

F322: Chains, Energy and Resources

2.2.4 Alcohols

167 marks

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

Which alcohol is an example of a tertiary alcohol?

.....

[Total 1 mark]

2. 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.

.....
.....
.....
.....

[Total 2 marks]

3. 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**.

[Total 2 marks]

4. 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]

[Total 4 marks]

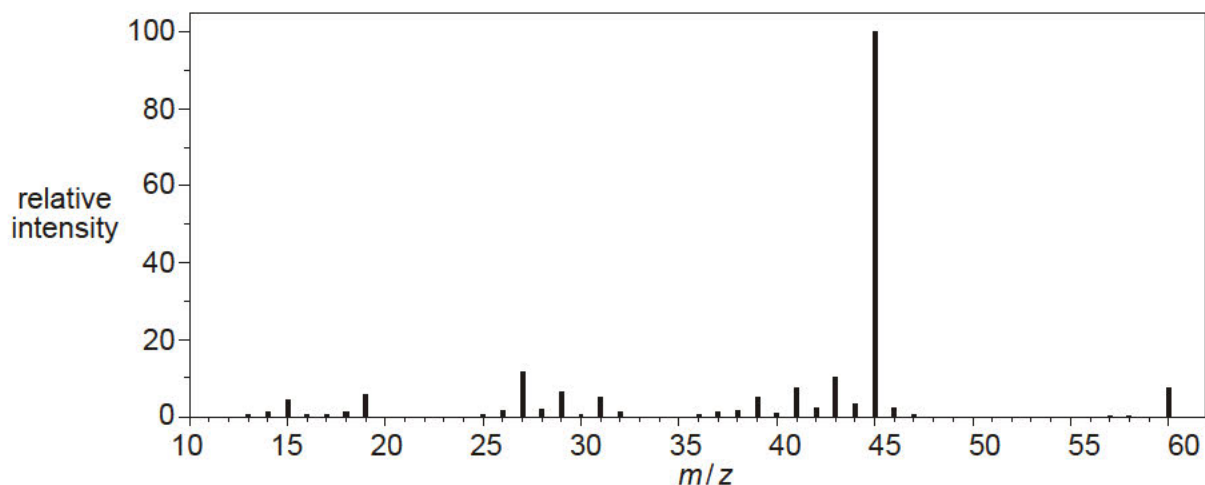
5. Alcohol **E** is one of the following alcohols.

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

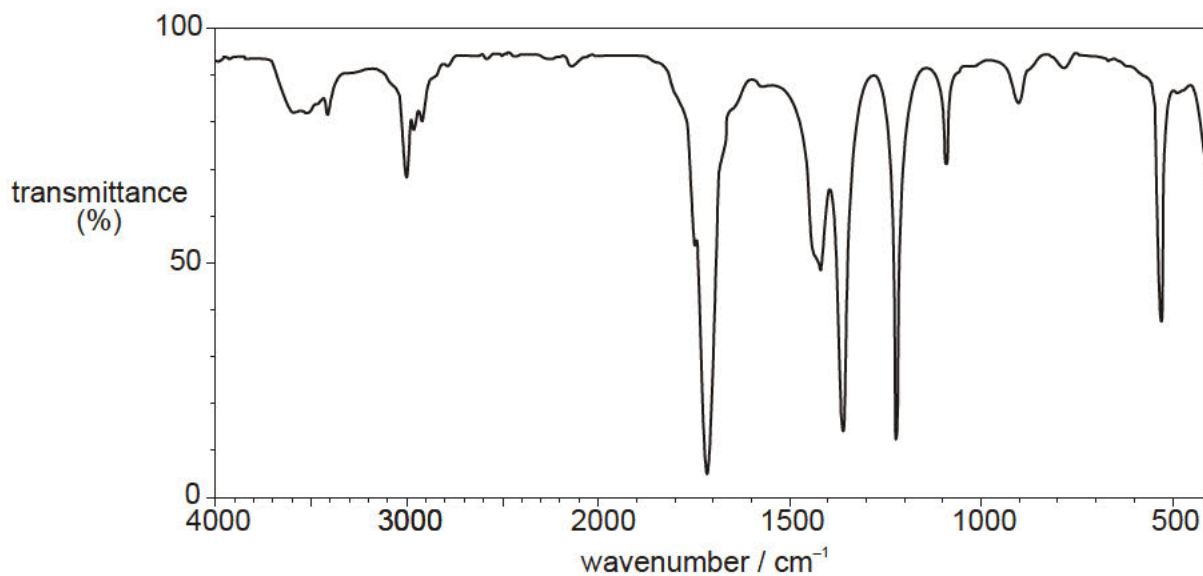
ethane-1,2-diol
2-methylpropan-2-ol
propan-2-ol

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.



- 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).

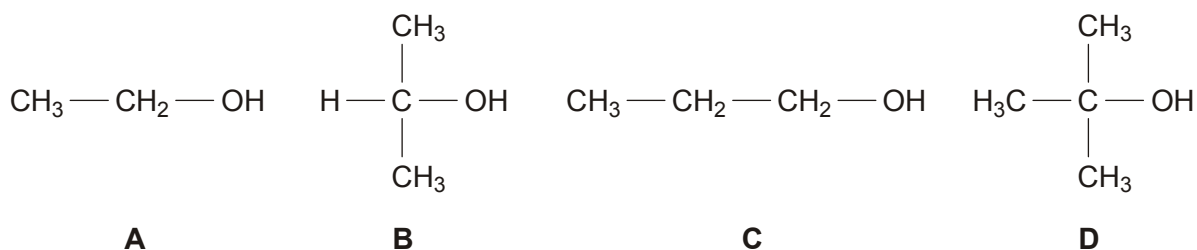
Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).



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

[Total 7 marks]

6. Alcohols **A**, **B**, **C** and **D** are shown below.



- (a) Compound **A** is ethanol, a very useful alcohol.

Identify the two main methods used in the industrial production of ethanol.
Write an equation for each method.

method 1

.....

equation

.....

method 2

.....

equation

[4]

- (b) A student heated each alcohol, **A–D**, with acidified potassium dichromate(VI) as the oxidising agent. With alcohols **A**, **B** and **C**, the colour turned from orange to green.

- (i) Identify the organic product and write a balanced equation for the reaction of alcohol **B** with acidified potassium dichromate(VI).

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

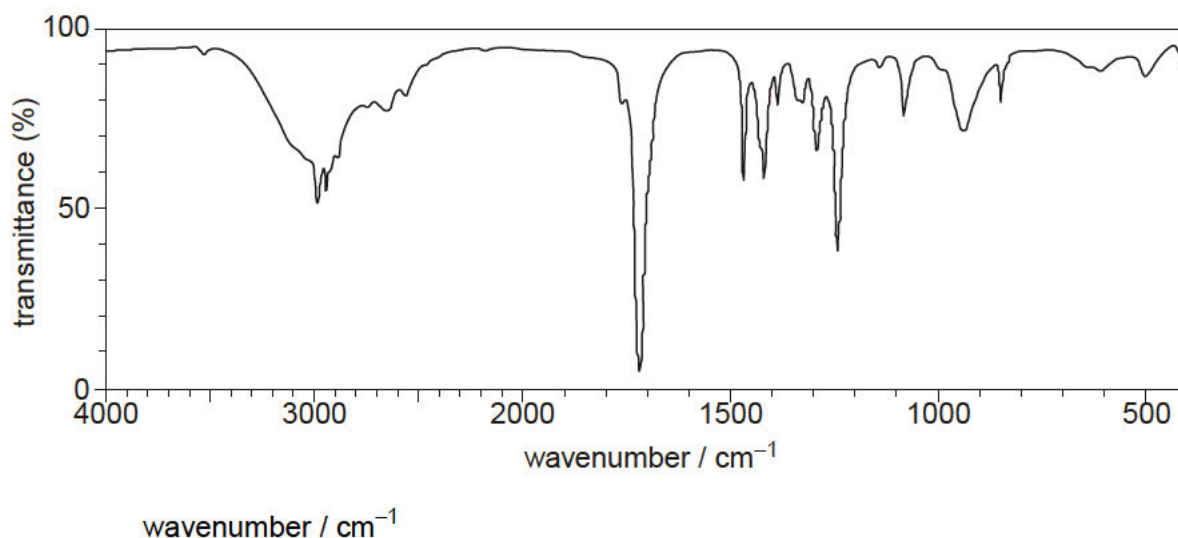
organic product:

balanced equation:

[2]

- (ii) The organic product obtained from **C** was analysed by infrared (IR) spectroscopy.

The IR spectrum of the product is shown below.



Use your *Data Sheet* to identify the organic product. Explain your reasoning.

organic product:

reasoning
.....
.....

[3]

- (c) The student heated alcohol **D** with ethanoic acid in the presence of an acid catalyst. An organic product **E** was formed with a fruity smell.

- (i) Name alcohol **D**.

.....

[1]

- (ii) Name the functional group in the organic product **E**.

.....

[1]

- (iii) Draw the structure of the organic product **E**.

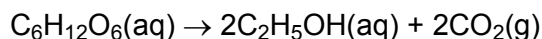
[2]

[Total 13 marks]

7. Ethanol, $\text{C}_2\text{H}_5\text{OH}$, is manufactured on a large scale for a wide range of uses such as alcoholic drinks, as an industrial solvent and as a raw material for the synthesis of many organic compounds.

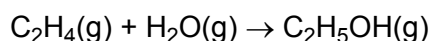
Ethanol, $\text{C}_2\text{H}_5\text{OH}$, is manufactured on a large scale by two methods:

- Fermentation, using yeast, of sugars, such as glucose, $\text{C}_6\text{H}_{12}\text{O}_6$.



The ethanol is then distilled off.

- Hydration of ethene, C_2H_4 , with steam in the presence of an acid catalyst.



Compare the sustainability of these methods of manufacturing ethanol in terms of:

- availability of starting materials and energy requirements;
- atom economy.



In your answer, you should make clear how the atom economy of the processes links with chemical theory.

.....

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.....

.....

.....

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.....

.....

[Total 7 marks]

8. In the laboratory, ethanol can be oxidised with acidified potassium dichromate(VI).

- (a) The ethanol can be oxidised to form either ethanal, CH_3CHO (**Fig. 1**), or ethanoic acid, CH_3COOH (**Fig. 2**).

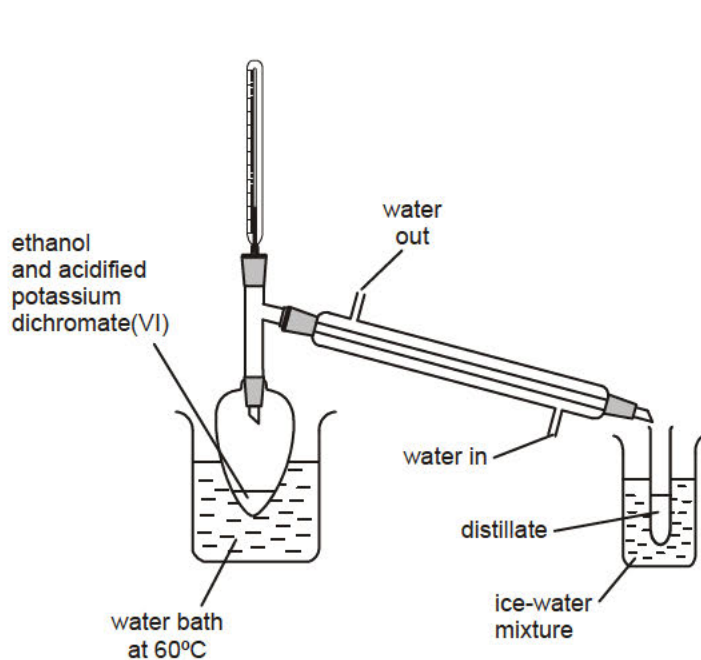


Fig. 1

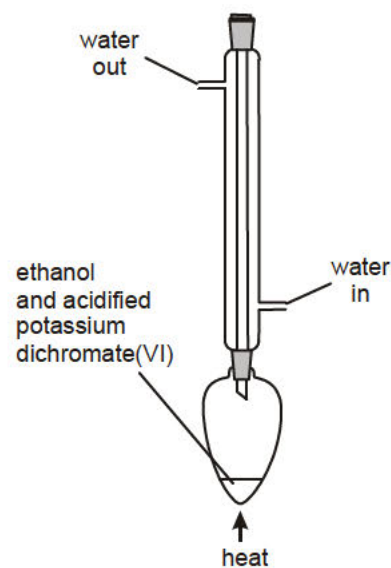


Fig. 2

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

	$\text{CH}_3\text{CH}_2\text{OH}$	CH_3CHO	CH_3COOH
boiling point / °C	8	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]

[Total 6 marks]

9. Ethanol can be formed by fermentation of glucose, $C_6H_{12}O_6$.

- (i) Write a balanced equation, including state symbols, for the formation of ethanol by fermentation.

.....

[2]

- (ii) Fermentation only occurs in the presence of yeast. State **two** other essential conditions.

.....
.....

[2]

- (iii) How would you know when fermentation of glucose is complete?

.....
.....

[1]

[Total 5 marks]

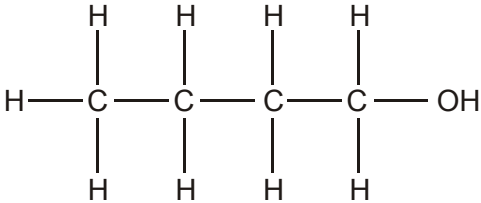
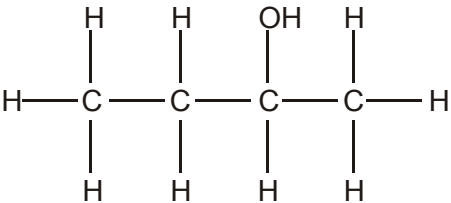
10. Propan-2-ol is flammable and readily burns.

Write a balanced equation for the complete combustion of propan-2-ol.

.....

[Total 2 marks]

11. Four possible structural isomers of $C_4H_{10}O$ are alcohols. Two are shown below.

	
butan-1-ol	butan-2-ol

- (i) Draw the other two structural isomers of $C_4H_{10}O$ that are alcohols

isomer 1	isomer 2

[2]

- (ii) Name isomer 1.

[1]

[Total 3 marks]

12. Butan-2-ol can be dehydrated to produce a mixture of three alkenes each with a molecular formula C_4H_8 .

Draw the displayed formula for each of the three alkenes.

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[Total 3 marks]

13. (a) Butan-1-ol can be oxidised to form butanal.

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

.....

[2]

- (ii) State the colour change you would see during this oxidation.

from to

[1]

- (b) A sample of the butanal from (a) was analysed using infra-red spectroscopy. The infra-red spectrum contained an absorption in the region $1680-1750\text{ cm}^{-1}$ but did **not** contain a broad absorption in the region $2500-3300\text{ cm}^{-1}$.

Refer to the Data Sheet for Chemistry provided.

- (i) What does the absorption in the region $1680-1750\text{ cm}^{-1}$ indicate?

.....

[1]

- (ii) What does the absence of a broad absorption in the region $2500-3300\text{ cm}^{-1}$ indicate?

.....

[1]

- (iii) The reaction in (a) was carried out using distillation and **not** reflux.

Explain why.

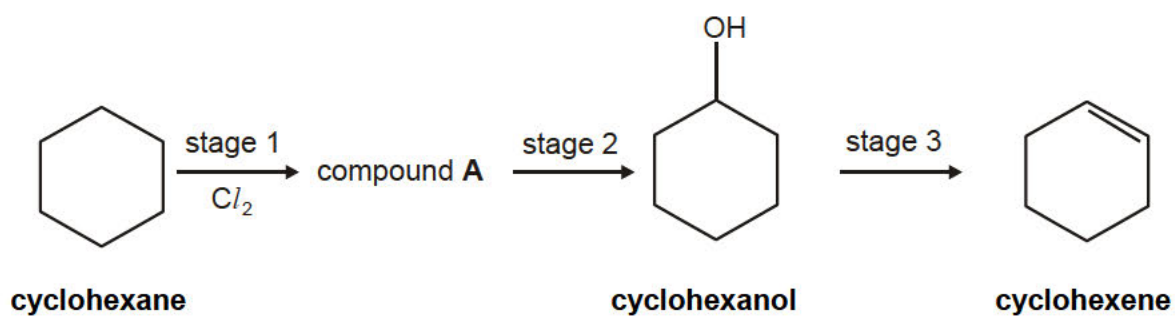
.....

.....

[2]

[Total 7 marks]

14. (a) Cyclohexane can be converted into cyclohexene via a three-stage synthesis.



- (i) In stage 1, cyclohexane reacts with chlorine to form the organic product, compound **A**.

Show the structure of compound **A**.

[1]

- (ii) Stage 3 involves the dehydration of an alcohol.

State a suitable reagent for dehydrating an alcohol.

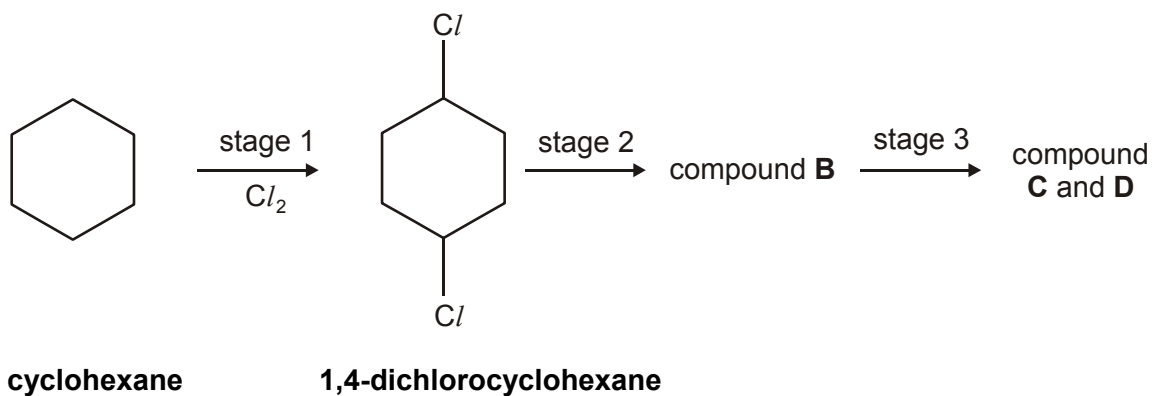
.....

[1]

(iii) Write a balanced equation for the dehydration of cyclohexanol, $C_6H_{11}OH$.

[1]

(b) The reaction in stage 1 is difficult to control. One other possible chlorinated product is 1,4-dichlorocyclohexane. This is shown below.



1,4-Dichlorocyclohexane reacts in the same way as compound A in stages 2 and 3.

(i) Suggest the structure of compound B.

[1]

- (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**.

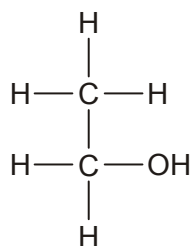
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[2]

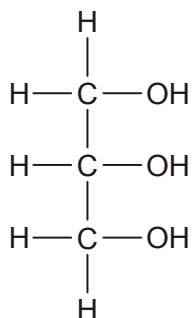
[Total 6 marks]

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, ...

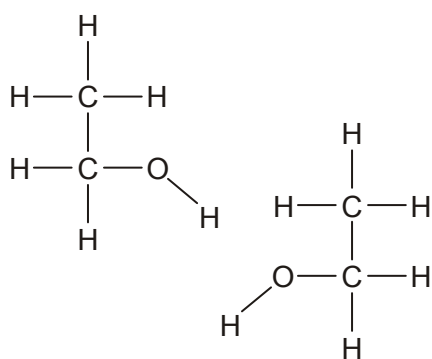
.....

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

.....

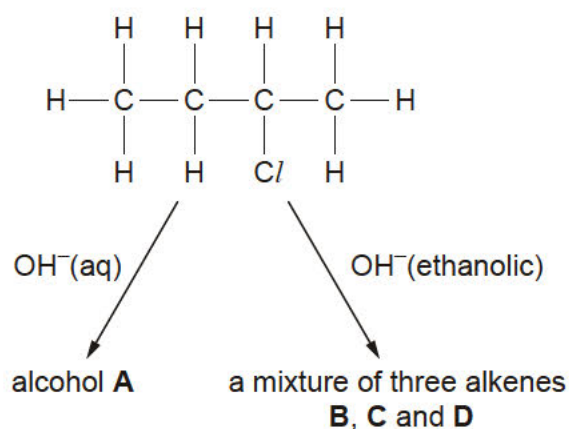
.....

[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.

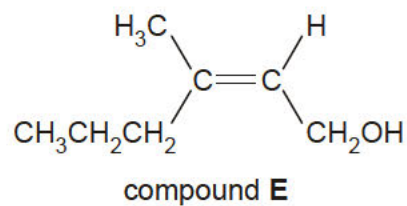
(i) State a suitable oxidising mixture for this reaction.

.....

[2]

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

Use [O] to represent the oxidising mixture.



[3]

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

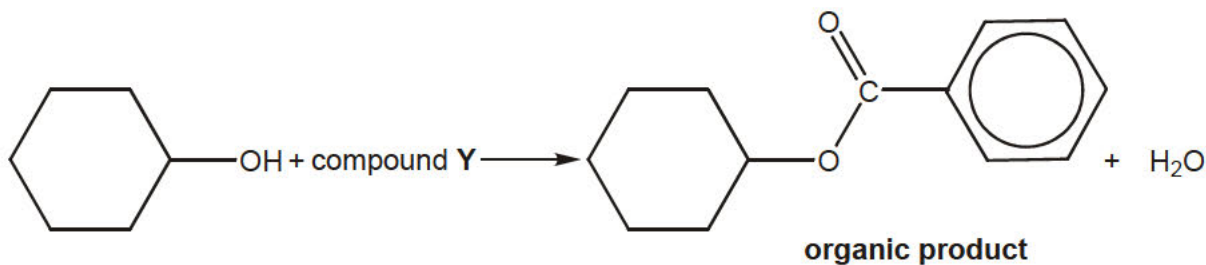
.....
.....

[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.



- (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, $\text{C}_2\text{H}_5\text{OH}$, can be produced by the fermentation of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$.

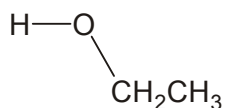
Write a balanced equation for the fermentation of glucose.

.....

[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).

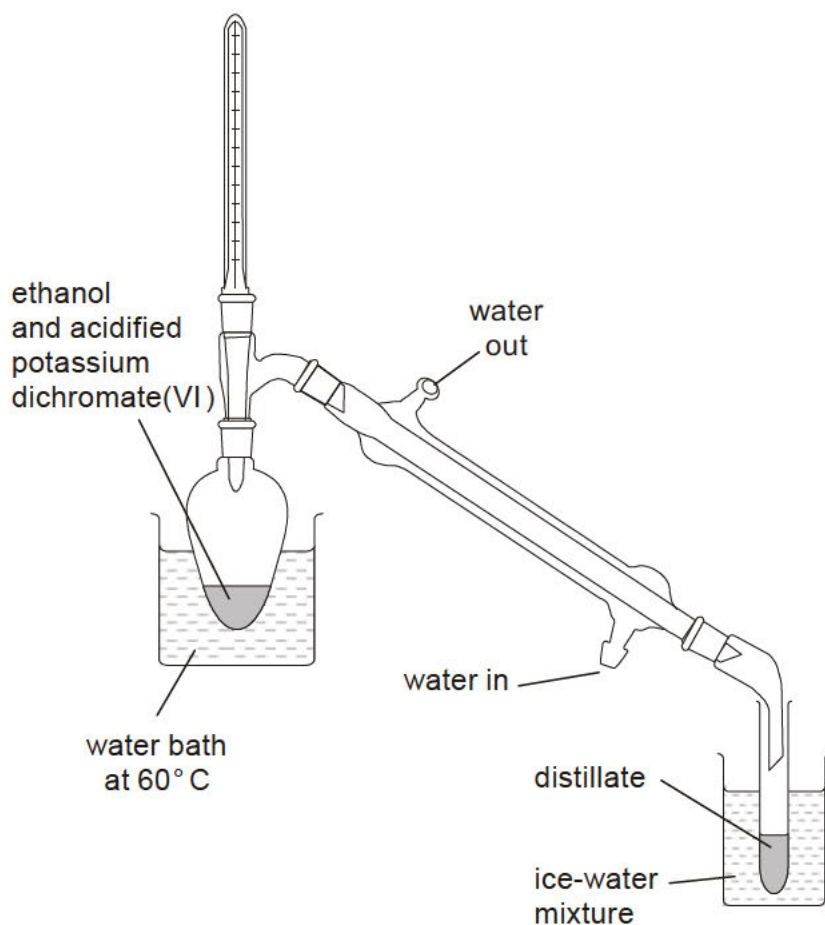


Fig. 1

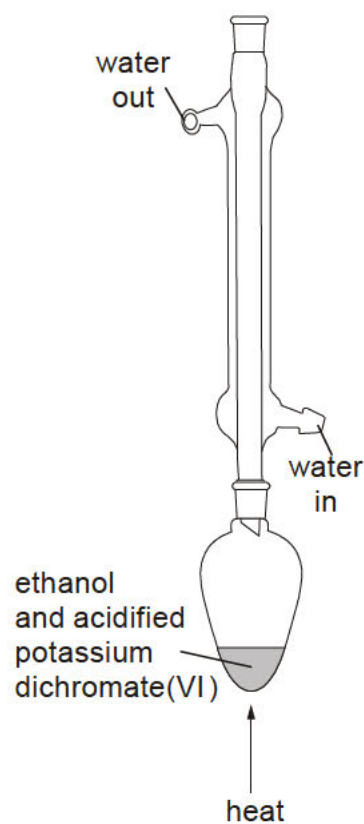


Fig. 2

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

	$\text{CH}_3\text{CH}_2\text{OH}$	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.

.....
.....

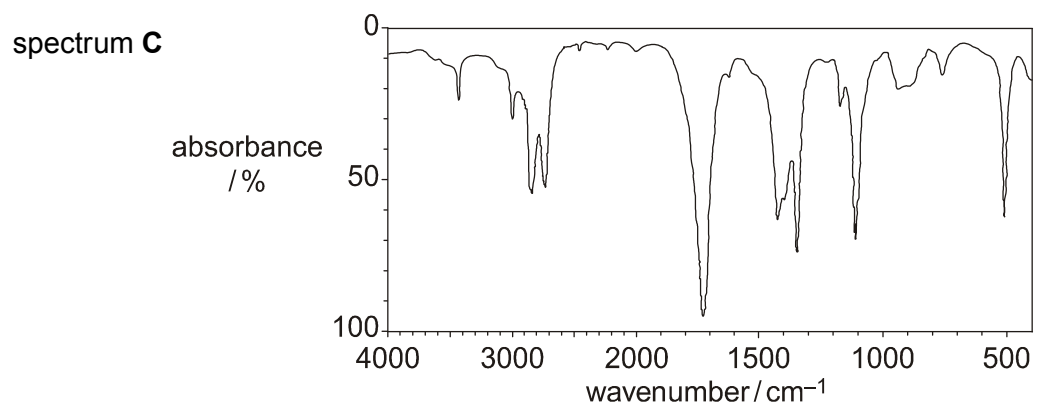
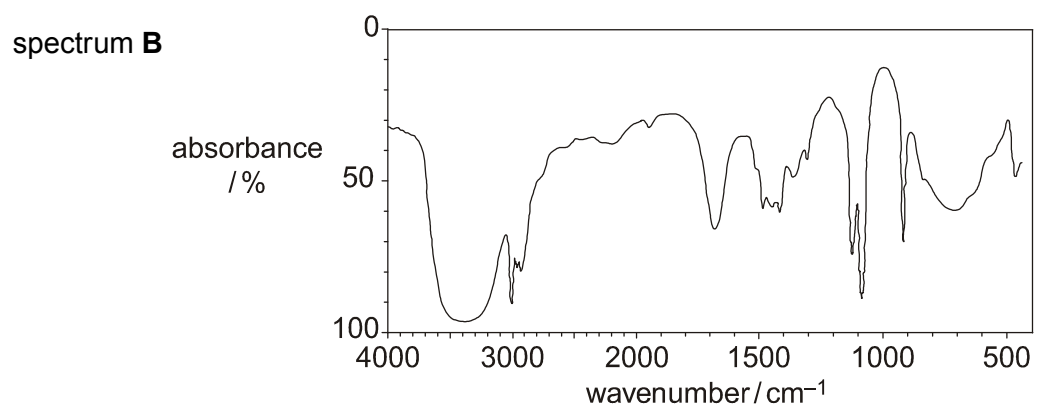
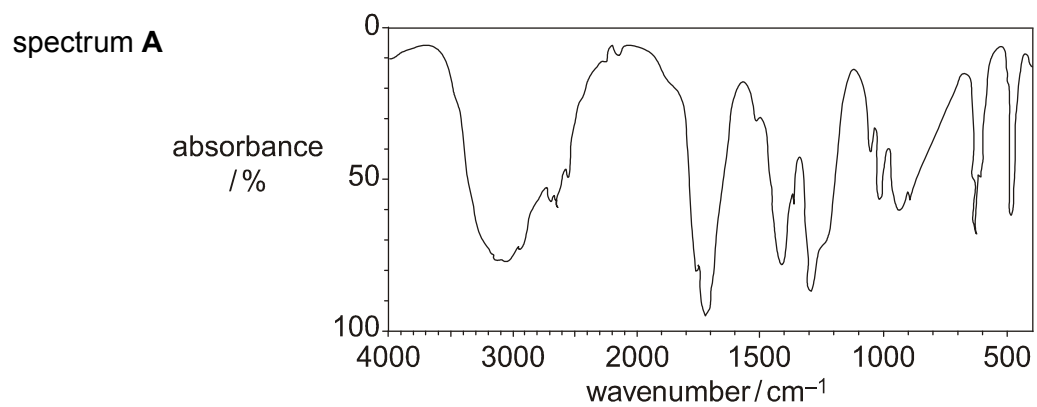
[2]

- (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.



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, $\text{CH}_2=\text{CHCHO}$, and acrylic acid, $\text{CH}_2=\text{CHCOOH}$, 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, $\text{CH}_2=\text{CHCH}_2\text{OH}$.

- (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.

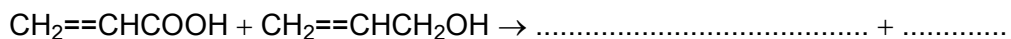
.....

[1]

[Total 6 marks]

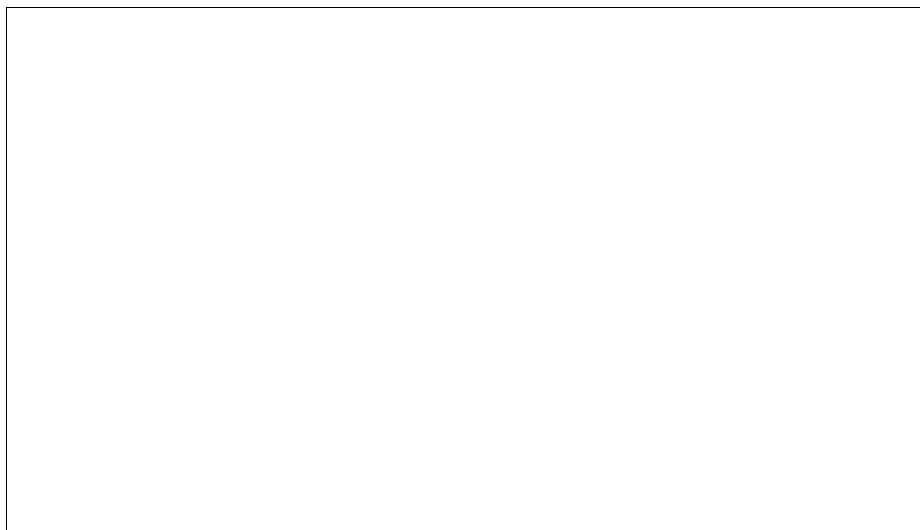
23. Acrylic acid reacts with prop-2-en-1-ol to produce an ester.

- (i) Complete the balanced equation for this reaction.



[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 $\text{C}_4\text{H}_{10}\text{O}$ that are alcohols. One of the isomers has been drawn for you.

Complete the table below to show the other structural isomers.

$ \begin{array}{cccc} \text{H} & \text{H} & \text{H} & \text{H} \\ & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & \\ \text{H} & \text{H} & \text{H} & \text{OH} \end{array} $			
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**.

.....

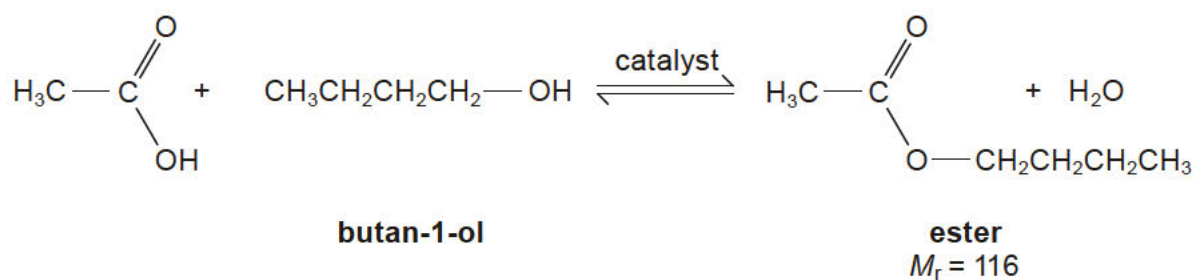
[1]

- (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, $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, was formed by reacting ethanoic acid with butan-1-ol.



- (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.

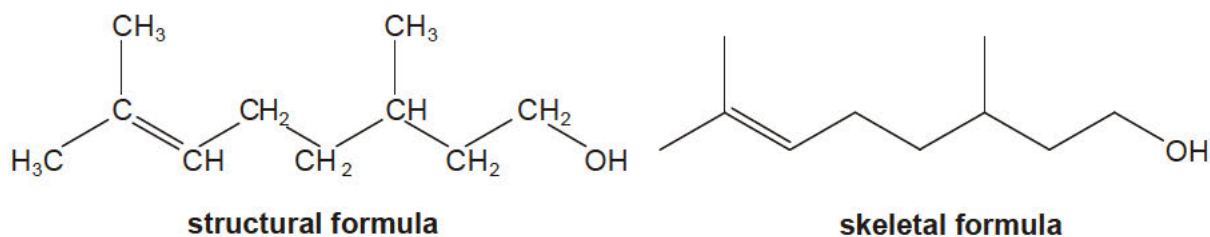
[1]

- (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.



- (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.

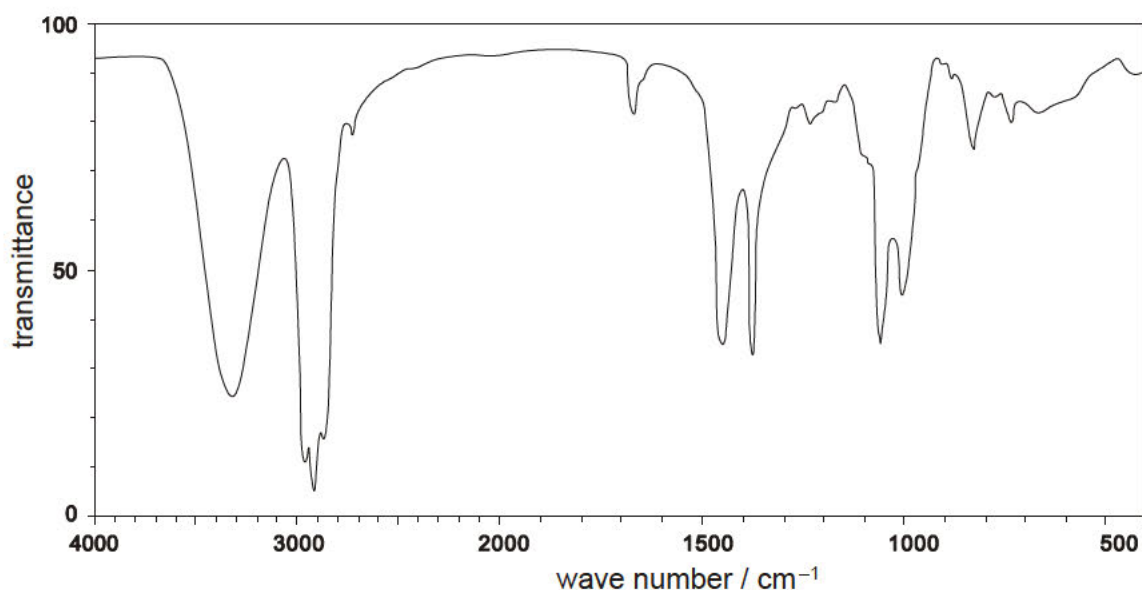
.....

[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, C₁₀H₂₀O, 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.

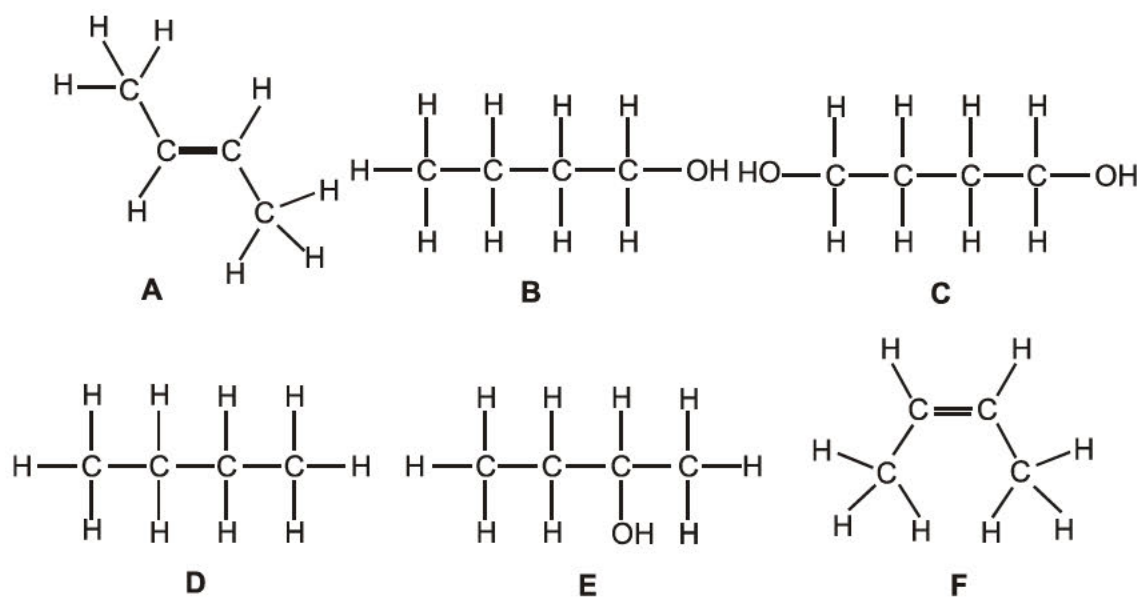
Future supplies of ethanol are likely to come from glucose rather than from ethene. Explain why.

[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

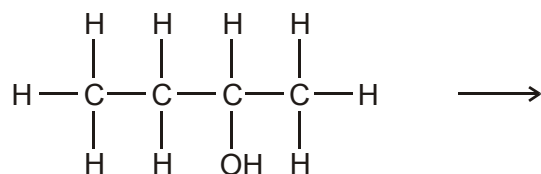
[1]

(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]

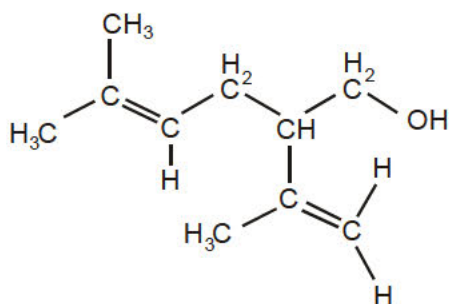
(c) Compound **C** can be dehydrated to form a new compound, **G**, with the molecular formula, C_4H_6 . Suggest a structural formula and a name for **G**.

name

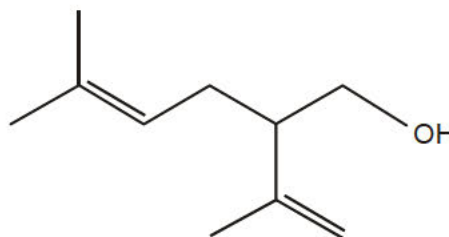
[2]

[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.

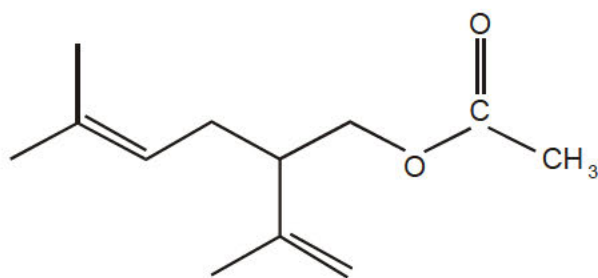
observation

[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.

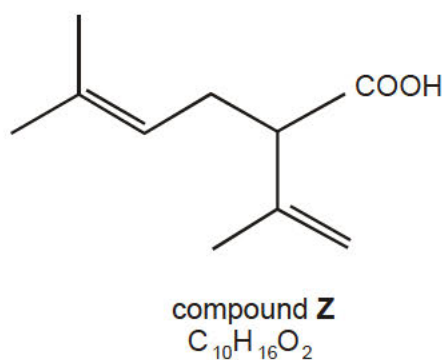
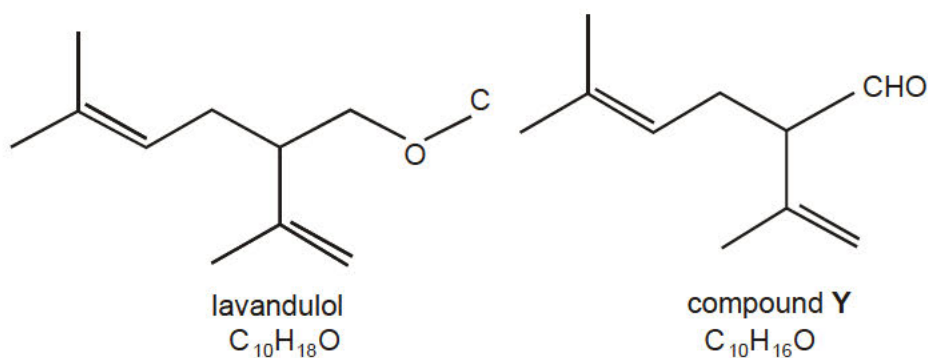
reagent

[1]

catalyst

[1]

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



- (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 $1680 - 1750 \text{ cm}^{-1}$. However, there was no broad absorption between $2500 - 3300 \text{ cm}^{-1}$.

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]