Introduction to the Study of Proteins

Proteins - the most plentiful organic compounds in the body, making up more than half its dry weight

Proteins can be categorized by function.

Catalytic proteins, or enzymes:
Catalyze the synthesis and utilization of proteins, carbohydrates, lipids, nucleic acids, and almost all other biomolecules.

Regulatory proteins:
Control cellular activity.

Contractile proteins:
Provide cells and organisms with the ability to change shape and move.

Transport proteins:
Bind and carry specific molecules from place to place.

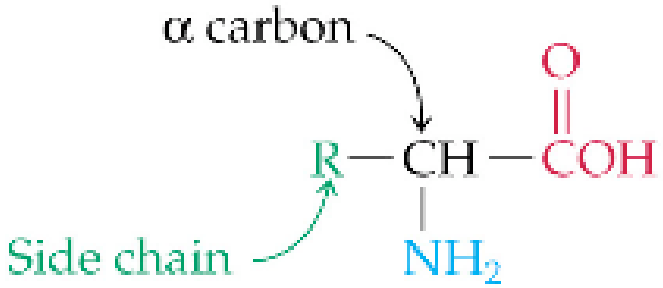
Structural proteins:
Give physical shape, and the strength to maintain it, to structures in animals.

Protective proteins:
Defend against invaders and prevent or minimize damage after injury.

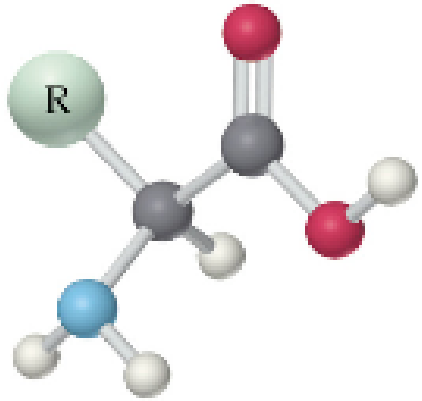
Storage proteins:
Provide a reservoir of nitrogen and other nutrients, especially when external sources are low or absent.

Proteins are Made of Amino Acids

Proteins --------*Hydrolysis*--------> Amino Acids



Generalized structure of an α-amino acid

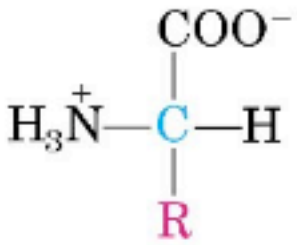


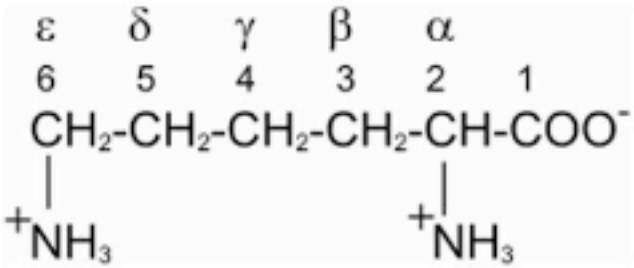
Mammals require all 20 amino acids for protein synthesis but can synthesize only 10 of them.

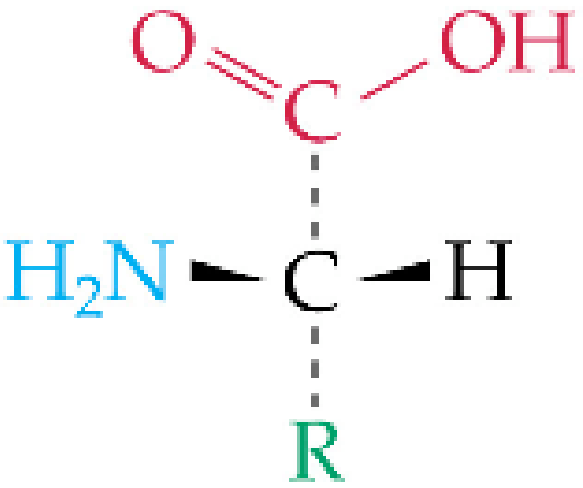
There are 10 **essential amino acids** that must be obtained from the diet.

Phenylalanine, Valine, Tryptophan, Threonine, Isoleucine, Methionine, Histidine, Arginine, Lysine, Leucine

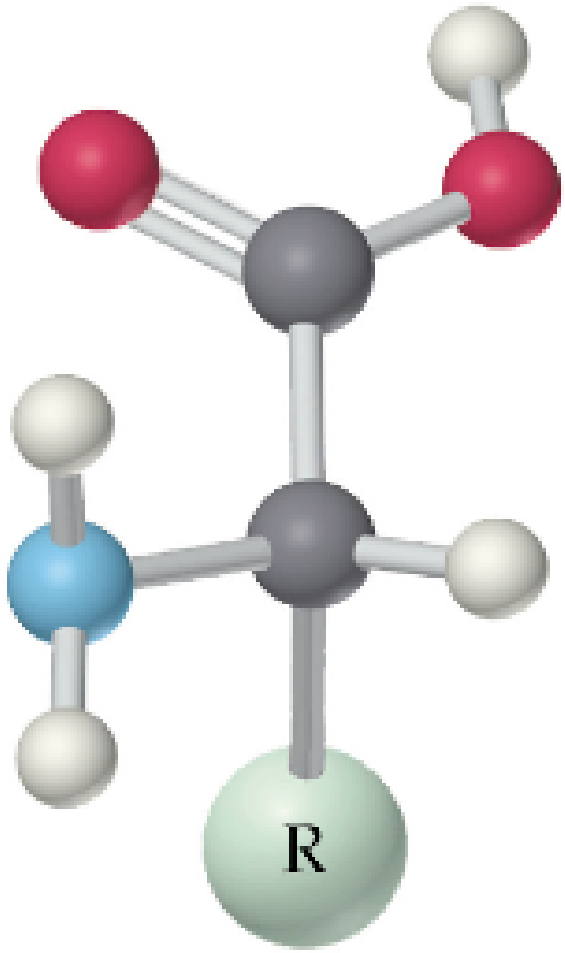
Amino Acids



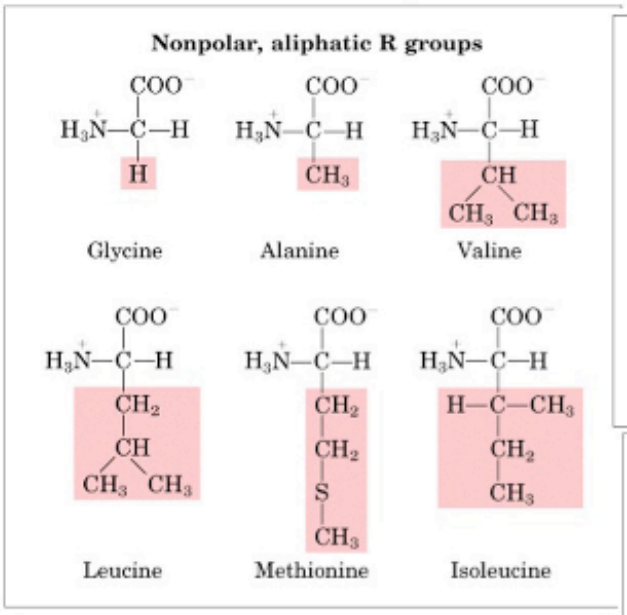


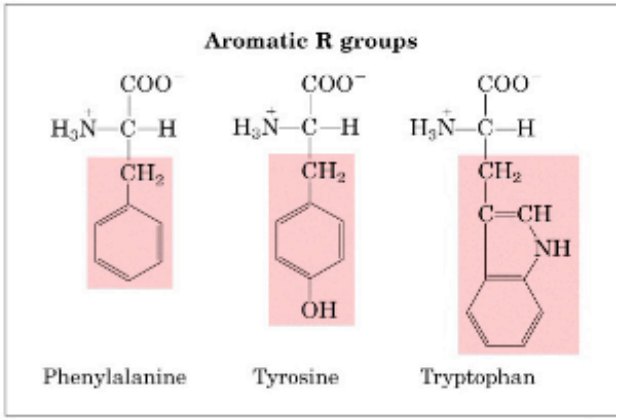


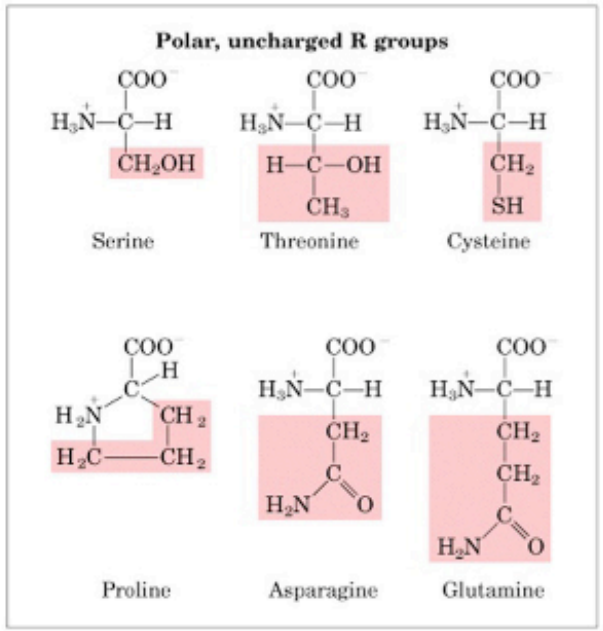
An L-amino acid

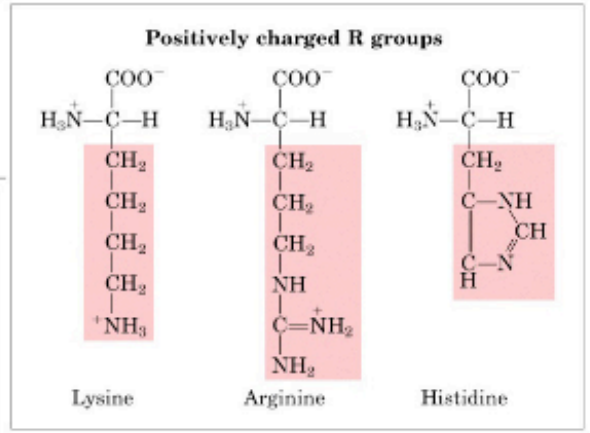


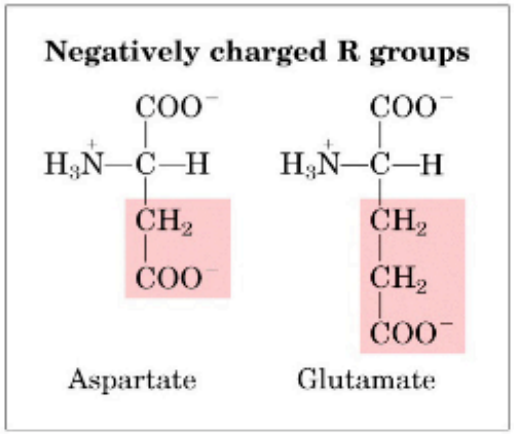
Twenty Standard Amino Acids











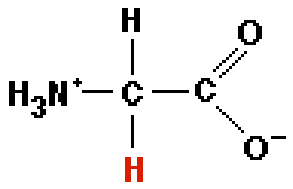
The amino acids are categorized chemically by the behavior of their R-groups:

Neutral side chains
- Aliphatic
- Polar
- Aromatic

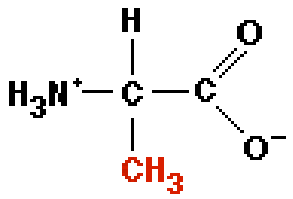
Basic - Positively charged

Acidic - Negatively charged

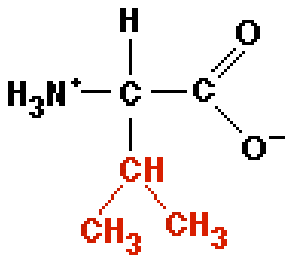
Amino Acids with Nonpolar, Uncharged Side Chains



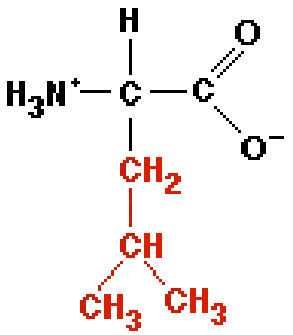
Glycine (Gly)



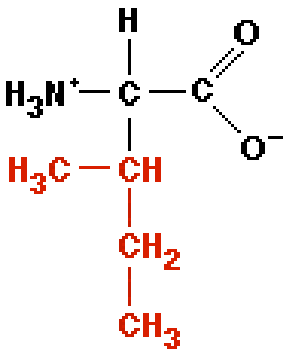
Alanine (Ala)



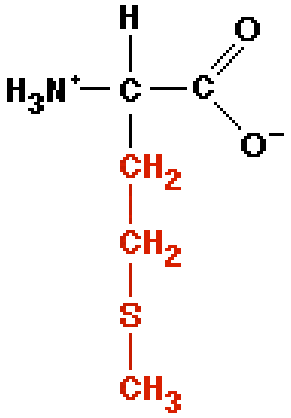
Valine (Val)



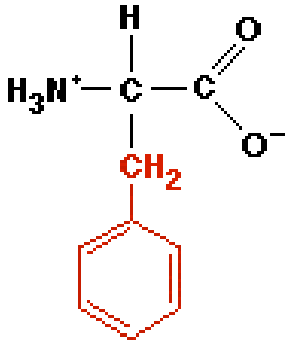
Leucine (Leu)



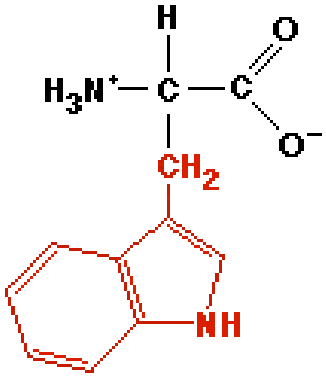
Isoleucine (Ile)



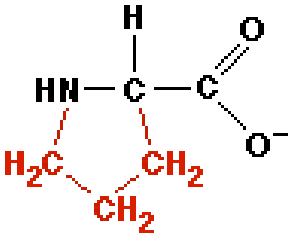
Methionine (Met)



Phenylalanine (Phe)

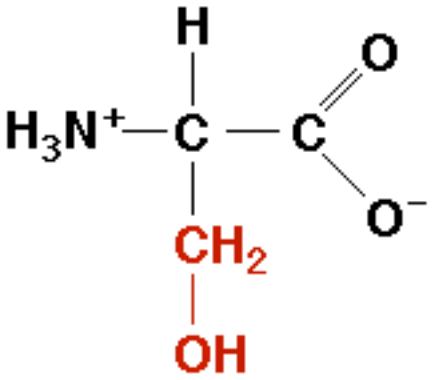


Tryptophan (Trp)

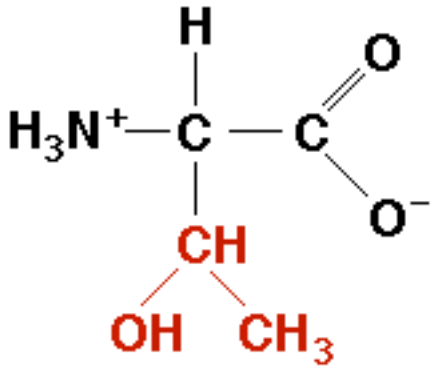


Proline (Pro)

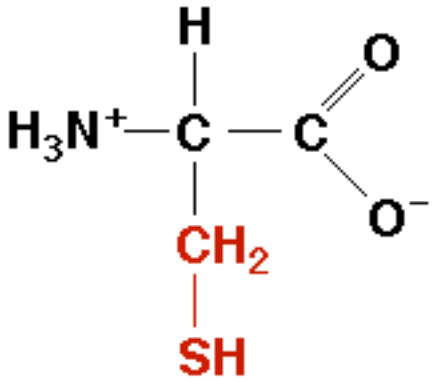
Amino Acids with Polar, Uncharged Side Chains



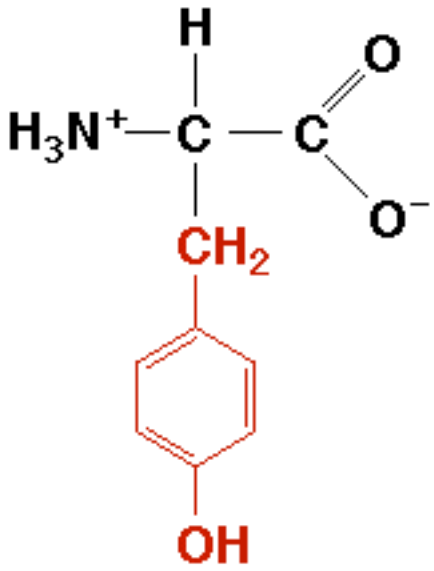
Serine (Ser)



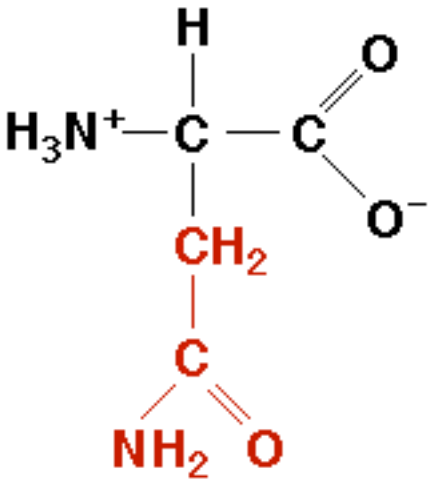
Threonine (Thr)



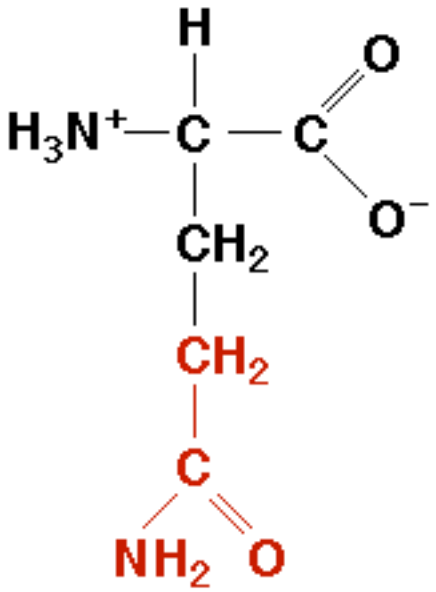
Cysteine (Cys)



Tyrosine (Tyr)

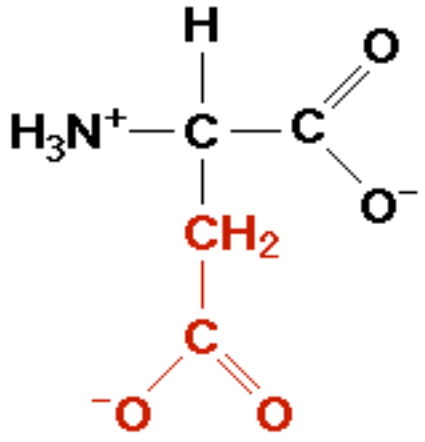


Asparagine (Asn)

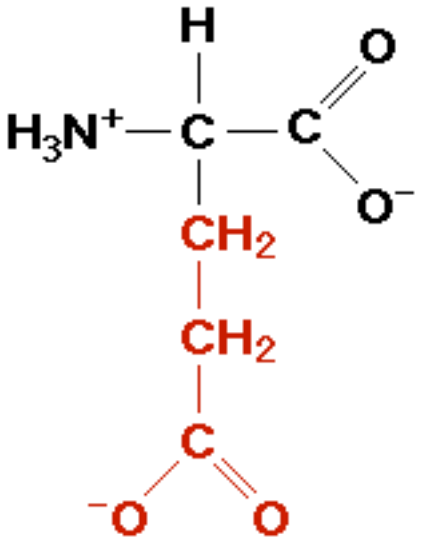


Glutamine (Gln)

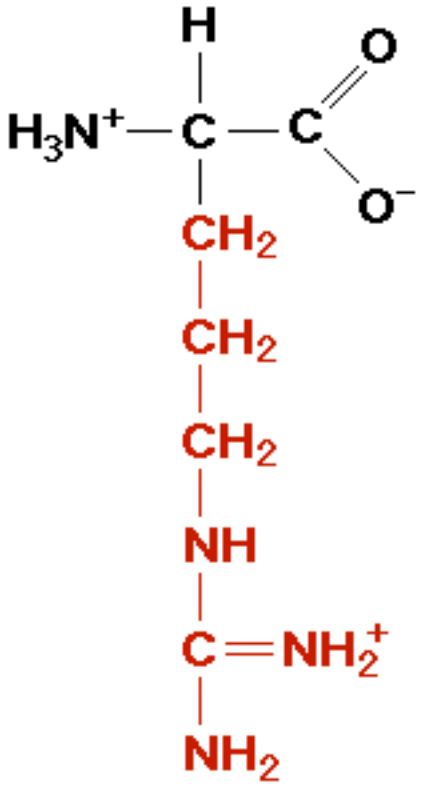
Amino Acids with Polar, Charged Side Chains



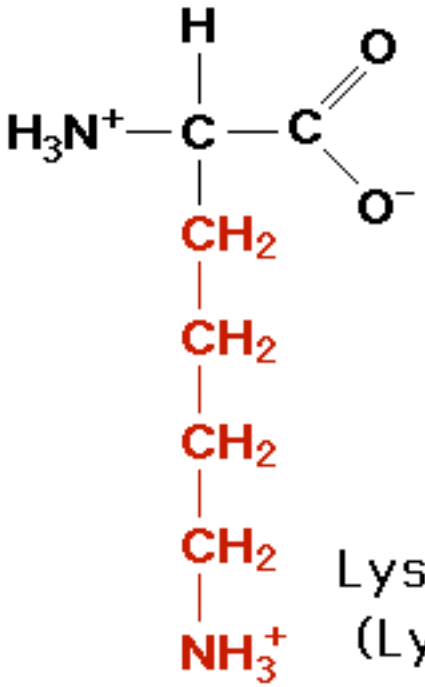
Aspartic acid (Asp)



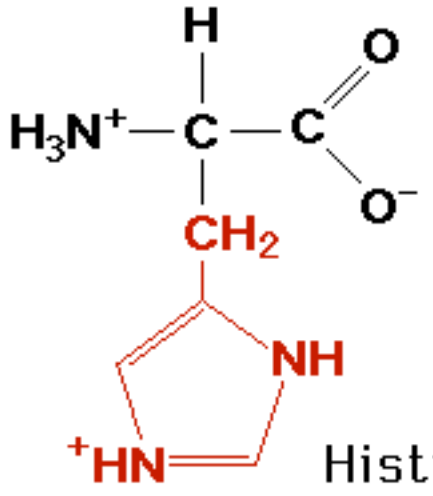
Glutamic acid (Glu)



Arginine (Arg)



Lysine
(Lys)

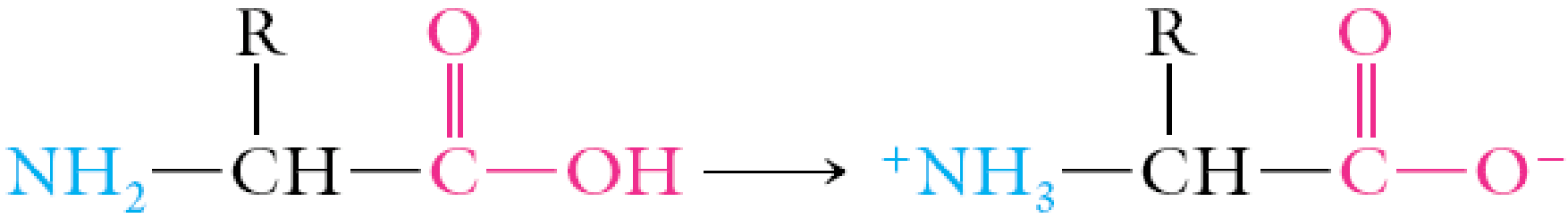


Histidine (His)

Charges on Amino Acids

α-Amino Acids May Exist in a Zwitterionic Form

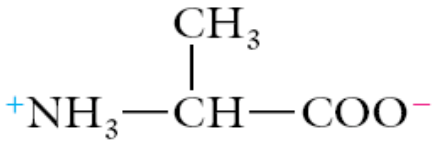
The actual structure of a neutral amino acid in neutral solution and in the solid is a charged molecule, containing a $-COO^-$ group and an $-NH_3^+$ group, called a zwitterion. The net charge on the molecule is zero.



Uncharged
(Nonexistent)

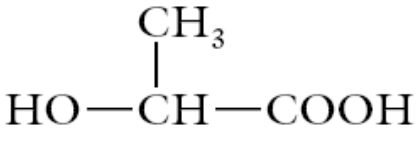
Zwitterion
(Exists in both solid and solution)

The presence of the charged groups in the zwitterion result in very strong secondary forces between the positive and negative charges:



L-Alanine

MP = 314°C



L-Lactic acid

MP = 53°C

Amino Acids in Solution

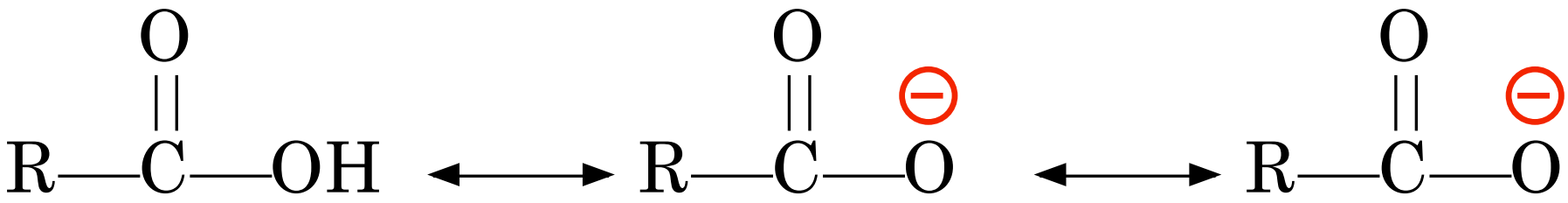
1) Amino acids are also soluble in water due to the strong secondary forces between the zwitterionic charge centers of the amino acids and the dipolar water molecules.

2) Free amino acids exist exclusively in the zwitterionic form in the solid state.

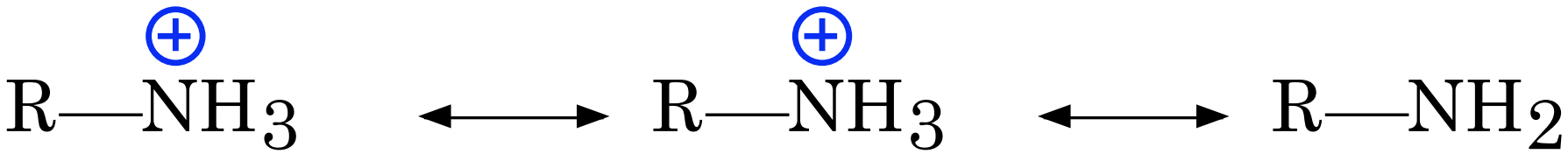
3) In solution, amino acids assume a charged form based on the pH of the solution.

Amino Acids in Solution

How do carboxylic acids and amines behave in acidic, neutral, and basic solutions ?

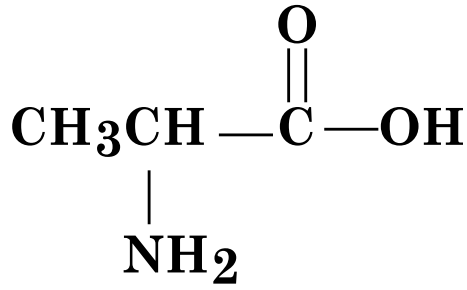


pH =1 pH = 7 pH = 12

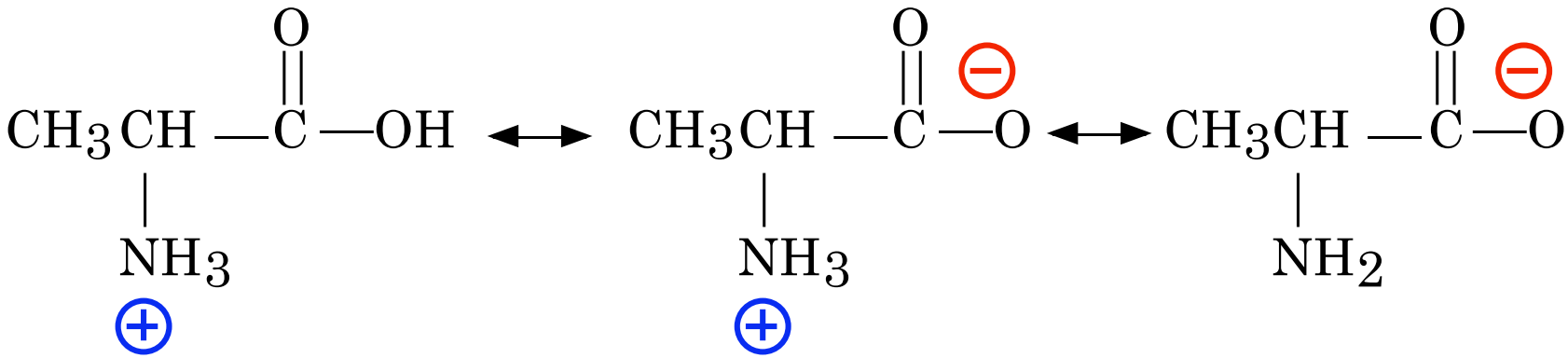


The behavior of the carboxylic acid and amine functional groups DOES NOT CHANGE when they are in the same molecule.

Amino Acids in Solution



How does the amino acid **alanine** behave in acidic, basic, and neutral solutions ?



pH =1 pH = 7 pH = 12

At low pH, the functional groups have accepted all of the protons possible, and at high pH, the functional groups have donated all of the protons possible.

Amino Acids in Solution

1) Each amino acid has a pH at which almost all of the molecules are present in a neutral form (0 net charge), called the **isoelectric point**.

2) At a **pH below that of the isoelectric point**, the cation concentration increases (**net positive charge**).

3) At a **pH above that of the isoelectric point**, the anion concentration increases (**net negative charge**).

4) **Most neutral amino acids have isoelectric points in the range 5 - 6.**

5) "Neutral" amino acids include 15 of the 20 common amino acids.

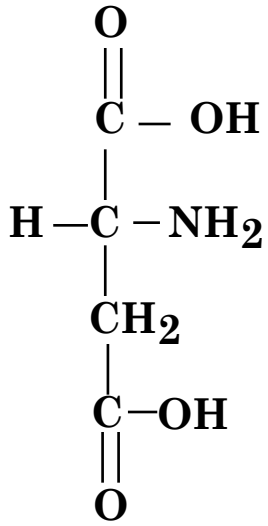
Amino Acids in Solution

Compounds with the ability to both release protons (acids) and absorb protons (bases) are called **amphoteric compounds*.**

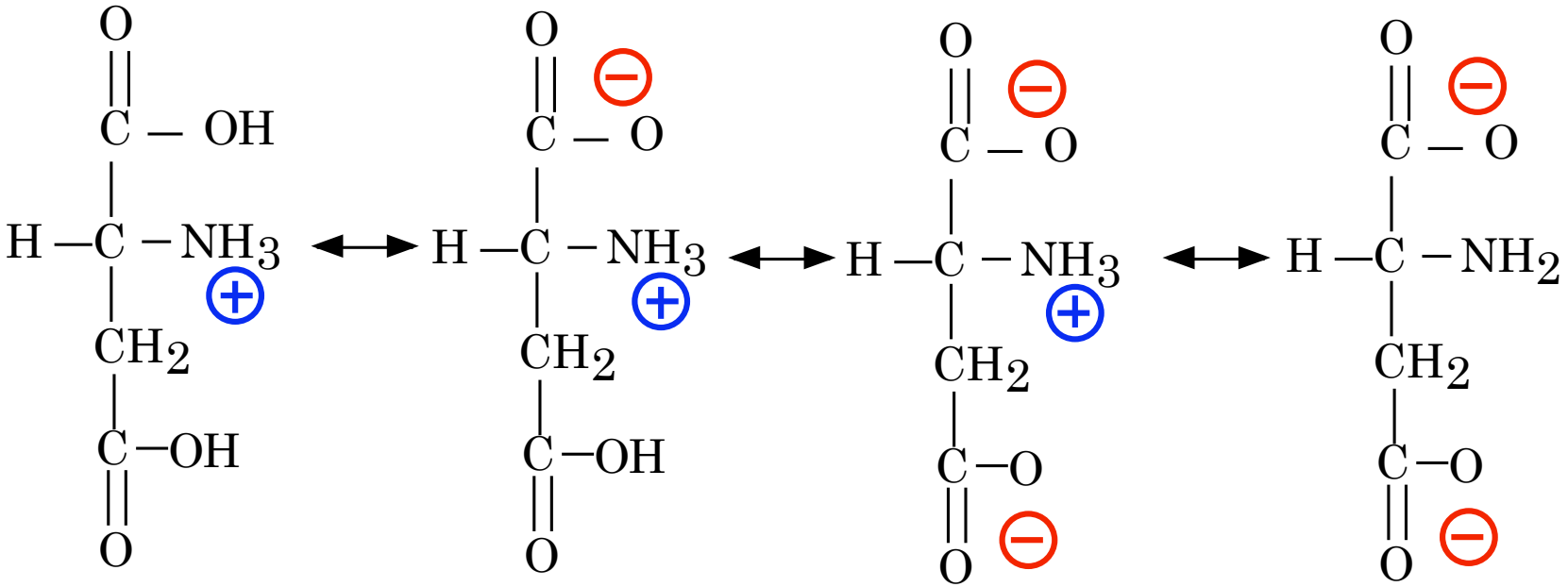
Amino acids are least soluble in their zwitterionic form, although even this form is fairly soluble.

***Is there a common chemical application for such compounds??**

Amino Acids in Solution

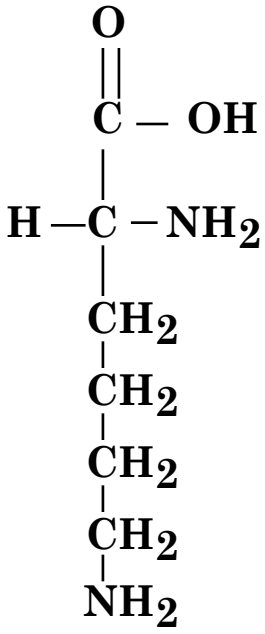


How does the amino acid **aspartic acid** behave ?

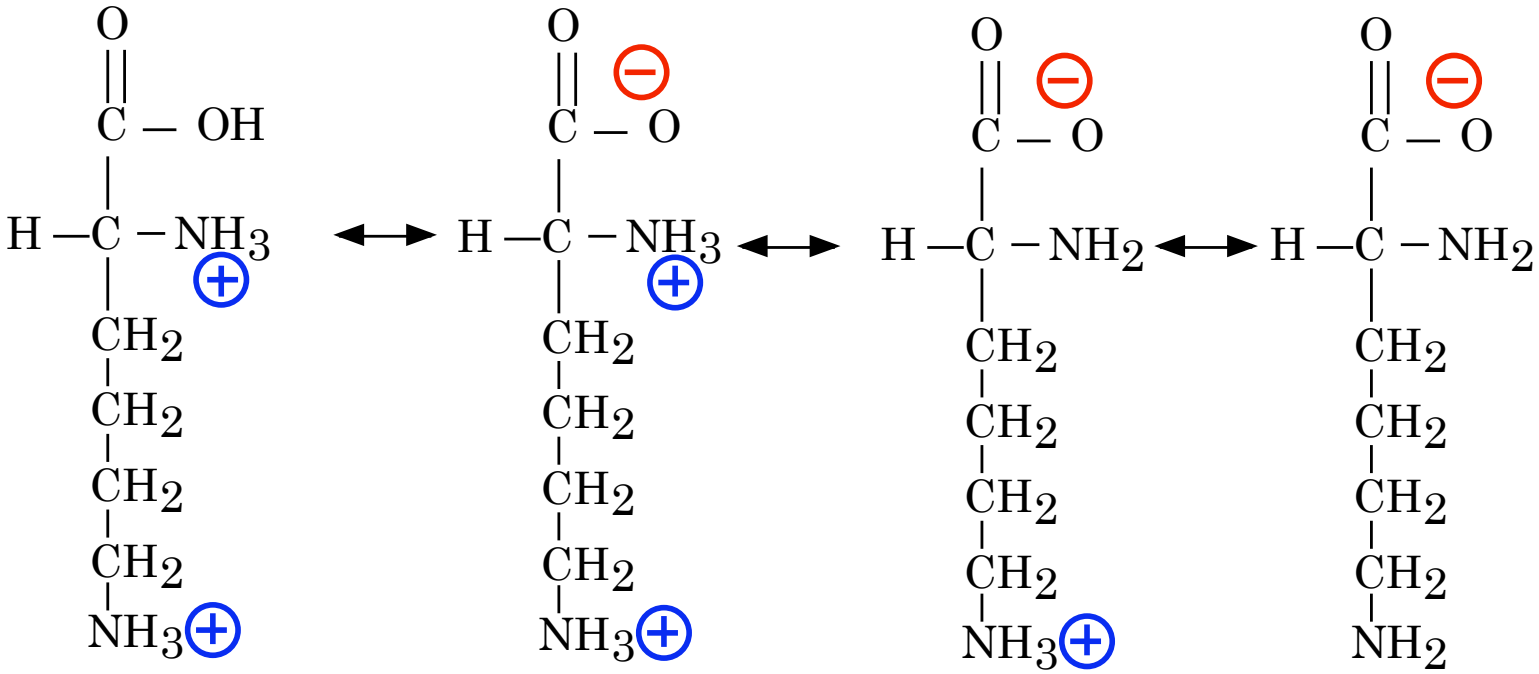


pH =1 pH = 3 pH = 7 pH 12

Amino Acids in Solution



How does the amino acid **lysine** acid behave ?



pH =1 pH = 7 pH = 10 pH 12

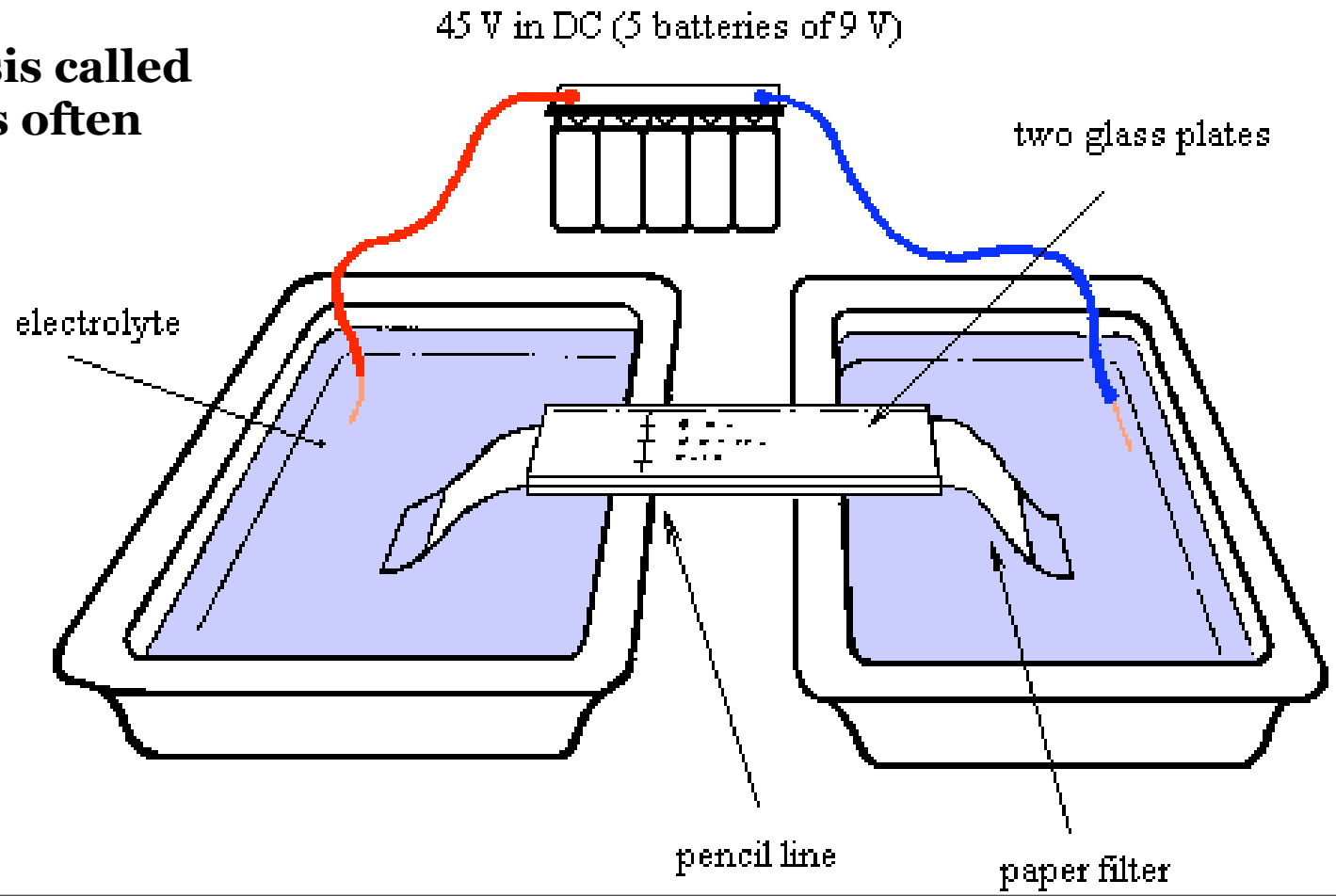
Electrophoresis of Amino Acids

Electrophoresis can be used to analyze mixtures of α-amino acids.

In this procedure, a strong electric field causes anions (acidic amino acids) to move towards the anode (positive electrode) and cations (basic amino acids) to move towards the cathode (negative electrode).

Amino acids whose isoelectric pH is close to the pH of the solution remain stationary in the electric field.

A form of electrophoresis called paper electrophoresis is often used for this analysis:



Electrophoresis of Amino Acids