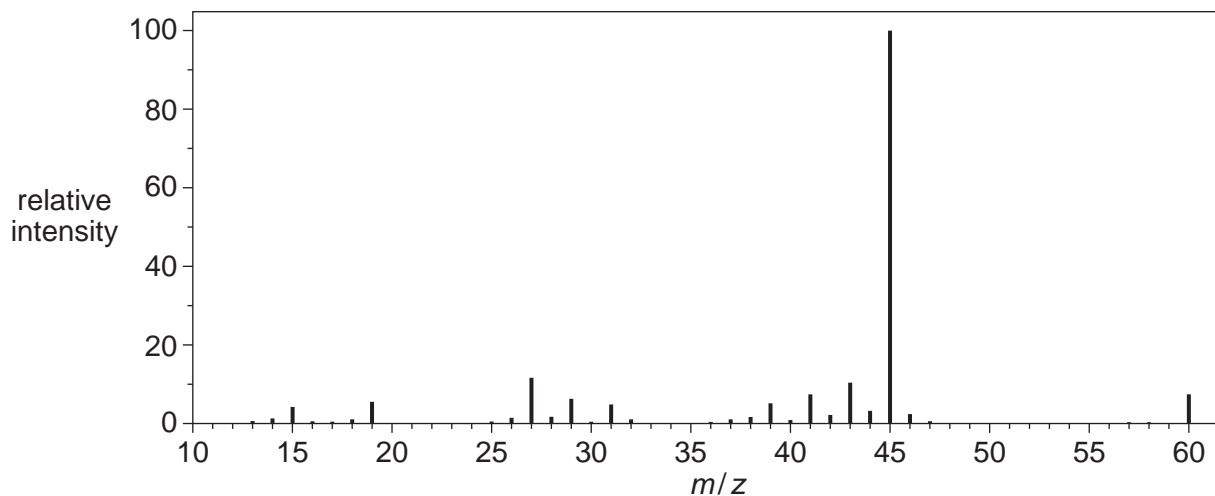
(g) Alcohol **E** is one of the following alcohols.

butan-2-ol
2-methylpentan-3-ol
propan-1-ol

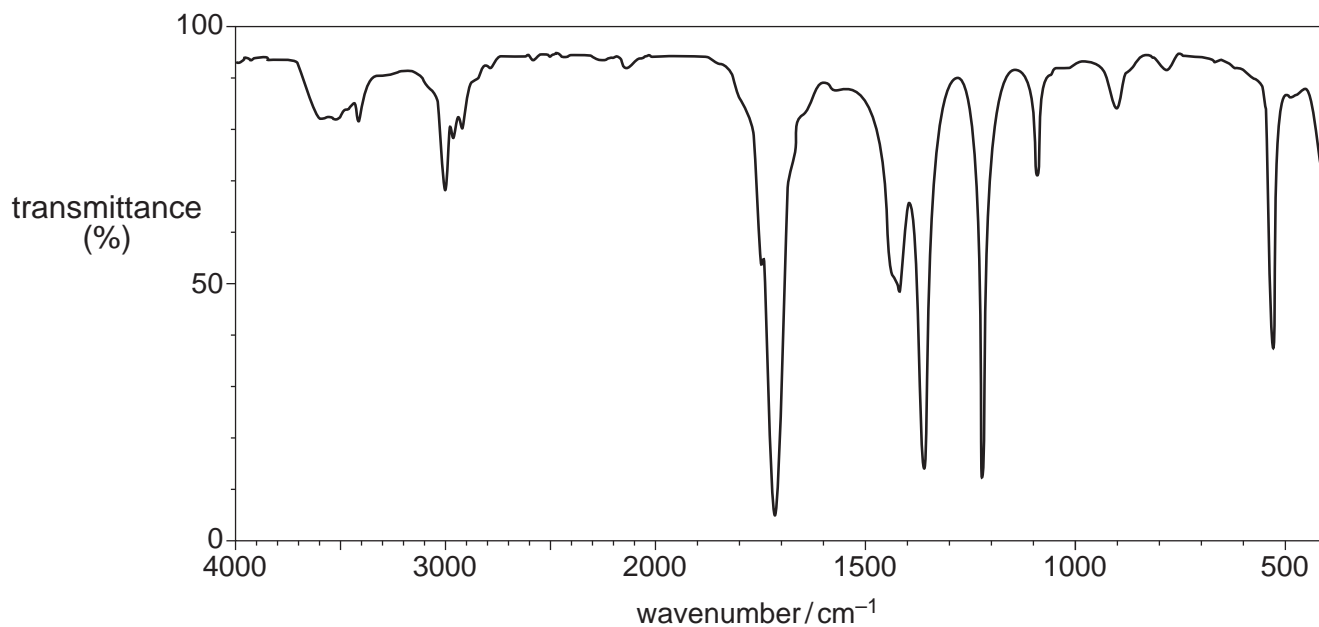
ethane-1,2-diol
2-methylpropan-2-ol
propan-2-ol

A student oxidises alcohol **E** by heating under reflux with excess acidified potassium dichromate(VI). An organic product **F** is isolated.

The mass spectrum of the alcohol **E** is shown below.



The infrared spectrum of the organic product **F** is shown below.

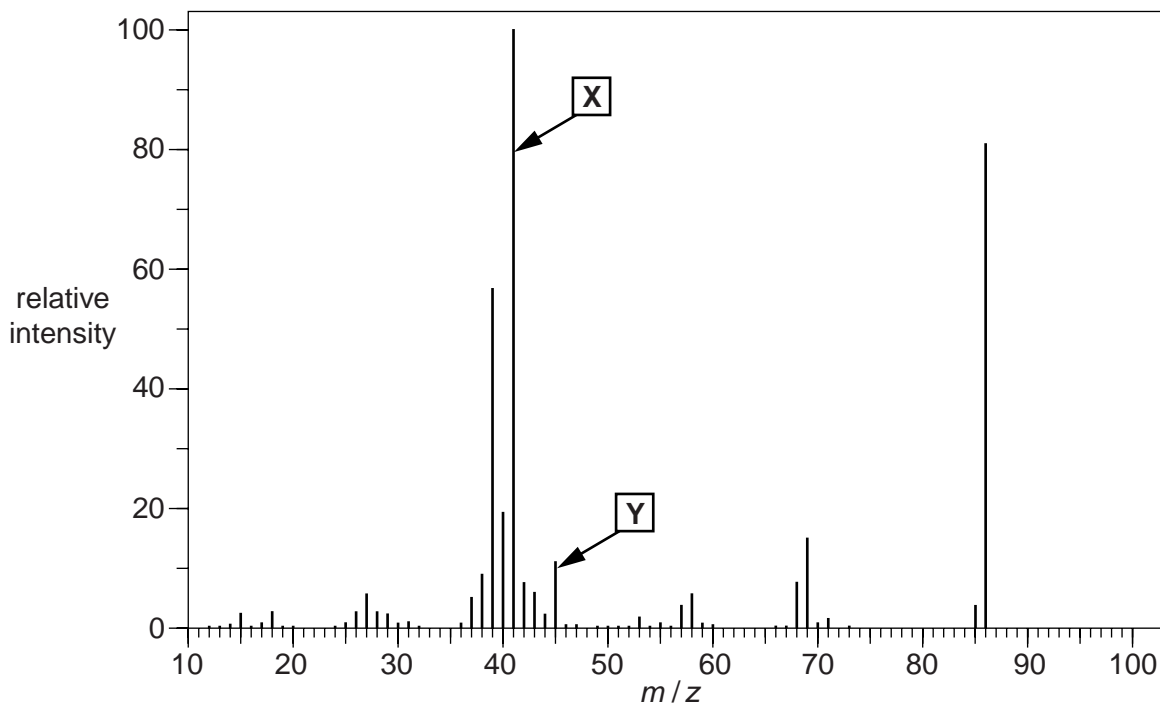


(b) Compound **G** is a branched-chain organic compound that does **not** have *E* and *Z* isomers.

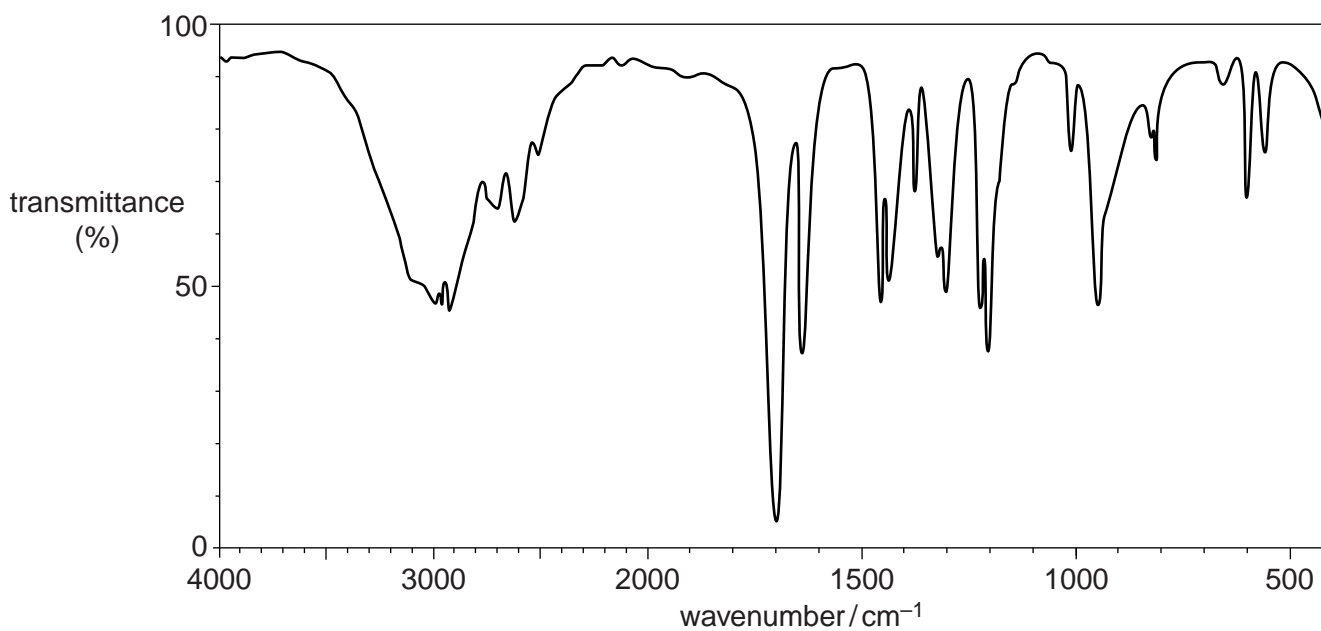
Elemental analysis of compound **G** gave the following percentage composition by mass: C, 55.8%; H, 7.0%; O, 37.2%.

The mass spectrum and infrared spectrum of compound **G** are shown below.

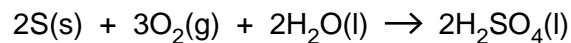
Mass spectrum



Infrared spectrum



- 3 Sulfuric acid is made from sulfur, oxygen and water in a three-stage process. This can be represented by the following overall equation.



- (a) Explain why the overall process to make sulfuric acid has an atom economy of 100%.

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

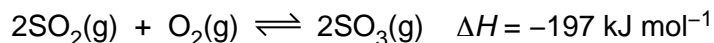
- (b) A factory uses 51.4 tonnes of sulfur to manufacture 147 tonnes of H_2SO_4 .

What is the percentage yield of H_2SO_4 ?

Give your answer to **two** significant figures. (1 tonne = 1×10^6 g)

percentage yield = % [3]

- (c) One of the reactions involved in making sulfuric acid converts sulfur dioxide, SO₂, into sulfur trioxide, SO₃.



This reaction can be carried out at 450 °C and 3 atmospheres pressure in the presence of a V₂O₅ catalyst.

Under these conditions the position of equilibrium is almost completely on the right-hand side.

- (i) A research chemist investigates this reaction.
He uses a temperature of 450 °C and 3 atmospheres pressure.
The research chemist does **not** use the catalyst.

Predict the changes, if any, on each of the following.

position of equilibrium

rate of backward reaction [2]

- (ii) The temperature of the reaction mixture is **increased** to 600 °C.

State and explain what will happen to the position of equilibrium.

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

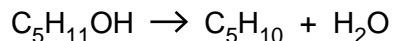
- (iii) The pressure of the reaction mixture is **decreased** to 2 atmospheres.

State and explain what will happen to the position of equilibrium.

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

(d) Concentrated H_2SO_4 is used as an acid catalyst in the elimination of water from alcohols.

There are several alcohols that are structural isomers with the formula $\text{C}_5\text{H}_{11}\text{OH}$. When these alcohols are heated with H_2SO_4 they form alkenes.



(i) Pentan-1-ol is a structural isomer of $\text{C}_5\text{H}_{11}\text{OH}$ that is a primary alcohol.

Draw the structure of another structural isomer of $\text{C}_5\text{H}_{11}\text{OH}$ that is a primary alcohol.

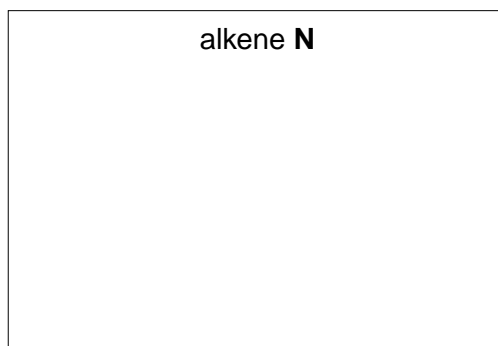
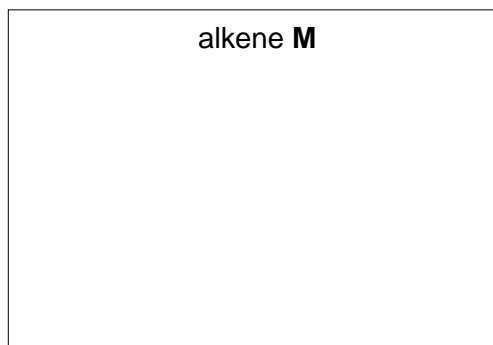
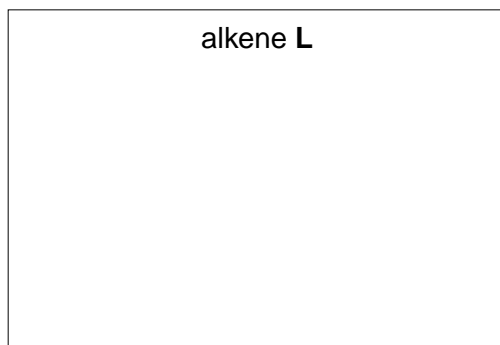
[1]

(ii) Pentan-2-ol is a structural isomer of $\text{C}_5\text{H}_{11}\text{OH}$ that is a secondary alcohol. Pentan-2-ol is heated with H_2SO_4 .

Three alkenes are formed, **L**, **M** and **N**.

- **L** and **M** are stereoisomers.
- **N** is a structural isomer of the stereoisomers **L** and **M**.

Draw the structures for alkenes **L**, **M** and **N**.



[3]

- (iii) One structural isomer of $C_5H_{11}OH$ is an alcohol that **cannot** be oxidised by heating with acidified potassium dichromate(VI).

Draw the structure of this alcohol.

[1]

[Total: 13]