FACTFILE:
GCE CHEMISTRY

5.9 AMINO ACIDS

Rewarding Learning

Electrode potentials

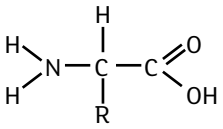
Learning Outcomes

5.9.1 recall the formulae of glycine and alanine;
5.9.2 explain the optical activity of amino acids;
5.9.3 explain the solubility of amino acids in water and their relatively high melting point;
5.9.4 explain the formation of dipolar ions (zwitterions) from amino acid molecules;
5.9.5 recall the reactions of amino acids with sodium carbonate, copper(II) sulfate and nitrous acid;
5.9.6 recall the primary secondary and tertiary structures of a protein and the formation of peptide links;
5.9.7 define enzymes as biological catalysts and use the concept of 'induced fit' to explain enzyme action;
5.9.8 recall the use of enzymes in washing powders and their economic advantage in operating at lower temperatures;
5.9.9 explain that an enzyme is a protein with an active site and provides a path of lower activation energy; and
5.9.10 explain the effect of pH and temperature on enzyme activity

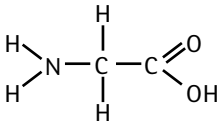
Amino acids

Amino acids have 2 functional groups –
- The amino group NH_2
- The carboxyl group COOH

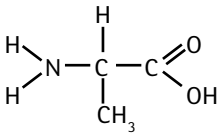
General formula



glycine (aminoethanoic acid)



alanine(2-aminopropanoic acid)

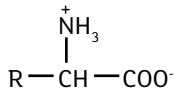


Glycine is not optically active. Alanine contains a carbon with four different groups attached and is optically active.

Physical properties

1.High melting points
Amino acids exist as zwitterions. There is an internal transfer of a hydrogen ion from the -COOH group to the -NH_2 group to leave an ion with both a negative charge and a positive charge.

This is called a **zwitterion** or a **dipolar ion**.



A zwitterion

Zwitterions are ions which have a permanent positive and negative charge but which are neutral overall.

Between amino acids, instead of intermolecular forces there are strong ionic attractions between each zwitterion and its neighbour. These ionic attractions take more energy to break and so the amino acids have high melting points for the size of the molecules.

2.Soluble in water
Amino acids are generally soluble in water. They are soluble in water as the zwitterions can form ionic attractions with the polar water, reflecting their ionic character – they dissolve in a similar fashion to ionic solids. The extent of the solubility in water varies depending on the size and nature of the "R" group.

At a certain pH (the isoelectric point) the amino acid acts as a zwitterion. However at other pH it may exist as a positive or negative ion

If alkali (OH^-) is added to an amino acid solution the hydrogen ion is removed from the NH_3^+ group. At high pH a negative ion exists.

If acid is added to a solution of an amino acid, the $-COO^-$ part of the zwitterion reacts with a hydrogen ion. At low pH a positive ion exists.

Reactions of amino acids

1.With sodium carbonate
The acid functional group of an amino acid reacts.

$2H_2NCH(CH_3)COOH + Na_2CO_3 \rightarrow 2H_2NCH(CH_3)COONa + CO_2 + H_2O$
alanine — sodium 2-aminopropanoate

Condition: room temp
Observation: fizzing, solid disappears

2.With nitrous acid
The NH_2 group reacts. The amino acid reacts as a aliphatic amine.

$2H_2NCH(CH_3)COOH + HNO_2 \rightarrow HOCH(CH_3)COOH + N_2 + H_2O$
alanine — 2-hydroxypropanoic acid

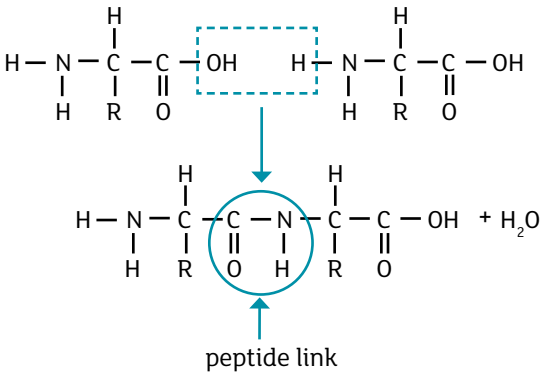
Conditions: nitrous acid is formed in situ by the reaction of sodium nitrite and hydrochloric acid.
Observation: bubbles

3.With copper(II) sulfate
$2H_2NCH_2COOH + Cu^{2+} \rightarrow [Cu(H_2NCH_2COOH)_2]^{2+}$
copper(II) glycine

Observation: dark blue solution formed

Proteins

Peptides are formed when amino acids react in a condensation reaction to form a dipeptide. Continued condensation results in a polypeptide and further folding and cross linking of the chain results in a protein.



There are 3 types of protein structure.

1. Primary structure – the sequence of amino acids joined by peptide links in the chain

2. Secondary structure – the twisting/coiling of the chain to form an alpha helix/beta pleated sheet bonded by intramolecular hydrogen bonding

3. Tertiary structure the bending/folding of the secondary structure to give a precise 3D shape held together by hydrogen bonding/disulfide bridges/ionic interactions/van der Waals' forces attraction / hydrophobic-hydrophilic interactions.

Enzymes

An enzyme is a protein which is a biological catalyst

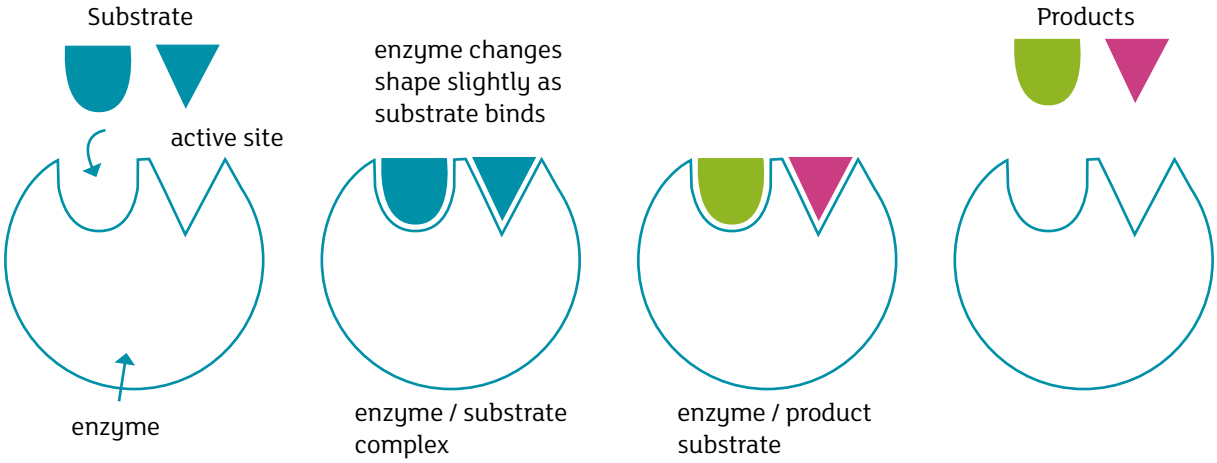
Enzymes are specific for each reaction. Enzymes have an active site.

The active site is the site on the surface of the enzyme into which the substrate fits.

The rest of the enzyme is much larger and is involved in maintaining the specific shape of the enzyme. When a reaction involving an enzyme occurs, a substrate is turned into a product.

The Induced-Fit Model
This is a model which is widely accepted as describing the way enzymes work, It states that the shape of active sites are not exactly complementary to the substrate, but change shape in the presence of a specific substrate to become complementary. When a substrate molecule collides with an enzyme, if its composition is specifically correct, the shape of the enzyme's active site will change so that the substrate fits into it and an enzymes substrate complex can form. The reaction is then catalysed and an enzyme-product complex forms.

Induced fit -the substrate induces a change of shape of the active site of the enzyme



Enzymes provide an alternative reaction pathway of lower activation energy and so speed up the chemical reaction.

Enzymes are stereospecific as only one optical isomer will fit into the active site.

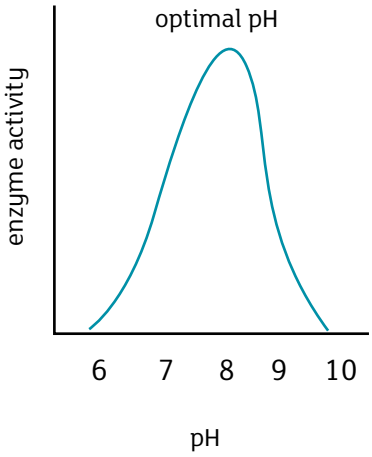
Effect of pH and temperature on enzyme activity

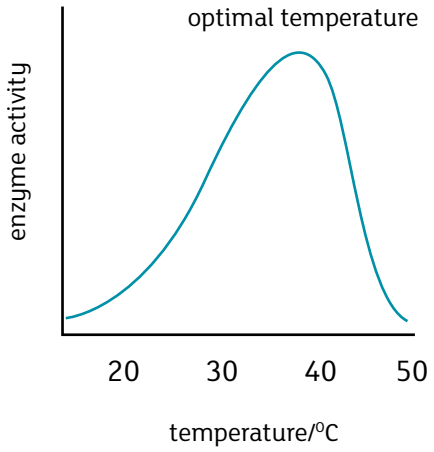
Changes in pH and temp can denature an enzyme so cause it to undergo an irreversible change which destroys the nature of the protein.
This occurs because the tertiary structure is broken

- the heat can cause the hydrogen bonds holding the tertiary structure to break.
- pH change can cause the ionic attractions holding the tertiary structure to break.

The peptide bonds do not break and the primary structure remains.

Enzymes have an optimum temperature and pH where their function is at a maximum.





Use of enzymes in washing powders
It is possible to remove most types of dirt from clothes using washing powder in water at high temperatures with vigorous mixing, but the cost of heating the water is high and lengthy mixing will shorten the life of clothing. The use of enzymes allows lower temperatures to be used and shorter periods of agitation are needed. Biological washing powders contain enzymes to help to remove stains from clothes. Biological washing powders do not work at extremes of pH and high temperatures.

Revision Questions

1 Which one of the following statements describes the primary structure of a protein?

A The formation of the α–helix
B The folding of the α–helix
C The sequence of amino acids in the chain
D The sequence of peptide links in the chain

2 Amino acids combine to form proteins. Describe the structure of proteins under the following headings.

Primary:
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.....
.....

Secondary:
.....
.....
.....

Tertiary:
.....
.....
.....
[3]

3 Some enzymes formed by proteins are used in biological washing powders.

i) Describe how enzymes act as catalysts.

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

ii) Explain why biological washing powders do not work at high temperatures.

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

Revision Questions

4 Valine, $CH_3CH(CH_3)CH(NH_2)COOH$, is an amino acid.

i) Amino acids form zwitterions. What is a **zwitterion**?

.....

.....

[2]

ii) Draw the zwitterion formed by valine.

[1]

iii) Valine is optically active. Draw the 3D representations of the optical isomers.

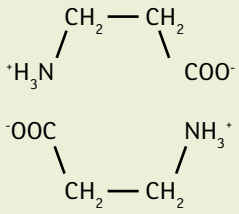
[2]

5 Which one of the following is a peptide?

A CH_2CONH_2

B $NH_2CHCONHCHCOOH$ (with CH_3 and CH_3 side chains)

C $HOOC(CH_2)_6CONH(CH_2)_4NH_2$

D 

[1]

Revision Questions

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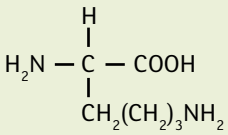
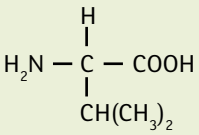


lysine



valine

i) Draw the zwitterion of valine.

[1]

ii) Draw the structure of lysine when it is dissolved in an *excess* of a strong acid.

[1]