3 A student was given three compounds, an aldehyde, a ketone, and a carboxylic acid.

(a) The student carried out the same two chemical tests on each compound. This allowed her to distinguish between all three compounds.

- Describe two suitable tests that the student could have used.
- Show how the observations would allow her to distinguish between the compounds.

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..... **[4]**

(b) Explain how the student could use infrared spectroscopy to confirm which compound is a carboxylic acid.

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..... **[1]**

(c) The aldehyde has the molecular formula $C_5H_{10}O$.

The ^1H NMR spectrum of the aldehyde contains a doublet at $\delta = 0.9$ ppm with a relative peak area of six compared with the aldehyde proton.

Analyse this information to deduce the structure of the aldehyde. Explain your reasoning.

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..... **[3]**

(d) The ketone also has the molecular formula $C_5H_{10}O$. There are three structural isomers of this formula that are ketones.

(i) Two of these isomers are shown below.

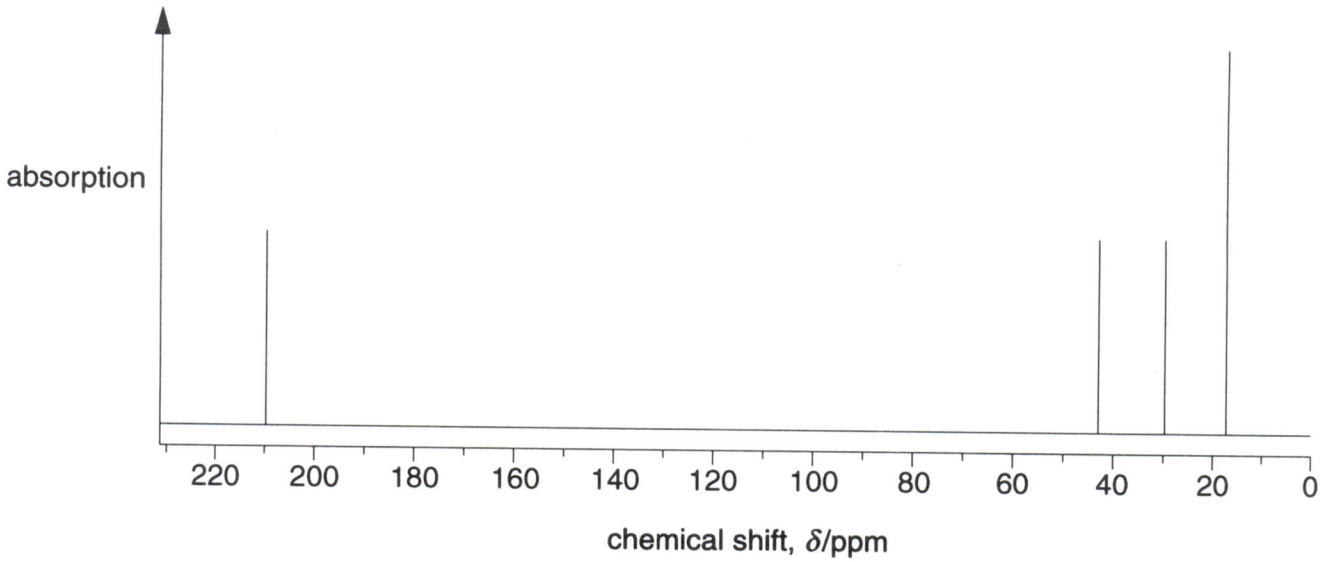
Draw the structural formula of the third structural isomer in the box below.

ketone 1	ketone 2	ketone 3
$CH_3-CH_2-CH_2-C(=O)-CH_3$	$CH_3-CH(CH_3)-C(=O)-CH_3$	

[1]

(ii) The ^{13}C NMR spectrum of the ketone given to the student is shown below.

- Use the spectrum to identify the ketone. Explain your reasoning.
- Identify the carbon responsible for the peak at $\delta = 210$ ppm.



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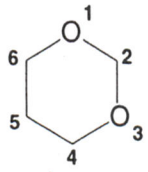
..... **[3]**

[Total: 12]

6 A company was planning to build a power station that will burn plastic waste. The local residents were concerned about possible emission of pollutants such as dioxanes and aromatic hydrocarbons. The residents employed an independent chemical engineer to advise about possible emissions.

Some scientists suspect that dioxanes, such as 1,3-dioxane, and aromatic hydrocarbons may be linked to some types of cancer.



1,3-dioxane

(a) Predict the splitting patterns in the proton NMR spectrum of 1,3-dioxane.

Identify which protons are responsible for each splitting pattern.

In your answer, you should use appropriate technical terms, spelled correctly.

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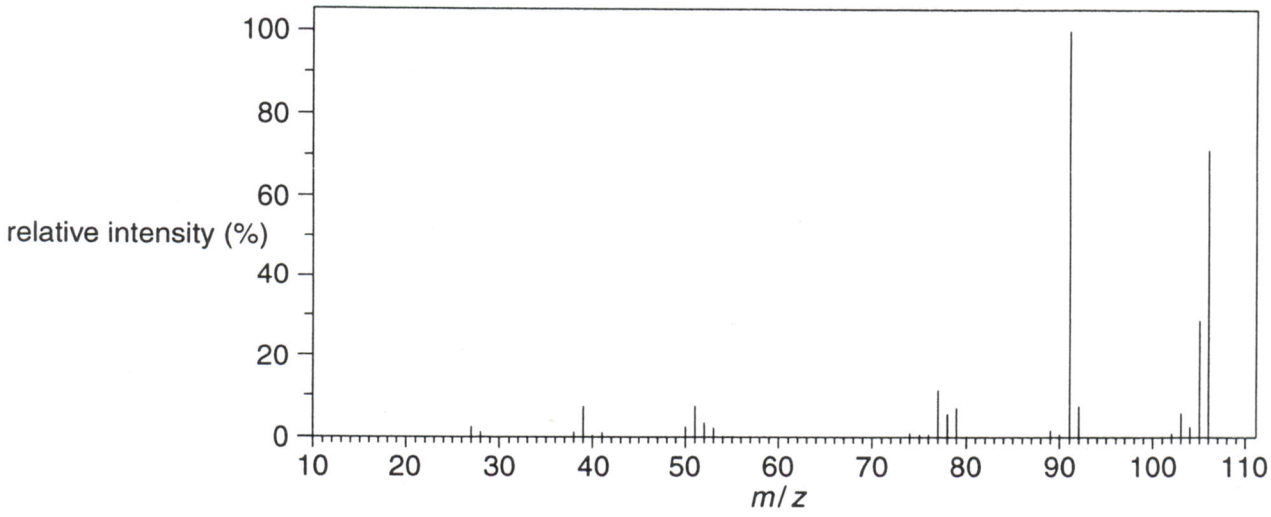
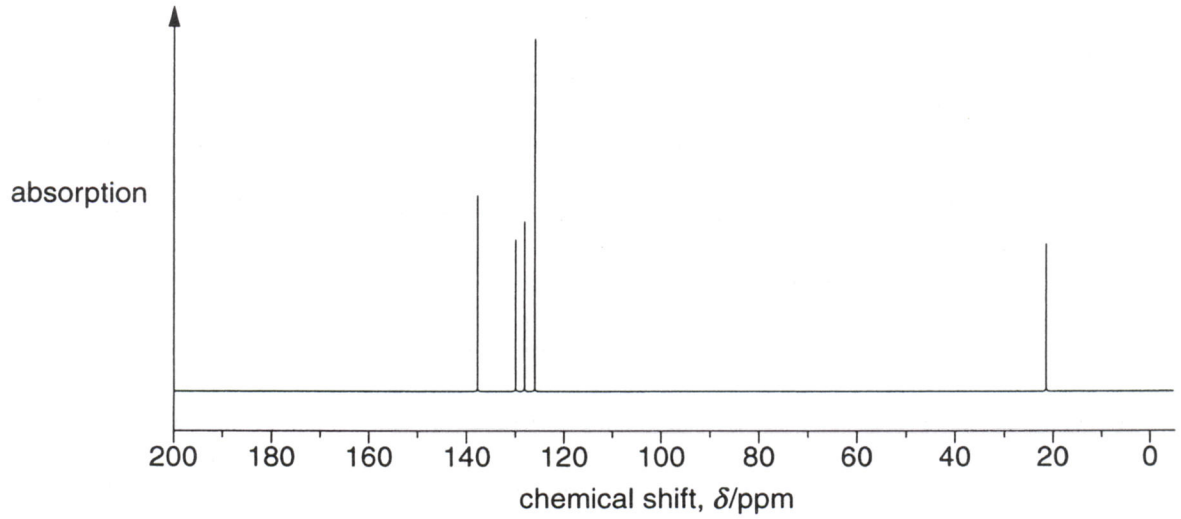
..... **[3]**

TURN OVER FOR QUESTION 6 (b)

(b) The independent chemical engineer investigated an unknown aromatic hydrocarbon.
He obtained the mass spectrum and the ^{13}C NMR spectrum of the aromatic hydrocarbon, which are shown below.





The aromatic hydrocarbon is one of **four** possible isomers.

Use the spectra to identify the aromatic hydrocarbon.

Show **all** of your working and explain how you ruled out the other three isomers.

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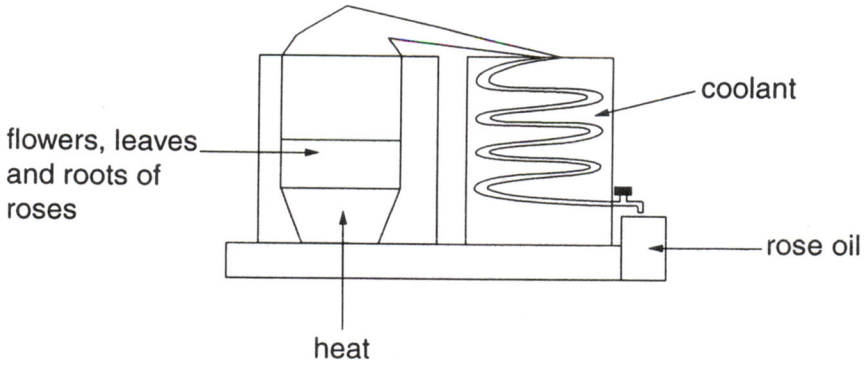
5 Rose oil can be extracted from the flowers, leaves and roots of roses using the apparatus below.



(a) The rose oil contains a mixture of compounds, some of which can be separated by using thin-layer chromatography (TLC). The chromatogram obtained is shown below.

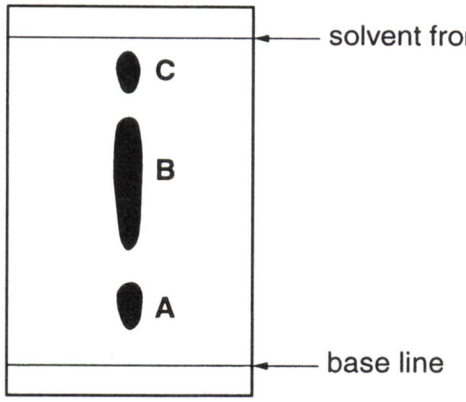


Fig. 5.1

(i) Explain how TLC separates compounds in the mixture.

In your answer, you should use appropriate technical terms, spelled correctly.

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..... **[1]**

(ii) Estimate the R_f value of **A**.

[1]

(iii) Using the chromatogram in **Fig. 5.1**, suggest why it is **not** possible to conclude that the rose oil contains **only** three different compounds.

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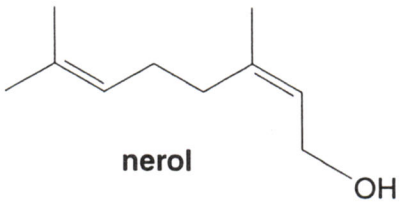
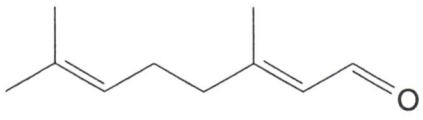
..... [1]

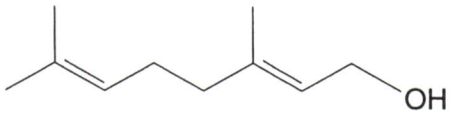
(b) GC–MS was used to identify the compounds present in the rose oil as nerol, geraniol, citral and menthol, shown below. These compounds all have stereoisomers.



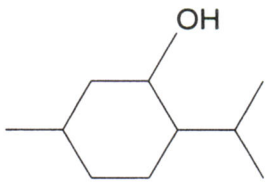
nerol



citral



geraniol



menthol

(i) Explain how GC–MS can be used to identify these compounds in the rose oil.

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..... [1]

(ii) Suggest, with a reason, which two compounds might be present in **B** in **Fig. 5.1**.

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..... [1]

(iii) Explain what is meant by the term *stereoisomers*.

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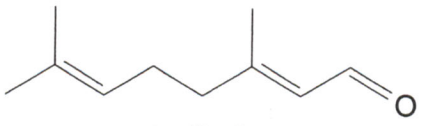
..... [1]

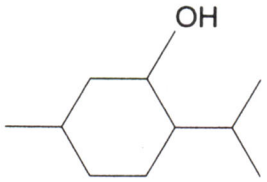
(iv) Draw a circle around the feature in citral that causes the stereoisomerism.



citral

[1]

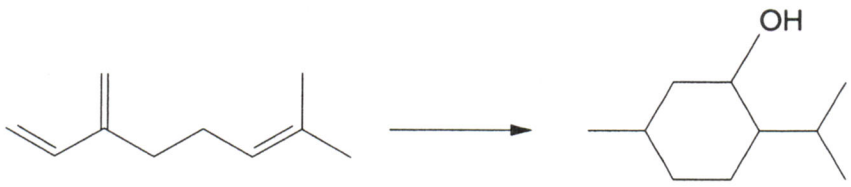
(v) Identify with asterisks (*) **all** the chiral centres in menthol that cause the stereoisomerism.



menthol

[2]

(c) Menthol is used in a wide range of products including lip balms, cough medicines and perfumery. The demand for menthol exceeds the supply from natural sources. Menthol is manufactured, using a chiral synthesis, from myrcene, a readily available starting material.



myrcene **menthol**

Calculate the mass of menthol that can be synthesised from 34.0 g of myrcene.
The percentage yield is 60%. M_r (Myrcene) = 136.

mass of menthol = ... g **[3]**

[Total: 12]

4 An industrial chemist discovered five bottles of different chemicals (three esters and two carboxylic acids) that were all labelled $C_5H_{10}O_2$.

The different chemicals had the structural formulae below.

$CH_3CH_2COOCH_2CH_3$ $(CH_3)_3CCOOH$ $CH_3COOCH(CH_3)_2$

$(CH_3)_2CHCH_2COOH$ $(CH_3)_2CHCOOCH_3$

(a) The chemist used both infrared and ^{13}C NMR spectroscopy to identify the two carboxylic acids and to distinguish between them.

How do both types of spectra allow the carboxylic acids to be identified and distinguished?

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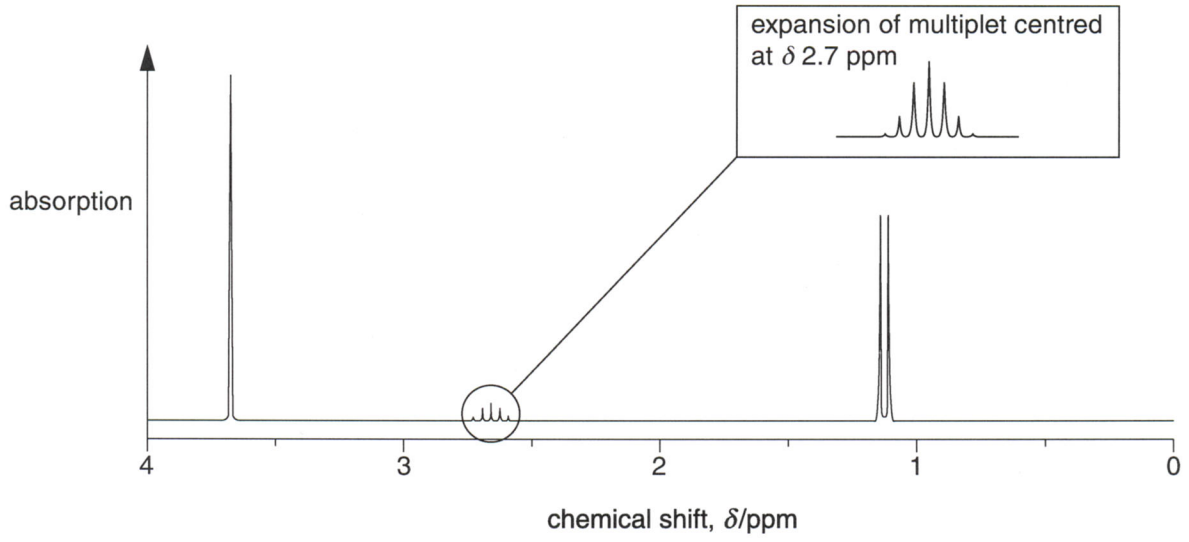
..... **[3]**

(b) The chemist analysed one of the esters by ^1H NMR spectroscopy. The spectrum is shown below.



Analyse the splitting patterns and the chemical shift values to identify the ester.

Give your reasoning.

In your answer, you should use appropriate technical terms, spelt correctly.

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[Total: 9]