Answer **all** the questions.

1 This question looks at the properties and chemistry of some α-amino acids. The general formula of an α-amino acid is $RCH(NH_2)COOH$.

(a) In the α-amino acid alanine, $CH_3CH(NH_2)COOH$, R is CH_3.
The isoelectric point of alanine is at pH 6.0.

(i) What is meant by the term *isoelectric point?*

....

....

.... **[1]**

(ii) Draw the structures of the ions formed by alanine at pH 6.0 and at pH 1.5.

ion formed at pH 6.0	**ion formed at pH 1.5**

[2]

(iii) Different R groups in α-amino acids result in different isoelectric points.

Suggest the functional group, in the R group, that results in the isoelectric point being lower than pH 3 and higher than pH 10.

functional group resulting in isoelectric point lower than pH 3: ....

functional group resulting in isoelectric point higher than pH 10: .... **[2]**

(b) The α-amino acid serine, where R is CH_2OH, readily forms a condensation polymer containing peptide links.

Draw a section of poly(serine), showing **two** repeat units.

Display the peptide linkage.

[2]

(c) Apart from glycine, where R is H, all α-amino acids show optical isomerism.

(i) Why does glycine **not** show optical isomerism?

....

....

.... **[1]**

(ii) Draw 3-D diagrams for the two optical isomers of the α-amino acid cysteine, where R is CH_2SH.

[2]

(iii) α-Amino acids are being used in the development of peptide-based pharmaceuticals. Optical isomerism has been found to be significant in the action of some pharmaceuticals.

- State **two** possible disadvantages of synthesising a peptide-based pharmaceutical that contains a mixture of optical isomers.
- State **two** methods that are used by manufacturers to synthesise pharmaceuticals containing just the required optical isomer.

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

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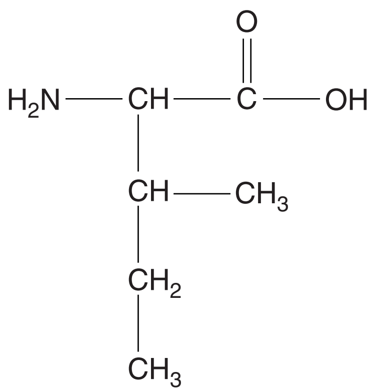
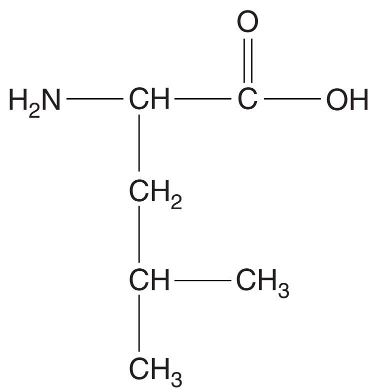
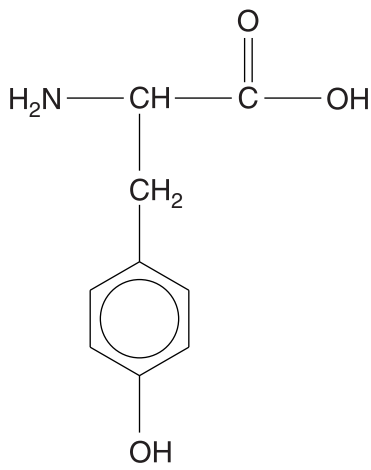
.... **[4]**

Turn over

(d) The structures of the α-amino acids isoleucine, leucine and tyrosine are shown below.

		
isoleucine	**leucine**	**tyrosine**

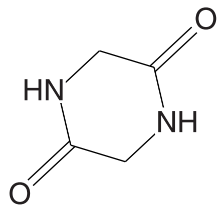
Predict the number of peaks in the carbon-13 spectrum of each of these α-amino acids.

α-amino acid	**isoleucine**	**leucine**	**tyrosine**
number of peaks			

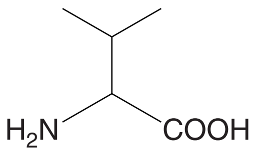
[3]

(e) When strongly heated, an α-amino acid can form a cyclic 'dimer' in a condensation reaction.

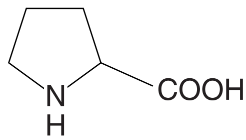
For example, glycine, where R is H, forms the cyclic dimer shown below.



Draw the structures of the cyclic dimers that could be formed from the α-amino acids valine and proline, shown below.



valine



proline

cyclic dimer formed from valine	**cyclic dimer formed from proline**

[2]

[Total: 19]

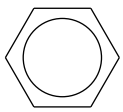
Turn over

2 Benzene is an important starting material in the production of dyes, detergents and medicines.

(a) Aromatic amines, such as 4-chlorophenylamine, are intermediates in the manufacture of azo dyes.

(i) Benzene can be converted into 4-chlorophenylamine in the three stages shown below.

In the boxes
- show the structures of the organic products
- state the chemicals used.



stage 1

chemicals: ....

....

organic product

stage 2

chemicals: ....

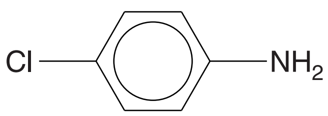
....

organic product

stage 3

chemicals: ....

....



4-chlorophenylamine

[5]

(ii) 4-Chlorophenylamine can be converted into a diazonium ion.
The diazonium ion can then be reacted with phenol in aqueous alkali to form an azo dye.

Draw the structures of the diazonium ion and the azo dye.

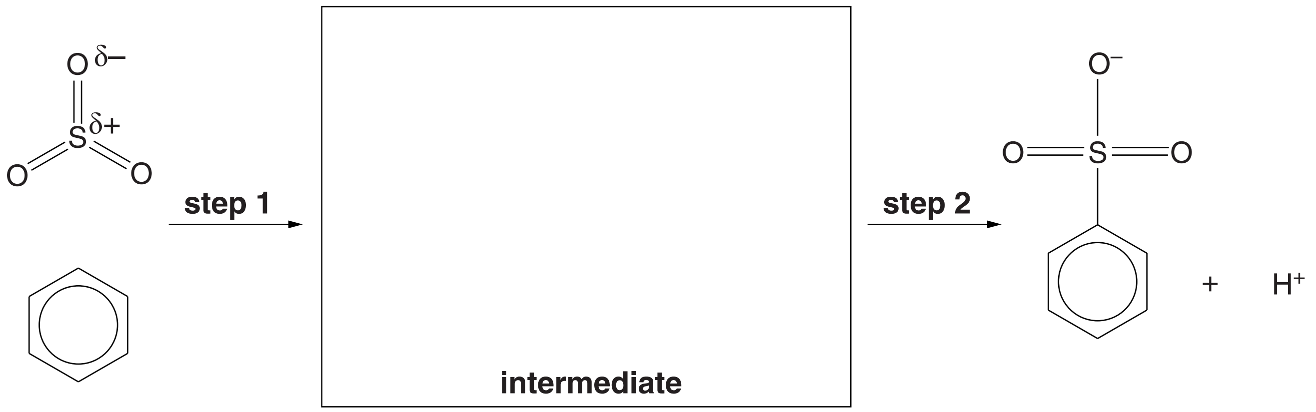
diazonium ion	**azo dye**

[2]

(b) Benzene can be converted into benzenesulfonic acid, $C_6H_5SO_3H$, which is used in the manufacture of many detergents.

The reaction between benzene and sulfuric acid is an electrophilic substitution reaction. Sulfur trioxide, SO_3, is the electrophile.

Part of the mechanism for this reaction is shown below.

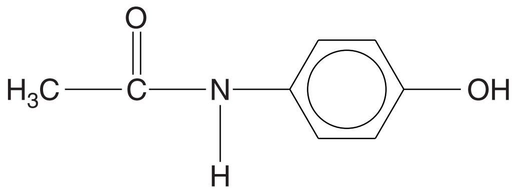


Complete the mechanism by drawing the intermediate and by adding curly arrows to show the movement of electron pairs in **steps 1** and **2**.

[4]

Turn over

(c) The painkiller paracetamol has the structure shown below.



(i) Separate samples of paracetamol are reacted with bromine, Br_2, and with sodium, Na.

Draw the structures of possible organic products formed in each reaction.

reaction with Br_2	**reaction with Na**

[2]

(ii) Another sample of paracetamol is hydrolysed by heating under reflux with hot aqueous sodium hydroxide, NaOH(aq).

Draw the structures of the two organic products formed in this hydrolysis.

[2]

[Total: 15]

3 This question is about different organic compounds containing C, H and O.

(a) A technician found an unlabelled bottle in a chemical store cupboard. The technician thinks that the bottle contains pentan-2-one, pentan-3-one or pentanal.

(i) Describe a series of chemical tests that the technician could use to confirm that the compound in the bottle is a ketone. Include appropriate reagents and any relevant observations.

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....

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....

.... **[2]**

(ii) Describe how the technician could use the product of one of the tests in **(i)** to show whether the bottle contains pentan-2-one or pentan-3-one.

The method used should **not** involve spectroscopy.

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....

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....

....

.... **[2]**

Turn over

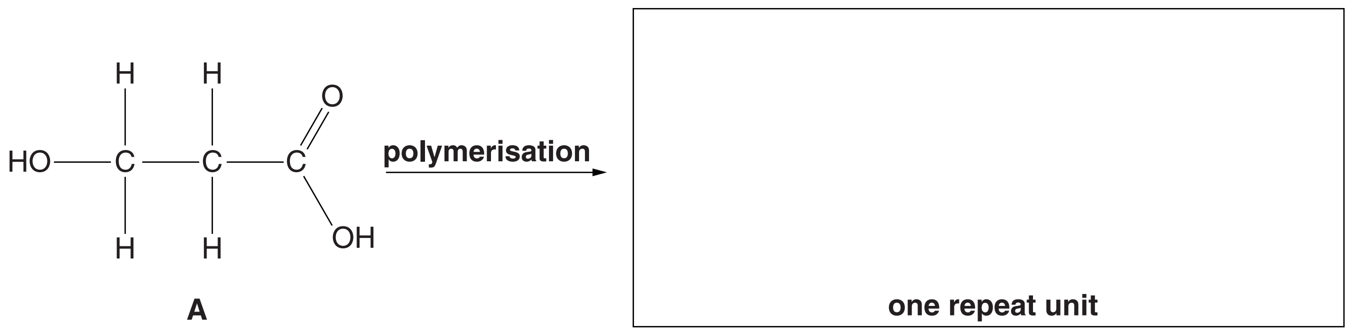
(b) 3-Hydroxypropanoic acid, $HOCH_2CH_2COOH$, can be produced microbiologically from sugars in corn. $HOCH_2CH_2COOH$ can be used as a 'green' starting material for the synthesis of many organic compounds including some important polymers.

Three synthetic routes are shown below for converting $HOCH_2CH_2COOH$, **A**, into different polymers.

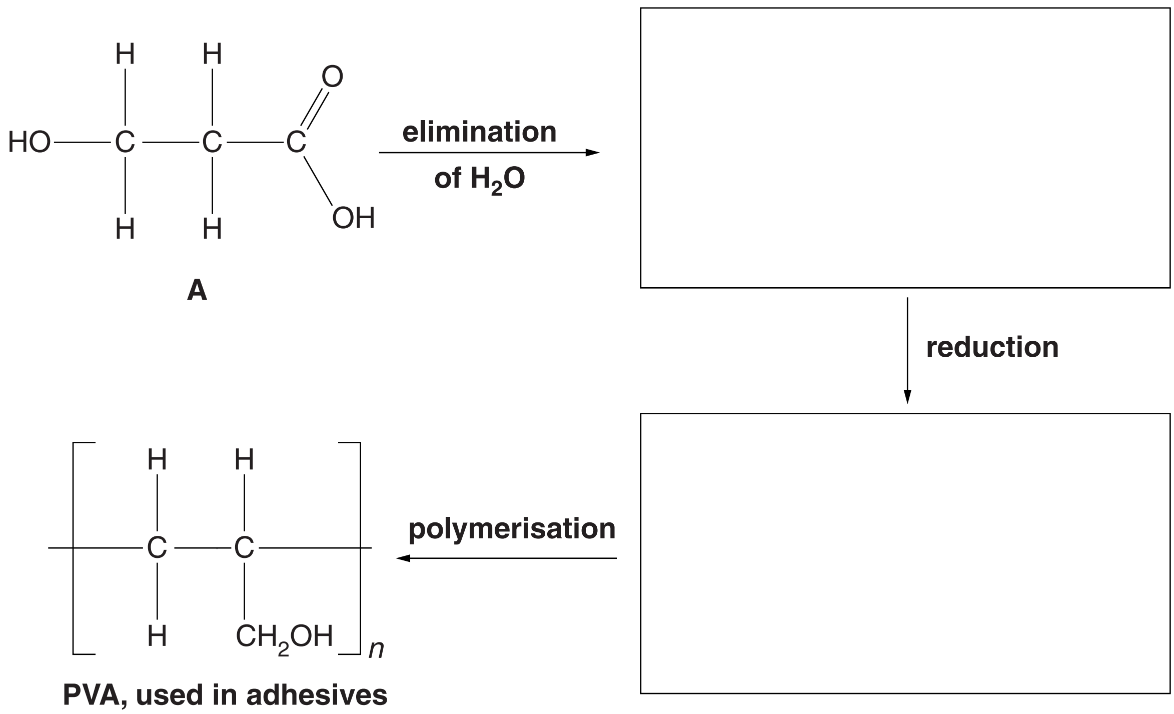
The names of the processes for each synthetic step are given.

(i) In the boxes below, give the structures of the organic compounds formed.

Synthesis 1

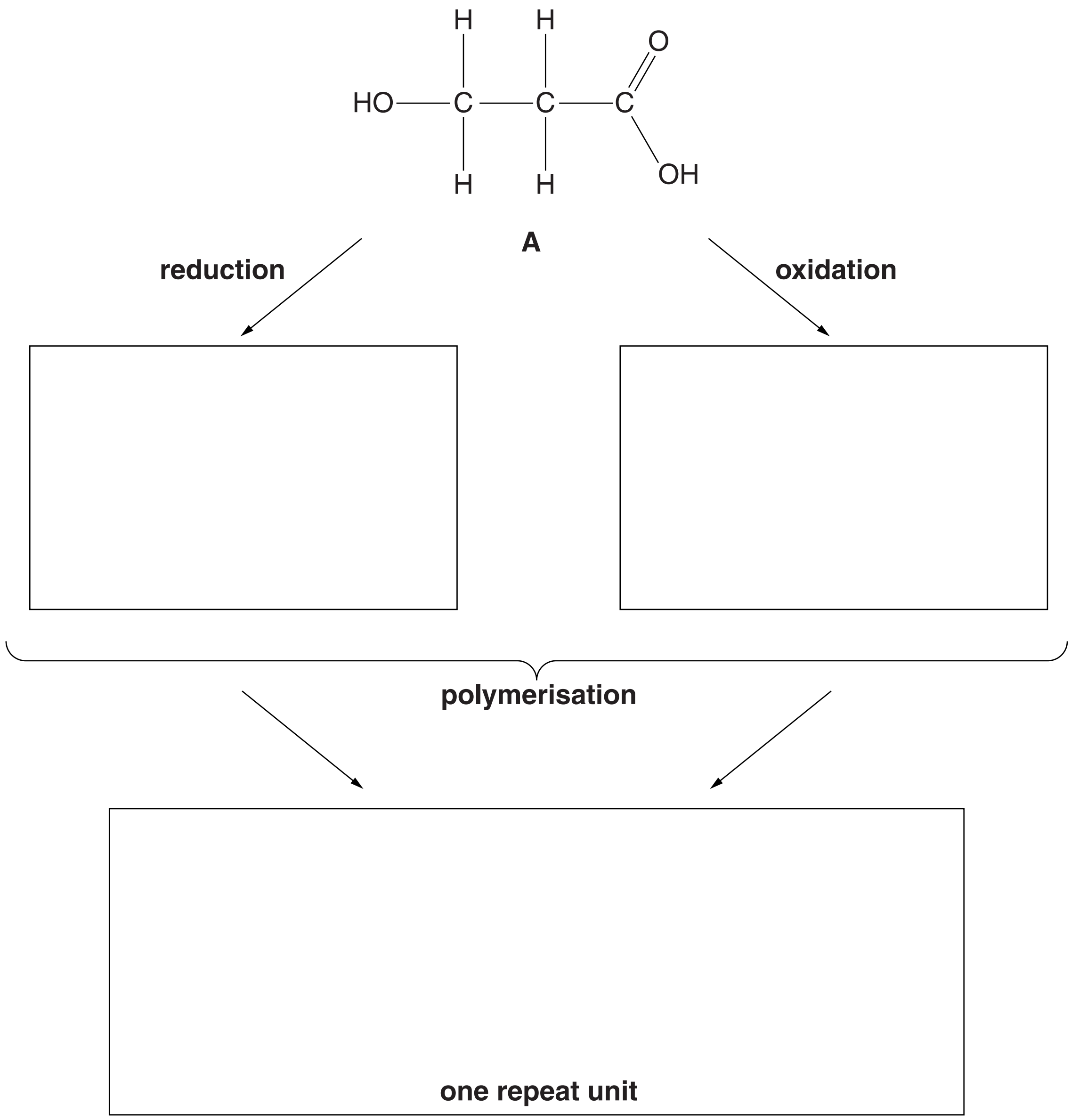


Synthesis 2



PVA, used in adhesives

Synthesis 3



[6]

(ii) State the type of polymerisation taking place in each synthetic route.

Synthesis 1: ....

Synthesis 2: ....

Synthesis 3: ....

[1]

[Total: 11]

Turn over

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?

....

.... **[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]**

Turn over

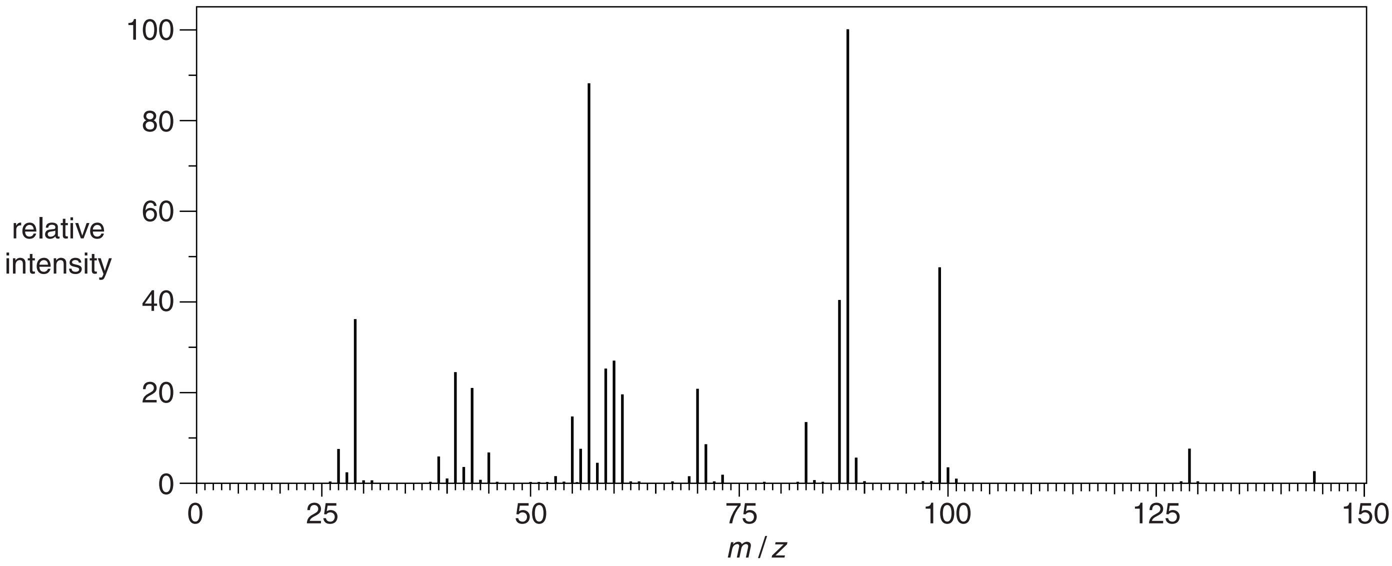
(c) GC is often used together with other techniques, such as mass spectrometry, MS, and NMR spectroscopy, to provide a far more powerful analytical tool than GC alone.

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

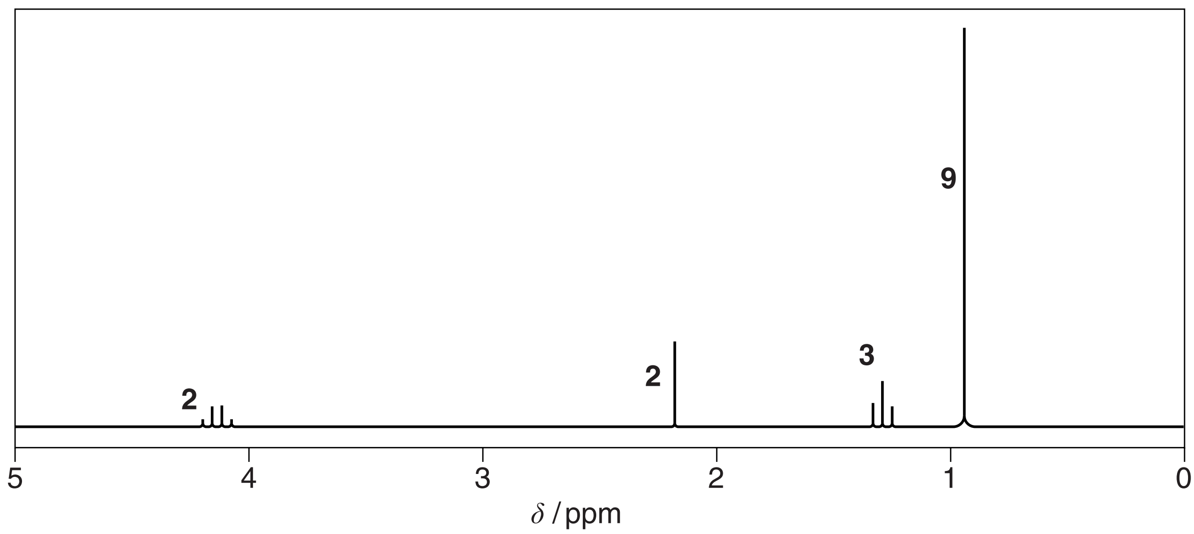
The results are shown below.

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.

.... **[10]**

[Total: 15]

END OF QUESTION PAPER