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**XVIII**

1583

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**234 Minutes**

Score

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**CHEMISTRY**

**OCR  
AS & A LEVEL**

**Topic Questions**

**Module 4: Core organic  
chemistry**

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1. A student reacted 8.72 g of bromobutane with an excess of  $\text{OH}^-$ . The student produced 4.28 g of butan-1-ol.

In this reaction the hydroxide ion acts as a nucleophile.

- (i) What name is given to this type of reaction?

.....

[1]

- (ii) Explain the term *nucleophile*.

.....

[1]

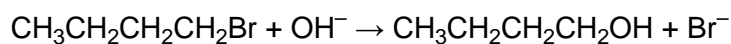
- (iii) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

[4]

[Total 6 marks]

2. Bromobutane,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ , can be reacted with hot aqueous sodium hydroxide to prepare butan-1-ol.



The butan-1-ol produced can be analysed by mass spectrometry.



- (i) Predict **two** fragment ions that you would expect to see in the mass spectrum of butan-1-ol and state the  $m/z$  value of each ion.

.....  
.....

[2]

- (ii) State a use of mass spectrometry outside of the laboratory.

.....

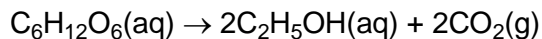
[1]

[Total 3 marks]

3. Ethanol,  $C_2H_5OH$ , 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.

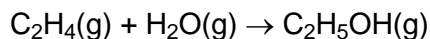
Ethanol,  $C_2H_5OH$ , is manufactured on a large scale by two methods:

- Fermentation, using yeast, of sugars, such as glucose,  $C_6H_{12}O_6$ .



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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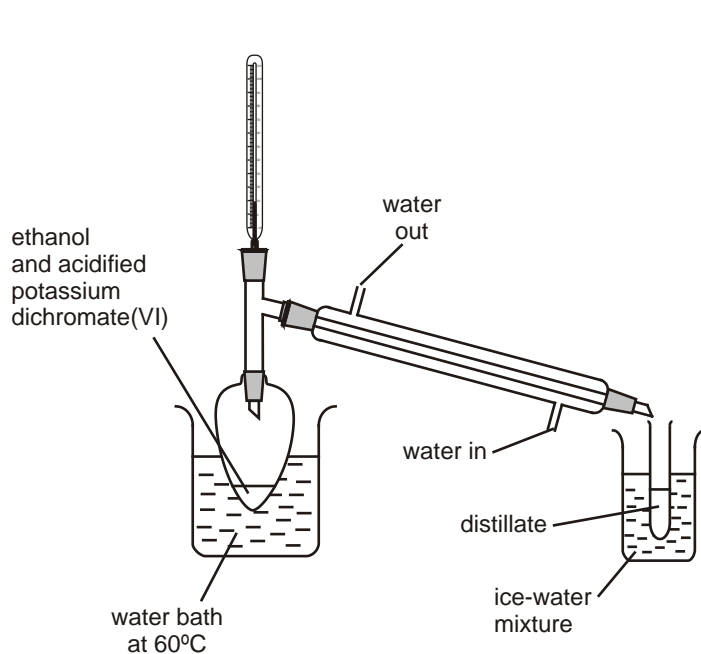
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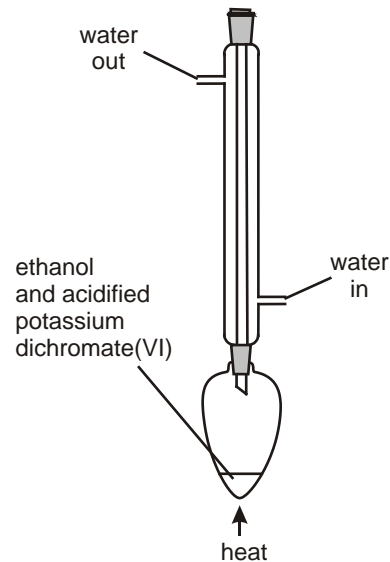
[Total 7 marks]

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

- (a) The ethanol can be oxidised to form either ethanal,  $\text{CH}_3\text{CHO}$  (**Fig. 1**), or ethanoic acid,  $\text{CH}_3\text{COOH}$  (**Fig. 2**).



**Fig. 1**



**Fig. 2**

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

	$\text{CH}_3\text{CH}_2\text{OH}$	$\text{CH}_3\text{CHO}$	$\text{CH}_3\text{COOH}$
<b>boiling point / °C</b>	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]

5. 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]

6. (a) Propan-2-ol can be formed by the hydration of an alkene in the presence of a catalyst.

(i) Suggest a suitable catalyst for this reaction.

.....

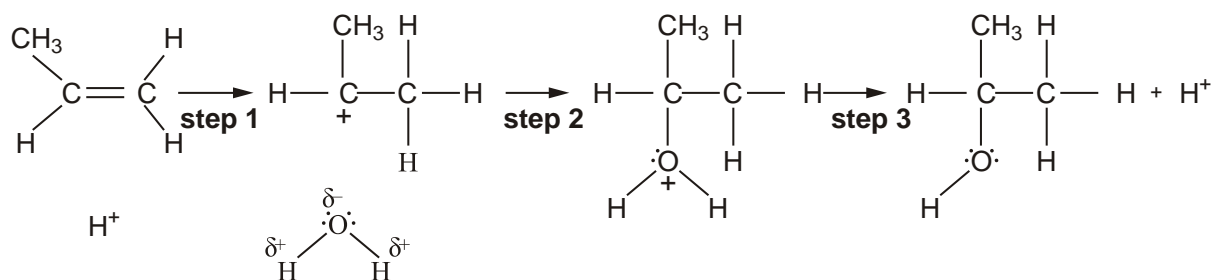
[1]

(ii) This is an electrophilic addition reaction. What is meant by the term *electrophile*?

.....

[1]

(b) A mechanism for the reaction in (a) is shown below.



(i) Add 'curly arrows' to the mechanism to show the movement of electron pairs in steps 1, 2 and 3.

[3]

(ii) Suggest, with a reason, the role of the  $\text{H}^+$ .

.....

[1]

[Total 6 marks]

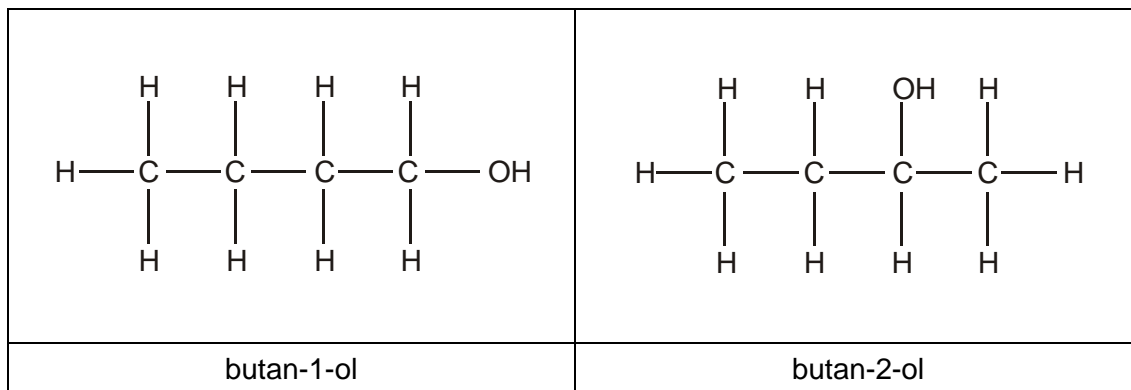
7. Propan-2-ol is flammable and readily burns.

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

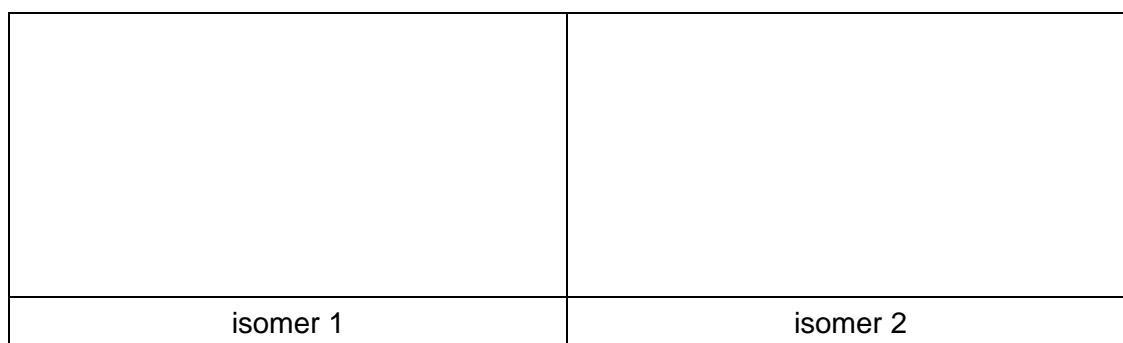
.....

[Total 2 marks]

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



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



[2]

(ii) Name isomer 1. ....

[1]

[Total 3 marks]



9. 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.

--	--	--

[Total 3 marks]

10. (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.

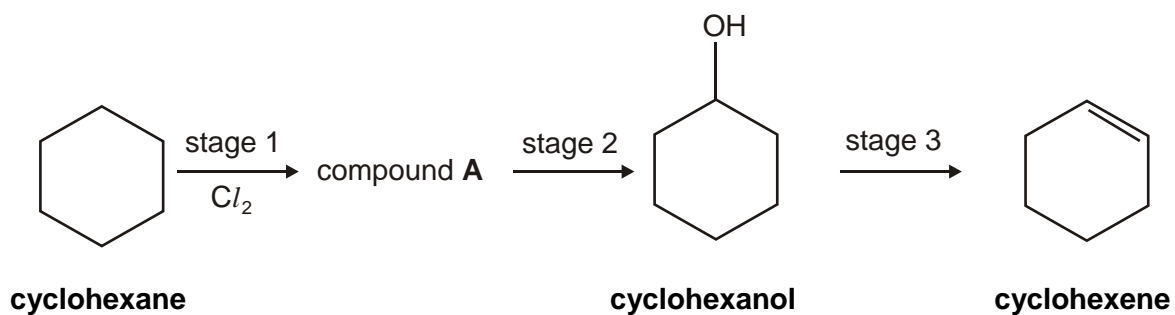
Explain why.

.....  
.....

[2]

[Total 7 marks]

11. (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.

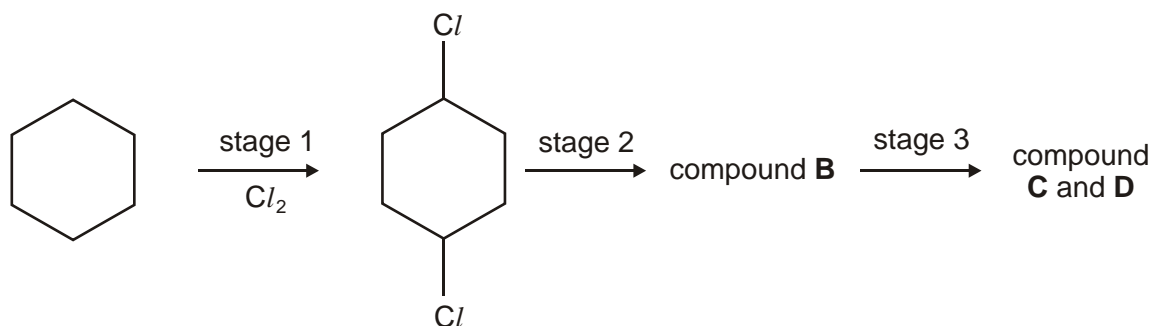
.....

[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.



**cyclohexane**

**1,4-dichlorocyclohexane**

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**.

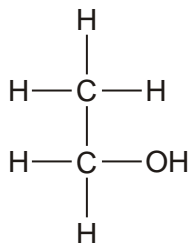
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[2]

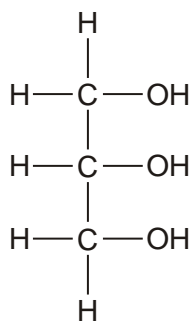
[Total 6 marks]

12. 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*, .....

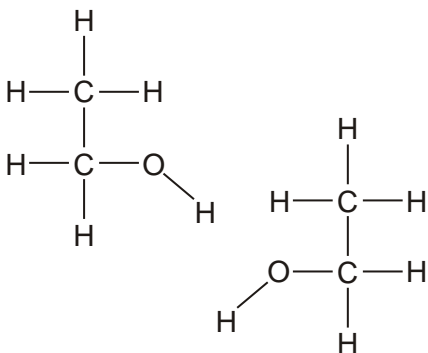
.....

*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

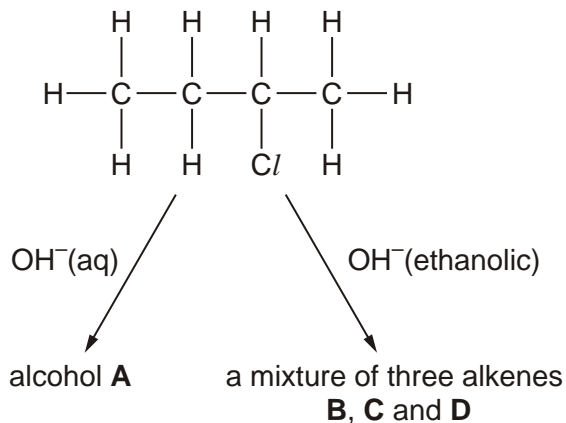
.....  
 .....

[1]

[Total 6 marks]

13. 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  $\text{OH}^-$  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]

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

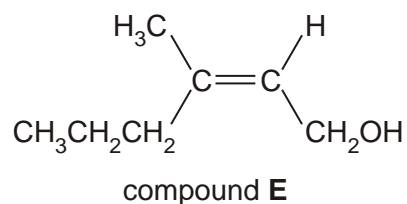
(i) State a suitable oxidising mixture for this reaction.

.....

[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.

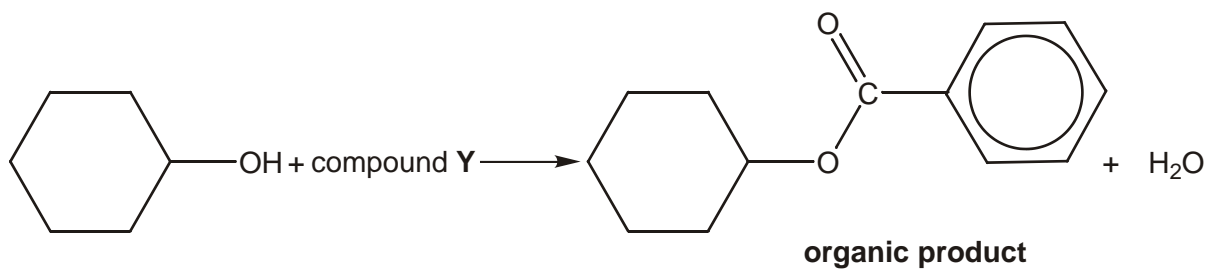
.....  
 .....

[1]

[Total 6 marks]

15. (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]

16. Trifluorochloromethane,  $CF_3Cl$ , is an example of a chlorofluorocarbon, CFC, that was commonly used as a propellant in aerosols. Nowadays, CFCs have limited use because of the damage caused to the ozone layer.

(i) Draw a diagram to show the shape of a molecule of  $CF_3Cl$ .

[1]

(ii) Predict an approximate value for the bond angles in a molecule of  $CF_3Cl$ .

bond angle .....

[1]

(iii) Suggest a property that made  $CF_3Cl$  suitable as a propellant in an aerosol.

.....

[1]

(iv) When CFCs are exposed to strong ultraviolet radiation in the upper atmosphere, homolytic fission takes place to produce free radicals.

Explain what is meant by the term *homolytic fission*.

.....

.....

[2]



- (v) Suggest which bond is most likely to be broken when  $\text{CF}_3\text{Cl}$  is exposed to ultraviolet radiation. Explain your answer.

bond .....

reason .....

[1]

- (vi) Identify the **two** free radicals most likely to be formed when  $\text{CF}_3\text{Cl}$  is exposed to ultraviolet radiation.

..... and .....

[2]

[Total 8 marks]

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

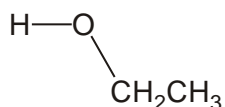
Write a balanced equation for the fermentation of glucose.

.....

[Total 2 marks]

18. 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]

19. (a) When ethanol is heated with acidified potassium dichromate(VI) solution, it can be oxidised to form either ethanal,  $\text{CH}_3\text{CHO}$  (Fig. 1), or ethanoic acid,  $\text{CH}_3\text{COOH}$  (Fig. 2).

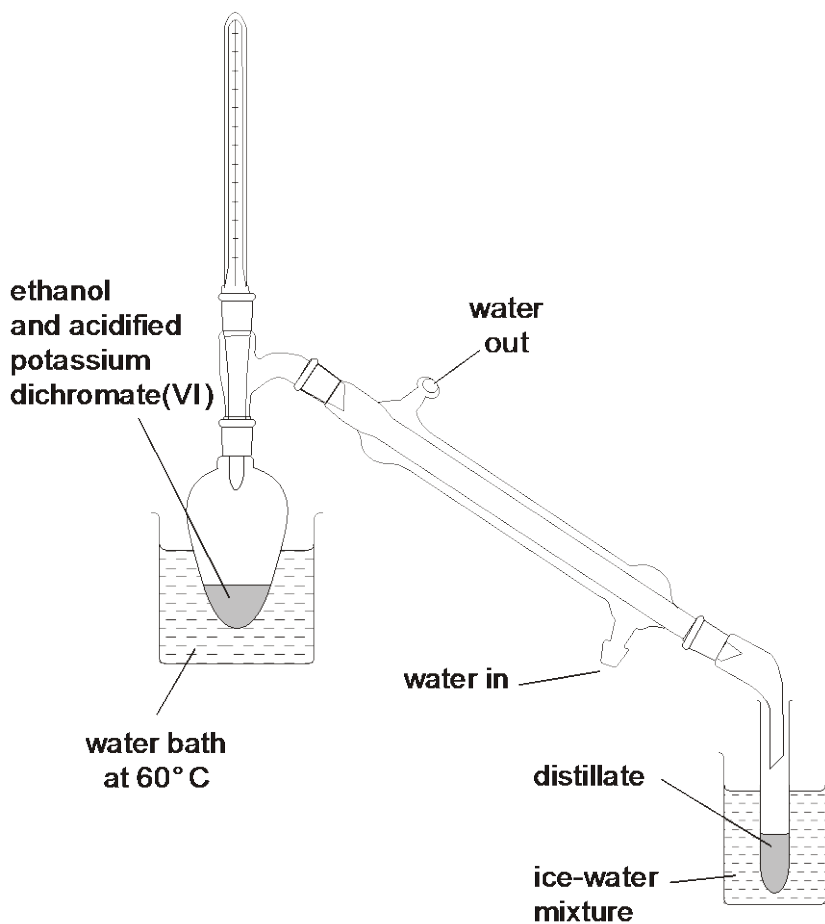


Fig. 1

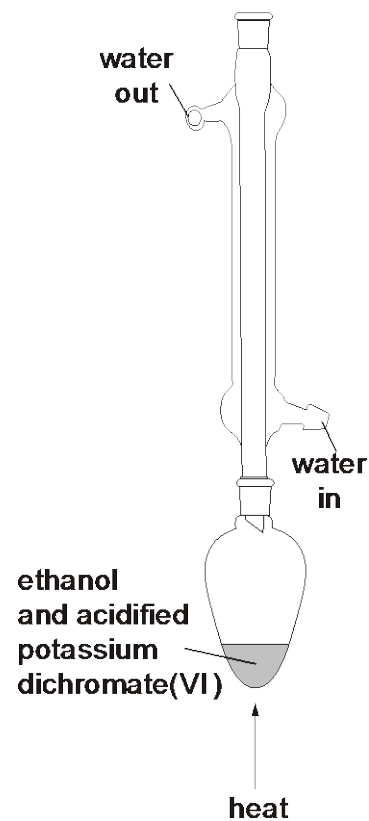


Fig. 2

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

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

.....  
.....

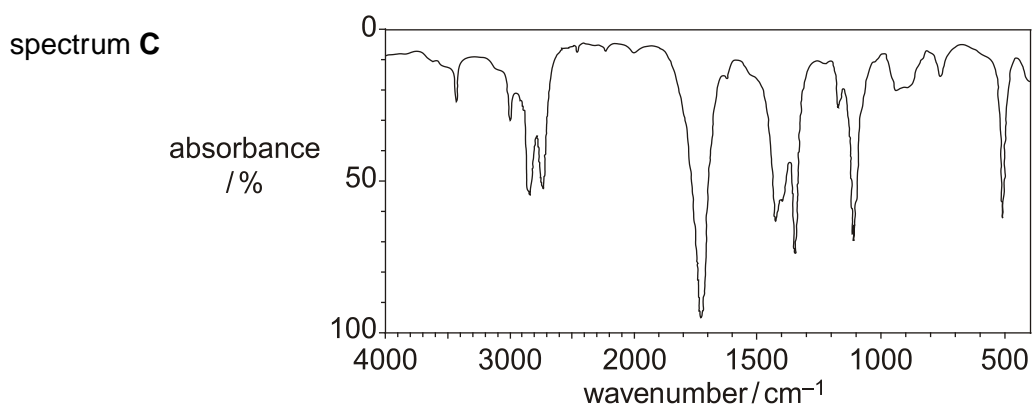
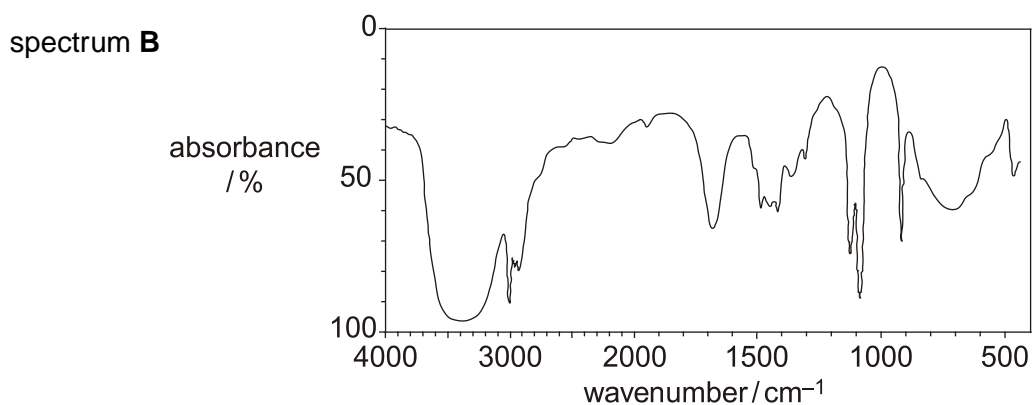
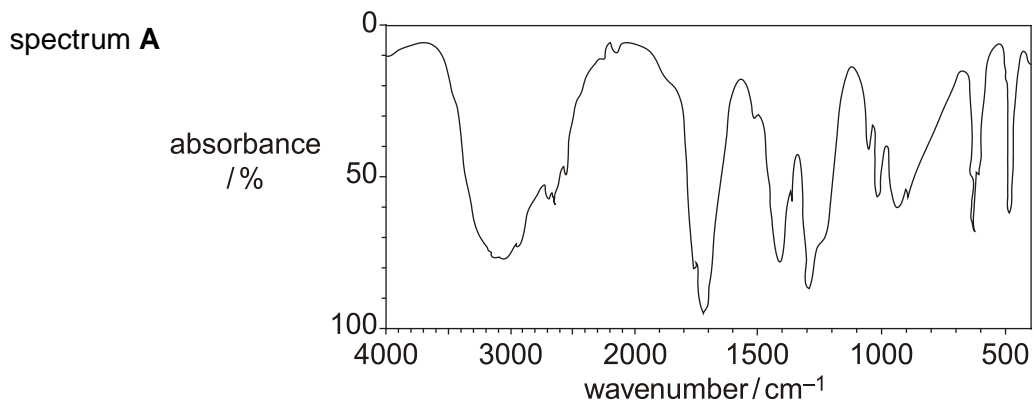
[2]

- (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.



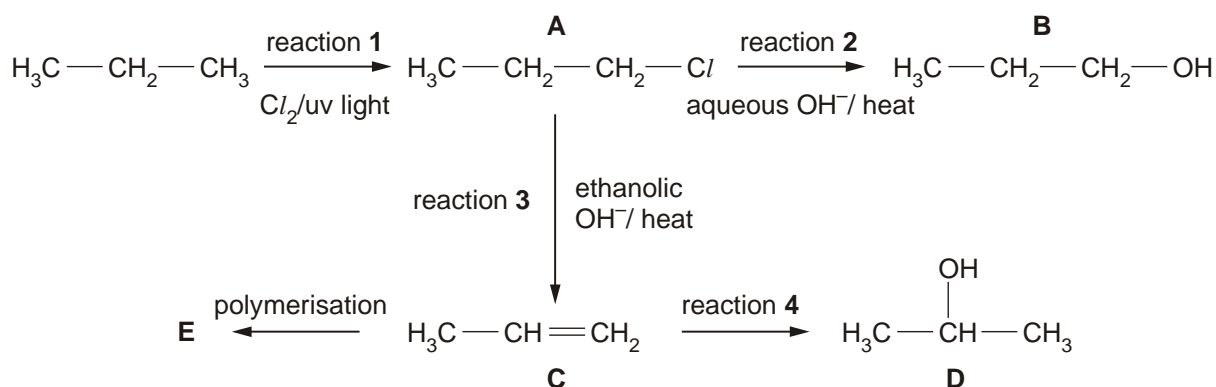
The organic product collected when using the apparatus shown in Fig. 1 is most likely to be that shown by spectrum ..... because.....

.....  
 .....

[3]

[Total 9 marks]

20. Propane, C<sub>3</sub>H<sub>8</sub>, is used in the reaction sequence shown below.



(a) The reaction sequence shows several important reaction mechanisms. Select from reactions 1 to 4, the reaction that shows

(i) free radical substitution, reaction .....

[1]

(ii) electrophilic addition, reaction .....

[1]

(iii) elimination, reaction .....

[1]

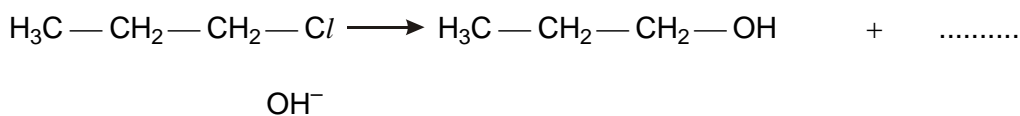
(b) In reaction 2, the aqueous OH<sup>-</sup> acts as a nucleophile.

(i) State what is meant by the term *nucleophile*.

.....

[1]

- (ii) Complete, with the aid of curly arrows, the mechanism involved in reaction 2. Show any relevant dipoles.



[4]

- (c) Compounds **B** and **D** are structural isomers of each other.

- (i) State what is meant by the term *structural isomers*.

.....  
 .....

[2]

- (ii) Draw the skeletal formulae of compounds **B** and **D**.

Compound <b>B</b>	Compound <b>D</b>

[2]

- (d) Compound **C** can be polymerised to form compound **E**.

- (i) State the type of polymerisation. ....

[1]

- (ii) Name compound **E**. ....

[1]

- (iii) Draw a section of compound **E**. Show **two** repeat units.

[1]

[Total 15 marks]

21. 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.

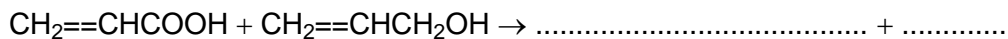
.....

[1]

[Total 6 marks]

22. 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]

- 23.** In this question, one mark is available for the quality of spelling, punctuation and grammar.

The rates of hydrolysis of chloroethane, bromoethane and iodoethane are different.

- Describe how you would monitor the reaction rates.
- Explain why chloroethane, bromoethane and iodoethane react at different rates.

Use suitable equations in your answer.

[Total 6 marks]





24. In 1930, an American engineer, Thomas Midgley, demonstrated a new refrigerant. As part of his demonstration, he inhaled a lung full of dichlorodifluoromethane,  $\text{CCl}_2\text{F}_2$ , and used it to blow out a candle.

Use Midgley's demonstration to suggest **two** properties of  $\text{CCl}_2\text{F}_2$ . Explain, with a reason, **two** other uses of chemicals such as  $\text{CCl}_2\text{F}_2$ , other than as a refrigerant.

.....

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.....

[Total 4 marks]

25. (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.

$\begin{array}{cccc} \text{H} & \text{H} & \text{H} & \text{H} \\   &   &   &   \\ \text{H}-\text{C} & -\text{C} & -\text{C} & -\text{C}-\text{H} \\   &   &   &   \\ \text{H} & \text{H} & \text{H} & \text{OH} \end{array}$			
<b>butan-1-ol</b>	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  $\text{CH}_2$  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**.

.....

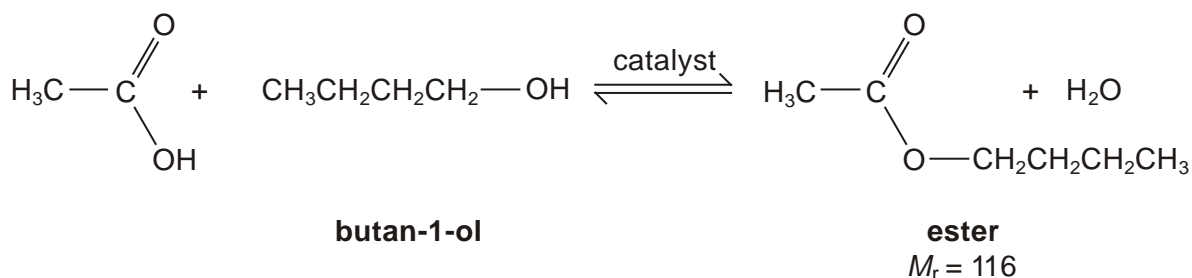
[1]

(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.

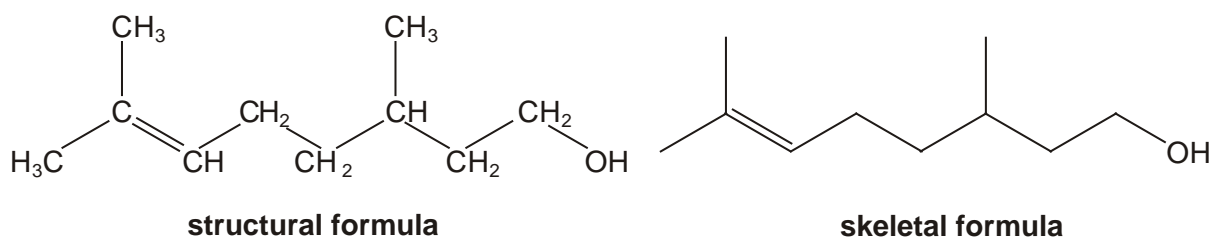
[1]

- (iii) Calculate the percentage yield.

[1]

[Total 14 marks]

26. Citronellol,  $\text{C}_{10}\text{H}_{20}\text{O}$ , 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.

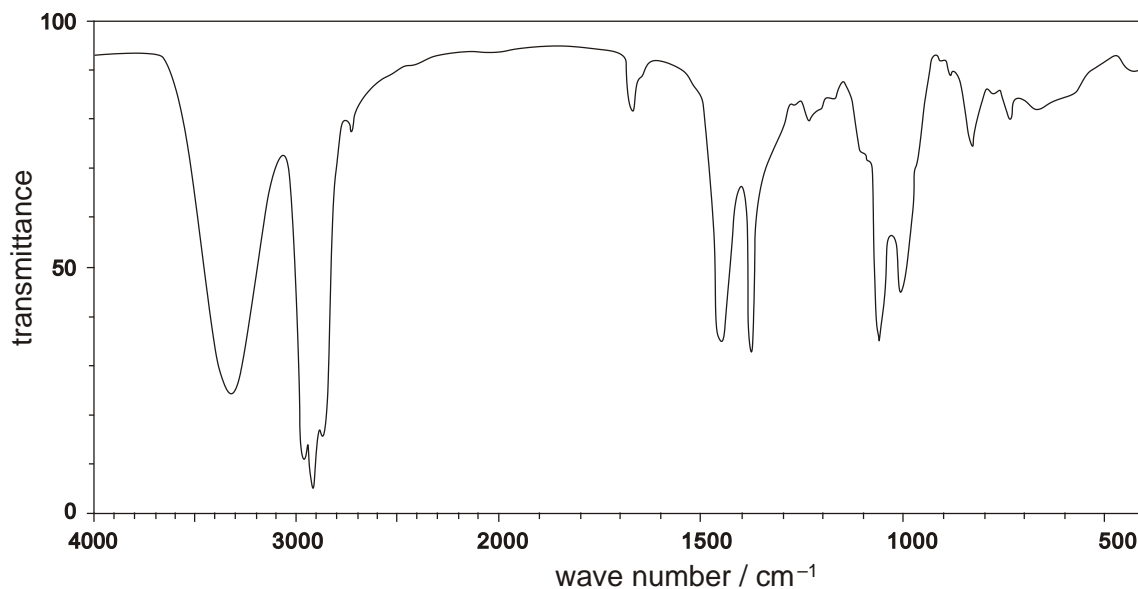
.....

[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,  $C_{10}H_{20}O$ , 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]

27. (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.

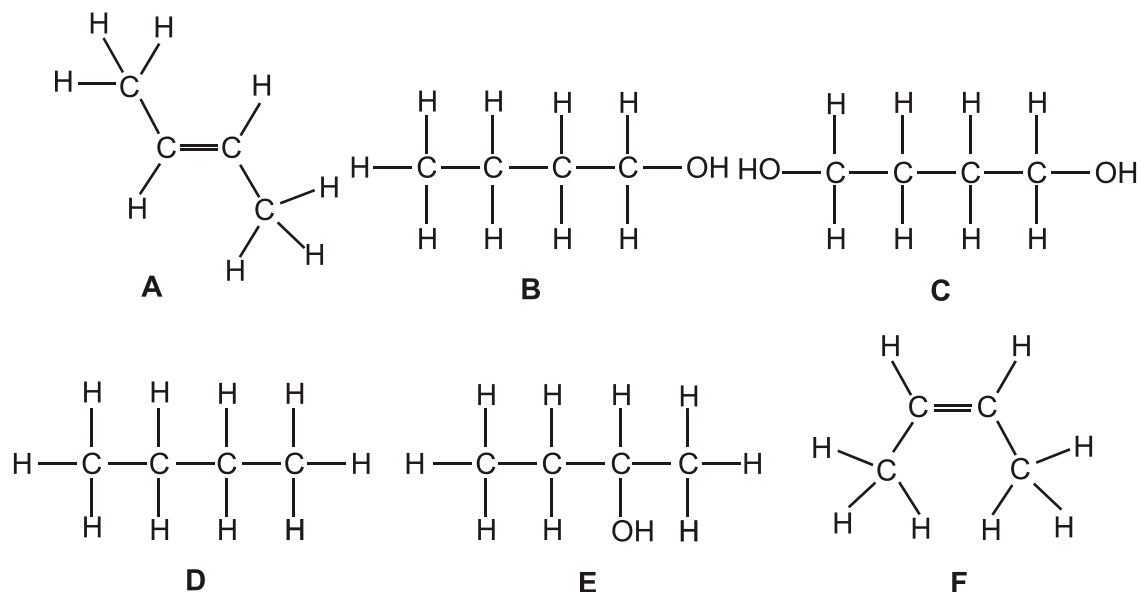
Future supplies of ethanol are likely to come from glucose rather than from ethene. Explain why.

[9]

Quality of Written Communication [1]

[Total 12 marks]

28. 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 .....

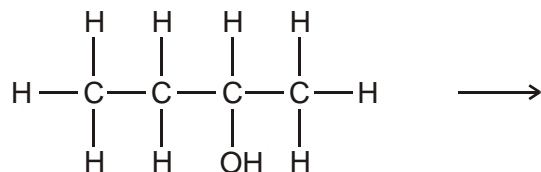
[1]

(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,  $\text{C}_4\text{H}_6$ . Suggest a structural formula and a name for **G**.

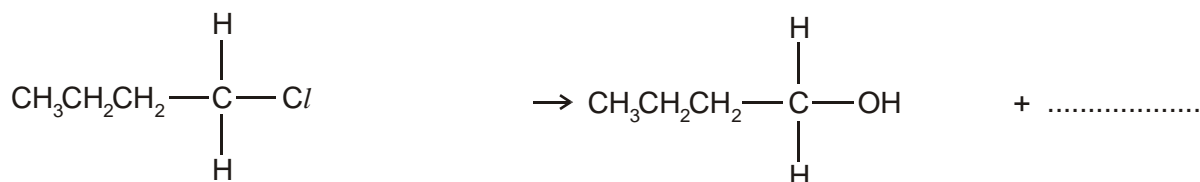
name .....

[2]

[Total 7 marks]

- 29.** Halogenoalkanes, such as 1-chlorobutane, are hydrolysed with hot aqueous alkali,  $\text{OH}^-(\text{aq})$ , to form alcohols.

- (a) Describe, with the aid of curly arrows, the mechanism of the hydrolysis of 1-chlorobutane with  $\text{OH}^-(\text{aq})$  ions to produce butan-1-ol. Show any relevant lone pairs of electrons and dipoles.



[4]

(b) Another halogenoalkane, **H**, has a relative molecular mass of 127 and has the following composition by mass:  
C, 37.8%; H, 6.3%; Cl, 55.9%.

(i) Show that the empirical formula of compound **H** is  $C_2H_2Cl$ .

[2]

(ii) Deduce the molecular formula of compound **H**.

[1]

(iii) Compound **H** can also be hydrolysed with hot aqueous alkali to form butane-1,3-diol. Draw the structure of butane-1,3-diol

[1]

(iv) Deduce the structure of compound **H**.

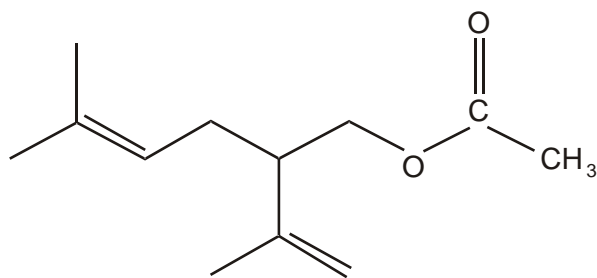
[1]

[Total 9 marks]





- (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.

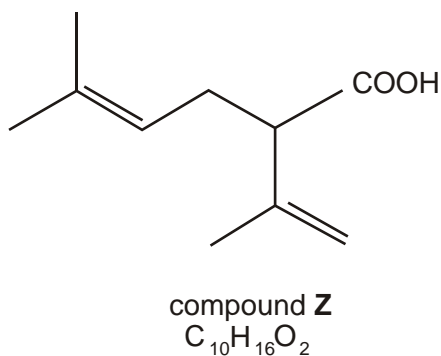
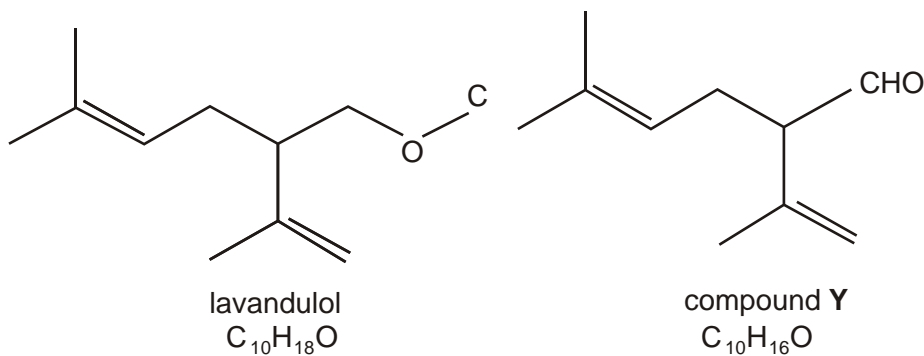
reagent .....

[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]