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Amino Acids: Its types and uses

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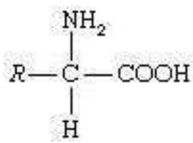
Abstract
Amino acids are the organic compounds which contain amine ($-NH_2$) and carboxyl (-COOH) functional groups, along with a side chain (R group) which is unique to each amino acid. In this paper, there is a description on how proteins are useful for living organisms. The focus is on acid- base properties of amino acids. This paper also tells about different types of amino acids and their functions. Different uses of amino acids are also mentioned significantly.

Keywords: Amino Acids, Acid-Base Properties

Introduction
Amino acids are the organic compounds which contain amine ($-NH_2$) and carboxyl (-COOH) functional groups, along with a side chain (R group) which is unique to each amino acid. The key elements of an amino acid are the central atom carbon (C), hydrogen (H), oxygen (O), and nitrogen (N). There are about 500 naturally occurring amino acids in existence. They can be classified on the basis of the structure of functional group's locations as alpha- (α-), beta- (β-), gamma- (γ-) or delta- (δ-) amino acids; according to polarity, pH level, and side chain group type (aliphatic, acyclic, aromatic, containing hydroxyl or sulfur, etc.). Amino acid residues form the second-largest component in the form of protein (water is the largest) of human muscles and other tissues. The amino acids differ from each other in their chemical structure of the R group. Amino acids participate in a number of processes such as transmission of neurons and biosynthesis. The formula of a general amino acid is:



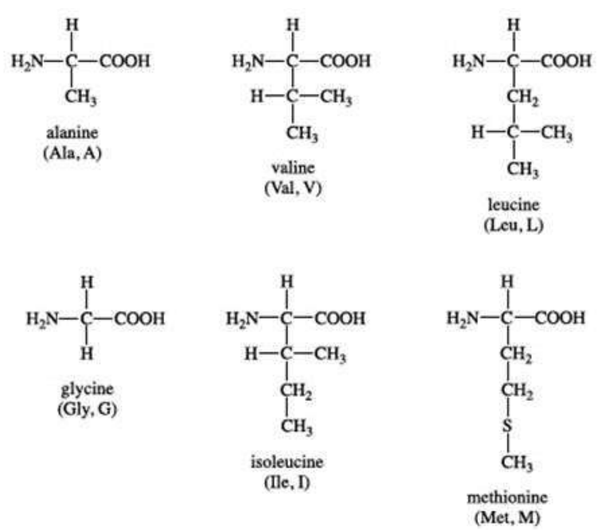
In biochemistry, amino acids having both the amine and the carboxylic acid groups attached to the first (alpha-) carbon atom are known as 2-, alpha-, or α-amino acids (generic formula $H_2NCHRCOOH$). They are very important as they contain the 22 proteinogenic ("protein-building") amino acids, which combine into peptide chains ("polypeptides") to form the building-blocks of a vast array of proteins.
Building Blocks of Proteins: Proteins are very important for continuing functioning of living organisms. Proteins act as catalyst for the chemical reactions that occur in the cell. They provide many structural elements of a cell, and help to bind cells together into tissues. Some proteins which help in movement act as contractile elements. Others are responsible for the transport of vital materials from the outside of the cell to the inside of cell. Proteins protect animals from disease in the form of antibodies. Many hormones are proteins. Proteins also control the activity of genes.
There are many different kinds of proteins in nature. Proteins are different in size, shape and charge. Amino acids are the building blocks of proteins. The simplest amino acid is called glycine ("sugar"). It was one of the first amino acids which are isolated from the protein gelatin.

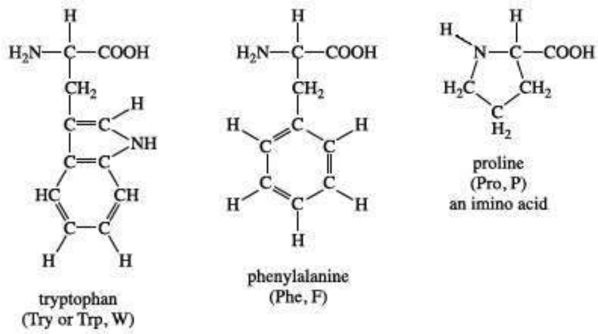
Chirality: All the amino acids but glycine are chiral molecules. They exist in two optically active asymmetric forms (called enantiomers) that are the mirror images of each other. One

enantiomer is known as D and the other L. Also the amino acids found in proteins almost always possess only the L-configuration.
This reflects that the enzymes responsible for protein synthesis have evolved to utilize only the L-enantiomers. Some D-amino acids are found in microorganisms, particularly in the cell walls of bacteria and in some antibiotics. However, these are not synthesized in the ribosome.

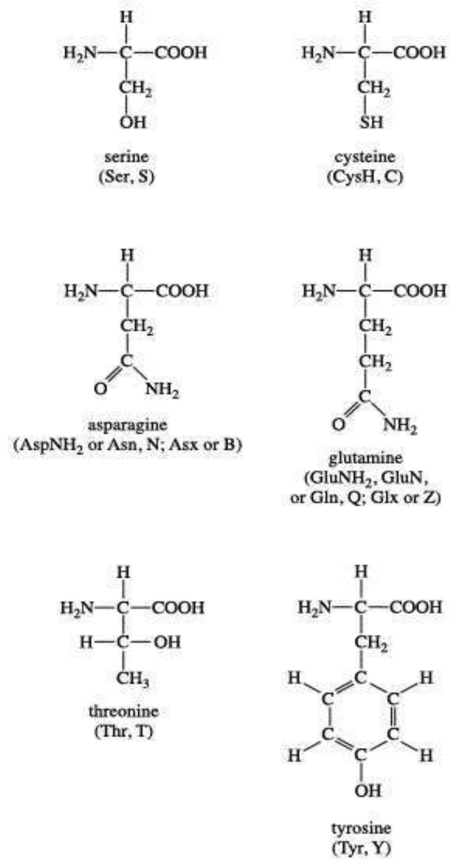
Acid-Base Properties: Free amino acids exist both as a basic and an acidic group at the α-carbon. Compounds which behave both either as an acid or a base is called amphoteric. The basic amino group has a pKa between 9 and 10, while the acidic α-carboxyl group has a pKa close to 2. The pKa of a group is the pH value at which the concentration of the protonated group equals that of the unprotonated group. Thus, at physiological pH (about 7–7.4), the free amino acids exist largely as dipolar ions or "zwitterions" (a zwitterion carries an equal number of positively and negatively charged groups). Any free amino acid and protein at some specific pH, exist in the form of a zwitterion. All amino acids and all proteins, when face changes in pH, pass through a state at which there is an equal number of positive and negative charges on the molecule. The pH at which this occurs is known as the isoelectric point (or isoelectric pH) and is denoted as pI. When dissolved in water, all amino acids and all proteins are present predominantly in their isoelectric form. Thus, there is a pH (the isoelectric point) at which the molecule has a net zero charge (equal number of positive and negative charges), but there is no pH at which the molecule has an absolute zero charge. Thus, amino acids and proteins always exist in the form of ions. They always carry charged groups.

Standard Amino Acids: Amino acids are classified on the basis of polarity (distribution of electric charge) of the R group.
Group I: Nonpolar amino acids:
These are glycine, alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, and tryptophan. The R groups of these amino acids have either aliphatic or aromatic groups and hence become hydrophobic ("water fearing"). The chemical structures of Group I amino acids are:





Isoleucine is an isomer of leucine, and it contains two chiral carbon atoms. Proline is unique amino acid. It does not have both free α-amino and free α-carboxyl groups, but its side chain forms a cyclic structure as the nitrogen atom of proline is linked with two carbon atoms. Phenylalanine consists of a phenyl group attached to alanine. Methionine is the amino acid that possesses a sulphur atom. Methionine plays a very important role in protein biosynthesis as it is almost always the initiating amino acid. Methionine also provides methyl groups for metabolism. Tryptophan contains an indole ring attached to the alanyl side chain.
Group II: Polar, uncharged amino acids
Group II amino acids are serine, cysteine, threonine, tyrosine, asparagine, and glutamine. The side chains in this group possess a spectrum of functional groups. However, most have at least one atom (nitrogen, oxygen, or sulfur) with electron pairs available for hydrogen bonding to water and other molecules. The chemical structures of Group II amino acids are:

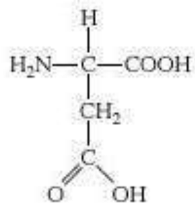


Two amino acids, serine and threonine contain aliphatic hydroxyl groups (−OH). Tyrosine possesses a hydroxyl group in the aromatic ring, making it a phenol derivative.

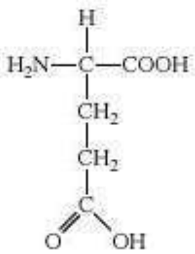
The hydroxyl groups in these three amino acids are of posttranslational modification. Like methionine, cysteine contains a sulphur atom. Unlike methionine's sulphur atom, however, cysteine's sulphur is very chemically reactive. Asparagine, first isolated from asparagus, and glutamine both contain amide R groups. The carbonyl group can function as a hydrogen bond acceptor, and the amino group (NH_2) can function as a hydrogen bond donor.

Group III: Acidic amino acids

The amino acids in this group are aspartic acid and glutamic acid. Each has a carboxylic acid on its side chain that gives it acidic properties. In an aqueous solution at physiological pH, all three functional groups on these amino acids will ionize, and gives an overall charge of −1. In the ionic forms, the amino acids are called aspartate and glutamate. The chemical structures of Group III amino acids are.



aspartic acid
(Asp, D; Asx or B)

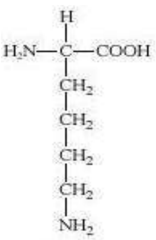


glutamic acid
(Glu, E; Glx or Z)

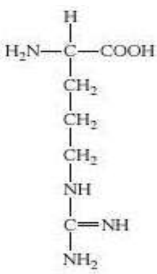
The side chains of aspartate and glutamate form ionic bonds and they can also function as hydrogen bond acceptors. Proteins that bind metal ions for structural or functional purposes possess metal-binding sites containing aspartate or glutamate side chains or both. Free glutamate and glutamine help in amino acid metabolism. Glutamate is the most available transmitter of neurons in the central nervous system.

Group IV: Basic amino acids

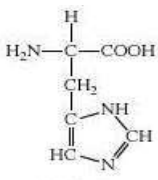
The three amino acids in this group are arginine, histidine, and lysine. Each side chain is basic. Lysine and arginine have a charge of +1 at physiological pH. The guanidino group in arginine's side chain is the most basic of all R groups. The side chains of arginine and lysine also form ionic bonds. The chemical structures of Group IV amino acids are



lysine
(Lys, K)



arginine
(Arg, R)



histidine
(His, H)

The imidazole side chain of histidine allows it to catalyse both as an acid and base near physiological pH values. Thus, histidine is an amino acid that makes up the active sites of protein enzymes.

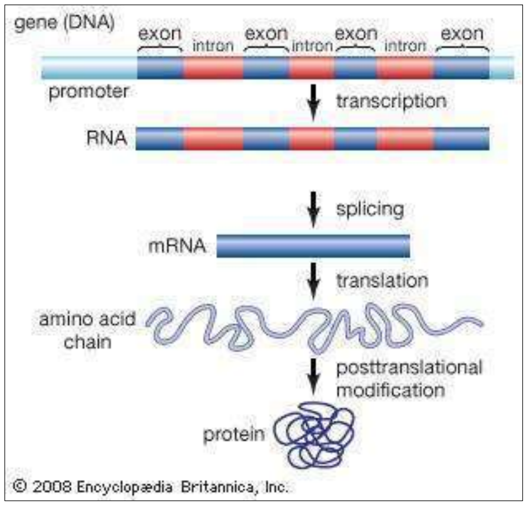
The majority of amino acids in Groups II, III, and IV are hydrophilic ("water loving"). Hence, they are mostly found clustered on the surface of globular proteins in aqueous medium.

Functions of Amino Acids: Amino acids possess a variety of complex nitrogen-containing molecules. The most prominent are the nitrogenous base components of nucleotides and the nucleic acids (DNA and RNA). There are complex amino-acid derived cofactors such as heme and chlorophyll. Heme is the organic group containing iron, required for the biological activity such as the oxygen-carrying haemoglobin and the electron-transporting cytochrome. Chlorophyll is a green pigment required for photosynthesis.

Some α-amino acids behave as chemical messengers. For example, γ-aminobutyric acid (GABA; a derivative of glutamic acid), serotonin and melatonin (derivatives of tryptophan), and histamine are neurotransmitters. Thyroxine and indole acetic acid are two hormones.

Many standard and nonstandard amino acids often are vital metabolic intermediates. For example: arginine, citrulline, and ornithine are all components of the urea cycle. The synthesis of urea is done for the removal of nitrogenous waste.

Nonstandard Amino Acids: Nonstandard amino acids are those amino acids that have been chemically modified after incorporated into a protein (called a "posttranslational modification") and those amino acids that occur in living organisms but are not found in proteins. Among these modified amino acids is γ-carboxyglutamic acid, a calcium-binding amino acid residue found in the blood-clotting protein prothrombin (as well as in other proteins that bind calcium as part of their biological function). The most abundant protein by mass in vertebrates is collagen. Significant proportions of the amino acids in collagen are modified forms of proline and lysine: 4-hydroxyproline and 5-hydroxylysine.



Genes are made up of promoter regions and alternating regions of introns (noncoding sequences) and exons (coding sequences). The production of a functional protein involves the transcription of the gene from DNA into RNA, the removal of introns and splicing together of exons, the translation of the spliced RNA sequences into a chain of amino acids, and the posttranslational modification of the protein molecule.

The most important posttranslational modification of amino acids in eukaryotic organisms (including humans) is the reversible addition of a phosphate molecule to the hydroxyl portion of the R groups of serine, threonine, and tyrosine. This mechanism is known as phosphorylation and is used to regulate the activity of proteins in their functioning in the cell. Serine, threonine and tyrosine are the most commonly phosphorylated residue in proteins.

Proteins covalently attached with carbohydrates are called glycoproteins. Glycoproteins provide the spectrum of functions. The sugar groups in glycoproteins are attached to amino acids through either oxygen or nitrogen atoms in the amino acid residues. The O-linked sugars are attached to proteins through the oxygen atoms in serine, threonine, hydroxylysine, or hydroxylproline residues. The N-linked sugars are attached to proteins through the nitrogen atom in asparagine.

The 21st amino acid is selenocysteine. It is part of only a few known proteins but it is considered because it is introduced during protein biosynthesis rather than created by a posttranslational modification. It iss derived from the amino acid serine, and it contains selenium instead of the sulphur of cysteine.

Uses of Amino Acids: The industrial production of amino acids is very important. The flavouring agent monosodium glutamate (MSG) was prepared from a type of large seaweed. This led to the commercial production of MSG, which is now produced using bacterial fermentation process with starch and molasses as carbon sources. Glycine, cystein e, and D, L-alanine are also used as food additives, and mixtures of amino acids serve as flavour enhancers in the food industry. The amino acid balance of soya or corn protein for animal feed is preferred over the addition of the nutritionally limiting amino acids methionine and lysine.

Fig: Monosodium glutamate (MSG) crystals

Amino acids are used for nutritional and pharmaceutical purposes. For example, patients are often infused with amino acids to supply these nutrients before and after surgical procedures. Treatments with single amino acids are part of the medical approach to control certain disease states. Examples include L-dihydroxyphenylalanine (L-dopa) for Parkinson disease; glutamineand histidine for the treatment of peptic ulcers; and arginine, citrulline, and ornithine to treat liver related diseases.

Certain derivations of amino acids, especially of glutamate, are used as surfactants in mild soaps and shampoos. D-Phenylglycine and D-hydroxyphenylglycine are used for the chemical synthesis of β-lactam antibiotics (e.g. penicillin). Aspartame is a sweetener prepared from the individual component amino acids aspartic acid and phenylalanine.

Conclusion

Amino acids are the organic compounds containing amine (-NH_2) and carboxyl (-COOH) functional groups, along with a side chain (R group) which is unique to each amino acid. Acid- base properties of amino acids are also described in a well manner. Different types of amino acids and their functioning are thoroughly discussed. There are various uses of amino acids like treatment of various diseases etc.

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