Amino Acids

Aims of The Lecture

The students should be learning about Amino acids:

- **The structures and types.**
- **The modified & uncommon types.**
- **Optical properties.**
- **Acid-Base properties and Buffer characteristic.**
- **The importance and functional role.**

Structural Feature of Proteins

Proteins functionally diverse molecules in living systems such as:

- Enzymes and polypeptide hormones.
- Myosin, a contractile protein of muscle.
- Bone, consisted from the protein collagen.
- Blood proteins, such as hemoglobin and plasma albumin and immunoglobulins.

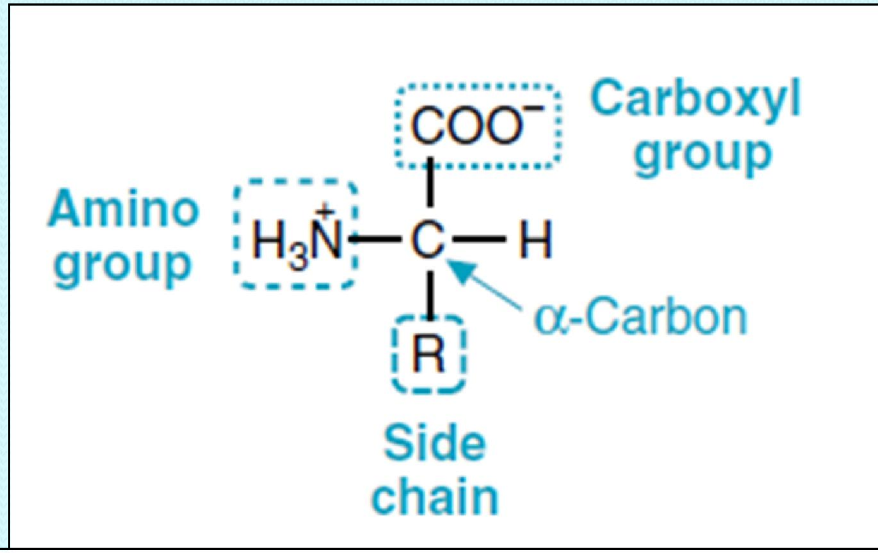
All share the common structural feature of being linear polymers of amino acids

STRUCTURE OF THE AMINO ACIDS

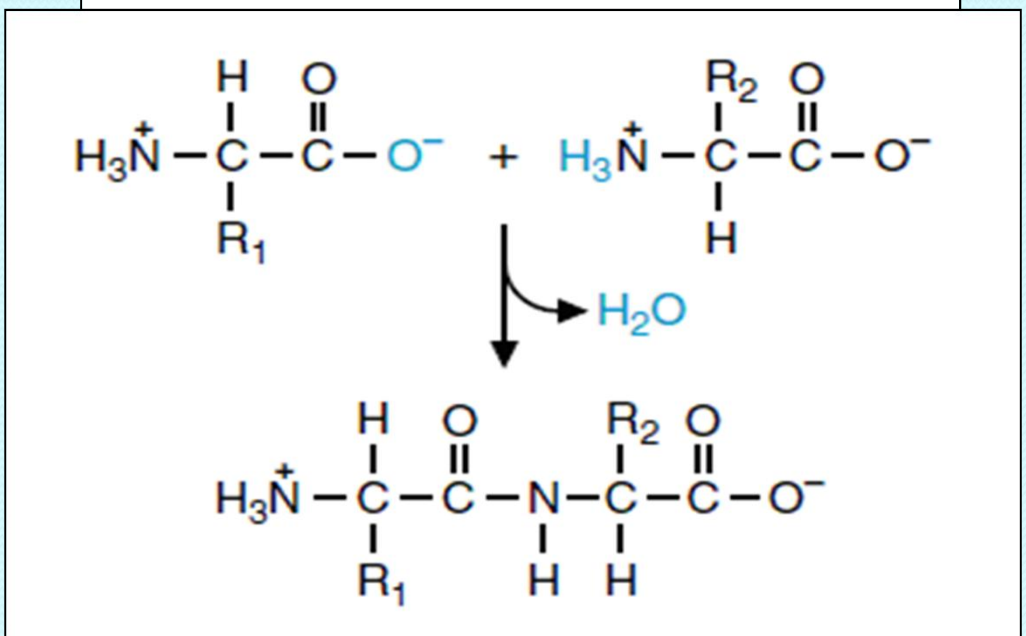
Each amino acid (except for proline) has:

1. A carboxyl group ($-COO^-$) .
2. An amino group ($-NH_3^+$) .
3. Side chain ("R-group") bonded to the α-carbon atom.

These carboxyl and amino groups are combined in peptide linkage.



Carboxyl group
COO⁻
Amino group
H3N
C
H
α-Carbon
R
Side chain

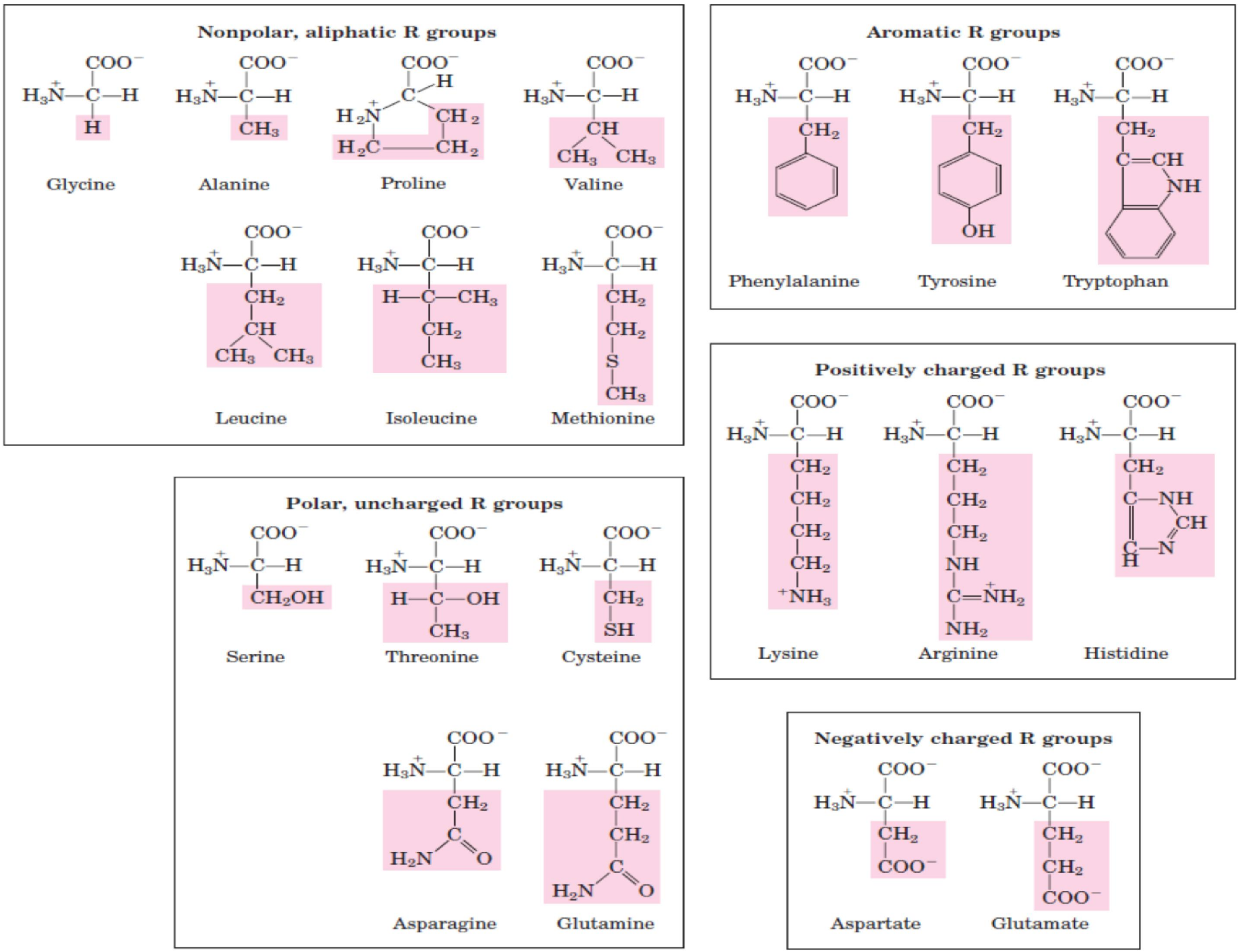


H2O

Classification of Amino Acids

They classified according to the side chain:

- Amino acids with nonpolar side chains.
- Aromatic R Groups.
- Amino acids with uncharged polar side chains.
- Positively Charged (Basic) R Groups.
- Amino acids with acidic side chains.


Nonpolar, aliphatic R groups
Glycine
Alanine
Proline
Valine
Leucine
Isoleucine
Methionine
Aromatic R groups
Phenylalanine
Tyrosine
Tryptophan
Polar, uncharged R groups
Serine
Threonine
Cysteine
Asparagine
Glutamine
Positively charged R groups
Lysine
Arginine
Histidine
Negatively charged R groups
Aspartate
Glutamate

A- Nonpolar Side Chains

- The side chains cluster in the interior of the protein due to hydrophobicity.
- The side chain of **proline** and its α-amino group form a ring structure.
- **Proline** gives the fibrous structure of collagen, and interrupts the α-helices found in globular proteins.

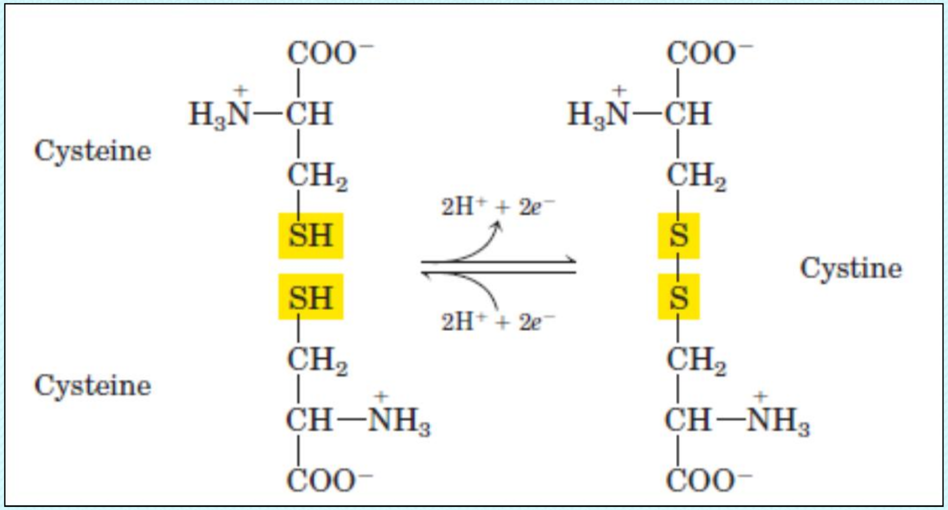
B- Aromatic (R) Groups

- Their aromatic side chains, are nonpolar so that participate in hydrophobic interactions.
- Tyrosine is an important in some enzymes.
- Most proteins absorb light at a wavelength of 280 nm due to aromatic groups.
- A property exploited by researchers in the characterization of proteins.

C. Uncharged polar side chains

- More hydrophilic because they form hydrogen bonds with water.
- includes **serine, threonine, cysteine, asparagine,** and **glutamine.**
- **Cysteine** contains a **sulfhydryl group** (-SH), an important component of the active site of many enzymes.
- Two cysteines can become oxidized to form a dimmer **cystine,** which contains a covalent cross-link called a disulfide bond (-S-S-).

- Serine and threonine contain a **polar hydroxyl group.**
- Serve as a site of attachment (in enzymes) for groups such as a phosphate.



- **Amide group** of asparagine, as well as the hydroxyl group of serine or threonine serve as a site of attachment for oligosaccharide chains in glycoproteins.

D. Basic (R) Groups

- The R groups have significant positive charge.
- **Lysine** has a second positive amino group at the ε position on its (R) chain.
- **Arginine** has a positively charged guanidino group.
- **Histidine** has a positive imidazole group facilitates the enzyme-catalyzed reaction by serving as a proton donor/acceptor.

E. Acidic Side Chains

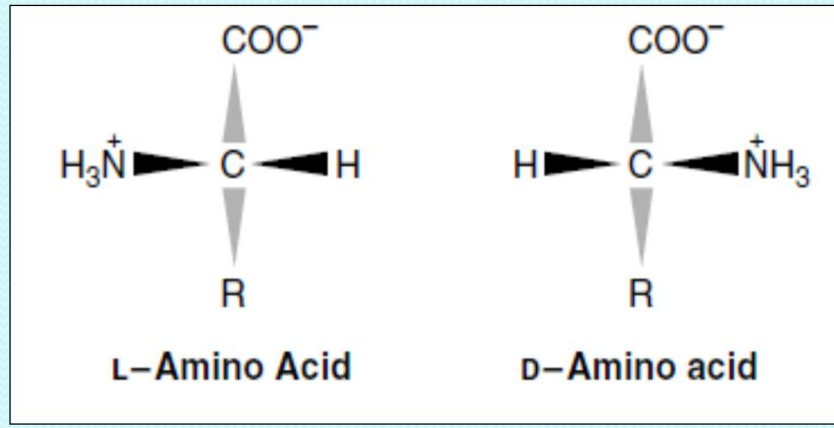
- Aspartic and glutamic acid are proton donors.
- At neutral pH, the side chains of these amino acids are fully ionized.
- They have a negatively charged carboxylate group ($-COO^-$) at physiologic pH.

Uncommon Amino Acids

- **Hydroxylysine** and **hydroxyproline,** are found in the collagen and gelatin proteins.
- **Thyroxin** and **3,3`,5-triiodothyronine,** iodinated a.a. are found in thyroglobulin, a protein produced by the thyroid gland.
- **γ-Carboxyglutamic acid** is involved in blood clotting.
- Finally, ***N*-methylarginine** and ***N*-acetyllysine** are found in histone proteins associated with chromosomes.

Optical Properties of Amino Acids

- The α-carbon of a.a. is attached to four different chemical groups is a chiral or optically active carbon atom.



- Glycine is the exception.
- amino acids exist in two forms, D and L, that are mirror images of each other.
- All amino acids found in proteins are of the L-configuration.

ACIDIC AND BASIC PROPERTIES OF AMINO ACIDS

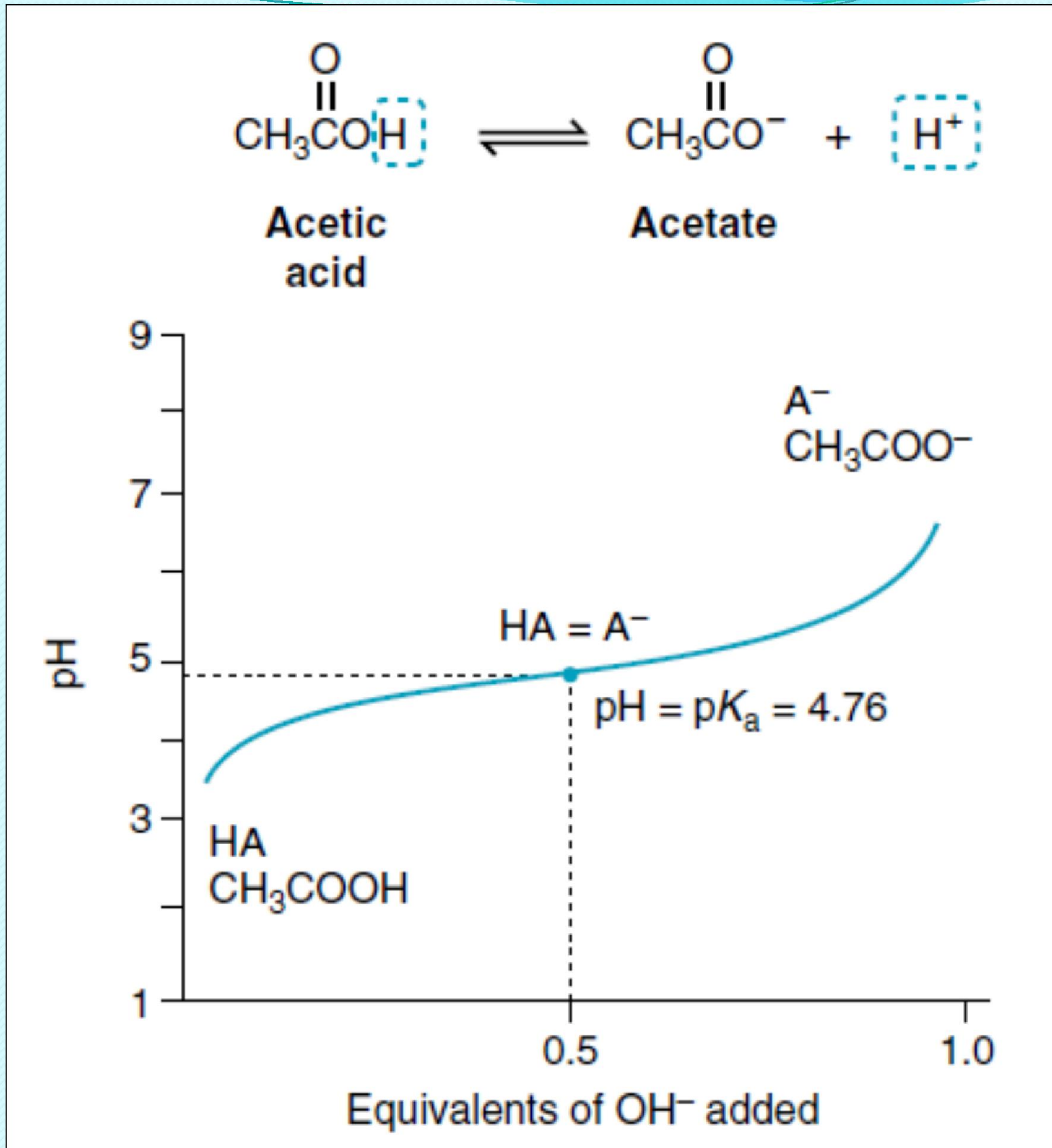
- Amino acids in aqueous solution contain weakly acidic α-carboxyl groups and weakly basic α-amino groups.
- Each of the acidic and basic amino acids contains an ionizable group in its side chain.
- Thus, both free and some of the combined amino acids in peptide linkages can act as **buffers.**
- The concentration of a weak acid (HA) and its conjugate base(A^-) is described by the **Henderson-Hasselbalch equation.**

Derivation of the equation

- For the reaction ($HA \rightleftharpoons A^- + H^+$)
- $$K_a = \frac{[H^+]\,[A^-]}{[HA]} \quad \text{------ (1)}$$
- By solving for the $[H^+]$ in the above equation, taking the logarithm of both sides of the equation, multiplying both sides of the equation by -1, and substituting $pH = -\log [H^+]$ and $pK_a = -\log [K_a]$ we obtain:
- $$pH = pK_a + \log \frac{[A^-]}{[HA]} \quad \text{------ (2)}$$

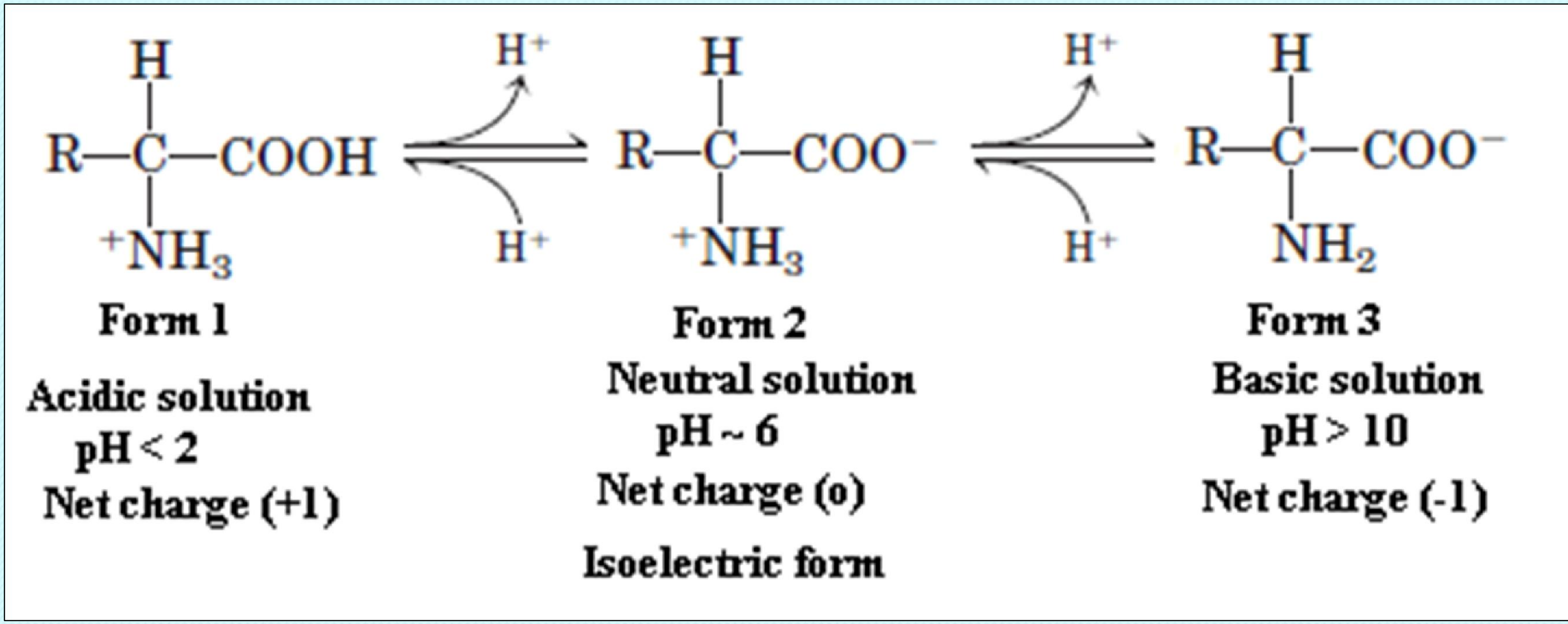
It is the <u>(Henderson-Hasselbalch equation)</u>

Buffers

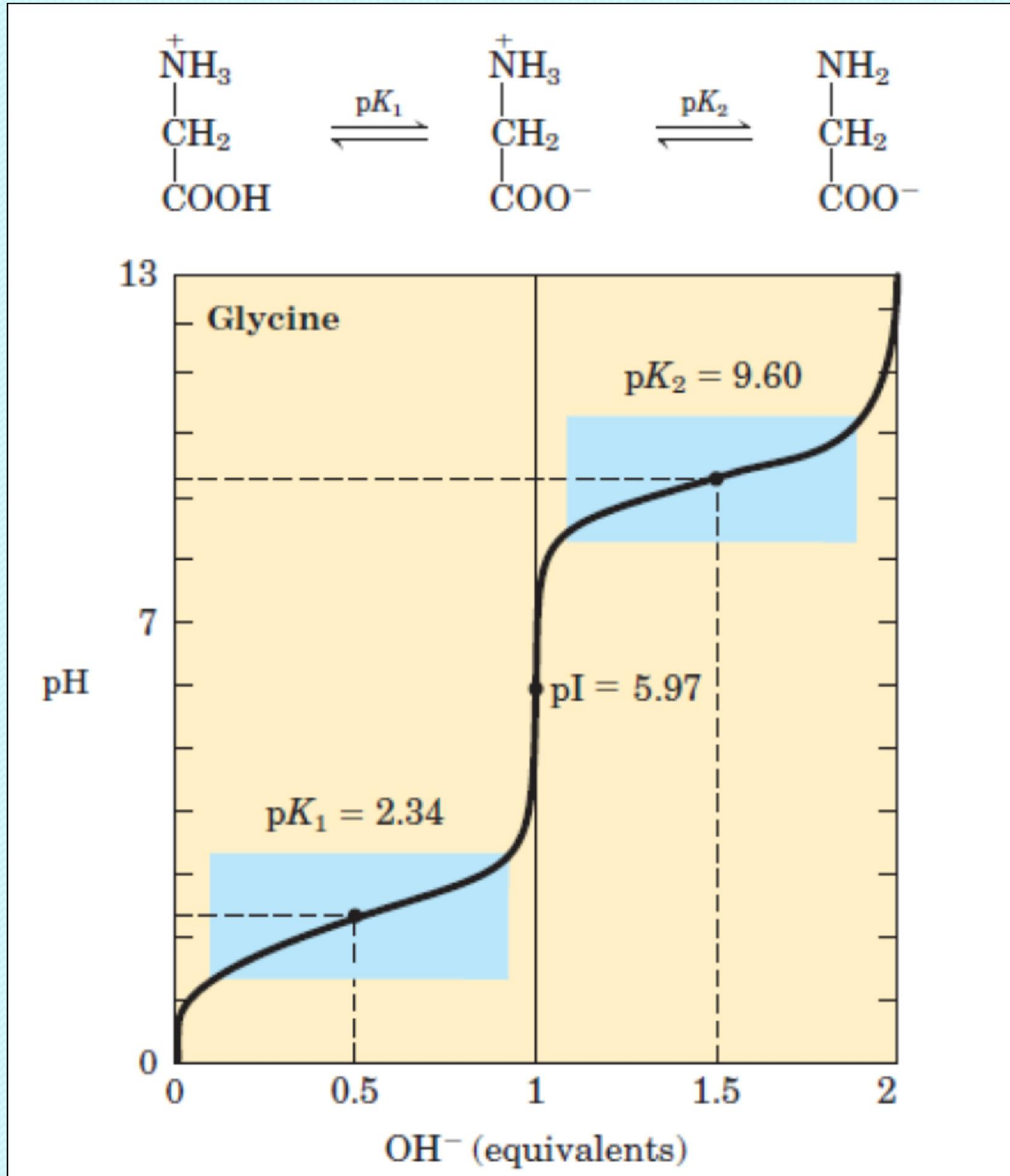


O
CH3COH
Acetic acid
O
CH3CO−
+
H+
Acetate
9
7
5
3
1
pH
A−
CH3COO−
HA = A−
pH = pKa = 4.76
HA
CH3COOH
0.5
1.0
Equivalents of OH− added

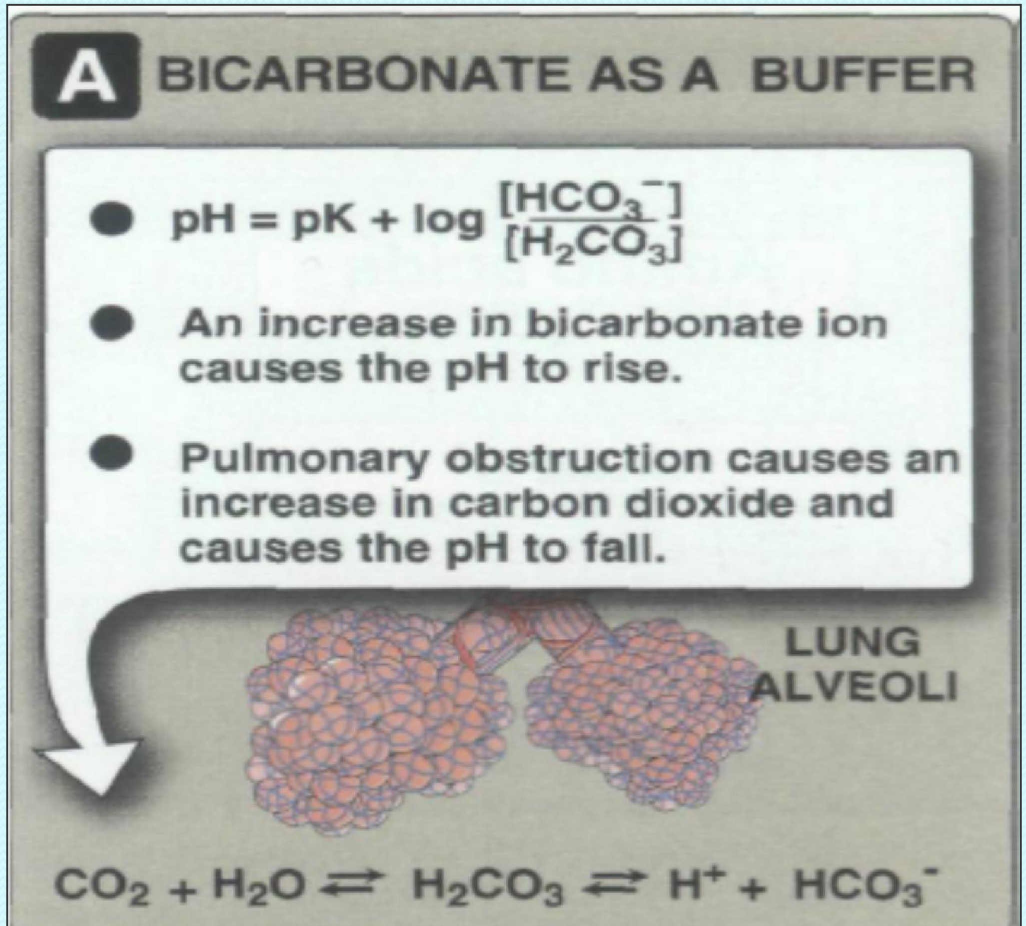
Titration Solution of an amino acid



Titration curve of glycine

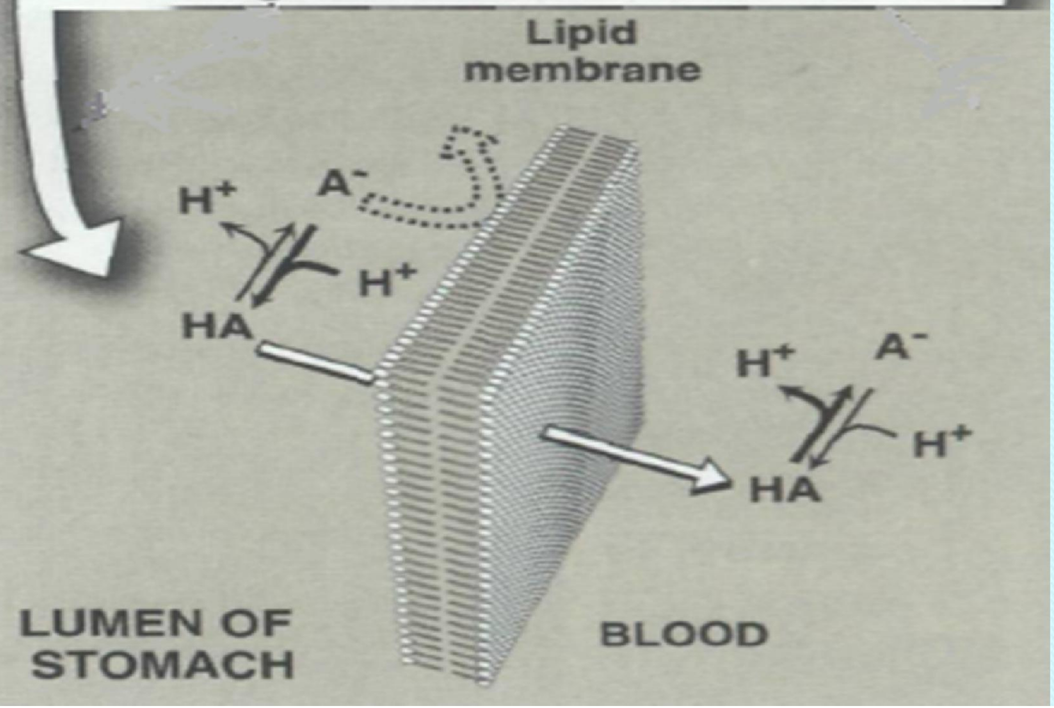


Other applications of the Henderson-Hasselbalch equation



B DRUG ABSORPTION

- $pH = pK + \log \frac{[Drug^-]}{[Drug\text{-}H]}$
- At the pH of the stomach (1.5), a drug like aspirin (weak acid, pK = 3.5) will be largely protonated (COOH) and, thus, uncharged.
- Uncharged drugs generally cross membranes more rapidly than charged molecules.



Summery

- The 20 amino acids commonly found as residues in proteins contain an α-carboxyl group, an α-amino group, and a distinctive R group substituted on the α-carbon atom. The α-carbon atom of all amino acids except glycine is asymmetric, and thus amino acids can exist in at least two stereoisomeric forms. Only the L stereoisomers, are found in proteins.
- Amino acids are classified into five types on the basis of the polarity and charge (at pH 7) of their R groups.
- Amino acids vary in their acid-base properties and have characteristic titration curves. Monoamino monocarboxylic amino acids (with nonionizable R groups) are diprotic acids ($^{+}$H3NCH(R)COOH) at low pH and exist in several different ionic forms as the pH is increased. Amino acids with ionizable R groups have additional ionic species, depending on the pH of the medium and the pK_a of the R group.

Refrences

- Lippincott Biochemistry Fourth Edition (2010).
- Lehninger Principles of Biochemistry, Fourth Edition (2006).
- Robert K. Murray, MD, PhD. ‘Harper’s Illustrated Biochemistry’. Twenty-Eighth Edition. 2009.
- Marks' Essential Medical Biochemistry, 2nd Edition Copyright 2007 Lippincott Williams & Wilkins.

Thank you