ChemFactsheet

www.curriculum-press.co.uk Number 108

Amino Acids and Polypeptides

Decide which of the following statements are true and which are false?

Statement	True	False
Amino acids all have the amino and carboxylic acid functional groups		
Amino acids have the general formula $NH_2CH_2(R)COOH$		
Amino acids can show acidic and basic properties		
Amino acids can exist as twitterions		
In the solid state amino acids display the physical properties of ionic compounds		
Amino acids are insoluble in water		
Polypeptides result from the combination of two or more amino acids		
Amino acids are proteins		

If you answered "true" then "false" *alternately* throughout, then you are an A student! Why not try the questions at the end of this Factsheet? If you answered in any other way, then read on.

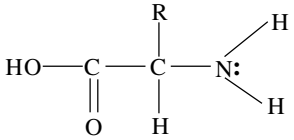
After you have worked through this Factsheet you will know about:
1. the structure and properties of amino acids
2. how they join together to form peptides and polypeptides.

You will also have worked through typical examination questions, and be ready to answer questions on this topic.

Proteins, peptides and amino acids are a very closely related group. All living matter has protein as an essential constituent. Complete hydrolysis of a protein will yield α-amino acids, which contain both the primary amino group ($-NH_2$) and the carboxylic acid group (-COOH) attached to the same carbon.

Key Facts

1) The amino acids included in your syllabus can be represented by the general formula:

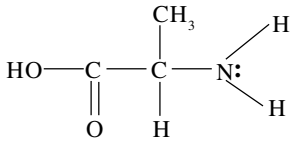


They are called α–amino acids because the amino ($–NH_2$) and carboxylic acid (–COOH) groups are both attached to the second or α–carbon atom.

The 20 or so different amino acids occurring in nature are the result of the different groups generally denoted by "R" above. Students are expected to be able to give the systematic name of a given amino acid, and give the formula for a named amino acid. However, they are not expected to recall trivial names or write down the formulae corresponding to these. For example: if –R is –H then the resultant amino acid is aminoethanoic acid. The trivial name is glycine; biologists tend to use the trivial names, whereas chemists prefer to use systematic nomenclature.

Typical Exam Question

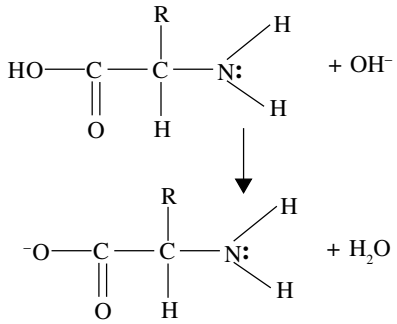
Name the amino acid whose structure is represented below



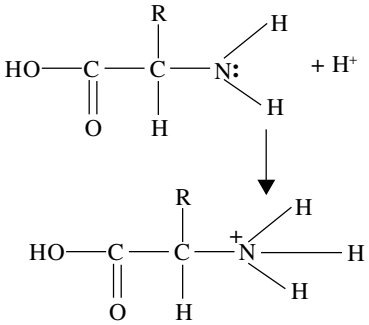
Credit worthy answer is 2-aminopropanoic acid (1 mark) (No marks for alanine)

2) Amino acids are **amphoteric** since they show both the properties of an acid and of a base. Consequently :

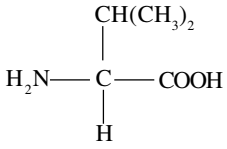
(a) In alkaline solution (excess OH^- ions present) the carboxylic acid group can lose a proton:-



b) In acid solution (excess H^+ ions present) the basic amino group can accept a proton via the lone pair of the nitrogen:-



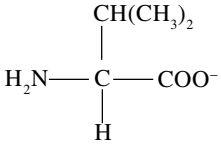
Typical Exam Question
The structural formula of an amino acid is given as :



Draw the structure of the amino acid species present in a solution at pH 13

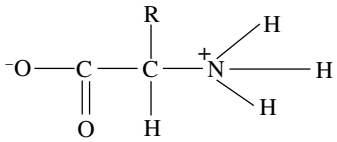
pH 13 is very alkaline resulting in the removal of a proton from the COOH group.

Correct answer is shown below and is worth 1 mark.



Note : the other parts of the molecule remain the same but look out for a second COOH group contained in the R group. This too would be deprotonated. Similarly, a second NH_2 group may be present in the R group and this too would be ***protonated to NH_3^+*** *at low pH.*

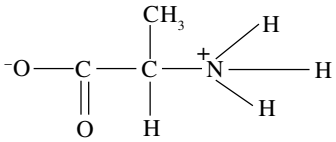
3) As a result of an internal proton transfer from the COOH group to the NH_2 group, amino acids often exist as dipolar ions called **zwitterions**:



This can occur:
(a) in solution at *about* pH 7 or b) in the solid state
Thus amino acids show important physical properties typical of ionic compounds:
(i) they are white solids which melt or decompose at relatively high temperatures, around 300ºC
(ii) they are soluble in water, but mostly insoluble in organic solvents.

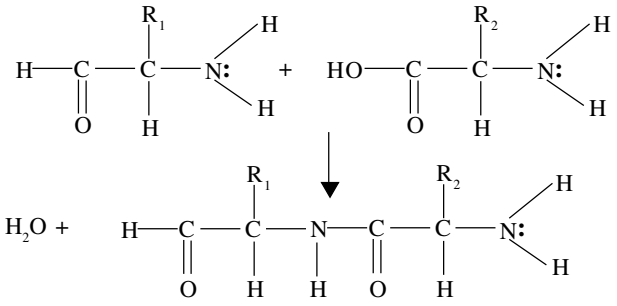
Typical Exam Question
Milk proteins can be broken down by enzymes to give á-amino acids such as 2-aminopropanoic acid, existing mainly in their zwitterion forms. Give the structural formula of the zwitterion form of 2-aminopropanoic acid.

Correct answer shown below is worth 1 mark



Note: It is important to ensure that the bonds are shown going to the nitrogen and carbon atoms from the α-carbon

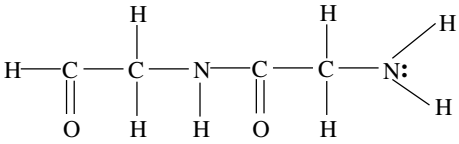
4) The combination of two amino acids via a condensation reaction (with the elimination of water) resulting in them being joined together by a peptide link, – NH.CO **–,** forming a ***dipeptide***.



If more than two amino acids combine in this way then a ***polypeptide*** is formed.

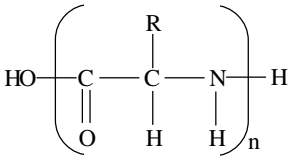
Typical Exam Question
Draw the organic product formed by the condensation of two molecules of aminoethanoic acid

The correct answer is shown below and is worth 2 marks.



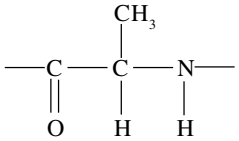
Note : Had the R group not been the same (ie H), TWO possible dipeptides can be formed with R1 left and R2 right or vice versa. Try this for yourself by condensing 2-aminoethanoic acid with 2-aminopropanoic acid.

5) As the dipeptide formed between any two amino acids has a free amino, – NH_2 and a free carboxylic acid, – COOH functional group at opposite ends of the molecule, the dipeptide can enter into further combination with amino acids (by similar condensation reactions) to form polypeptides.



The region enclosed by the brackets is referred to as the ***repeating unit*** of the polypeptide.

Typical Exam Question
Give the repeating unit of the polypeptide formed when 2-aminopropanoic acid molecules are reacted together.
The correct answer is below and is worth 1 mark



Name the type of polymerisation involved when the polypeptide is formed.
The correct answer is condensation or (nucleophilic addition-elimination) polymerisation and is also worth 1 mark.

6. Proteins are polypeptide chains which result from the peptide linking of *many* amino acids. 20 different α-amino acids are found to take part in protein structure. Small proteins contain 50 to 100 amino acid residues, large proteins may contain several thousand.

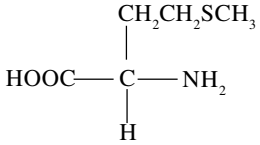
7. Proteins have a three dimensional structure which may be considered as follows.
   (a) **Primary structure** (as discussed above) which is dependant on the number and sequence of amino acids in the chain.
   b) **Secondary structure** which describes the coiling or zig-zagging of a polypeptide chain (e.g. a helix). This results from hydrogen bonding between the peptide bonds. (For more details of the hydrogen bonding mechanism in general – Factsheet 77 is useful.)
   (c) **Tertiary structure** which results when the chains twist in a regular or irregular fashion on themselves. This is caused by interactions between amino acid side chains. For example hydrogen bonding or the formation of disulphide bridges may occur.
   (d) **Quaternary structure** occurs only when two or more chains assemble to form a final protein, and concerns the way in which these protein chains come together.

8. Some proteins act as biocatalysts or enzymes. The three dimensional shape of the protein results in the formation of a unique active site on which a specific reaction can occur. If the protein is subjected to changes in temperature or pH, certain metal ions, the addition of a small polar molecule (such as urea) or a mild reducing agent, then the unique three dimensional shape of the protein may be lost and the active site destroyed – this is termed **denaturation**. Denaturation may be temporary or permanent.

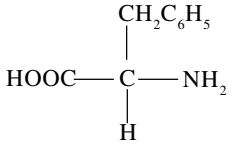
Practice Questions

1. Write down the full structural formula of:
   (a) aminoethanoic acid (1 mark)
   (b) the peptide link which forms when an aminoethanoic acid and a 2-aminopropanoic acid molecule react (1 mark)

2. Draw the structural formula for the zwitterion form of the á-amino acid shown below (1 mark)



3. The structure of an amino acid is given below

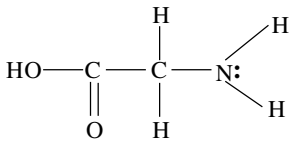


   (a) Draw the structure of the amino acid species present in solution at pH3 (1 mark)
   (b) What feature of the amino group means that it can accept a proton (H^+ ion) under certain conditions? (1 mark)
   (c) Draw the structures of the dipeptides formed when a molecule of this amino acid combines with a molecule of aminoethanoic acid. (2 marks)
   (d) Name the non-organic product of this reaction. (1 mark)
   (e) A protein chain is arranged in the shape of a helix. Name the type of bonding involved in forming and holding this shape. (1 mark)

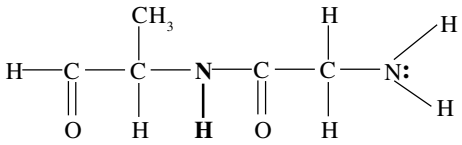
4. (a) Draw the structure of aminoethanoic acid in the solid state. (1 mark)
   (b) State the type of bonding involved between adjacent amino acid particles (1 mark)
   (c) Compare the strength of this bonding with the bonding present between molecules of hydroxyethanoic acid (1 mark)

Answers

1. (a)

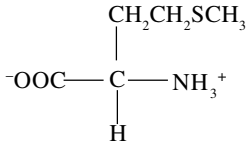


   (b)

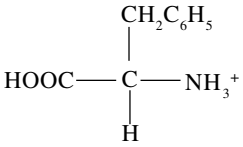


   N.B. the actual peptide link (highlighted above) does not depend on which two amino acids are reacting. However, if the full structure is given by a candidate, then it must all be correct. Also, the CH_3 group could be on either the first or second amino acid redidue.

2.

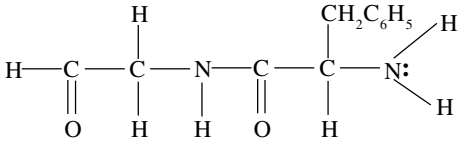


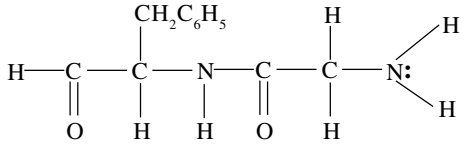
3. (a)



   (b) The amino group has a **lone pair of electrons on the N atom**. Thus it can accept a proton and show the properties of a base.

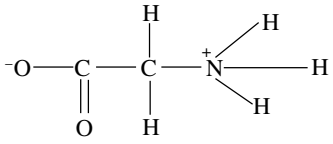
   (c)





   (d) Water
   (e) Hydrogen bonding

4. (a)



   (b) Ionic
   (c) The electrostatic interactions involved in the ionic bonding between the glycine ions is much stronger than the hydrogen bonding present between molecules of hydroxyethanoic acid

Acknowledgements: *This Factsheet was researched and written by Christine Collier.* ***Curriculum Press, Bank House, 105 King Street, Wellington, Shropshire, TF1 1NU. ISSN 1351-5136***