F324: Rings, Polymers and Analysis
4.2.1 Amino Acids and Chirality

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

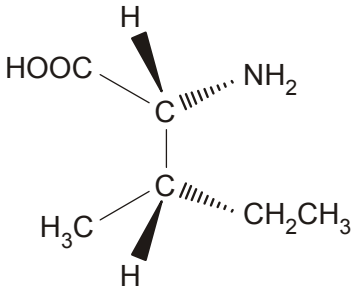
α-amino acid	**R group**
glycine	H
leucine	$CH_2CH(CH_3)_2$
isoleucine	$CH(CH_3)CH_2CH_3$
alanine	CH_3
valine	$CH(CH_3)_2$
lysine	$(CH_2)_4NH_2$
glutamic acid	$(CH_2)_2COOH$

(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]

[Total 4 marks]

2.

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	$(CH_2)_2COOH$

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** **lysine, pH = 9.7**

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

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

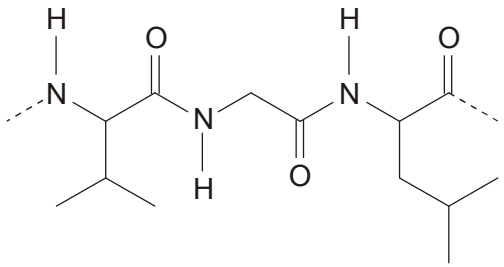
[Total 3 marks]

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	$(CH_2)_2COOH$

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 the table above.

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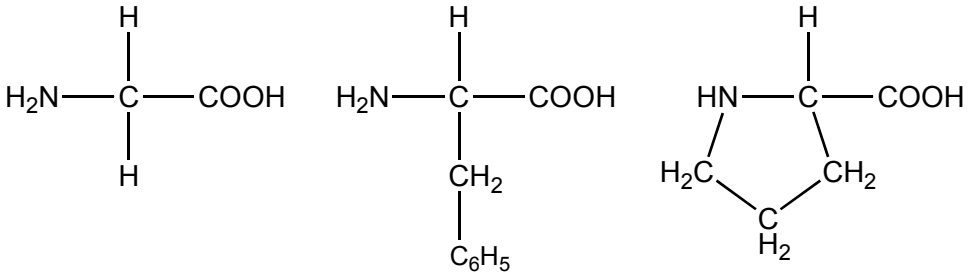
[Total 1 mark]

4. Amino acids can act as monomers in the formation of polypeptides and proteins. The structures below show three amino acids, glycine, phenylalanine and proline.



glycine **phenylalanine** **proline**

Glycine, phenylalanine and proline can react together to form a mixture of tripeptides.

(i) Draw the structure of the **tri**peptide formed in the order glycine, phenylalanine and proline.

[3]

(ii) How many different **tri**petides could have been formed containing glycine, phenylalanine and proline?

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[1]

(iii) The mixture of tripeptides can be analysed by using gas chromatography, coupled with mass spectrometry.

Summarise how each method contributes to the analysis.

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[3]

[Total 7 marks]

5. In this question, one mark is available for the quality of the use and organisation of scientific terms.

In all living organisms a large variety of polypeptides and proteins are formed naturally from α-amino acids.

State the general formula of an α-amino acid and use it to describe how amino acids can be combined to give a variety of polypeptides and proteins.

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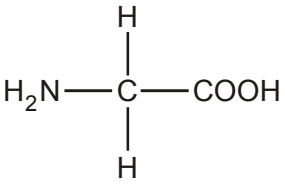
[6]

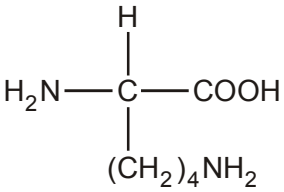
Quality of Written Communication [1]

[Total 7 marks]

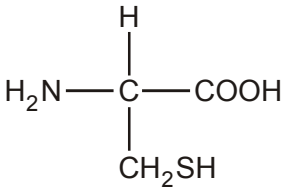
6. The four amino acids shown below are found in proteins and enzymes.



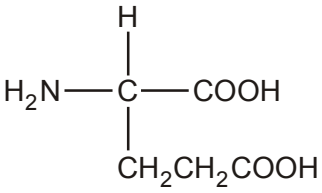
glycine



lysine



cysteine

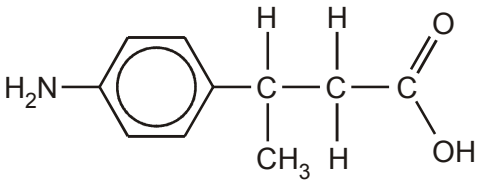


glutamic acid

Write down the structural formula for a dipeptide formed from one molecule of glycine and one of lysine.

[Total 2 marks]

7. Compound **A**, shown below, is an amino acid that is being used in the development of a new anti-inflammatory drug.



compound **A**

(a) (i) Explain why this molecule is described as an *amino acid*.

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[1]

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

Explain whether or not compound **A** fits this general formula.

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[2]

(b) Compound **A** exists as a zwitterion in aqueous solution.

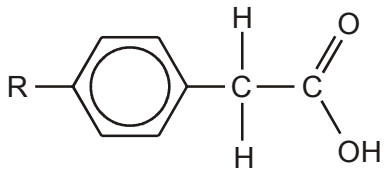
(i) Draw the structure of this zwitterion.

[1]

(ii) Show how the structure of the zwitterion would change if the solution was acidified with dilute hydrochloric acid.

[1]

(c) The anti-inflammatory drug is made by combining compound **A** with compound **B**, shown below. R represents a side chain.



compound **B**

Show the structure of the anti-inflammatory drug formed from compound **A** and compound **B**.

[2]

[Total 7 marks]

8. But-2-enal, $CH_3CH=CHCHO$, is a pale yellow, flammable liquid with an irritating odour.

But-2-enal exists as two stereoisomers.

Draw skeletal formulae to show the structure of the two stereoisomers of but-2-enal.

[Total 2 marks]

9. Leucine (2-amino-4-methylpentanoic acid) is a naturally occurring α-amino acid that is often used in protein supplements.

Leucine has a structural formula of $(CH_3)_2CHCH_2CH(NH_2)COOH$.

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

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[1]

(ii) Draw a displayed formula of leucine.

[1]

(b) Leucine can exist as a zwitterion.

(i) State what is meant by the term *zwitterion*.

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[1]

(ii) Explain with the aid of a diagram how the zwitterion is formed from the functional groups in leucine.

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[2]

(c) Leucine can be obtained from a source of protein such as meat.

(i) State suitable reagents and conditions to break down a protein into amino acids.

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[2]

(ii) State the type of reaction occurring.

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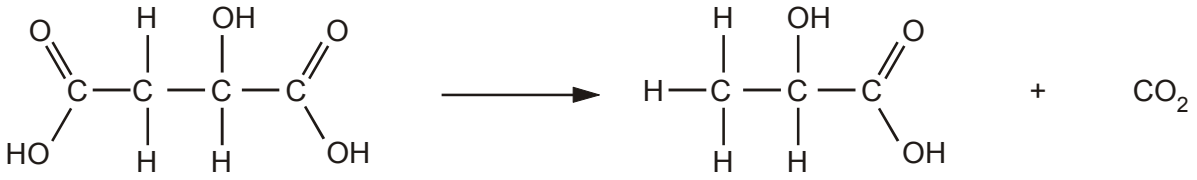
[1]

[Total 8 marks]

10. One of the final stages in winemaking involves the fermentation of malic acid to lactic acid.

An equation for the reaction is shown below.



malic acid **lactic acid**

Both acids contain a chiral centre.

(i) Identify the chiral centre on the structure of **malic acid** above using an asterisk *.

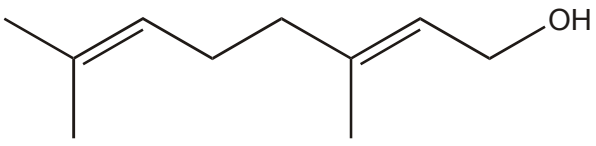
[1]

(ii) Draw a diagram to show the 3-D arrangement of groups around the chiral centre in malic acid.

[1]

[Total 2 marks]

11. Geraniol, $C_9H_{15}CH_2OH$, is a naturally occurring compound that contributes to the smell of roses. The skeletal formula of geraniol is shown below.



geraniol

(a) Name the two different functional groups in geraniol.

..... and .....

[1]

(b) Geraniol has stereoisomers due to one of the double bonds in the molecule.

(i) What is meant the term *stereoisomer*?

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[1]

(ii) Name the type of stereoisomerism shown by geraniol.

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[1]

(iii) State how this type of stereoisomerism arises in organic molecules.

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[1]

(iv) Explain why one of the double bonds in geraniol does **not** give rise to stereoisomerism.

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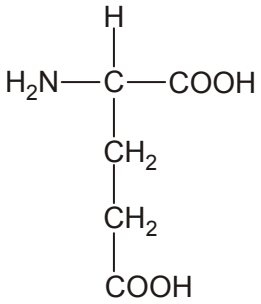
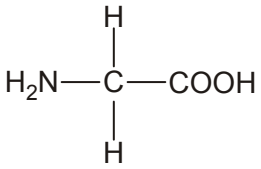
[1]

[Total 5 marks]

12. Glutamic acid and glycine are both α-amino acids that occur widely in living organisms. Their structures are shown below.



glutamic acid



glycine

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

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[1]

(ii) Explain how glutamic acid and glycine both fit the general formula given in part (i)

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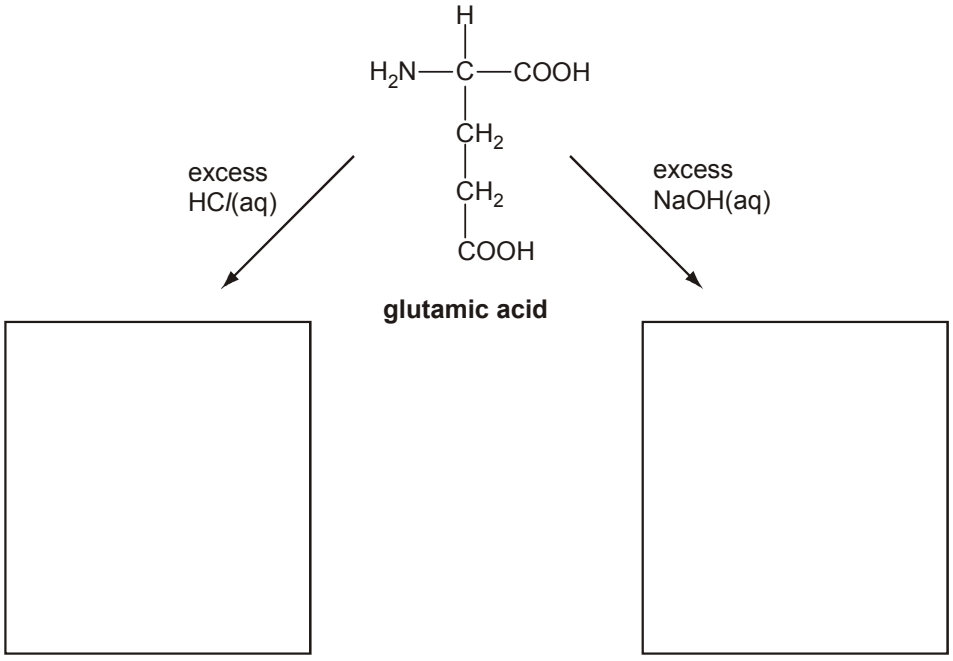
[2]

(b) Amino acids react with both acids and alkalis.

Draw structures below to show how the glutamic acid molecule is changed in the presence of excess acid and alkali.



glutamic acid

[5]

(c) In this question, one mark is available for the quality of use and organisation of scientific terms.

Glutamic acid exists as two optical isomers, but glycine does not.

Explain what structural feature causes optical isomerism in organic molecules. Include appropriate diagrams and use these two amino acids to illustrate your answer.

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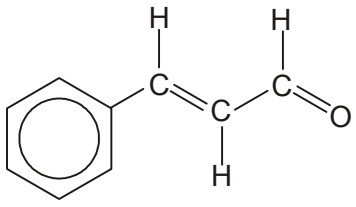
[7]

Quality of Written Communication [1]

[Total 16 marks]

13. Cinnamaldehyde is the compound that gives cinnamon its distinctive flavour.



cinnamaldehyde

(a) Draw the skeletal formula of cinnamaldehyde.

[1]

(b) Cinnamaldehyde shows *cis-trans* isomerism.

(i) Explain how *cis-trans* isomerism arises in cinnamaldehyde.

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[2]

(ii) State and explain whether cinnamaldehyde is a *cis* or a *trans* isomer.

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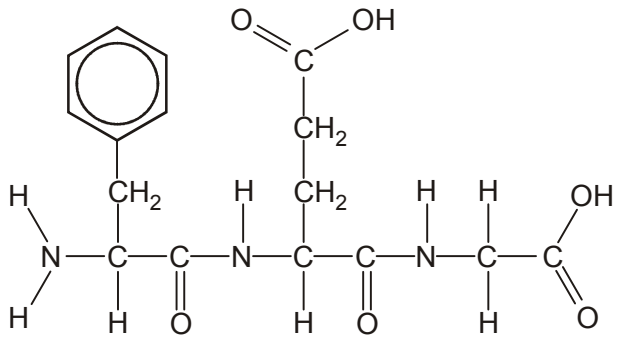
[1]

(iii) Draw a skeletal or displayed formula to show the structure of the other *cis-trans* isomer of cinnamaldehyde.

[1]

[Total 5 marks]

14. Compound **A** is currently being tested as a possible anti-allergic drug.



compound **A**

Compound **A** can be hydrolysed to form three organic products.

(i) Name a suitable reagent and conditions for the hydrolysis of compound **A**.

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[2]

(ii) The three organic products all belong to the same class of compound. State the general name for this class of organic compound.

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[1]

(iii) Draw the structure of **one** of the organic products from the hydrolysis of **A** using the reagent you have given in (a)(i) above.

[2]

(iv) Explain what is meant by the term *hydrolysis*. Use this reaction to illustrate your answer.

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[2]

[Total 7 marks]

15. Kevlar is a very tough polymer made from 1,4-diaminobenzene and benzene-1,4-dicarboxylic acid.

(i) State a use for Kevlar.

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[1]

(ii) Describe the polymerisation reaction that forms Kevlar. Include in your answer:

- an explanation of the type of polymerisation involved
- an equation for the reaction
- a repeat unit to show the structure of Kevlar.

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[5]

[Total 6 marks]