Department of Medical Biochemistry,
Osun State University,

BCH 201:

Amino Acid Chemistry: Properties and Functions

PROPERTIES OF AMINO ACIDS

- The amino acids differ in their physicochemical properties, which ultimately determine the characteristics of proteins.

- **The α-R groups determine the properties of amino acids!**

A. Physical properties

- 1. Solubility: Most of the amino acids are *usually soluble in water* and *insoluble in organic solvents*.
- 2. Melting points: Amino acids generally ***melt at higher temperatures***, often above 200°C.

- 3. Taste: Amino acids may be sweet (Gly, Ala, Val), tasteless (Leu), or bitter (Arg, Ile).
- Monosodium glutamate (MSG; ajinomoto) is used as a flavoring agent in the food industry and in Chinese foods to increase taste and flavor.
- In some individuals intolerant to MSG, **Chinese restaurant syndrome** (brief and reversible flu-like symptoms) is observed

- 4. Optical properties: *All the amino acids except glycine possess optical isomers* due to the presence of an asymmetric carbon atom.
- Some amino acids also have a second asymmetric carbon, e.g., isoleucine and threonine.

- 5. Amino acids as ampholytes: Amino acids contain ***both acidic (-COOH) and basic -NH2)*** groups.
- *They can donate a proton or accept a proton*; hence, amino acids are regarded as ampholytes.

- *Zwitterion or dipolar ion*: The name "zwitter" is derived from the German word, which means **hybrid**. A zwitterion (or dipolar ion) **is a hybrid molecule** containing positive and negative ionic groups

- Isoelectric pH (symbol pI): is defined as *the pH at which a molecule exists as a zwitterion or dipolar ion and carries no net charge*. Thus, the molecule is electrically neutral.

- The pI value can be calculated by taking the average pKa values corresponding to the ionizable groups. For instance, ***leucine has two ionizable groups***, and its pI can be calculated as follows:

$$pH = \frac{pK_1(COO^-) + pK_2(NH_3^+)}{2}$$

$$pI = \frac{2.4 + 9.6}{2} = 6.0$$

- Leucine exists as cation at pH below 6 and anion at pH above 6. At the isoelectric pH (pI = 6.0), leucine is found as a zwitterion. Thus, the pH of the medium determines the ionic nature of amino acids.

- For the calculation of pI of amino acids with more than two ionizable groups, the pKas for all the groups have to be taken into account.

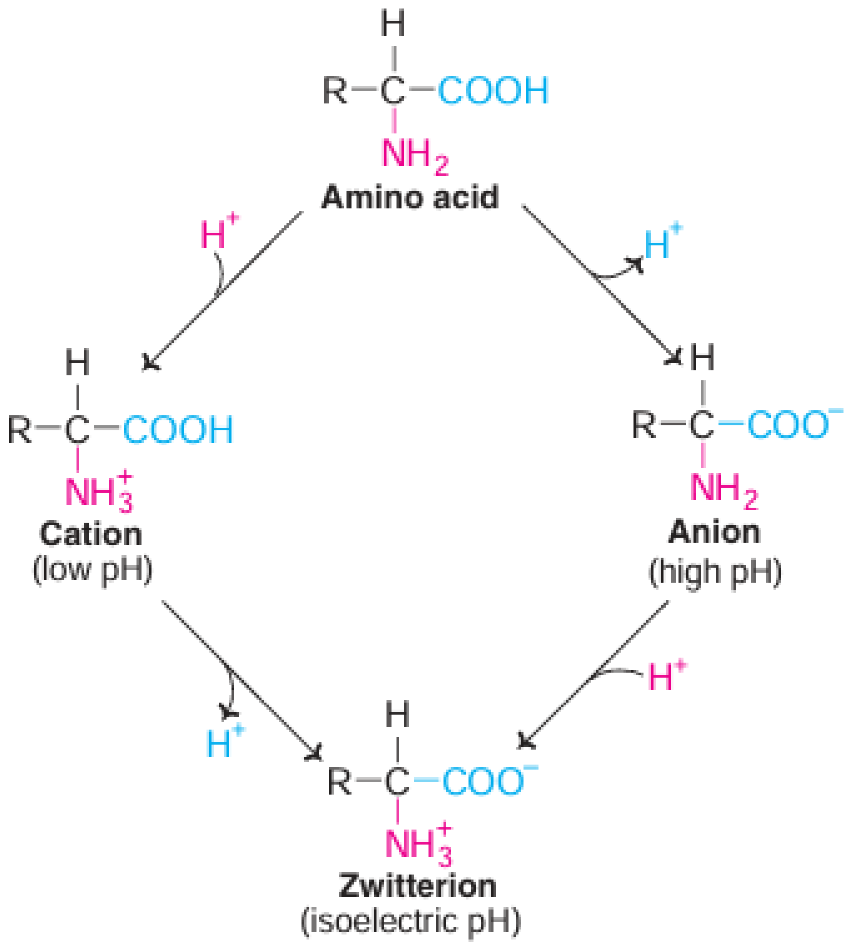
<u>TITRATION OF AMINO ACIDS</u>:

- The existence of different ionic forms of amino acids can be more easily understood by the titration curves

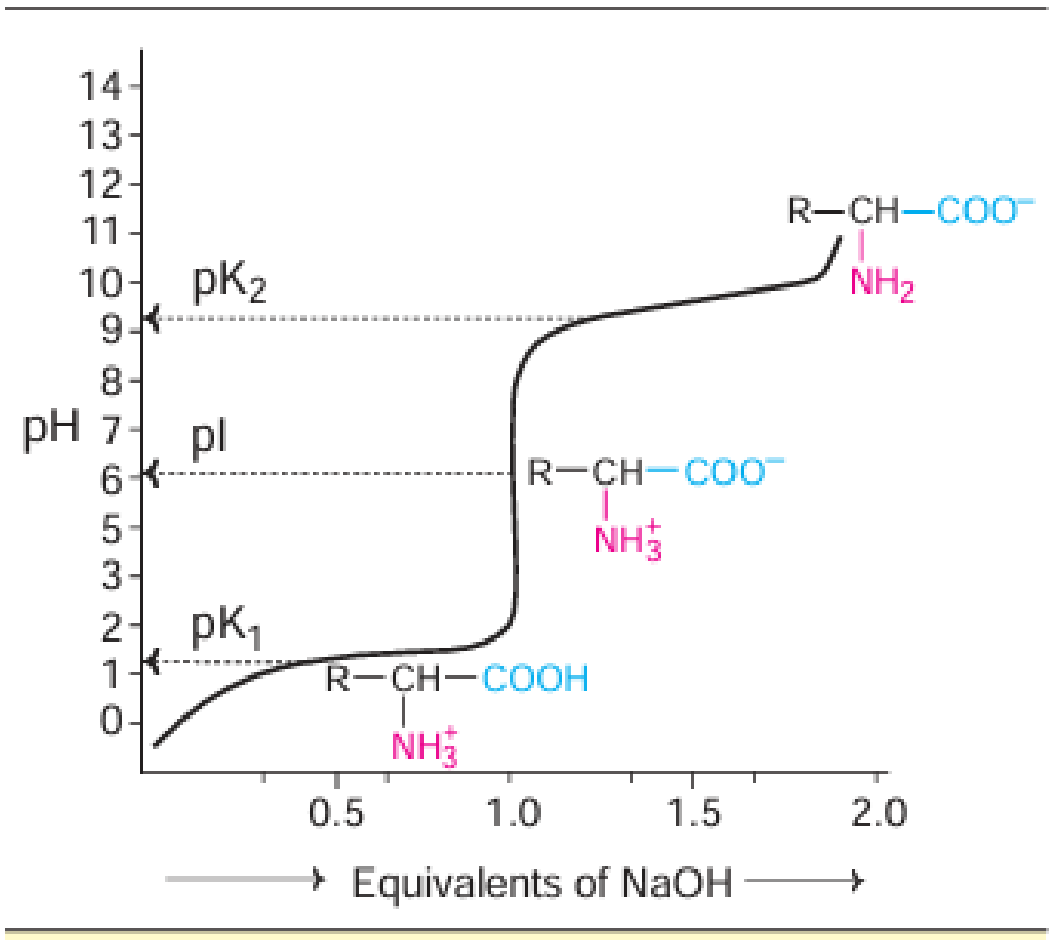
- The graphic representation of leucine titration is depicted in the figure below.

- <u>At low pH</u>, leucine exists in a **fully protonated form as a cation**. As the titration proceeds with NaOH, leucine loses its protons and **at its isoelectric pH (pI), it becomes a zwitterion**.

- Further titration results in the formation of the **anionic form of leucine**.



Existence of an amino acid as cation, anion and zwitterion.

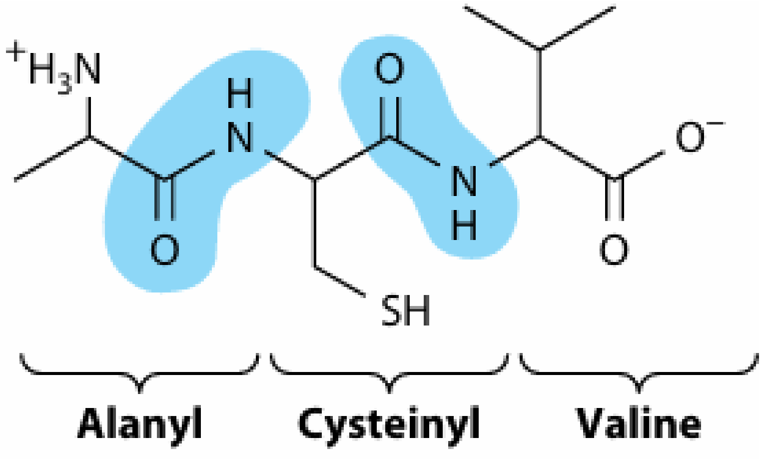


Titration curve of an amino acid-leucine (R = (CH3)2 —CH—CH2 —; pK1 = Dissociation constant for COOH; pI = Isoelectric pH; pK2 = Dissociation constant for NH3 +)

B. Chemical properties.

- The general reactions of amino acids are mostly due to the presence of two functional groups, namely the carboxyl (COOH) group and the amino (NH2) group.

- ***The most important reaction of amino acids is the formation of a peptide bond*** (**shaded blue**).

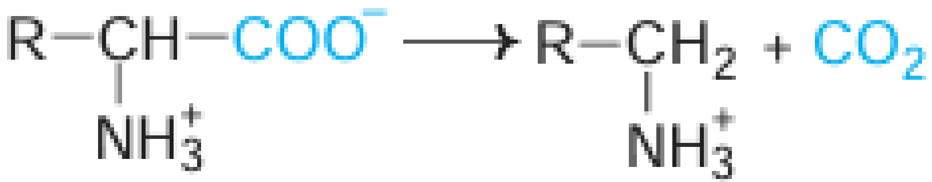


Reactions due to the COOH group:

1. Salts and Ester Formation: Amino acids form salts (COONa) with bases and esters (COOR) with alcohols.

2. Decarboxylation: Amino acids undergo decarboxylation to produce corresponding amines. This reaction assumes significance in the living cells due to the formation of many biologically important amines.

- These include **histamine**, **tyramine** and **γ-aminobutyric acid (GABA)** from the amino acids **histidine**, **tyrosine**, and **glutamate**, respectively.



3. Reaction with ammonia:

- The carboxyl group of dicarboxylic amino acids reacts with NH3 to form an amide

  - Aspartic acid + NH3 = Asparagine
  - Glutamic acid + NH3 = Glutamine

Reactions due to NH2 group:

4. **Reactions as a Base**: The amino groups behave as bases and combine with acids (e.g. HCl) to form salts ($NH_3^+Cl^-$).

5. **Reaction with ninhydrin**: The α-amino acids react with ninhydrin to form a purple, blue or pink colour complex (Ruhemann's purple).

- **Amino acid + Ninhydrin Keto acid = NH_3+CO_2+Hydrindantin**

- **Hydrindantin + NH_3 + Ninhydrinm = Ruhemann's purple.**

- The ninhydrin reaction is effectively ***used for the quantitative determination of amino acids and proteins***. (Note: **Proline** and **hydroxyproline give yellow colour with ninhydrin**).

6. **Colour reactions of amino acids**:

- Amino acids can be identified by specific colour reactions, e.g.

1. Ninhydrin Reaction - Most α-amino acids give a **purple colour** when they react with **ninhydrin.**

2. Millon's reaction - used to detect the presence of proteins containing the amino acid tyrosine. The test involves adding Millon's reagent (a solution of mercuric nitrate in nitric acid) to a sample and heating it. ***A positive result is indicated by a red-colored solution or precipitate***

3. Cyanide-nitroprusside test - detects **cystine** and other thiols by using **sodium cyanide to break down disulfides**, which then react with **nitroprusside and ammonia** to produce **a purple or red color**. This test is used to screen for conditions like **cystinuria**, an inherited disease that causes an excess of cystine in the urine.

4. Pauly's test - identifies the presence of **histidine** by reacting its **imidazole ring** with a **diazonium salt in an alkaline solution** to form a **red-colored complex**.

7. Transamination:

- Transfer of an amino group **from an amino acid to a keto acid** to form a new amino acid is a very important reaction in amino acid metabolism.

- In the process of transamination, the amino groups of most amino acids are transferred to α-ketoglutarate (an intermediate in the TCA/Krebs' Cycle) to produce glutamate.

- E.G., By reacting with α-ketoglutarate, Aspartate can be converted to Glutamate, catalyzed by aspartate transaminase (AST).

8. **Oxidative deamination**:

- The amino acid glutamate (e.g. from 7 above) can undergo oxidative deamination, catalysed by glutamate dehydrogenase (GDH), to liberate ammonia

Functions of Amino Acids

- Amino acids primarily function as the building blocks of proteins, which are essential for growth, tissue repair, and countless other bodily functions.

1. Protein synthesis and repair

- Building proteins: Amino acids link together to form proteins, which are necessary for building muscles, bones, and internal organs.
- Tissue repair: They are crucial for repairing and rebuilding body tissues.

2. Metabolic functions

- Energy source: The body can break down amino acids for energy, especially during fasting or intense exercise.
- Metabolism: Certain amino acids are converted into carbohydrates (glucogenic amino acids) or used in other metabolic processes.
- Nutrient transport: Some amino acids, like lysine, help with the absorption of other nutrients, such as calcium.

3. **Chemical and cellular functions**

- Hormone production: Amino acids are used to synthesize hormones like insulin and growth hormone.

- Neurotransmitters: They are precursors for neurotransmitters that transmit signals in the nervous system, such as glutamate and GABA.

- Immune function: Antibodies, which fight off infections, are made of proteins built from amino acids.

- pH regulation: Some amino acids act as buffers to help maintain proper pH levels in the body.

4. **Non-protein amino acids and their functions**;

- Ornithine, citrulline, and arginosuccinic acids are α-amino acids that **serve as intermediates in the biosynthesis of urea**
- β-Alanine is a non-α amino acid that serves as a component of vitamin **pantothenic acid** and **coenzyme A**
- δ-Aminolevulinic acid (ALA) is a non-α amino acid that acts as an Intermediate in the synthesis of porphyrin (finally heme)
- Taurine is another non-α amino acid that is found in association with bile acids

5. **Other functions**

- Mood regulation: For example, tryptophan is used to make serotonin, a neurotransmitter that helps **regulate mood** and **sleep**.

- Hair, skin, and nail health: Amino acids like methionine and cysteine play a role in the health and strength of skin, hair, and nails.