(ii) Two cyclic alkenes, **C** and **D** are formed in stage 3. **C** and **D** are structural isomers. Suggest the structures of **C** and **D**.

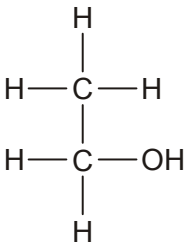
| | |
|---|---|
| | |

[2]

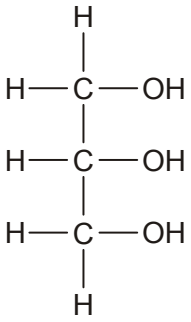
[Total 6 marks]

**15.** Ethanol and glycerol (propane-1,2,3-triol) are both produced industrially on a large scale.

Ethanol is manufactured by both fermentation and the hydration of ethene.
Glycerol is produced as a by-product of soap manufacture.



**ethanol**



**glycerol**

The relatively low volatility of alcohols such as ethanol can be explained by the existence of intermolecular bonds.

(i) Explain what is meant by the terms:

*low volatility*, .....

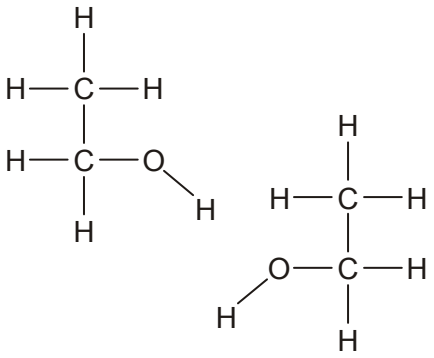
.....

*intermolecular bonds* .....

.....

[2]

(ii) On the ethanol molecules below, label any relevant dipoles, show the intermolecular bond formed and state the type of intermolecular bond.



type of intermolecular bond .....

[3]

(iii) Glycerol forms the same type of intermolecular bonds as ethanol. Predict, with a reason, whether the boiling point of glycerol will be higher or lower than that of ethanol.

The boiling point of glycerol will be ..... than that of ethanol because

.....

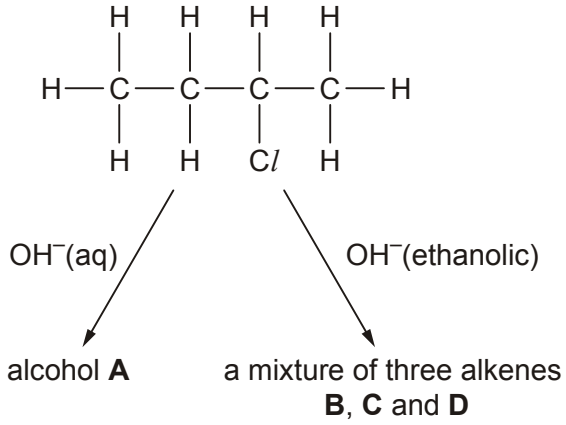
.....

[1]

[Total 6 marks]

**16.** This question is about the halogenoalkane 2-chlorobutane.

2-Chlorobutane reacts with NaOH, but the products are dependent on the solvent used.




2-Chlorobutane reacts with $OH^-$ in aqueous conditions to produce alcohol **A**.

(i) Identify alcohol **A**.

[1]

(ii) Describe, with the aid of curly arrows, the movement of the electrons in the mechanism. Show any relevant dipoles, lone pairs of electrons and the products.

[4]

[Total 5 marks]

**17.** Compound **E** can be oxidised to form a carboxylic acid.

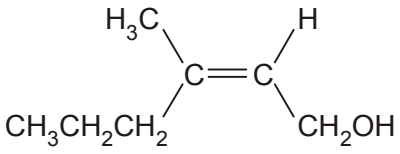
(i) State a suitable oxidising mixture for this reaction.

.....

[2]

(ii) Write a balanced equation for this oxidation of compound **E**.

Use [O] to represent the oxidising mixture.




compound **E**

[3]

(iii) Explain how compound **E** and the carboxylic acid could be distinguished by infra-red spectroscopy.

.....

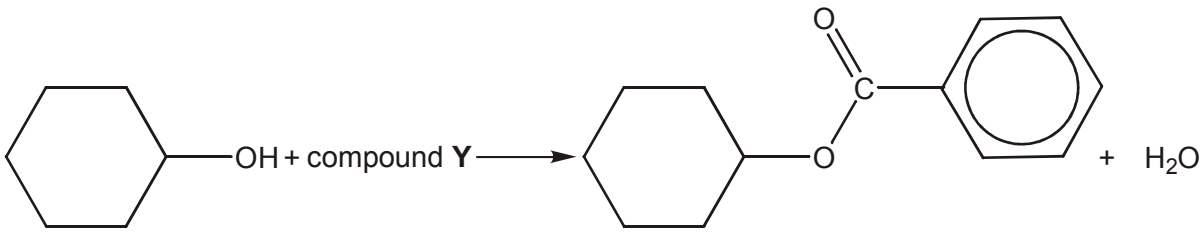
.....

[1]

[Total 6 marks]

**18.** (a) In the presence of a suitable catalyst, cyclohexanol reacts with compound **Y**.

The organic product is shown in the equation below.




**organic product**

(i) State a suitable catalyst.

.....

[1]

(ii) Identify compound **Y**.

[1]

(b) Cyclohexanol can also be oxidised to form cyclohexanone.

(i) State a suitable oxidising agent for this reaction.

.....

[1]

(ii) Write a balanced equation for the oxidation of cyclohexanol to cyclohexanone. Use [O] to represent the oxidising agent.

[1]

[Total 4 marks]

**19.** Ethanol, $C_2H_5OH$, can be produced by the fermentation of glucose, $C_6H_{12}O_6$.

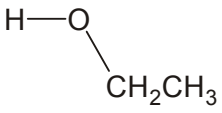
Write a balanced equation for the fermentation of glucose.

.....

[Total 2 marks]

**20.** Ethanol has a relatively high boiling point. This can be explained in terms of intermolecular hydrogen bonds.

Draw a second molecule of ethanol alongside the one drawn below and show how a hydrogen bond could be formed. Clearly show any relevant dipoles and lone pairs of electrons.




[Total 3 marks]

**21.** (a) When ethanol is heated with acidified potassium dichromate(VI) solution, it can be oxidised to form either ethanal, $CH_3CHO$ (Fig. 1), or ethanoic acid, $CH_3COOH$ (Fig. 2).

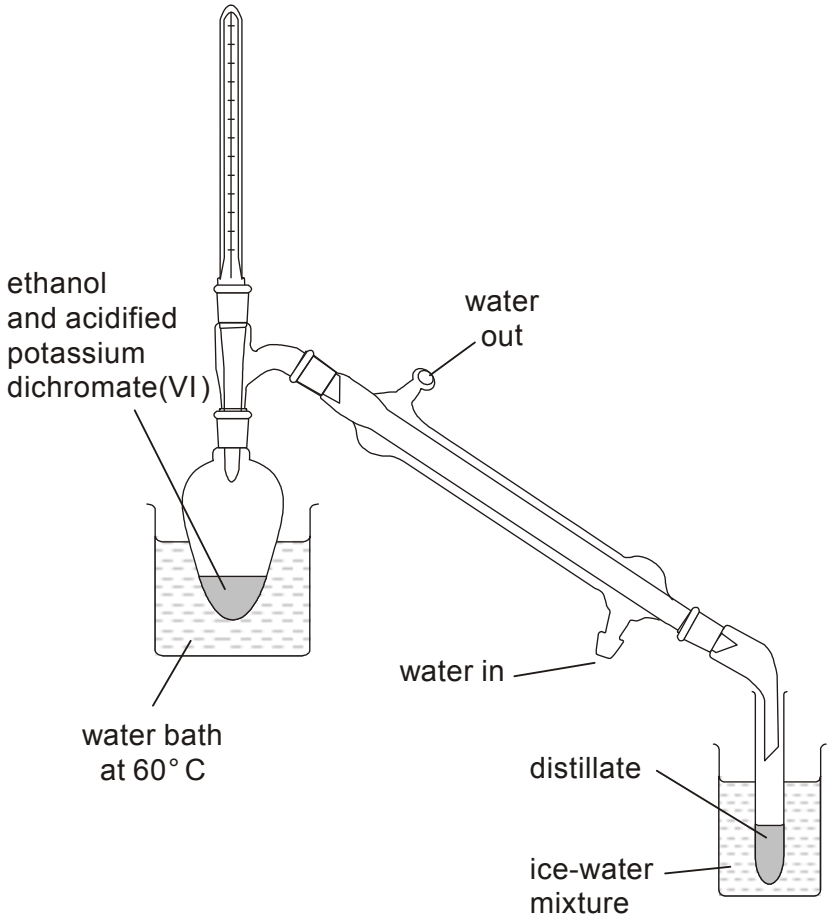



**Fig. 1**

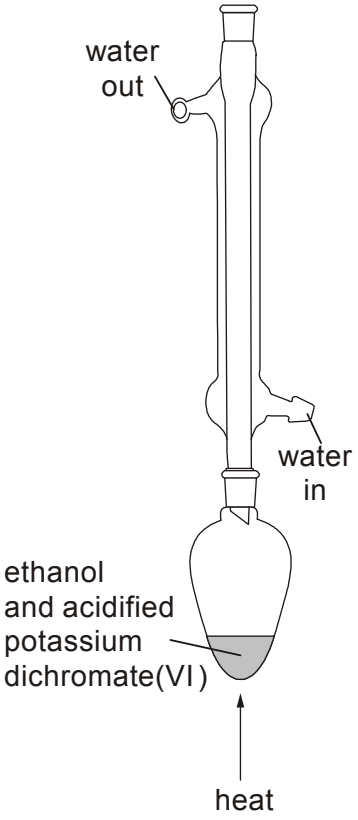



**Fig. 2**

The boiling points of ethanol, ethanal and ethanoic acid are given in the table below.

| | $CH_3CH_2OH$ | $CH_3CHO$ | $CH_3COOH$ |
|---|---|---|---|
| boiling point/ °C | 78 | 21 | 118 |

Use this table of boiling points to explain

(i) why the organic product is likely to be ethanal if the apparatus shown in Fig. 1 is used,

.....

.....

[2]

(ii) why the organic product is likely to be ethanoic acid if the apparatus shown in Fig. 2 is used.

.....

.....

[2]

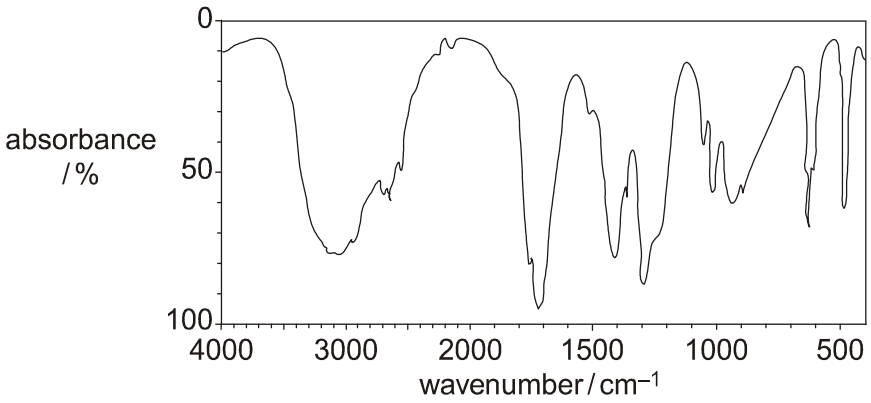
(b) Write a balanced equation for the oxidation of ethanol to ethanoic acid. Use (O) to represent the oxidising agent.

.....

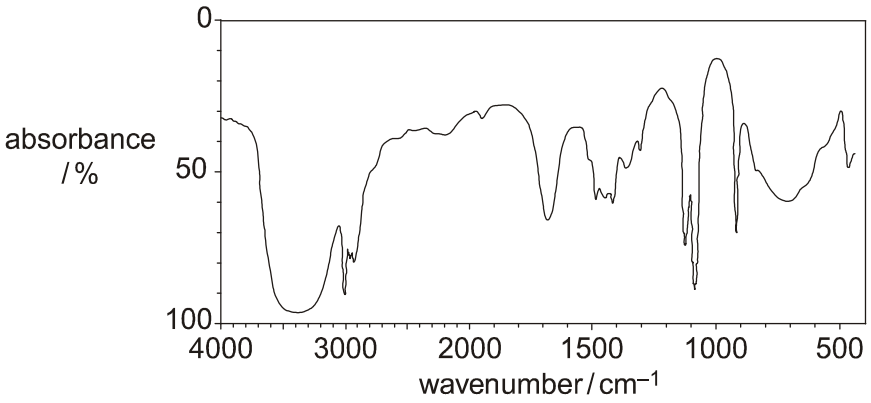
[2]

(c) The ethanal collected using the apparatus shown in Fig. 1 was analysed by infra-red spectroscopy. Use your *Data Sheet* to justify which of the three spectra shown below is most likely to be that of ethanal.

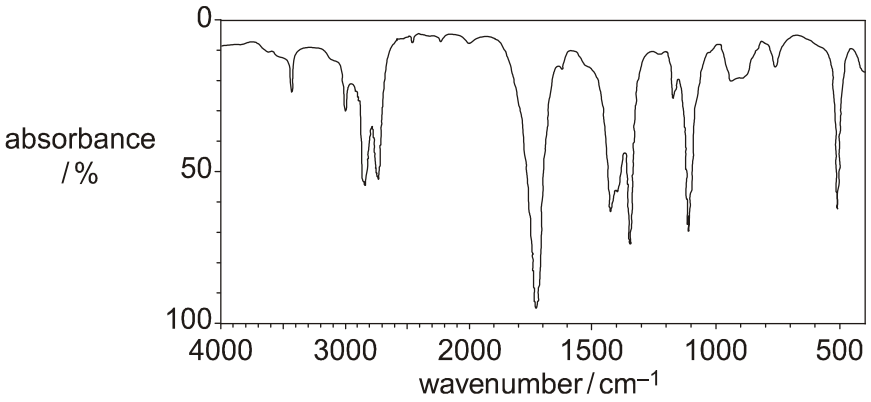
spectrum **A**




spectrum **B**




spectrum **C**



The organic product collected when using the apparatus shown in Fig. 1 is most likely to be that shown by spectrum ..... because.....

.....

.....

[3]

[Total 9 marks]

**22.** Acrolein, $CH_2$==CHCHO, and acrylic acid, $CH_2$==CHCOOH, are both used in industry for the manufacture of plastic resins and polymers. Both acrolein and acrylic acid can be made from prop-2-en-1-ol, $CH_2$==$CHCH_2OH$.

(a) (i) Draw the structures of prop-2-en-1-ol and acrolein. Clearly display the functional groups in each compound.

| **prop-2-en-1-ol** | **acrolein** |
|---|---|
| | |

[2]

(ii) Name the functional group common to **both** prop-2-en-1-ol and acrolein.

.....

[1]

(b) Prop-2-en-1-ol can be oxidised to form either acrolein or acrylic acid.

(i) Identify a suitable oxidising mixture.

.....

[2]

(ii) Write a balanced equation for the oxidation of prop-2-en-1-ol into acrolein. Use (O) to represent the oxidising agent.

.....

[1]

[Total 6 marks]

**23.** Acrylic acid reacts with prop-2-en-1-ol to produce an ester.

(i) Complete the balanced equation for this reaction.

$CH_2{=}{=}CHCOOH + CH_2{=}{=}CHCH_2OH \rightarrow$ ..... + .....

[2]

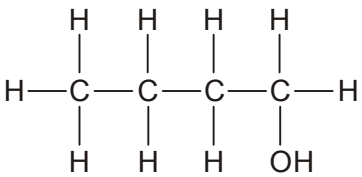
(ii) Draw the structure of the ester. Clearly display **all** of the functional groups.

[2]

[Total 4 marks]

**24.** (a) There are four structural isomers of $C_4H_{10}O$ that are alcohols. One of the isomers has been drawn for you.

Complete the table below to show the other structural isomers.

| | | | |
|---|---|---|---|
|  | | | |
| **butan-1-ol** | isomer **1** | isomer **2** | isomer **3** |

[3]

(b) Butan-1-ol is oxidised by an acidified solution of potassium dichromate(VI) to

form a carboxylic acid.

(i) State the colour change that you would see.

Colour changes from ..... to .....

[1]

(ii) Write a balanced equation for this oxidation of butan-1-ol to form a carboxylic acid. Use [O] to represent the oxidising agent.

.....

[2]

(iii) Identify which of the isomers, **1**, **2** or **3**, in (a) could also be oxidised to form a carboxylic acid.

isomer …….....

[1]

(c) Butan-1-ol reacts with hot concentrated sulphuric acid to form compound **B**.

(i) Compound **B** has an empirical formula of $CH_2$ and a relative molecular mass of 56. Use this information to deduce the molecular formula of compound **B**. Show your working.

[2]

(ii) Write a balanced equation to show the conversion of butan-1-ol into compound **B**.

.....

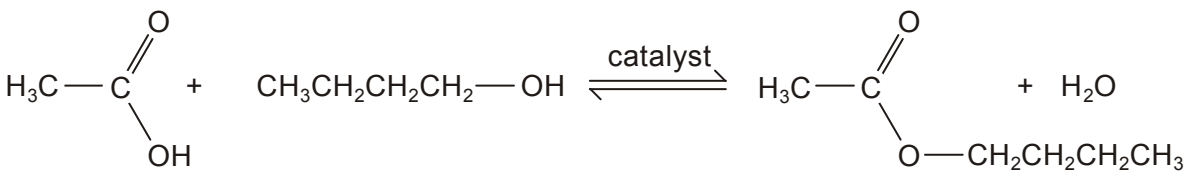
[1]

(iii) One of the isomers, **1**, **2** or **3**, in (a) also reacts with hot concentrated sulphuric acid to form compound **B**.

Identify which isomer. isomer …….....

[1]

(d) The ester, $CH_3COOCH_2CH_2CH_2CH_3$, was formed by reacting ethanoic acid with butan-1-ol.




**butan-1-ol**

**ester**
$M_r$ = 116

(i) State a catalyst for this reaction.

.....

[1]

(ii) In an experiment, 6.96 g of the ester was produced from 0.100 mol of butan-1-ol.
Calculate the number of moles of ester produced.

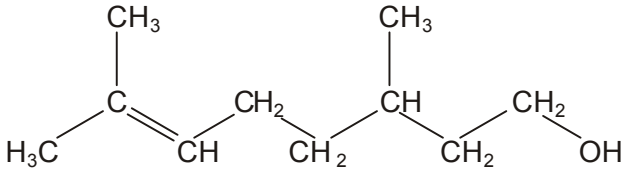
[1]

(iii) Calculate the percentage yield.

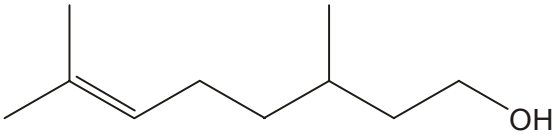
[1]

[Total 14 marks]

**25.** Citronellol, $C_{10}H_{20}O$, occurs naturally in both rose and geranium oils. The structural and skeletal formulae of citronellol are shown below.




**structural formula**




**skeletal formula**

(a) Name the **two** functional groups present in citronellol.

……..……..…… and .....

[2]

(b) The functional groups in citronellol can be identified either by chemical tests or by infrared spectroscopy.

(i) State which of the two functional groups you named in (a) is:

1 identified when bromine is added to citronellol, .....

2 more easily identified from the infra-red spectrum. .....

[1]

(ii) State what you would **see** when bromine is added to citronellol.

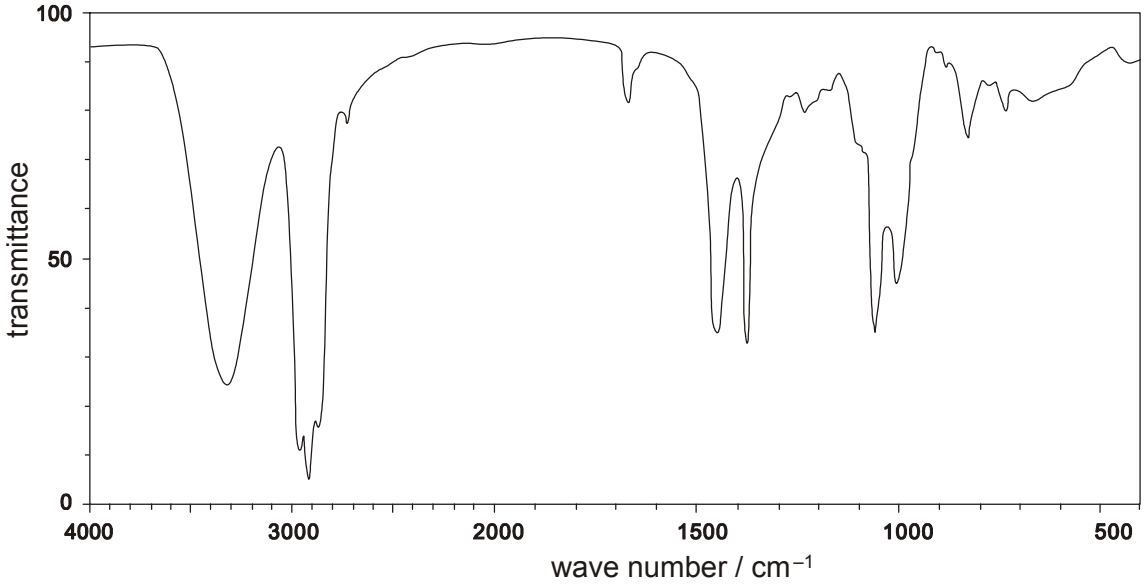
.....

[1]

(iii) Draw the skeletal formula of the organic product formed when bromine is added to citronellol.

[1]

(iv) The infra-red spectrum of citronellol is shown below. Mark on this spectrum, with the letter **X**, the absorption that confirms the presence of the functional group that is most easily identified from this spectrum.




[1]

(c) Reaction of a sample of citronellol, $C_{10}H_{20}O$, with hydrogen in the presence of a catalyst results in the formation of a saturated compound **C**.

(i) Suggest a catalyst for this reaction.

.....

[1]

(ii) Determine the molecular formula of the saturated compound **C**.

.....

[1]

(iii) Construct a balanced equation for this reaction.

.....

[1]

[Total 9 marks]

**26.** (a) Write an equation for the combustion of ethanol.

.....

[2]

(b) In this question, one mark is available for the quality of written communication.

Describe, with the aid of equations, the industrial manufacture of ethanol from glucose, $C_6H_{12}O_6$, and from ethene, $C_2H_4$. Name each type of reaction and state all essential conditions.

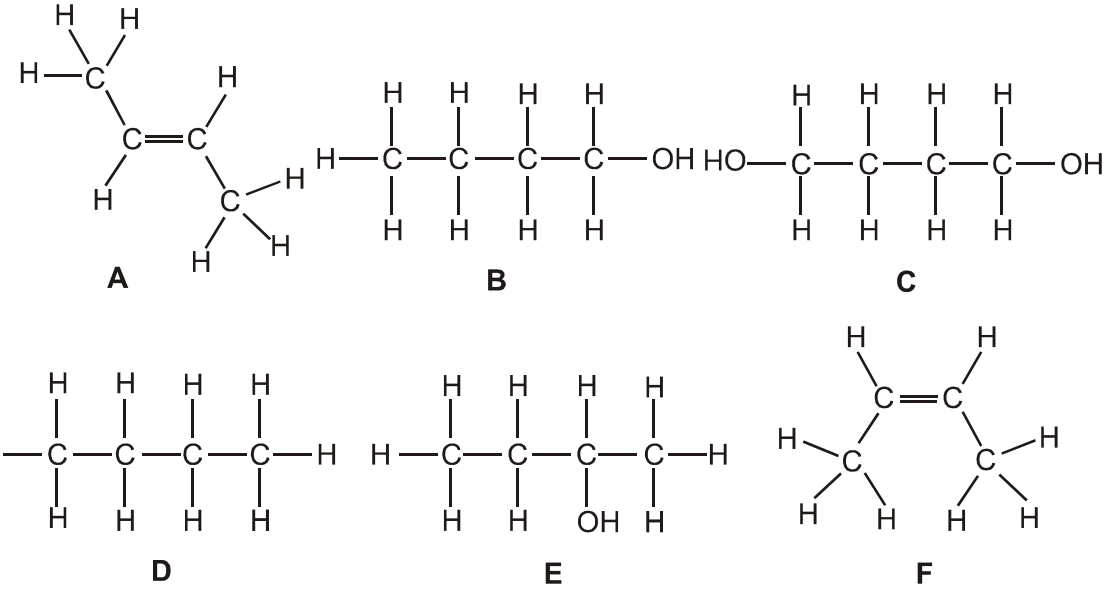
Future supplies of ethanol are likely to come from glucose rather than from ethene. Explain why.

[9]

Quality of Written Communication [1]

[Total 12 marks]

**27.** This question is about the compounds **A-F** below.




(a) Answer the following questions by referring to the compounds **A-F**.

(i) What is the molecular formula of compound **D**?

.....

[1]

(ii) What is the empirical formula of compound **C**?

.....

[1]

(iii) Which two compounds are structural isomers of each other?

..... and .....

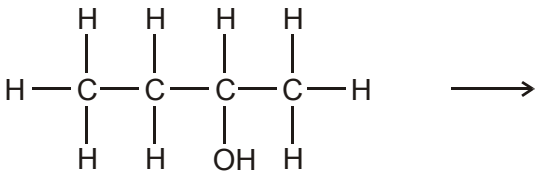
[1]

(iv) Which two compounds are *cis-trans* isomers of each other?

..... and .....

[1]

(b) Compound **E** can be dehydrated to form compound **A**. Complete a balanced equation for this reaction.



[1]

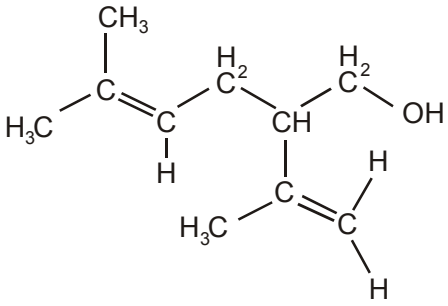
(c) Compound **C** can be dehydrated to form a new compound, **G**, with the molecular formula, $C_4H_6$. Suggest a structural formula and a name for **G**.

name .....

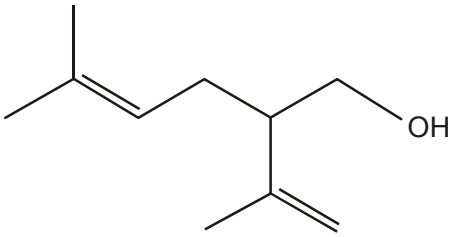
[2]

[Total 7 marks]

**28.** Lavandulol, $C_{10}H_{18}O$, is a fragrant oil which is found in lavender. The structural and the skeletal formulae of lavandulol are shown below.




**structural formula**




**skeletal formula**

(a) (i) Identify **two** different functional groups in lavandulol.

..... and .....

[2]

(ii) Why does lavandulol **not** have *cis-trans* isomerism?

.....

.....

[1]

(b) Lavandulol, $C_{10}H_{18}O$, also reacts with bromine to form a saturated organic product.

State what you would see in this reaction and deduce the molecular formula of the organic product.

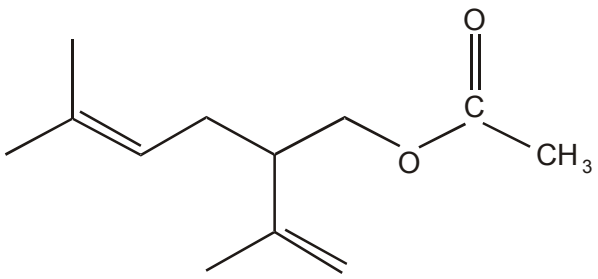
observation .....

[1]

molecular formula .....

[2]

(c) Lavandulol could be converted into an ester **X**, which is also found in lavender oil.




ester **X**

State a reagent and a catalyst that could be used to form ester **X** from lavandulol.

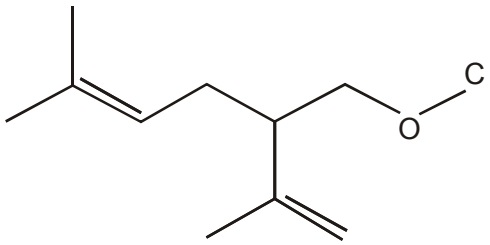
reagent .....

[1]

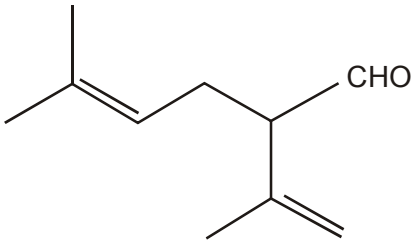
catalyst .....

[1]

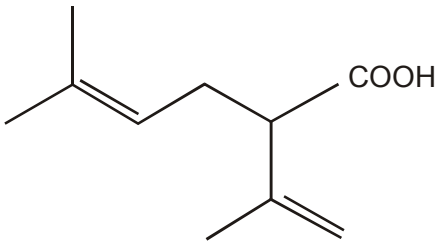
(d) Lavanduloi can be oxidised to produce either compound **Y** or compound **Z**.




lavandulol
$C_{10}H_{18}O$




compound **Y**
$C_{10}H_{16}O$




compound **Z**
$C_{10}H_{16}O_2$

(i) Write a balanced equation for the oxidation of lavandulol to produce compound **Z**. Use the molecular formulae given above and use [O] to represent the oxidising agent.

.....

[2]

(ii) An infra-red spectrum of either compound **Y** or compound **Z** was obtained and was found to contain an absorption between 1680 – 1750 $cm^{-1}$. However, there was no broad absorption between 2500 – 3300 $cm^{-1}$.

By referring to your *Data Sheet*, use this information to deduce whether the infra-red spectrum was of compound **Y** or of compound **Z**. Show your reasoning.

The infra-red spectrum was of compound ..... because .....

.....

.....

.....

[2]

[Total 12 marks]