ST. LAWRENCE HIGH SCHOOL

A JESUIT CHRISTIAN MINORITY INSTITUTION

STUDY MATERIAL FOR CHEMISTRY (CLASS-12)

TOPIC-BIOMOLECULES (AMINO ACIDS)

PREPARED BY: MR. ARNAB PAUL CHOWDHURY

SET NUMBER-17

DATE: 30.01.2021

What is an Amino Acid?

Amino Acids are the organic compounds which combine to form proteins, hence they are referred to as the building components of proteins. These biomolecules are involved in several biological and chemical functions in a human body and are the necessary ingredients for the growth and development of human beings. There are about 300 amino acids which occur in nature.

Amino acids contain the basic amino groups (-NH2) and carboxyl groups (-COOH). The ingredients present in proteins are of amino acids. Both peptides and proteins are the long chains of amino acids. Altogether, there are twenty amino acids, which are involved in the construction of proteins.

Listed below are the names of twenty amino acids along with their chemical formula.

General properties of Amino Acids

- They have a very high melting and boiling point.
- Amino acids are white crystalline solid substances.
- In taste, few Amino acids are sweet, tasteless, and bitter.
- Most of the amino acids are soluble in water and are insoluble in organic solvents.

Essential and Nonessential Amino Acids

Out of 20 amino acids, our body can easily synthesize a few on their own and are called non-essential amino acids. They include alanine, asparagine, arginine, aspartic acid, glutamic acid, cysteine, glutamine, proline, glycine, serine, and tyrosine.

Apart from these, there are other nine amino acids, which are very much essential as they cannot be synthesized by our body. They are called as essential amino acids and they include Isoleucine, histidine, lysine, leucine, phenylalanine, tryptophan, methionine, threonine, and valine.

General properties of Amino Acids

- They have a very high melting and boiling point.
- Amino acids are white crystalline solid substances.
- In taste, few Amino acids are sweet, tasteless, and bitter.
- Most of the amino acids are soluble in water and are insoluble in organic solvents.

Essential and Nonessential Amino Acids

Out of 20 amino acids, our body can easily synthesize a few on their own and are called non-essential amino acids. They include alanine, asparagine, arginine, aspartic acid, glutamic acid, cysteine, glutamine, proline, glycine, serine, and tyrosine.

Apart from these, there are other nine amino acids, which are very much essential as they cannot be synthesized by our body. They are called as essential amino acids and they include Isoleucine, histidine, lysine, leucine, phenylalanine, tryptophan, methionine, threonine, and valine.

Structure of Amino Acids

The general structure of Amino acids is H2NCH RCOOH and it can be written as:

COOH

|

H_2N – – C – – H

|

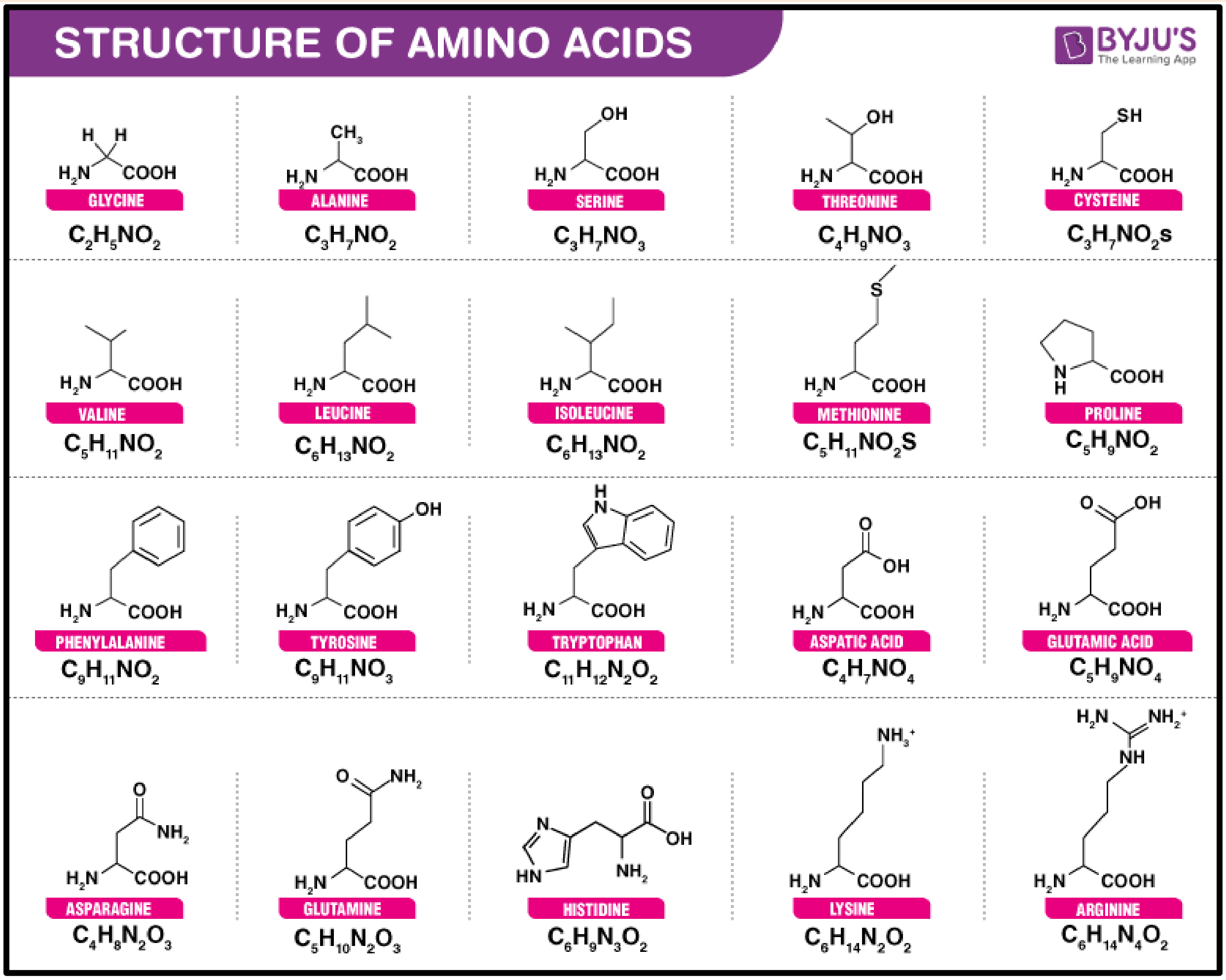
R

There are 20 naturally occurring amino acids and all have common structural features – an amino group (-NH3+), a carboxylate (-COO-) group and a hydrogen-bonded to the same carbon atom. They differ from each other in their side-chain called R group. Each amino acid has 4 different groups attached to α- carbon.

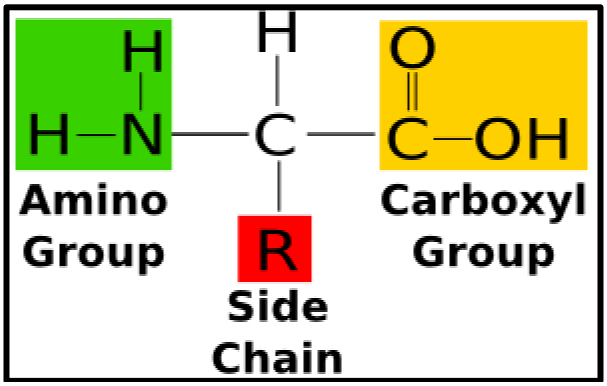
These 4 groups are:

- Amino group,
- COOH,
- Hydrogen atom,
- Sidechain (R).

Here is the structure of twenty amino acids with their chemical formula.



Amino Acids are molecules, which contain two functional groups, one is carboxylic group and another is amino group. Amino acids are derivatives of carboxylic acids in which one hydrogen atom of carbon chain is substituted by Amino group. Amino group may be at alpha, beta or gama position with respect to carboxylic group



Formula of amino acid	Name of Amino Acids
H_2N-CH_2-COOH	Amino acetic acid, or Glycine
$CH_3-CH(NH_2)-COOH$	α - Amino propionic acid or Alanine
$H_2N-CH_2-CH_2-COOH$	β - Amino propionic acid
$H_2N-CH_2-(CH_2)_2-COOH$	γ - Amino butyric acid

Some amino acids contain a second carboxyl group or a potential carboxyl group in the form of carboxamide: these are called ***acidic amino acid*** some contain a second basic group which may be an amino group these are called ***basic amino acids***.

- **Physical Properties of Amino Acids**

Although the amino acids are commonly shown as containing an amino group and a carboxyl group, certain properties are not consistent with this structure. In contrast to amines and carboxylic acids, the amino acids are nonvolatile solids, which melt at fairly high temperatures.They are insoluble in organic solvents [i.e. non polar solvents] and are highly soluble in water.Their aqueous solution is neutral.Their aqueous solutions behave like solutions of substances of high dipole moment. Acidity and basicity constants are ridiculously low for - COOH and – NH_2 groups In the physical properties melting points, solubility, and high dipole moment are just what would be expected of such a salt. The acid base properties also become understandable when it is realized that the measured Ka actually refers to the acidity of an ammonium ion, RNH_3^+

$$^+H_3NCHRCOO^- + H_2O \rightleftharpoons H_3O^+ + H_2NCHRCOO^-$$

$$K_a = \frac{[H_3O^+][H_2NCHRCOO^-]}{[^+H_3N-CH-RCOO^-]}$$

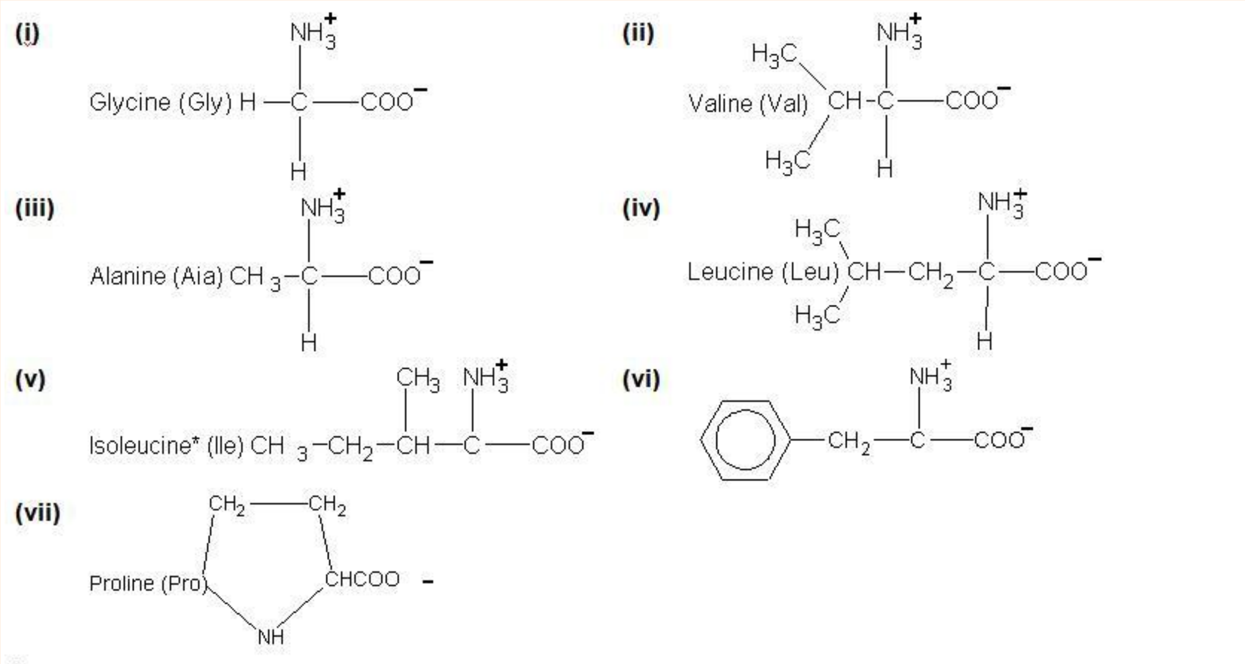
and K_b actually refers to the basicity of a carboxylate ion, $RCOO^-$

$$^+H_3N-CH-RCOO^- + H_2O \rightleftharpoons {}^+H_3N-CHR-COOH + OH^-$$

$$K_b = \frac{[^+H_3N-CHR-COOH][OH^-]}{[^+H_3NCHRCOO^-]}$$

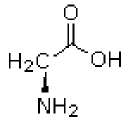
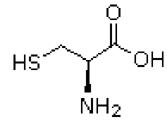
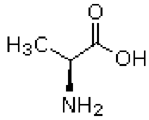
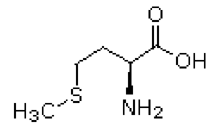
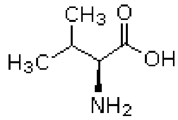
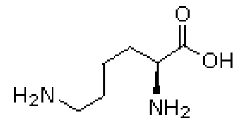
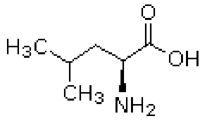
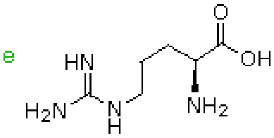
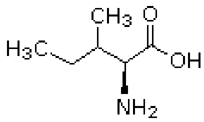
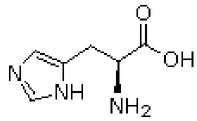
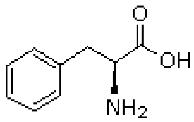
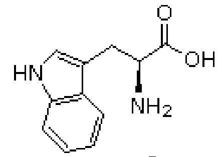
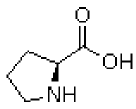
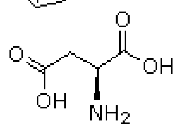
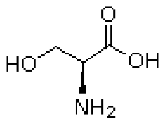
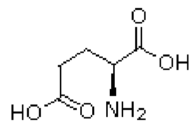
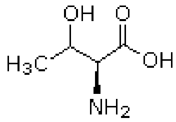
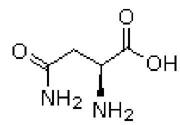
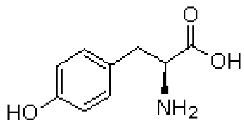
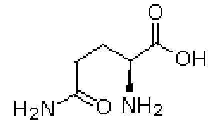
- **Classification of Amino Acid**

Amino acid with non – polar side chain



Acidic Amino Acid*:* These amino acids contain a second carboxyl group or a potential carboxyl group in the form of carboxamide.

Basic Amino Acids: These contain a second basic group which may be an amino group.

Name	Formula	Abbreviations		Name	Formula	Abbreviations	
Glycine		Gly	G	Cysteine		Cys	C
Alanine		Ala	A	Methionine		Met	M
Valine		Val	V	Lysine		Lys	K
Leucine		Leu	L	Arginine		Arg	R
Isoleucine		Ile	I	Histidine		His	H
Phenylalanine		Phe	F	Tryptophan		Trp	W
Proline		Pro	P	Aspartic Acid		Asp	D
Serine		Ser	S	Glutamic Acid		Glu	E
Threonine		Thr	T	Asparagine		Asn	N
Tyrosine		Tyr	Y	Glutamine		Gln	Q

- **Essential & Non-Essential Amino Acids**

Those amino acids which must be supplied to our diet as are not synthesized in body are known as essential amino acids. Some of them are

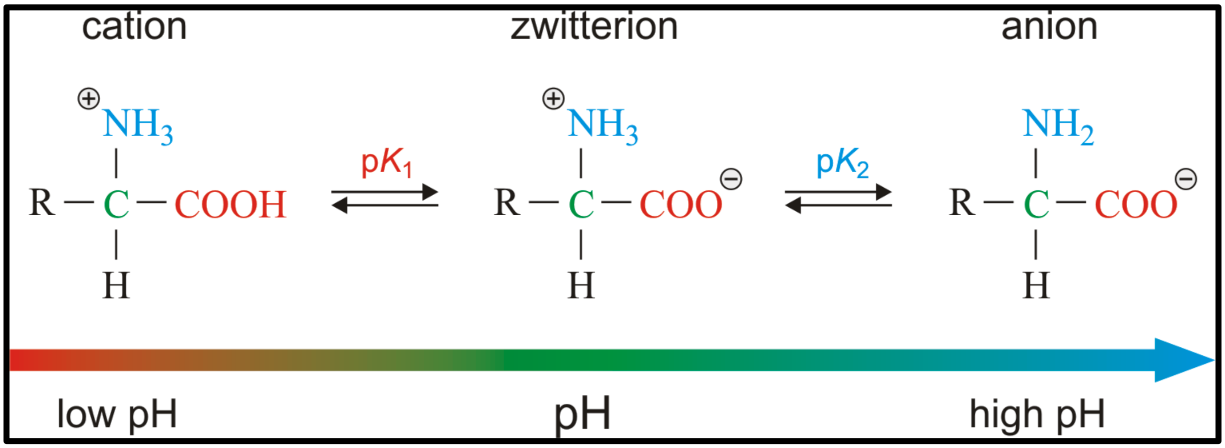
Valine, Leucine, Isoelucine, Phenylalanine, Arganine, Threonine , Tryptophan, Methionine, Lysine, Arginine, Histadine

Note: Histidine and arginine are essential i.e. can be syntrhesized but not in quantities sufficient to permit normal growth.

Those amino acids which are synthesized in body are non-essential amino acids. Some of them are.
Glycine, Alanine, Tyrosine, Serine, Cystine, Proline, Hydroxyprocine , Cysteine, Aspartic acid, Glutonic acid

- **Zwiter Ion**

Amino acids contain both acidic carboxyl group -(COOH) and basic amino group in the same molecules. In aqueous solution, the acidic carboxyl group can lose a proton and basic amino group can gain a proton in a kind of internal acid – base reaction. The product of this internal reaction is called a Dipolar or a Zwitter ion. The Zwitter ion is dipolar, changed but overall electrically neutral and contain both a positive and negative charge. Amino acid in the dipolar ion form are amphoteric in nature. Depending upon the pH of the solution, the amino acid can donate or accept proton.



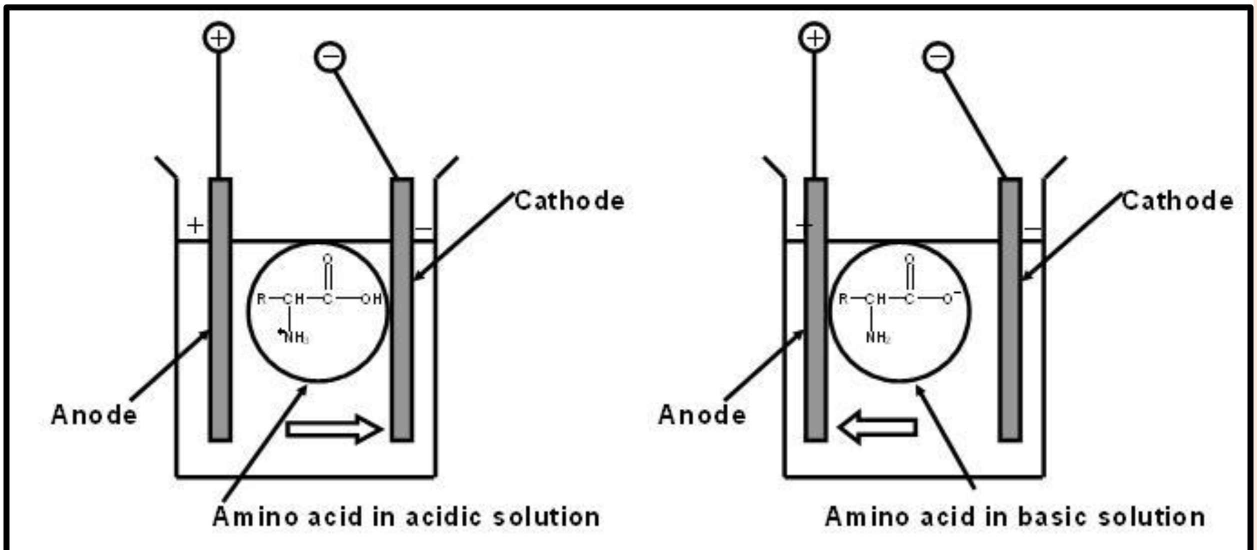
- **Iso Electric Point of Amino Acids?**

When ionized form of amino acid is placed in an electric field it will migrate towards the opposite electrode. Depending upon the pH of the medium following three thing may happen.

1. In acidic medium, the cation move towards cathode.
2. In basic medium, the anion move towards anode.
3. The Zwitter ion does not move towards any of the electrodes.

At a certain pH (i.e. H+ concentration), the amino acid molecules show no tendency to migrate towards any of the electrodes and exists as a neutral dipolar ion, when placed in electric field is known as isoelectric point. All amino acids do not have the same isoelectric point & it depends upon the nature of R – linked to α- carbon atom.

Amino acids have minimum aqueous solubility at isoelectric point.



Effect of electric field on an amino acid ion Acidic and Basic solution

- **Synthesis of α - Amino Acids**

1. Protein can be hydrolyzed by refluxing with dilute hydrochloric acid to give a mixture of α - amino acids. The resulting mixture can be separated by fractional crystallization.
2. Fractional distillation of their ester followed by hydrolysis (Fischer's method)
3. Selective precipitation as salt with phosphotungstic and picric acid.
4. Distribution of amino acid between n – butanol saturated with water (Dakin's method).
5. Column, paper and gas chromatography.
6. Electrophoresis.

By amination of α- halo acid

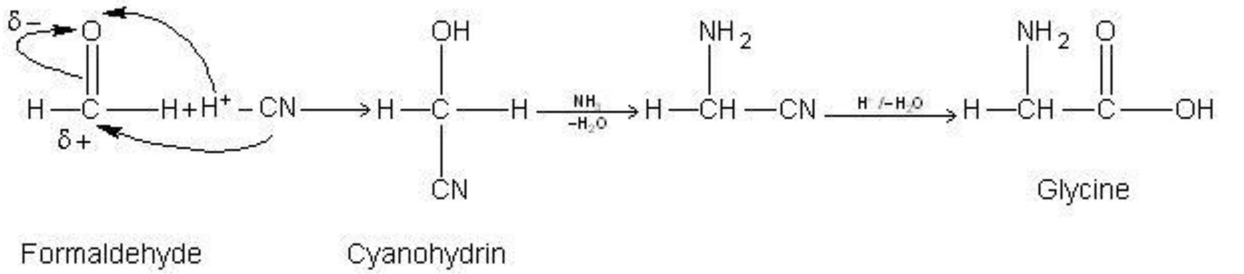
(i) $$\underset{\text{Chloro acetic acid}}{Cl-CH_2-COOH} + \underset{\text{(excess)}}{3NH_3} \xrightarrow[(-NH_4Cl)]{50^0C} H_2N-CH_2-COO^-NH_4^+ \xrightarrow{H^+/H_2O} \underset{\text{Glycine}}{H_2N-CH_2-COOH}$$

(ii) $$H_3C-\underset{\underset{Br}{|}}{CH}-COOH + 3NH_3 \xrightarrow[(-NH_4Cl)]{50^0C} H_3C-\underset{\underset{NH_2}{|}}{CH}-CO\bar{O}NH_4^+ \xrightarrow{H^+/H_2O} H_3C-\underset{\underset{NH_2}{|}}{CH}-COOH$$

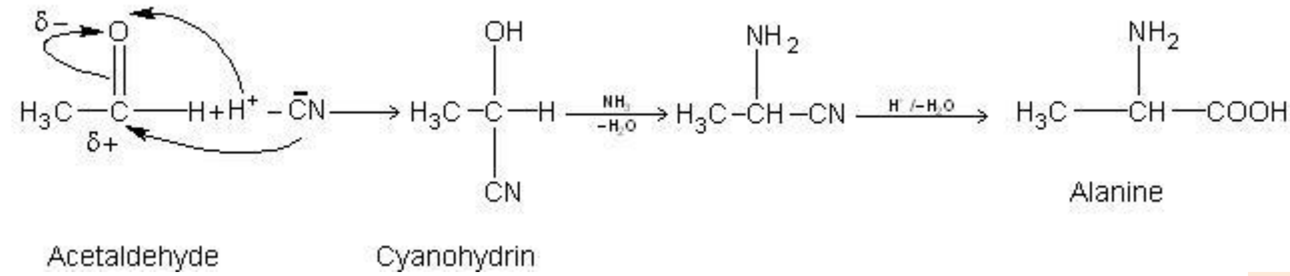
Alanine

By Strecker Synthesis

(i)



(ii)



Note: Generally the aldehyde is treated with a mixture of ammonium chloride and potassium cyanide in aqueous solution

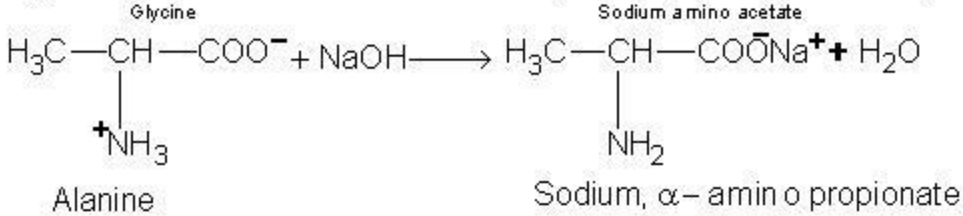
$$NH_4Cl + KCN \xrightarrow{\text{Aqueous}} NH_4CN + KCl$$

$$NH_4CN \xrightarrow{\text{Aqueous}} NH_3 + HCN$$

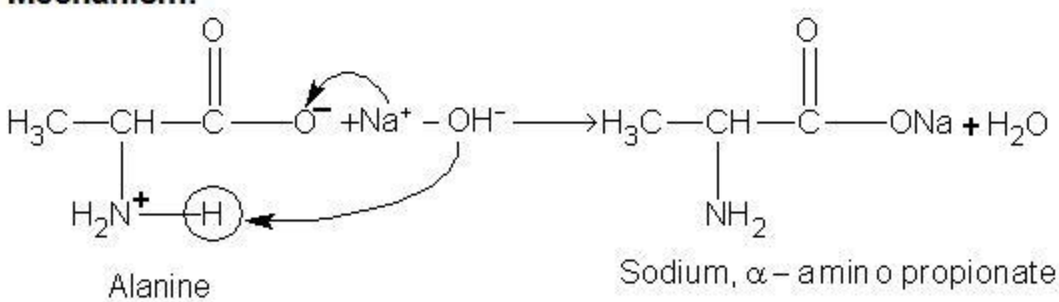
- **Chemical Properties of Amino Acids**

(i) $\underset{\text{Glycine}}{H_3N^+ - CH_2 - COO^-} + NaOH \longrightarrow \underset{\text{Sodium amino acetate}}{H_2N - CH_2 - COO^-Na^+} + H_2O$

(ii)



Mechanism:



- **Esterification**

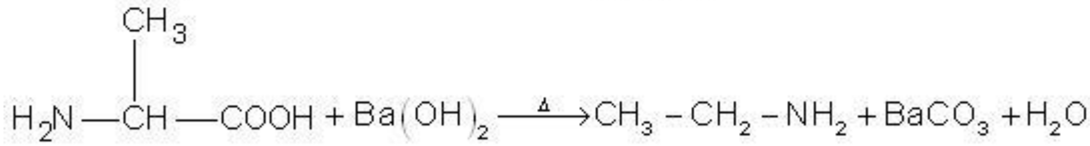
$$H_3N^+ - \underset{\text{Glycine}}{CH_2} - COO^- \xrightarrow{HCl} Cl^- H_3N^+ - CH_2 - COOH \xrightarrow{C_2H_5OH} Cl^- H_3N^+ - CH_2 - COOC_2H_5$$

$$\xrightarrow{AgOH} \underset{\text{Ethyl-}\alpha\text{-amino acetate}}{H_2N - CH_2 - COOC_2H_5} + AgCl + H_2O$$

Note: HCl first converts the dipolar ion into an acid which is subsequently esterified.

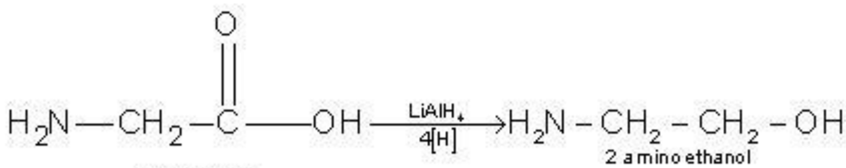
Decarboxylation

$$H_2N - \underset{\text{Glycine}}{CH_2} - COOH + Ba(OH)_2 \xrightarrow{\Delta} \underset{\text{Methyl amine}}{CH_3 - NH_2} + BaCO_3 + H_2O$$

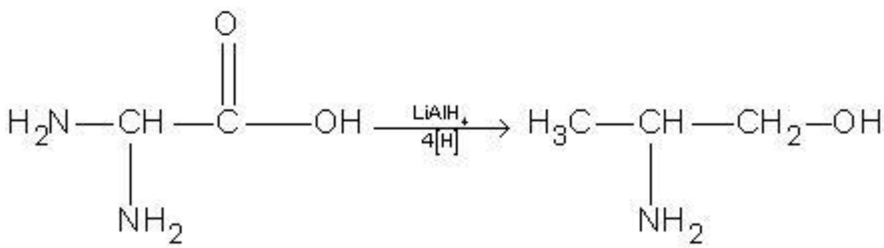


Alanine

Reduction

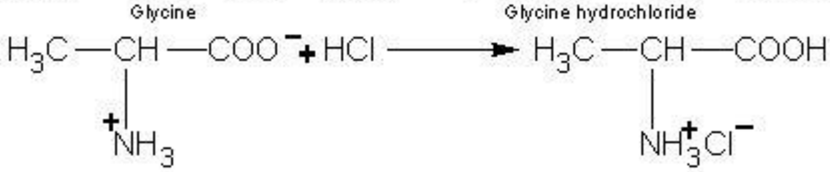


Glycine



Reaction with strong acid

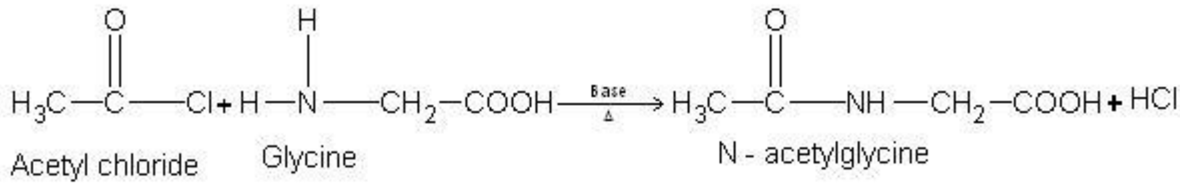
$$H_3N^+ - \underset{\text{Glycine}}{CH_2} - COO^- + HCl \longrightarrow \underset{\text{Glycine hydrochloride}}{Cl^- H_3N^+ - CH_2 - COOH}$$

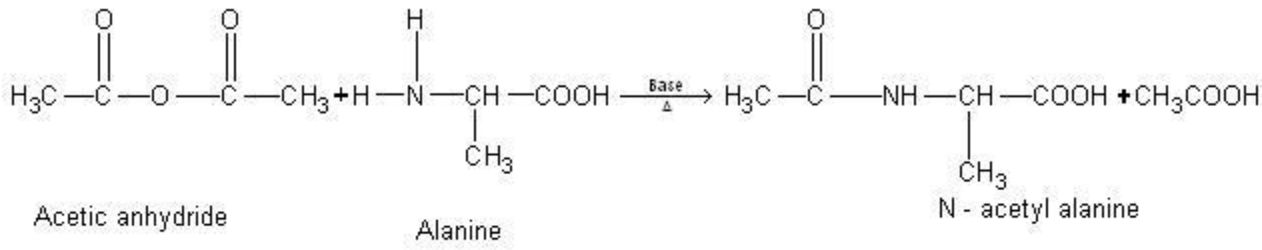


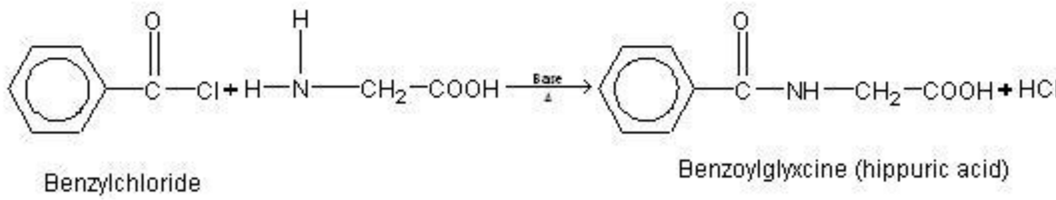
Alanine

Alanine hydrochloride

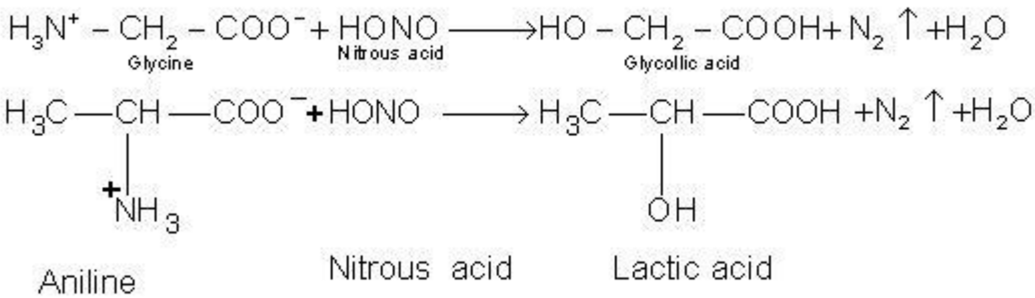
Acetylation







Reaction with Nitrous acid



Note:

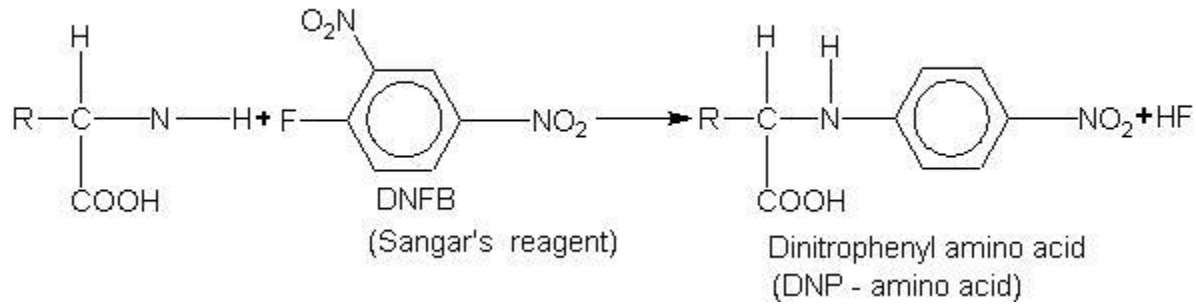
1. This reaction forms the basis of the “van slyke method” for the estimation of amino acids.
2. The nitrogen is evolved (one half comes from the amino acid) quantitatively and its volume measured.

Reaction with Nitrosyl halide

1. This reaction forms the basis of the “van slyke method” for the estimation of amino acids.
2. The nitrogen is evolved (one half comes from the amino acid) quantitatively and its volume measured.

Reaction with Nitrosyl halide

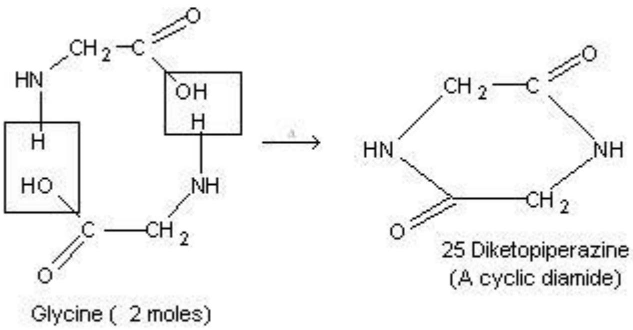
Reaction with 2, 4 – Dintrofluorobenzene (DNFB)



Reaction involving both the carboxyl & the amino group

Effect of heat

α - amino acids undergo dehydration on heating (200°C) to give diketopiperazines



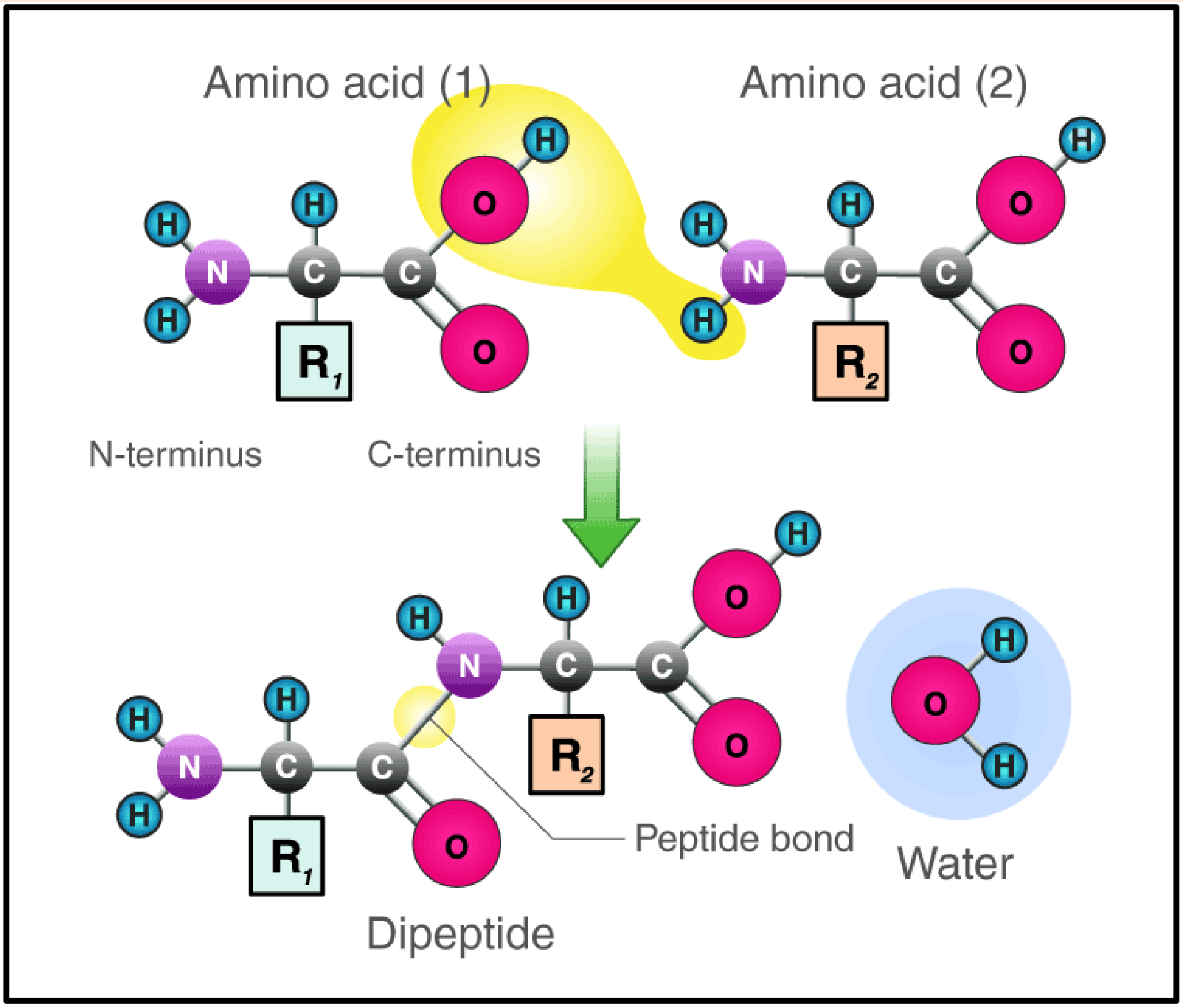
PEPTIDE LINKAGE:

A peptide is a Greek word which means “digested”. A peptide is a short polymer of amino acid monomers linked by an amide bond. A peptide bond is a chemical bond that is formed by joining the carboxyl group of one amino acid to the amino group of another. During this bond formation, there is a release of water (H_2O) molecule. A peptide bond is usually a covalent bond (CO-NH bond) and since the water molecule is eliminated it is considered as a dehydration process. Generally, this process occurs mostly between amino groups.

A peptide bond is also sometimes called eupeptide bond.

Peptide Bond Formation or Synthesis

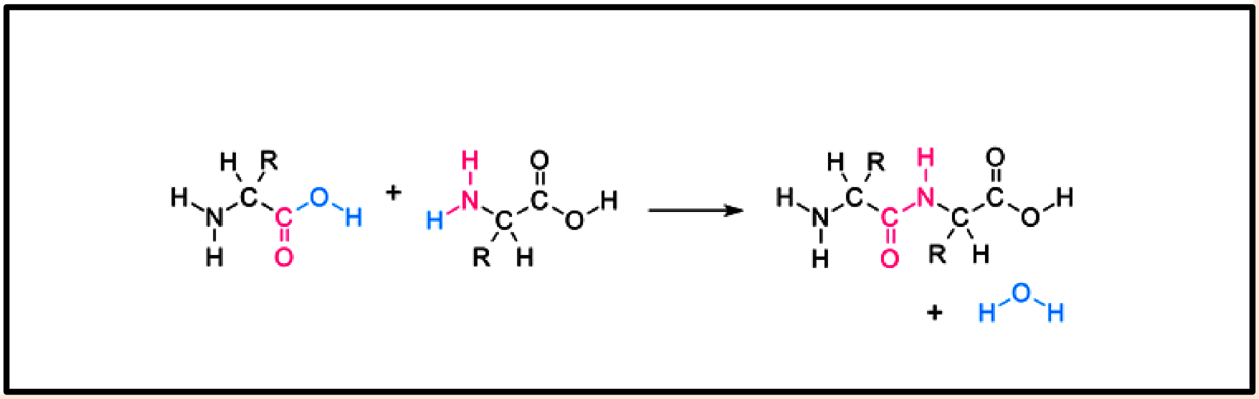
A peptide bond is formed by a dehydration synthesis or reaction at a molecular level. As depicted in the figure given below, two amino acids bond together to form a peptide bond by the dehydration synthesis. During the reaction, one of the amino acids gives a carboxyl group to the reaction and loses a hydroxyl group (hydrogen and oxygen).



The other amino acid loses hydrogen from the NH_2 group. The hydroxyl group is substituted by nitrogen thus forming a peptide bond. This is one of the primary reasons for peptide bonds being referred to as substituted amide linkages. Both the amino acids are covalently bonded to each other.

The newly formed amino acids are also called a dipeptide.

Let's have a look at a simpler diagram depicting the formation of the peptide bond.



Characteristics of Peptide Bonds

1. Peptide bonds are strong with partial double bond character:

- They are not broken by heating or high salt concentration.
- They can be broken by exposing them to strong acid or base for a long time at elevated temperature. Also by some specific enzymes (digestive enzymes).

2. Peptide bonds are rigid and planar bonds therefore they stabilize protein structure.

3. Peptide bond contains partial positive charge groups (polar hydrogen atoms of amino groups) and partial negative charge groups (polar oxygen atoms of carboxyl groups).

Different Forms of Peptide Bond

- **Dipeptide =** contains 2 amino acid units.
- **Tripeptide =** contains 3 amino acid units.
- **Tetrapeptide =** contains 4 amino acid units.
- **Oligopeptide =** contains not more than 10 amino acid units.
- **Polypeptide =** contains more than 10 amino acid units, up to 100 residues.
- **Macropeptides =** made up of more than 100 amino acids.

Degradation of Peptide Bond

Degradation of peptide bond involves a reaction in which breaking of the peptide bonds between the molecules occurs. Hydrolysis (addition of water) is the reaction used for the degradation of the peptide bond. During the reaction, they will emit Gibbs energy in an amount of 8-16 kJ/mol. But generally, this is a very slow process having a half-life of 350 to 600 years per bond at a temperature of 25^{o}C. Enzymes like proteases are used as the catalysts for this process.

Peptide Bond Structure

A peptide bond is a planar, trans and rigid configuration. It also shows a partial double bond character. The coplanarity of the peptide bond denotes the resonance or partial sharing of two pairs of electrons between the amide nitrogen and carboxyl oxygen.

The atoms C, H, N, O of the peptide bond lies in the same plane, like the hydrogen atom of the amide group and the oxygen atom of the carboxyl group are trans to each other.

Linus Pauling and Robert Corey are the scientists who found that the peptide bonds are rigid and planar.

Peptide Bond Features

Some of the key features of this bond include;

Writing Of the Peptide Bond Structure

Generally, these bonds are written in a form where free amino acids are at the left and the free carboxyl on the right side. The left side is N-terminal residue and the right side is C-terminal residue. This amino acid sequence is read from the N-terminal to the C-terminal. And also the protein biosynthesis also starts in the same direction.

Representation of the Peptide Bond

Rattlesnake moving representation is used for the peptide bond representation, from left to right of the page. The N-terminal residues to its rattle and C-terminal residues are considered as the fangs.

Shorthand to Read the Peptide Bond

Peptide or protein of the amino acid is represented by the 3 letters or one-letter abbreviation.

The Naming Of the Peptide Bond

To name the peptides, we should know the suffixes of the amino acids. -ine for glycine, -an for tryptophan, -ate for glutamate, are changed to -yl except in the case of C-terminal of the amino acid.

Stereochemistry of The Peptide Bond

We know that every protein is made of simpler units of amino acids with the L-configuration. The steric arrangement of the alpha carbon is fixed by that configuration.

PREPARED BY: MR. ARNAB PAUL CHOWDHURY