

F322: Chains, Energy and Resources

2.2.3 Modern Analytical Techniques

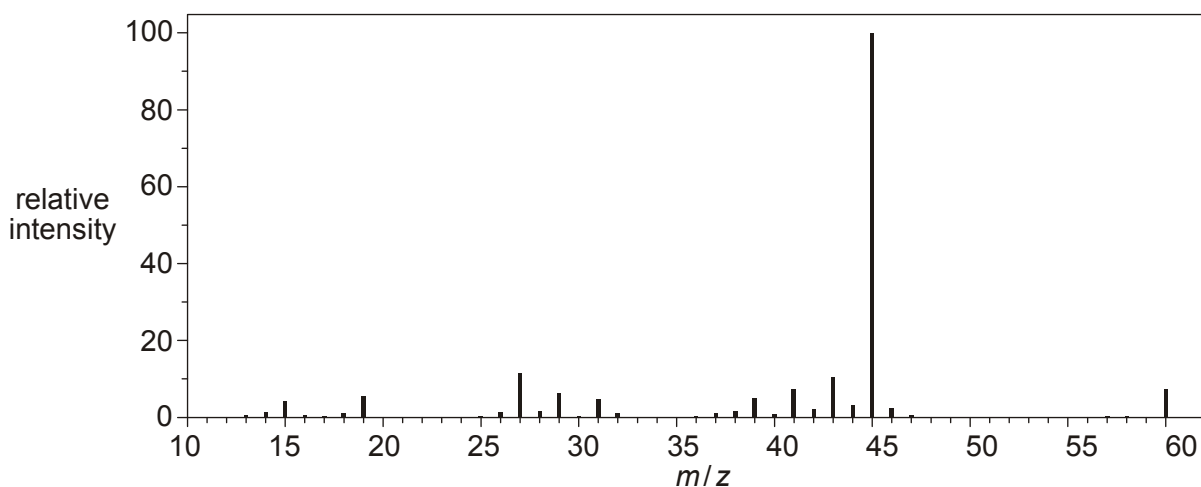
1. Alcohol **E** is one of the following alcohols.

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

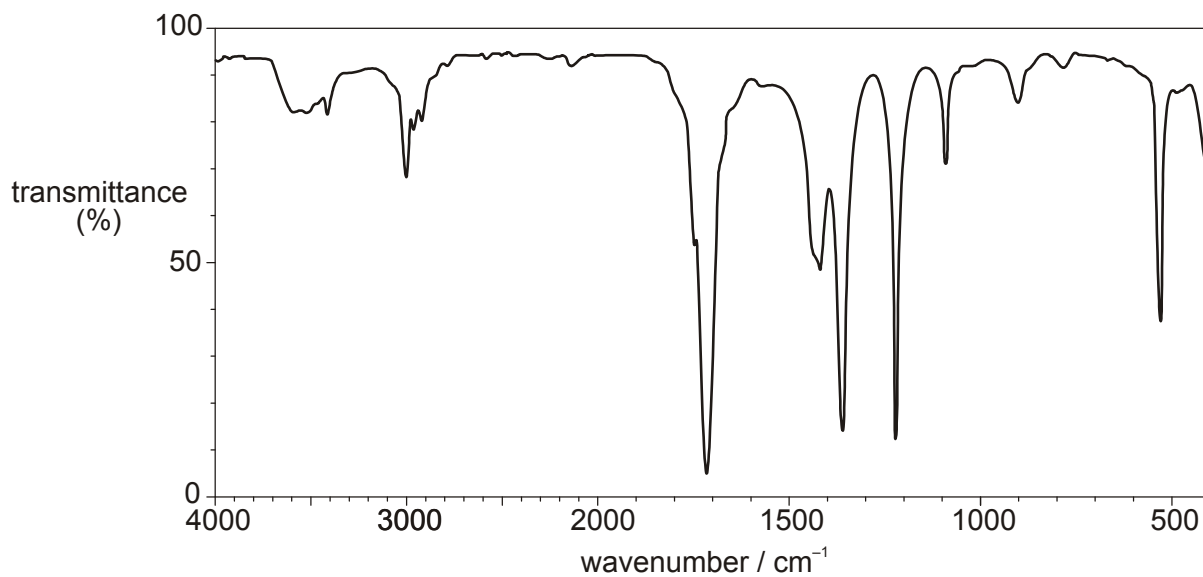
ethane-1,2-diol
2-methylpropan-2-ol
propan-2-ol

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).

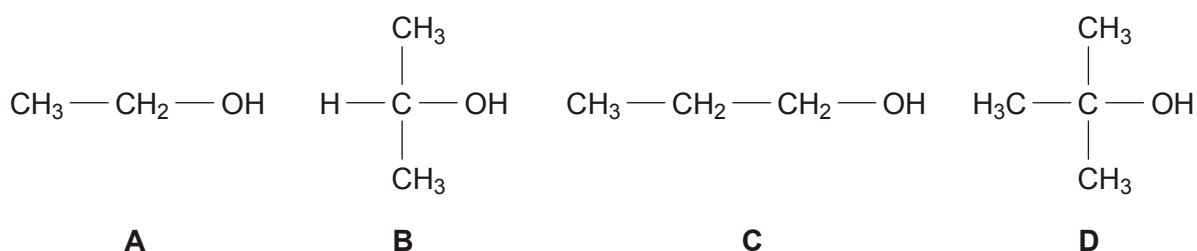
Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).



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

[Total 7 marks]

2. 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).

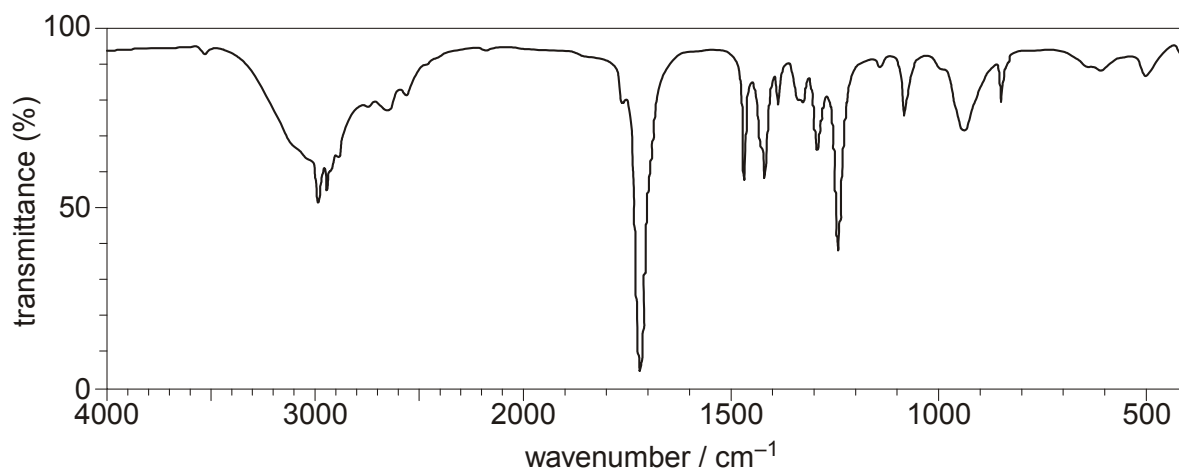
organic product:

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.



wavenumber / cm⁻¹

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]

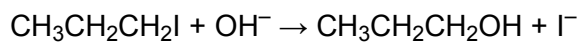
(iii) Draw the structure of the organic product **E**.

[2]

[Total 13 marks]

3. A student carried out an investigation to compare the rates of hydrolysis of 1-iodopropane and 1-bromopropane. The student heated hot aqueous sodium hydroxide with each halogenoalkane and found that 1-iodopropane was hydrolysed faster.

The equation for the reaction with 1-iodopropane is shown below.



- (a) (i) Outline the mechanism for this hydrolysis of 1-iodopropane.
Show curly arrows and relevant dipoles.

[3]

- (ii) State the name of this type of mechanism.

.....

[1]

- (b) Explain why 1-iodopropane is hydrolysed faster than 1-bromopropane.

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

[2]

[Total 6 marks]

4. An analytical chemist was provided with a compound **J** which has an unbranched carbon skeleton. After analysis, the chemist obtained the following results.

type of analysis	evidence
infrared spectroscopy	broad absorption at 3350 cm^{-1}
percentage composition by mass	C, 70.59%; H, 13.72%; O, 15.69%
mass spectrometry	molecular ion peak at $m/z = 102.0$

Use this information to suggest all the possible structures for the **unbranched** compound **J**.



In your answer you should make clear how your explanation is linked to the evidence.

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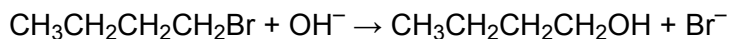
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.....

.....

[Total 8 marks]

5. 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]

6. Compound **X** is an atmospheric pollutant emitted from fuel combustion of petrol and diesel vehicles. Compound **X** is a potent human carcinogen.

- Analysis of compound **X** showed the following percentage composition by mass: C, 88.89%; H, 11.1%.
- Mass spectrometry showed a molecular ion peak at $m/z = 54$.
- Compound **X** reacts with H_2 in the presence of a nickel catalyst in a 1 : 2 molar ratio.

Analyse and interpret this information to determine a possible structure for compound **X**.

Show all your working.

[Total 5 marks]

7. (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 $1680\text{--}1750\text{ cm}^{-1}$ but did **not** contain a broad absorption in the region $2500\text{--}3300\text{ cm}^{-1}$.

Refer to the Data Sheet for Chemistry provided.

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

.....

[1]

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

.....

[1]

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

Explain why.

.....

.....

[2]

[Total 7 marks]

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

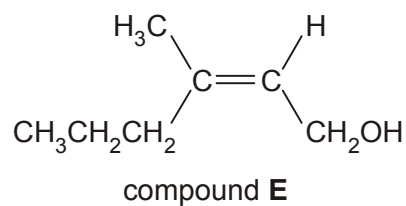
(i) State a suitable oxidising mixture for this reaction.

.....

[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]

9. (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).

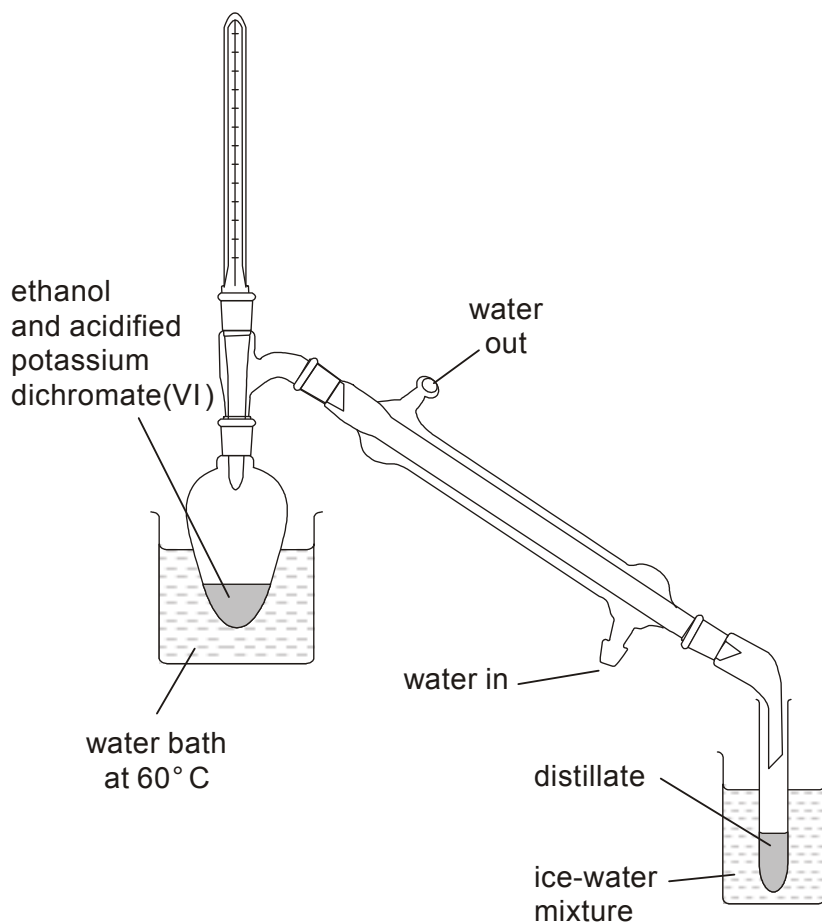


Fig. 1

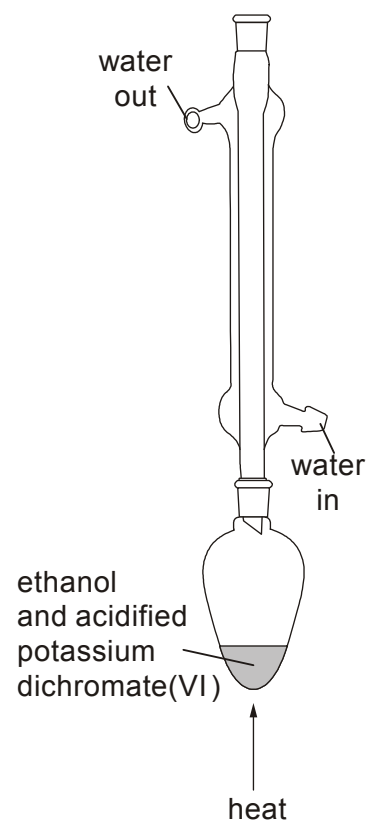


Fig. 2

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

	CH ₃ CH ₂ OH	CH ₃ CHO	CH ₃ 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]

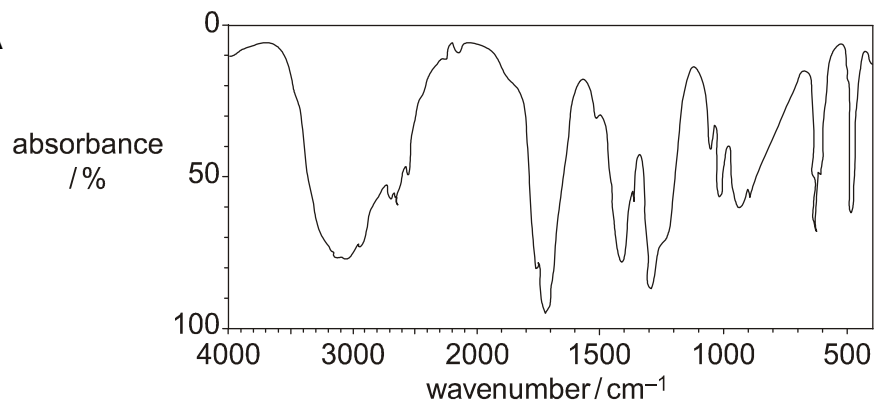
- (b) Write a balanced equation for the oxidation of ethanol to ethanoic acid. Use (O) to represent the oxidising agent.

.....

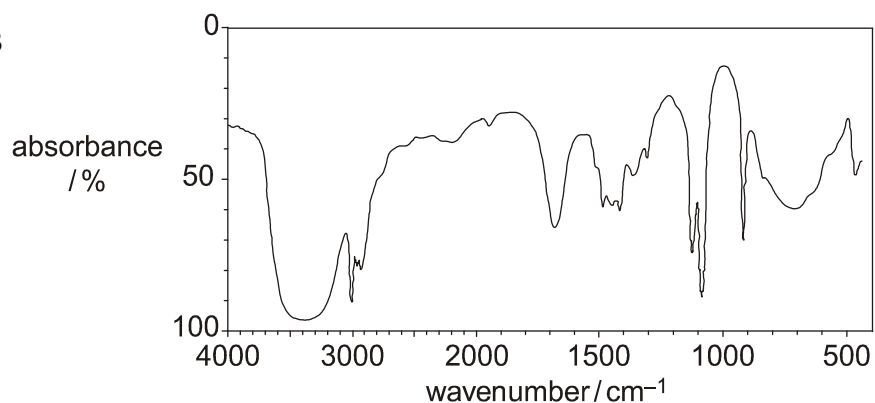
[2]

- (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.

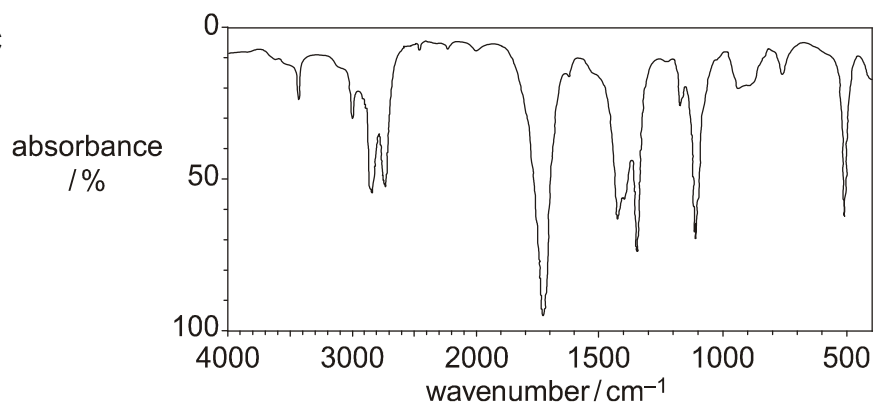
spectrum A



spectrum B



spectrum C



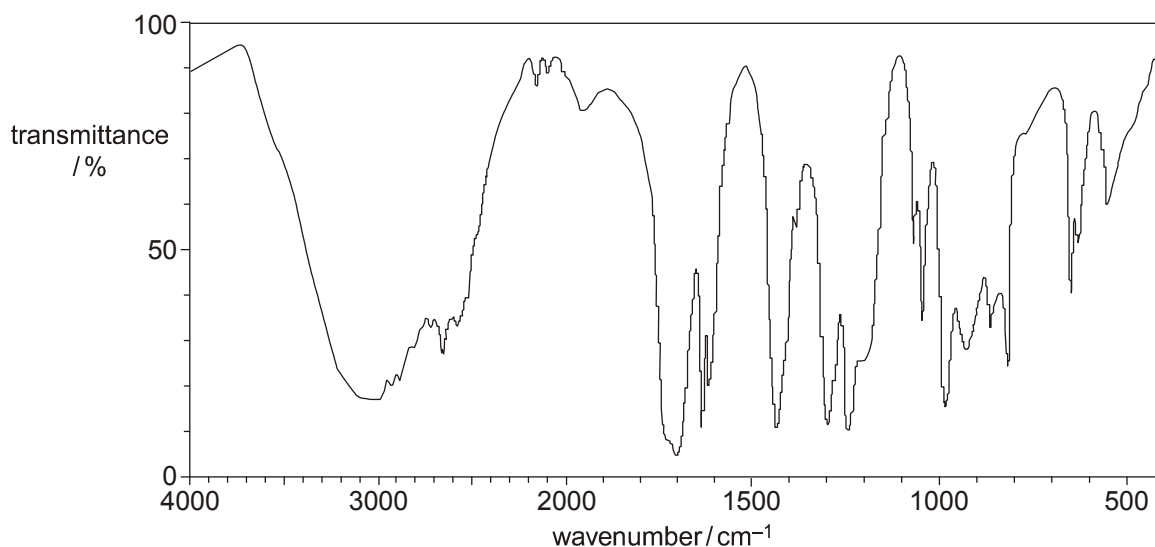
The organic product collected when using the apparatus shown in Fig. 1 is most likely to be that shown by spectrum because.....

.....

[3]

[Total 9 marks]

10. A sample of prop-2-en-1-ol was oxidised and an infra-red spectrum of the organic product was obtained.



By referring to your Data Sheet, decide whether acrolein, $\text{CH}_2=\text{CHCHO}$, or acrylic acid, $\text{CH}_2=\text{CHCOOH}$, was formed.

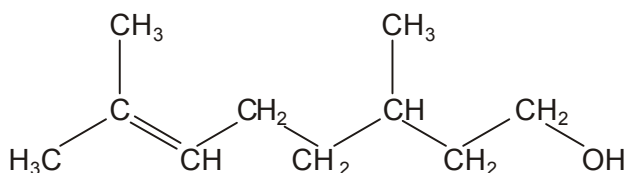
The infra-red spectrum above is of

because

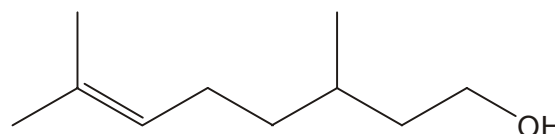
.....

[Total 3 marks]

11. 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.



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.

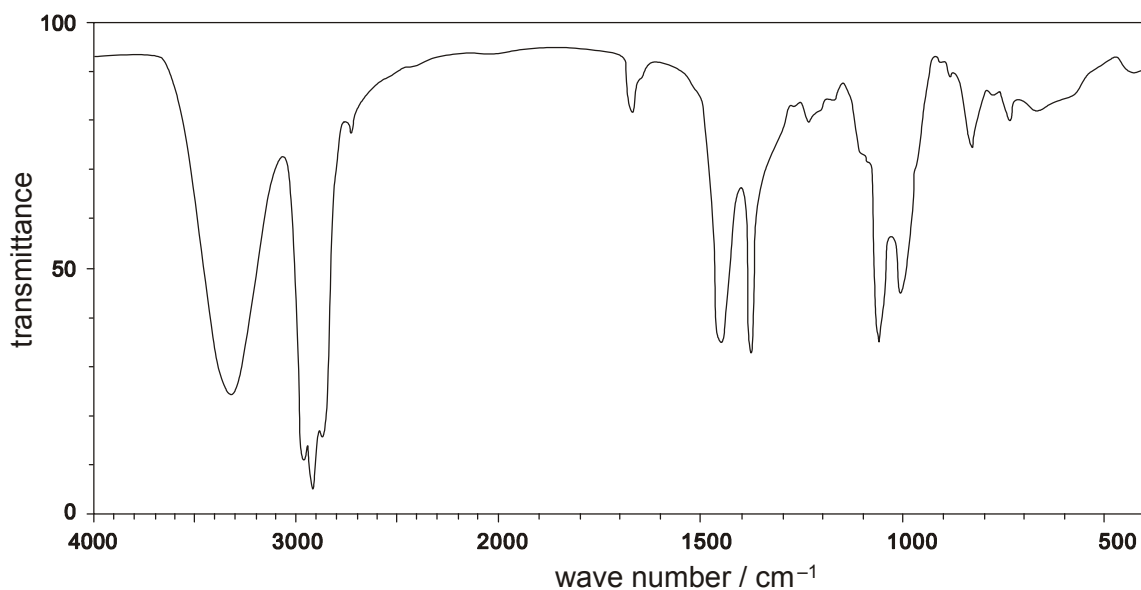
.....

[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]

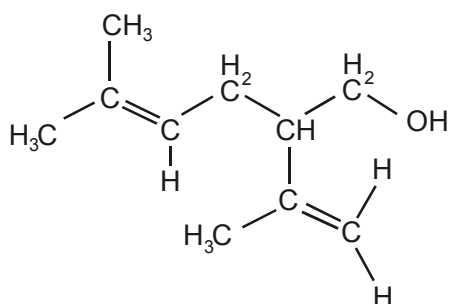
(iii) Construct a balanced equation for this reaction.

.....

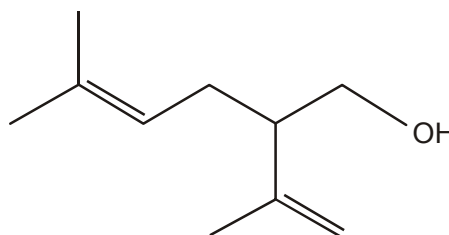
[1]

[Total 9 marks]

12. 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.

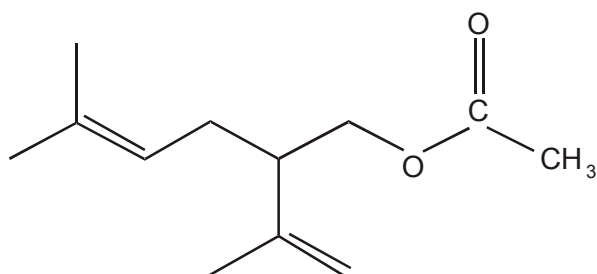
observation

[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.

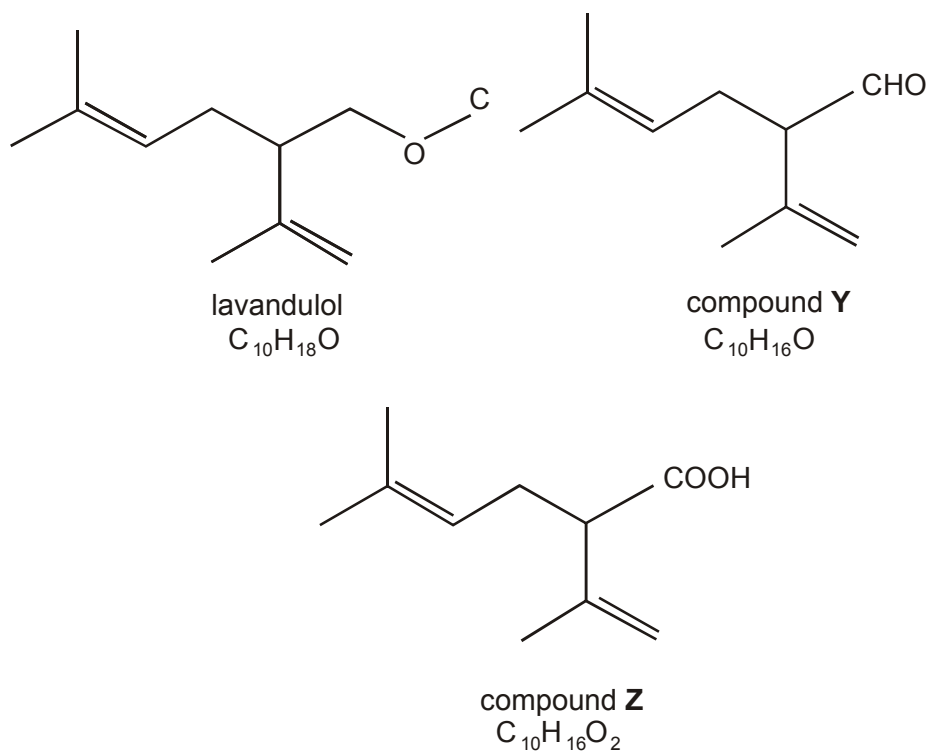
reagent

[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 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]