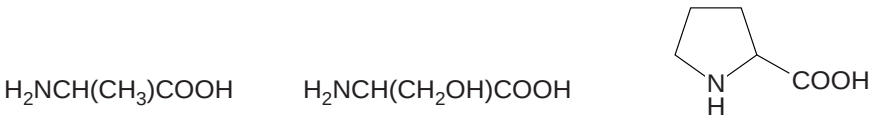
1 Alanine, serine and proline are α-amino acids.



alanine **serine** **proline**

(a) (i) Alanine and serine react together to form two different dipeptides.

Draw the structures of the **two** dipeptides that can form when alanine and serine react together.

[2]

(ii) The isoelectric points of alanine and serine are shown below.

alanine, pH = 6.0

serine, pH = 5.6

Draw the structures of the ions formed at the following pH values.

structure of **alanine** ion at **pH 6.0**

structure of **serine** ion at **pH 10.0**

[2]

(iii) Proline can polymerise to form poly(proline).

Draw the structure of the repeat unit in poly(proline).

[1]

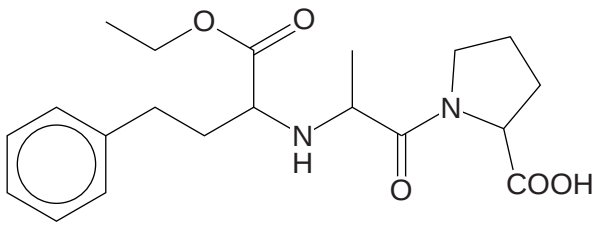
(b) A solution of serine was shaken with a few drops of D_2O. The solution was then analysed using ^1H NMR spectroscopy.

Complete the table to predict the ^1H NMR spectrum of serine after the addition of D_2O.

^1H NMR spectrum for serine		
Chemical shift, δ / ppm	**Relative peak area**	**Splitting pattern**

[2]

(c) Enalapril is a drug used in the treatment of high blood pressure.



enalapril

(i) **On the structure above**, mark each chiral centre with an asterisk (*). **[1]**

(ii) Suggest **two** benefits of using single stereoisomers in the synthesis of drugs such as enalapril.

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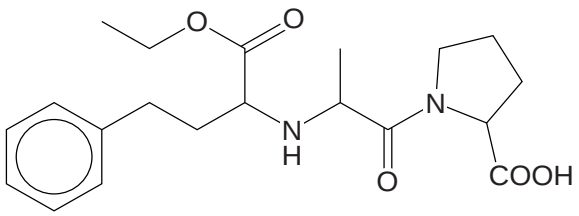
..... **[2]**

(iii) Enalapril is broken down in the body by acid hydrolysis.



enalapril

Draw the structures of the **three** organic products of the **acid hydrolysis** of enalapril.

[4]

(iv) A scientist hydrolysed enalapril in the laboratory. The scientist then analysed the mixture of products using GC–MS.

Explain how GC–MS enables the products to be identified.

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

[Total: 15]

2 Benzene and other arenes can be chlorinated to produce chloroarenes which are used in the manufacture of pesticides, drugs and dyes.

(a) Chlorobenzene, C_6H_5Cl, is formed by the reaction of benzene and chlorine in the presence of a suitable catalyst, such as $AlCl_3$.

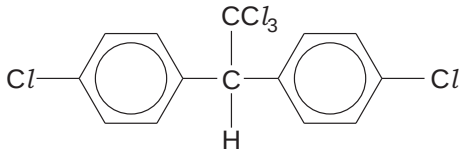
$$C_6H_6 + Cl_2 \rightarrow C_6H_5Cl + HCl$$

Outline the mechanism for the formation of chlorobenzene from benzene.

Show how $AlCl_3$ behaves as a catalyst.

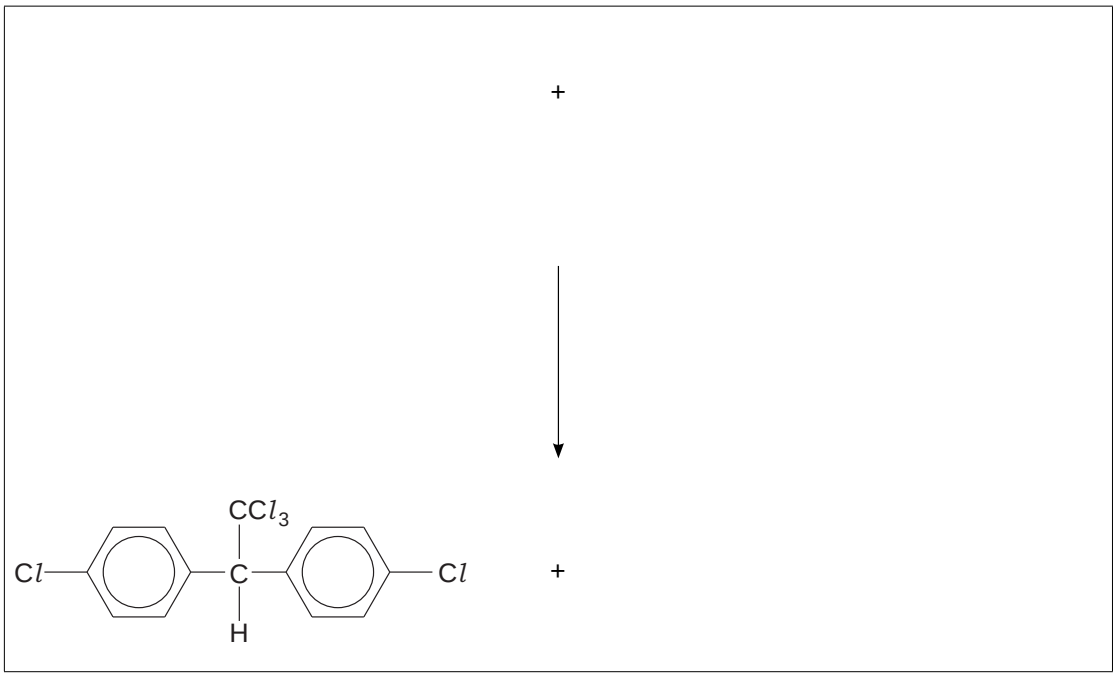
[6]

(b) Chlorobenzene reacts with trichloroethanal, Cl_3CCHO, to produce the pesticide DDT.



DDT

(i) Construct an equation for the reaction of chlorobenzene with trichloroethanal to form DDT.



[2]

(ii) Predict the number of peaks in the ^{13}C NMR spectrum of DDT.

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

(c) Chlorobenzene can be nitrated to form a mixture of products.

Suggest why the reaction forms a mixture of products.

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

(d) Explain why phenol reacts more readily with chlorine than benzene reacts with chlorine.

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

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

[Total: 13]

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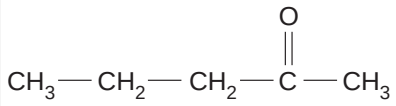
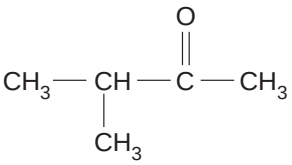
..... **[3]**

(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.

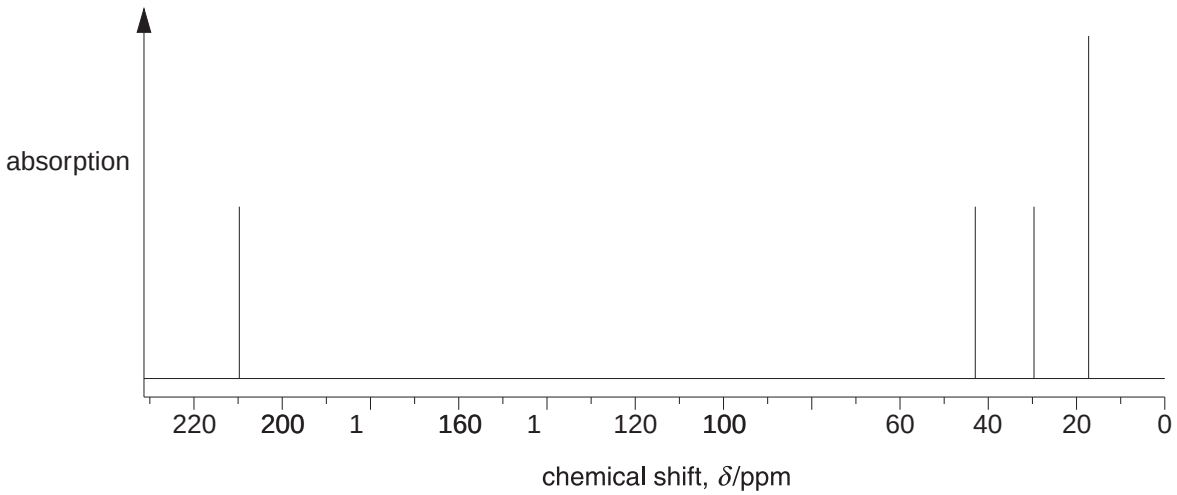
Draw the structural formula of the third structural isomer in the box below.

ketone 1	ketone 2	ketone 3
		

[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 δ = 210 ppm.



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

[Total: 12]

4 A chemist prepares and analyses some esters.

(a) The chemist prepares an ester of propan-2-ol, $CH_3CH(OH)CH_3$, by reacting $CH_3CH(OH)CH_3$ with ethanoic anhydride, $(CH_3CO)_2O$.

Using structural formulae, write an equation for the reaction of propan-2-ol and ethanoic anhydride.

[2]

(b) A sample contains a mixture of two esters contaminated with an alkane and an alcohol.

The chemist attempts to separate the four organic compounds in the mixture using gas chromatography, GC.

The column in the gas chromatograph contains a liquid alkane which acts as the stationary phase.

(i) How does a liquid stationary phase separate the organic compounds in a mixture?

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

(ii) Suggest how well these four compounds would be separated using the alkane stationary phase. In your answer, include some indication of the length of the retention times.

Explain your answer.

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..... **[2]**

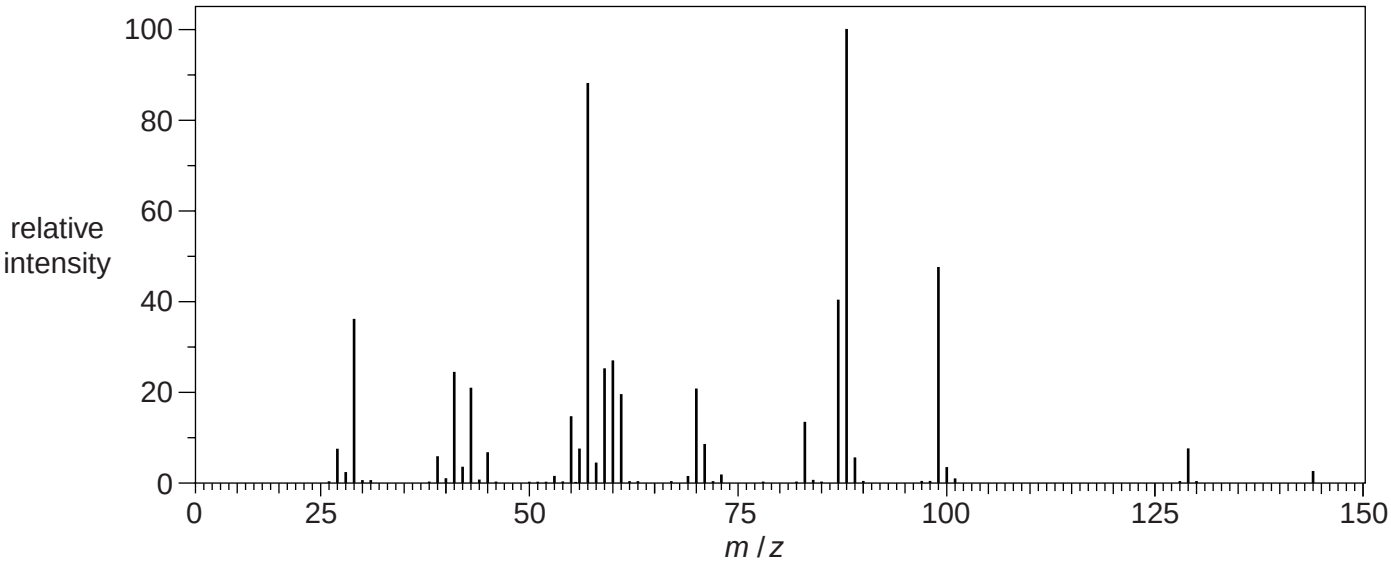
(c) GC is often used together with other techniques, such as mass spectrometry, MS, and NMR spectroscopy, to provide a far more powerful analytical tool than GC alone.

One of the esters in a perfume is separated by GC and then analysed.

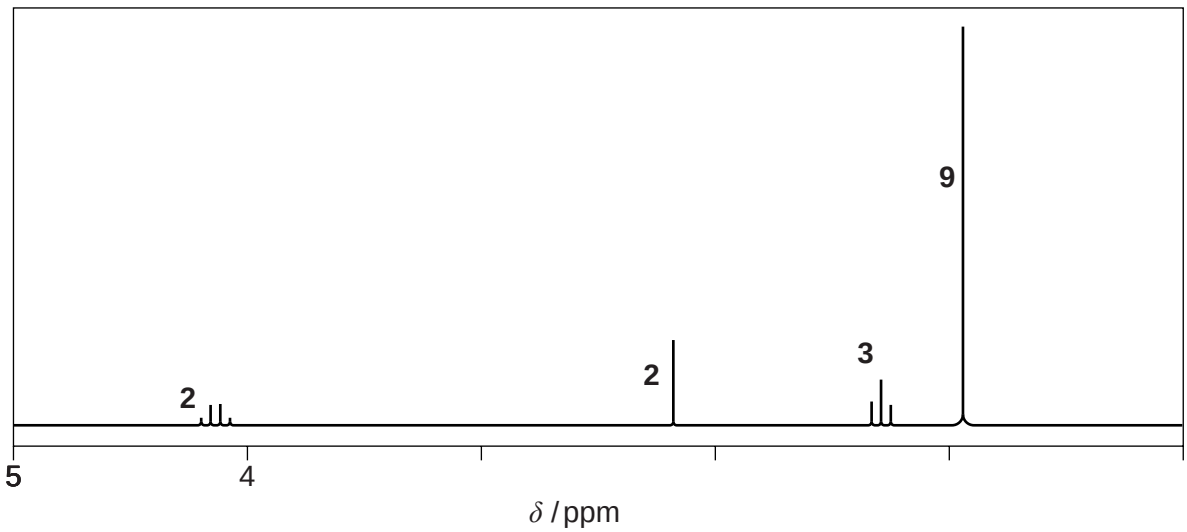
The results are shown below.

Elemental analysis by mass
C, 66.63%; H, 11.18%; O, 22.19%

Mass spectrum



Proton NMR spectrum
The numbers by each peak are the relative peak areas.



Use the results to identify the ester. Show **all** your reasoning.

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

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[Total: 15]