1 This question is about the six alcohols below.

butan-2-ol	**ethane-1,2-diol**
2-methylpentan-3-ol	**2-methylpropan-2-ol**
propan-1-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*?

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..... **[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]**

(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 $C_6H_{10}O_4$.

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.

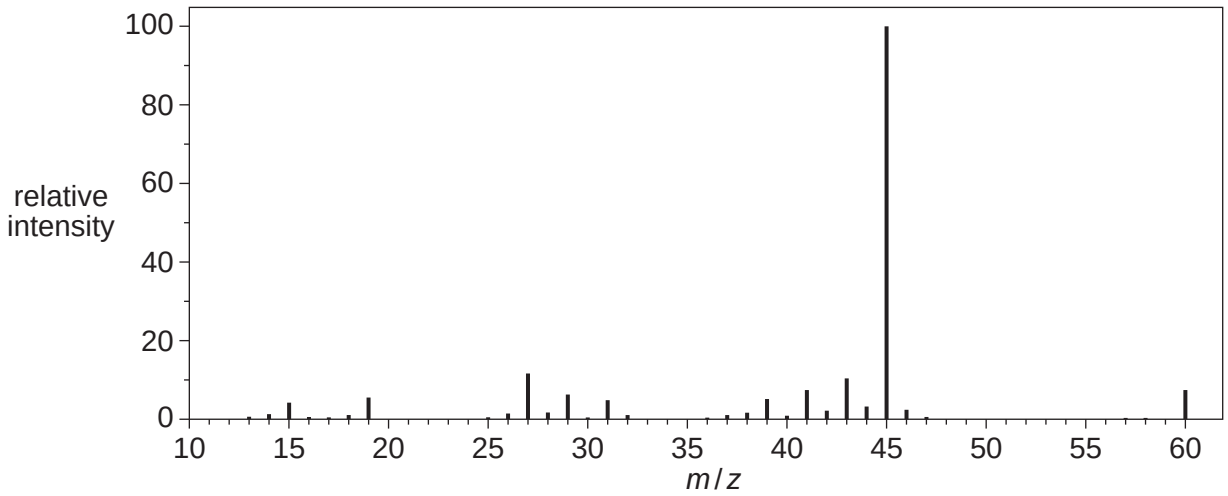
[1]

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

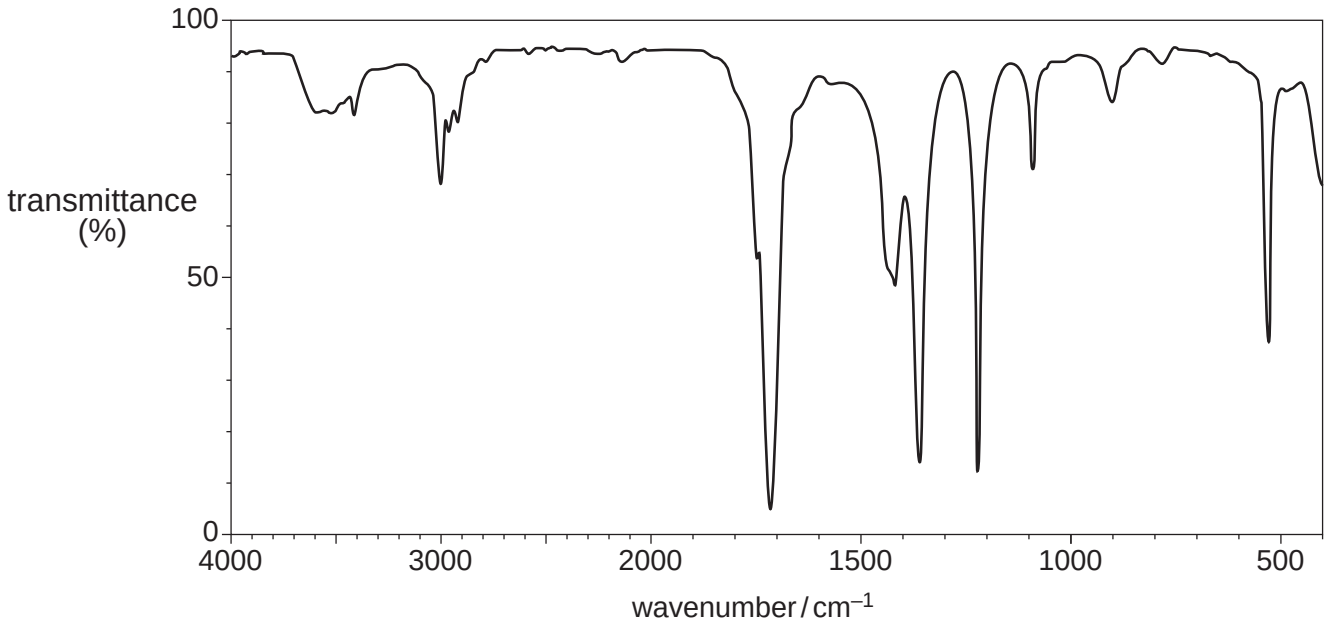
butan-2-ol	**ethane-1,2-diol**
2-methylpentan-3-ol	**2-methylpropan-2-ol**
propan-1-ol	**propan-2-ol**

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.



- Name **or** draw the structures of the alcohol **E** and the organic product **F**.
- Write an equation for the reaction of alcohol **E** with acidified potassium dichromate(VI).

Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).

In your answer, you should make clear how each structure fits with the information given above.

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..... **[7]**

[Total: 19]

2 **(a)** Compound **B**, C_xH_yO, can be oxidised to form a ketone **C**.

0.035 mol of **B** has a mass of 2.59 g.

Compound **B** reacts with compound **D**, $C_3H_6O_2$, in the presence of an acid catalyst to form two compounds **E** and **F**.

- Calculate the molar mass of compound **B**.
- Give the structures of compounds **B**, **C**, **D**, **E** and **F**.

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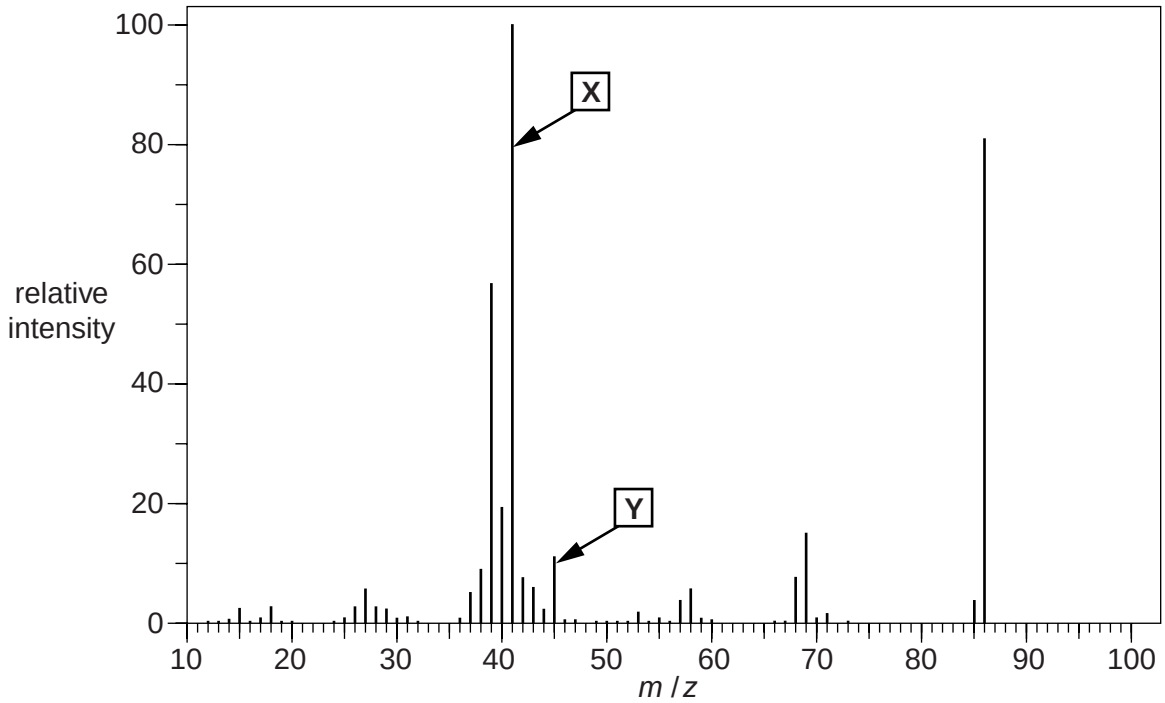
..... **[6]**

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

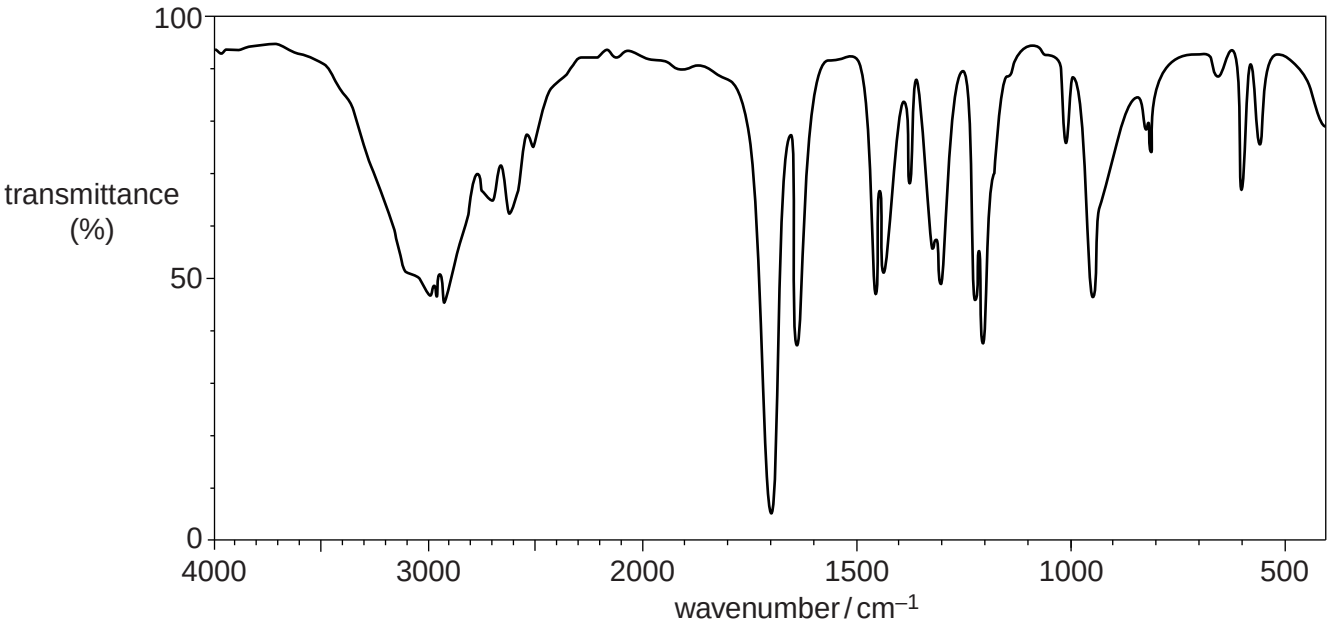
Elemental analysis of compound **G** gave the following percentage composition by mass: C, 55.8%; H, 7.0%; O, 37.2%.

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

Mass spectrum



Infrared spectrum



- Calculate the empirical and molecular formulae for compound **G**.
- Write the formulae for the particles responsible for peak **X** and peak **Y** in the mass spectrum.
- Draw the structure of compound **G**.

*Explain fully how you arrive at a structure for compound **G** using all the evidence provided.*

[7]

[Total: 13]

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

$$2S(s) + 3O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4(l)$$

(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, SO_2, into sulfur trioxide, SO_3.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -197 \text{ kJ mol}^{-1}$$

This reaction can be carried out at 450 °C and 3 atmospheres pressure in the presence of a V_2O_5 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.

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..... **[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 $C_5H_{11}OH$. When these alcohols are heated with H_2SO_4 they form alkenes.

$$C_5H_{11}OH \rightarrow C_5H_{10} + H_2O$$

(i) Pentan-1-ol is a structural isomer of $C_5H_{11}OH$ that is a primary alcohol.

Draw the structure of another structural isomer of $C_5H_{11}OH$ that is a primary alcohol.

[1]

(ii) Pentan-2-ol is a structural isomer of $C_5H_{11}OH$ 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**.

alkene **L**

alkene **M**

alkene **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]