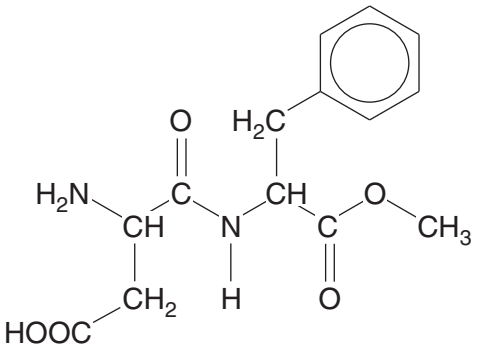
1 The addition of sucrose, table sugar, to food and drink has been linked to the increased risk of obesity and insulin resistance. Aspartame is used as an alternative to sugar.

The structure of aspartame is shown below.



aspartame

(a) Aspartame contains five functional groups including the benzene ring, and has two chiral carbon atoms.

(i) Circle the **two** chiral carbon atoms on the structure above. **[1]**

(ii) **Name** the **four** functional groups, other than the benzene ring, in aspartame.

....

.... **[2]**

(b) Aspartame consumed in food or drink might be hydrolysed by the acid in the stomach. This acid consists mainly of hydrochloric acid.

Draw the structures of the **three** organic products formed by the **complete** acid hydrolysis of aspartame.

[4]

(c) Some artificial sweeteners commonly available many years ago have now been withdrawn from use.

Suggest why.

.....

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

[Total: 8]

2 This question looks at the properties and chemistry of someα-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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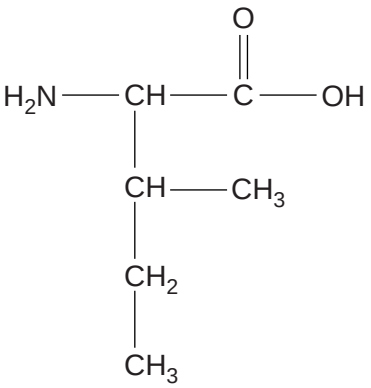
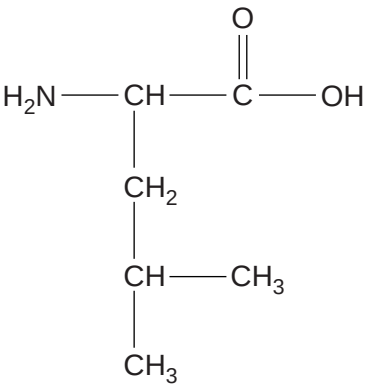
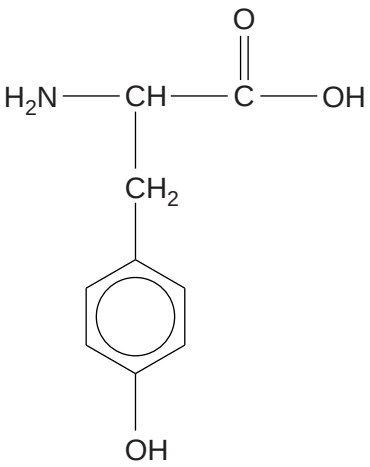
..... **[4]**

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

		
isoleucine	**leucine**	**tyrosine**

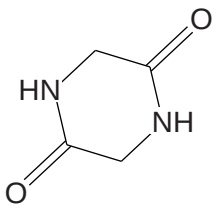
Predict the number of peaks in the carbon-13 spectrum of each of these α-amino acids.

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

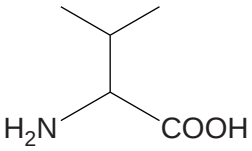
[3]

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

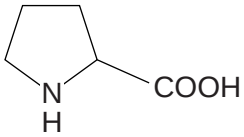
For example, glycine, where R is H, forms the cyclic dimer shown below.



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]

3 Read the passage below and answer the questions that follow.

α-Amino acids can be synthesised in the laboratory by the two synthetic routes below.

Synthesis 1

An α-chlorocarboxylic acid is reacted with an excess of concentrated ammonia solution. The resulting solution is neutralised to produce an α-amino acid.

$$C\mathit{l}CH(R)COOH \xrightarrow[\text{concentrated ammonia solution}]{\textbf{step 1}} H_2NCH(R)COO^- \xrightarrow[\text{neutralisation}]{\textbf{step 2}} H_2NCH(R)COOH$$

Synthesis 2

An aldehyde is reacted with an aqueous solution of potassium cyanide and ammonium chloride. The resulting product is hydrolysed with aqueous acid and then neutralised to produce an α-amino acid.

$$RCHO \xrightarrow{KCN(aq)/NH_4C\mathit{l}(aq)} H_2NCH(R)CN \xrightarrow[\text{followed by neutralisation}]{\text{aqueous acid}} H_2NCH(R)COOH$$

(a) A chemist attempted the synthesis of the α-amino acid alanine (where R is CH_3) using **synthesis 1**.

(i) Write the equation for the reaction of $C\mathit{l}CH(CH_3)COOH$ with excess concentrated ammonia solution, $NH_3(aq)$, in **step 1** of **synthesis 1**.

[1]

(ii) A disadvantage of **synthesis 1** is that the α-amino acid can react further. For example, in the synthesis of alanine, an impurity with molecular formula $C_6H_{11}NO_4$ is also formed.

Draw the structure of this impurity.

[1]

(b) A chemist attempted the synthesis of the α-amino acid aspartic acid (where R is CH_2COOH) using **synthesis 2**.

(i) Draw the **skeletal** formula of the organic compound that could be used to synthesise aspartic acid using **synthesis 2**.

[1]

(ii) Draw **3D** diagrams of the optical isomers of aspartic acid.

[2]

(c) Many pharmaceuticals also have a chiral centre.

Discuss two possible **disadvantages** of producing a chiral drug as a mixture of stereoisomers.

State **two** ways in which a single optical isomer might be synthesised.

.....

.....

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.....

.....

.....

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

[Total: 9]

4 α- Amino acids are found in human sweat. A student had read that chromatography could be used to separate and identify the amino acids present in human sweat.

(a) The student used Thin-Layer Chromatography (TLC) to separate the α-amino acids in a sample of human sweat and discovered that three different α-amino acids were present.

(i) Name the process by which TLC separates α-amino acids.

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

(ii) The chromatogram was treated to show the positions of the separated α-amino acids.

Explain how the student could analyse the chromatogram to identify the three α-amino acids that were present.

.....

.....

.....

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

(iii) Several α-amino acids have structures that are very similar.

Suggest why this could cause problems when using TLC to analyse mixtures of α-amino acids.

.....

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

(b) Some of the α-amino acids found in human sweat are shown in the table below.

α-amino acid	**R group**
glycine	H
leucine	$CH_2CH(CH_3)_2$
isoleucine	$CH(CH_3)CH_2CH_3$
alanine	CH_3
valine	$CH(CH_3)_2$
lysine	$(CH_2)_4NH_2$
glutamic acid	$(CH_2)_2COOH$

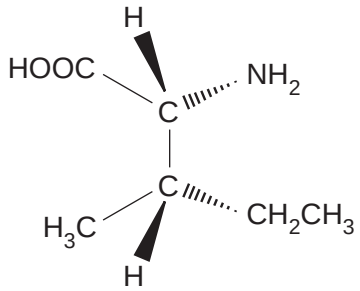
Table 1

(i) State the general formula of an α-amino acid.

[1]

(ii) There are four stereoisomers of isoleucine.

One of the stereoisomers is shown below.



Draw 3D diagrams for the other **three** stereoisomers of isoleucine.

[3]

α-amino acid	R group
glycine	H
leucine	$CH_2CH(CH_3)_2$
isoleucine	$CH(CH_3)CH_2CH_3$
alanine	CH_3
valine	$CH(CH_3)_2$
lysine	$(CH_2)_4NH_2$
glutamic acid	$(CH_2)_2COOH$

Table 1

(c) α-Amino acids form different ions at different pH values. Zwitterions are formed when the pH is equal to the isoelectric point of the α-amino acid.

The isoelectric points of three α-amino acids are given below:

alanine, pH = 6.0 **glutamic acid, pH = 3.2** **ysine, pH = 9.7**

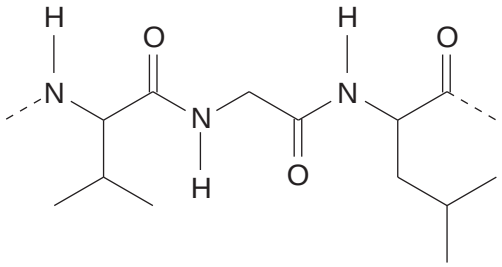
Draw the structures of the ions formed by these α-amino acids at the pH values below. Refer to **Table 1** above.

alanine at pH = 6.0	glutamic acid at pH = 10	lysine at pH = 2.0

[3]

(d) α-Amino acids can react to form polypeptides.

A short section of a polypeptide is shown below.

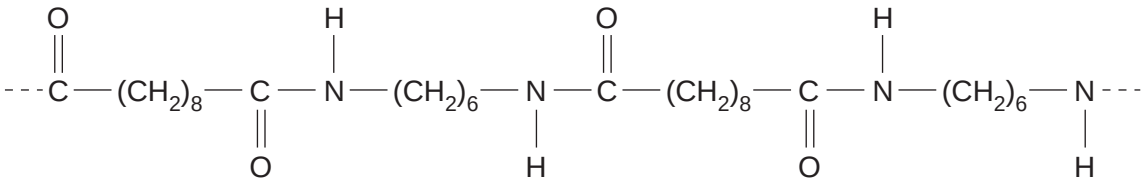


Name the α-amino acid sequence in this section of the polypeptide. Refer to **Table 1**.

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

(e) Synthetic polyamides, such as nylon, contain the same link as polypeptides. Nylon is the general name for a family of polyamides.

A short section of a nylon polymer is shown below.



Draw the structures of **two** monomers that could be used to make this nylon.

[2]

[Total: 14]