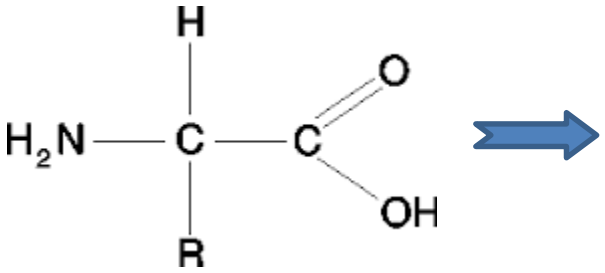
AMINO ACIDS-PROTEINS

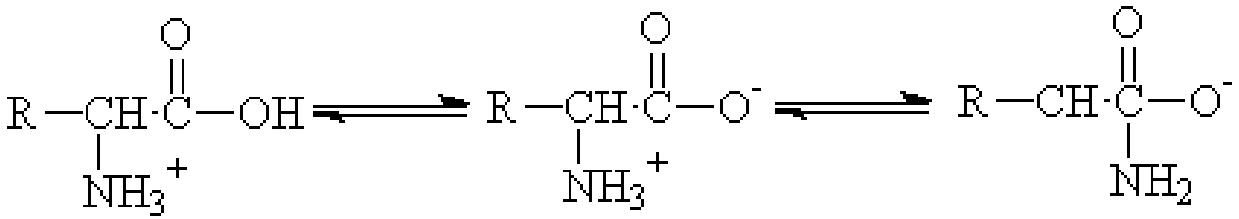
Food Chemistry

Food Chemistry: Amino Acids

Basic Formula



✓ Basic formula for proteins



low pH

At low pH values they behave as cations

neutral pH

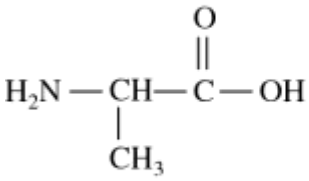
At neutral pH they form a dipole

high pH

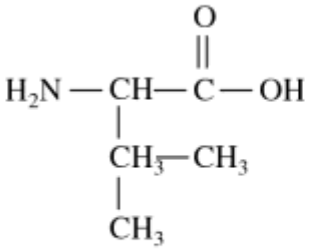
At high pH values they behave as anions

Amino acid classification

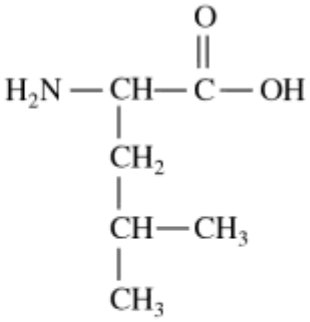
a) Amino acids with non-polar R amino group



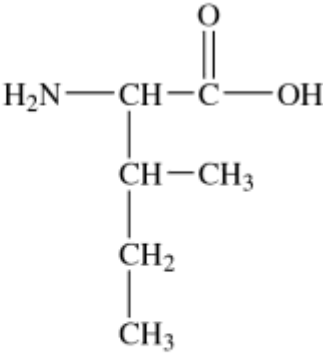
Alanine



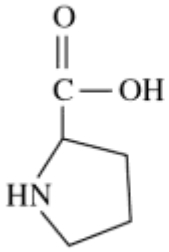
Valine



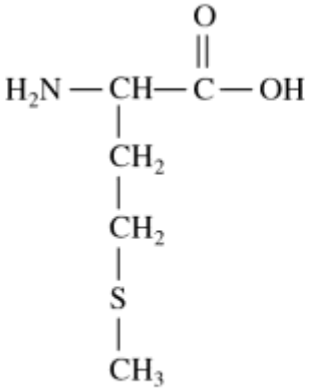
Leucine



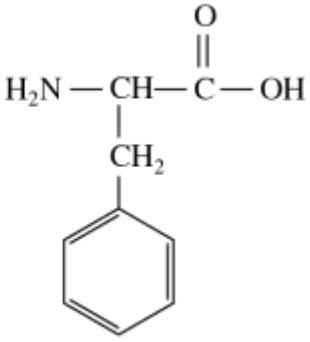
Isoleucine



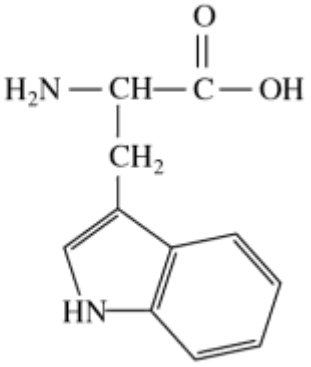
Proline



Methionine



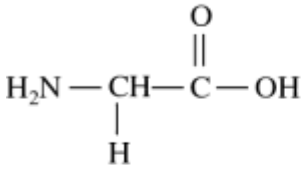
Phenylalanine



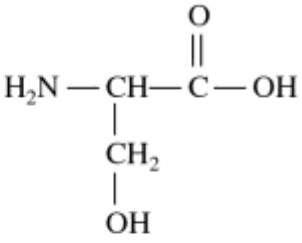
Tryptophan

Amino acid classification

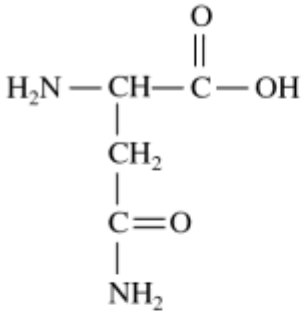
b) Amino acids with polar R amino group



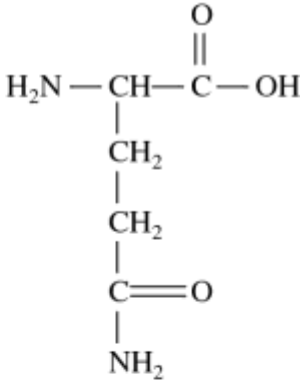
Glycine



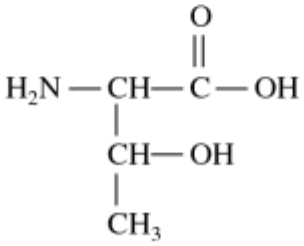
Serine



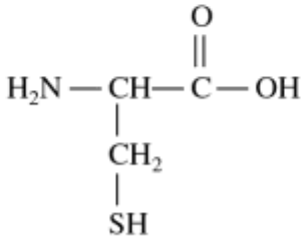
Asparagine



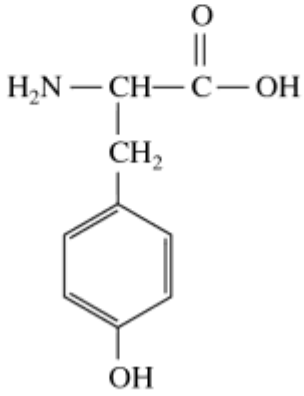
Glutamine



Threonine



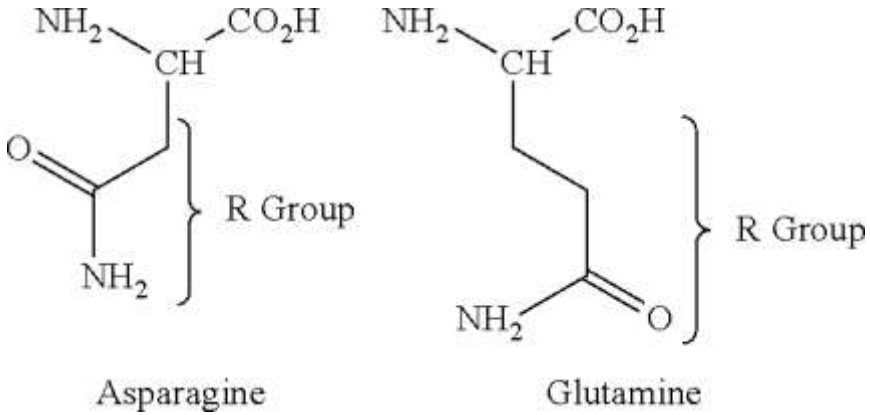
Cysteine



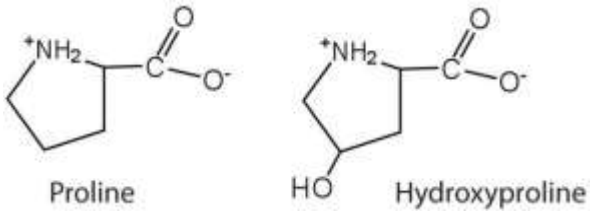
Tyrosine

Amino acid classification

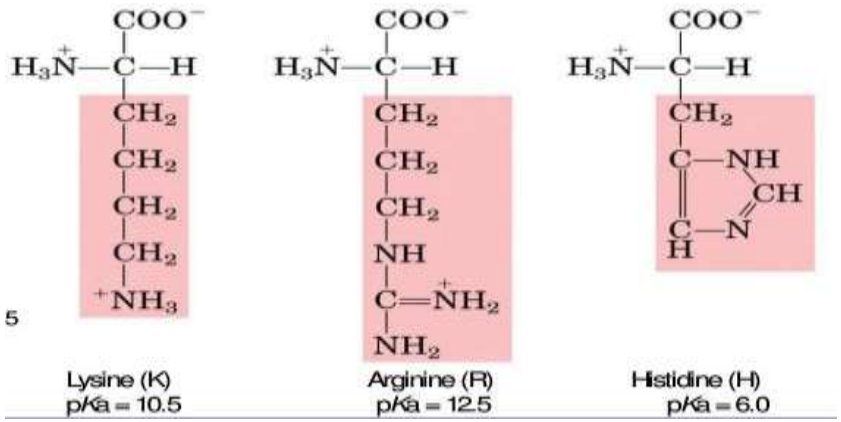
c) Amino acids with negatively charged R groups



e) Iminacids



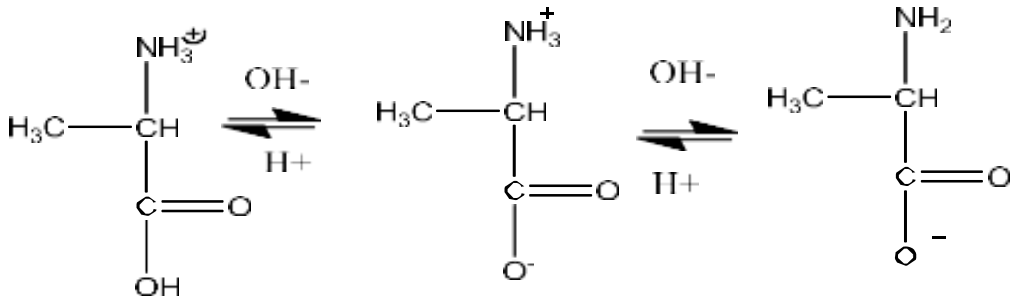
d) Amino acids with positively charged groups

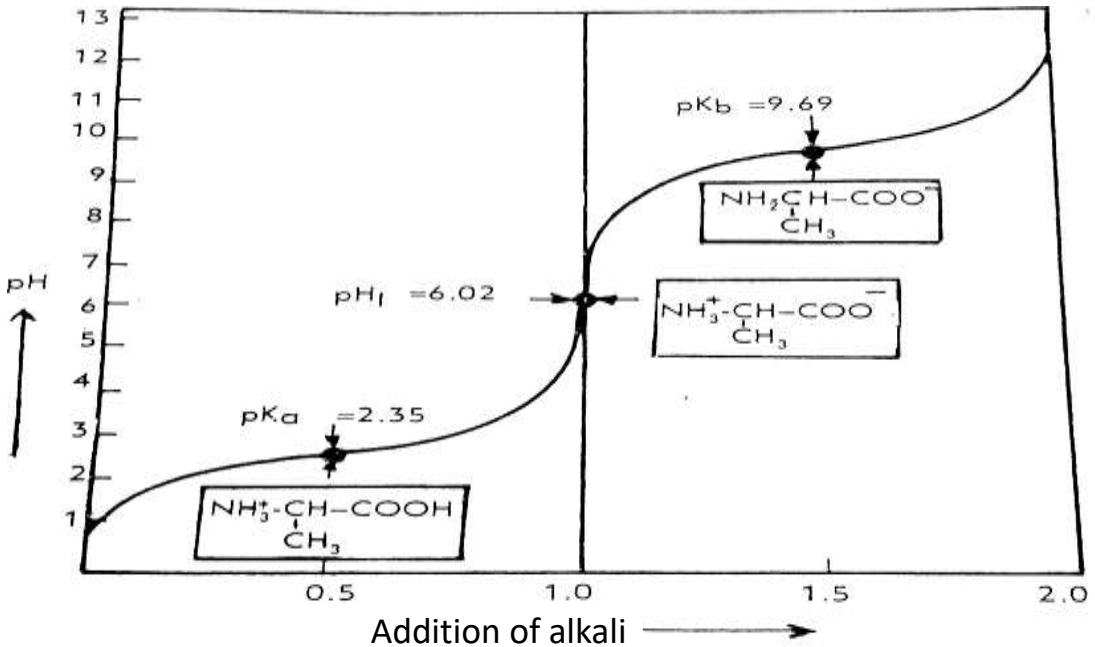


Food Chemistry: Amino Acids

Alanine, depending on the pH, will be ionized as follows:

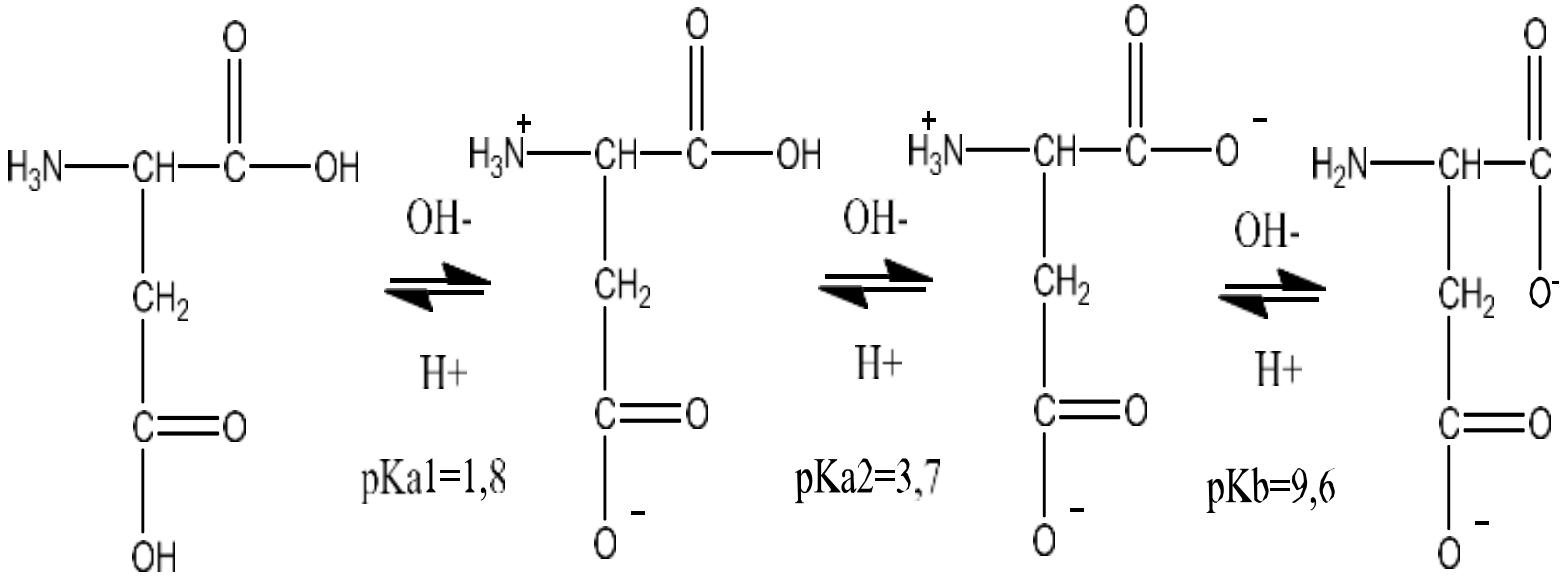
$$pI = \frac{pKa + pKb}{2}$$



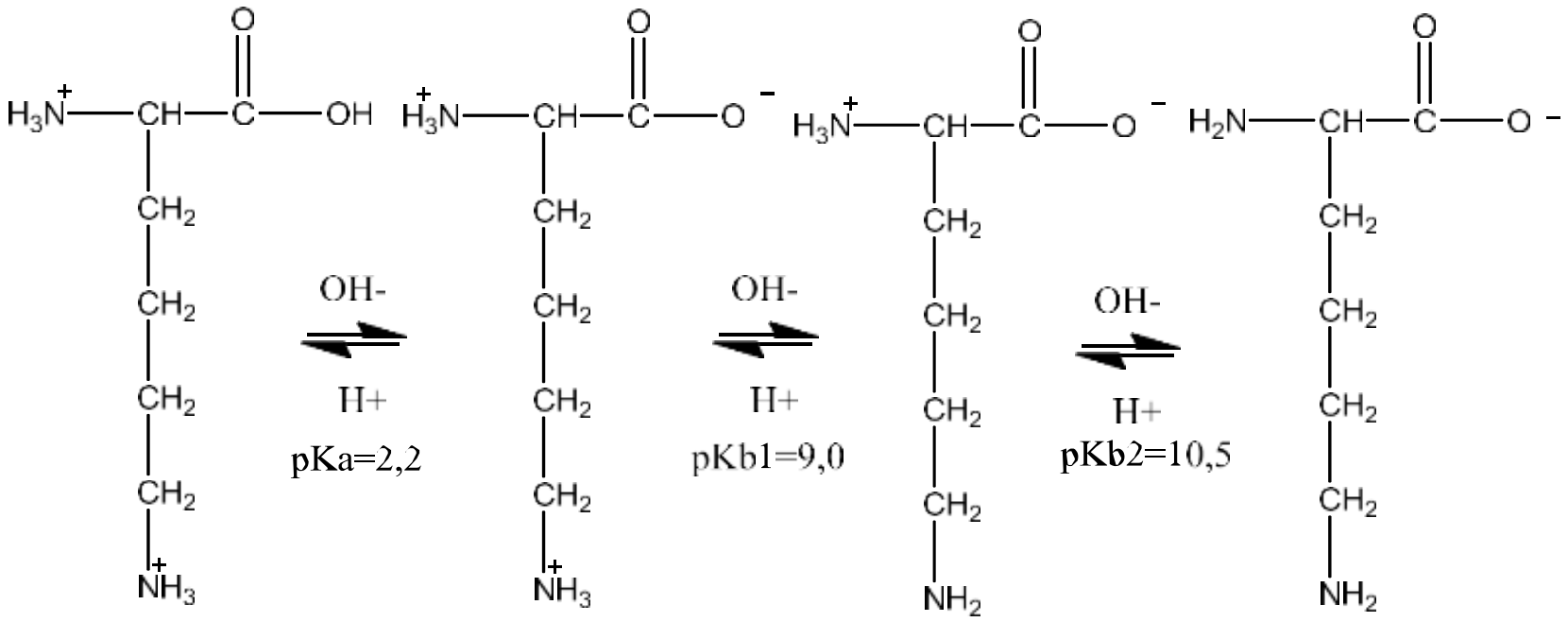


Alanine titration curve

Aspartic acid equilibrium reaction (acidic amino acid)



Lysine equilibrium reaction (basic amino acid)

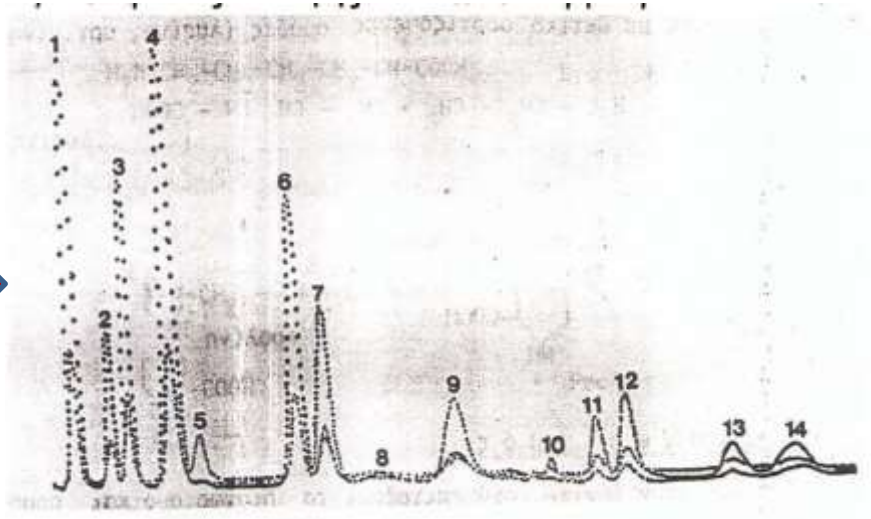


Total Charge: +2 +1 0 -1

pI=10,5

Food Chemistry: Amino Acids

HPLC is used for amino acid analysis



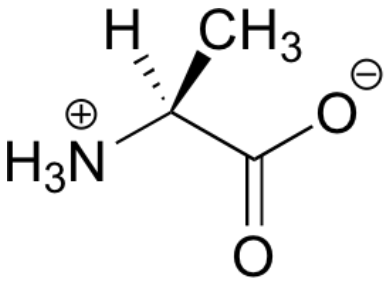
1. Asparaginic acid
2. Threonine
3. Serine
4. Glutamic acid
5. Proline
6. Glycine
7. Alanine
8. Cysteine
9. Valine
10. Methionine
11. Isoleucine
12. Leucine
13. Tyrosine
14. Phenylalanine

Food Chemistry: Amino Acids

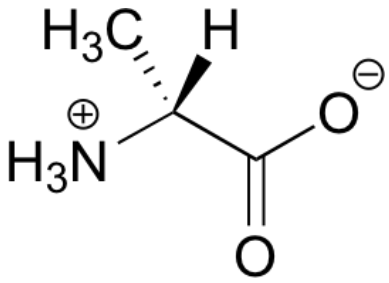
Physical properties of amino acids

- ✓ High solubility
- ✓ High melting point
- ✓ High dipole torque values
- ✓ They are buffer solutions

Amino acid stereochemistry



L-alanine

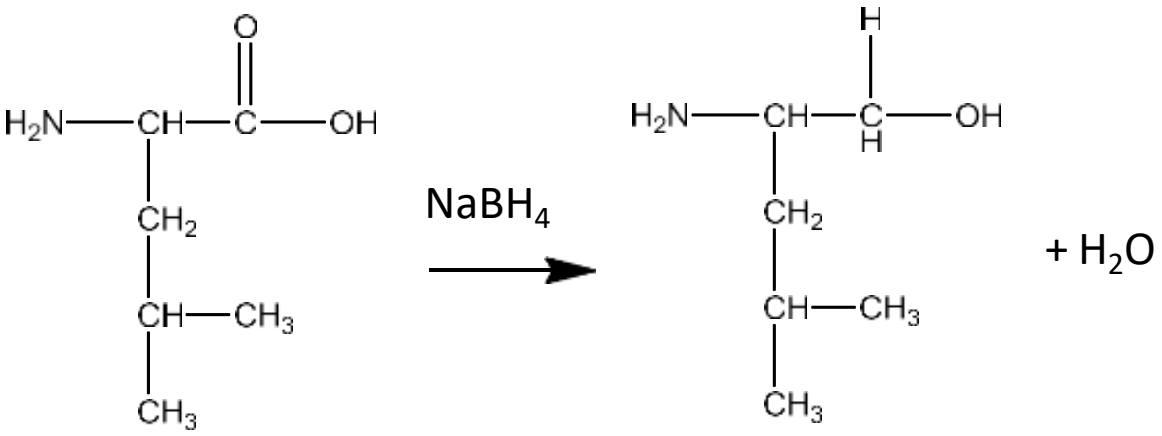


D-alanine

They are pH dependent

Chemical properties of amino acids
Reactions of the carboxyl group

Reduction

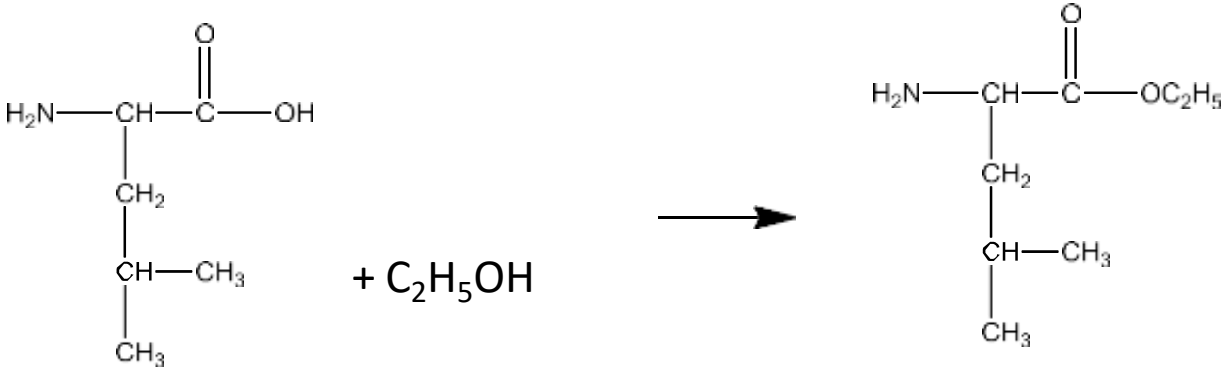


Reduction to an alcohol serves to identify a terminal group on a peptide

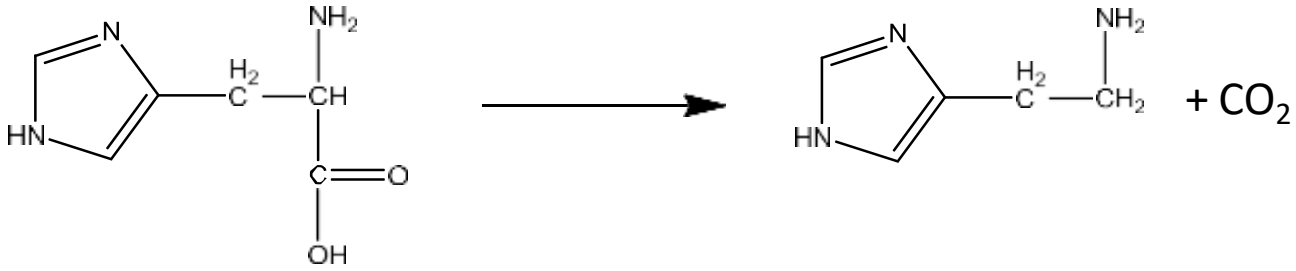
Food Chemistry: Amino Acids

Chemical properties of amino acids
Reactions of the carboxyl group

Esterification



Decarboxylation

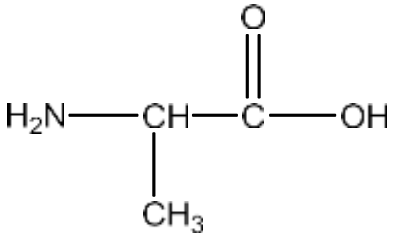


The decarboxylation of histidine gives histamine which is a powerful vasospastic agent, irritates muscles and stimulates the flow of gastric juice

Food Chemistry: Amino Acids

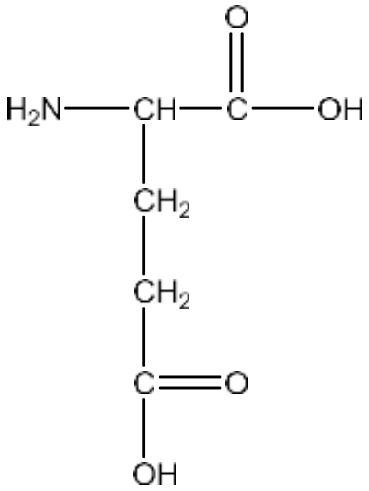
Chemical properties of amino acids
Reactions of the carboxyl group

Oxidation



$+NaOCl + H_2O \longrightarrow CH_3CHO + NH_3 + NaCl + CO_2$

Reaction with bases

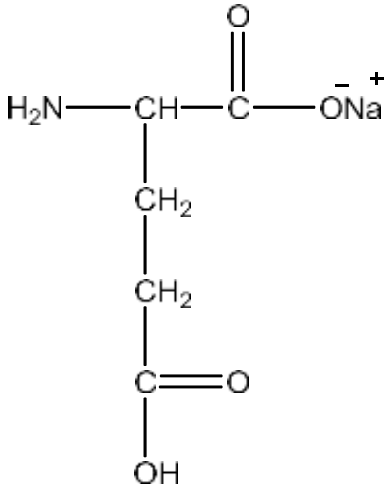


Glutamic acid

$+NaOH$

$\longrightarrow$

$- H_2O$



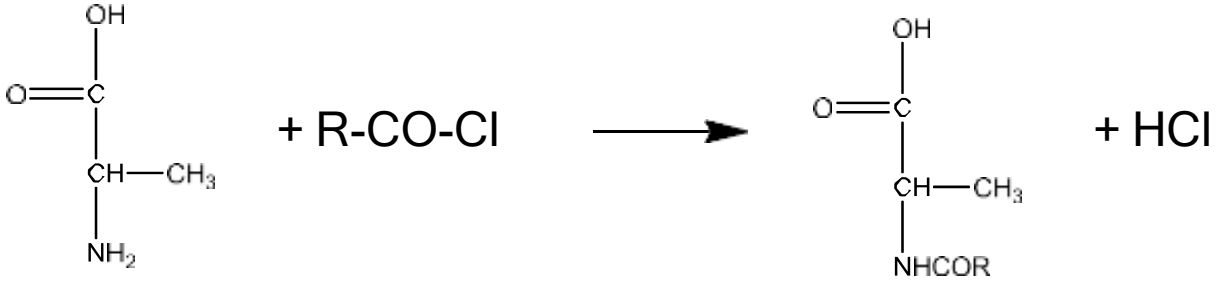
Glutamic acid monosodium

Flavour enhancer

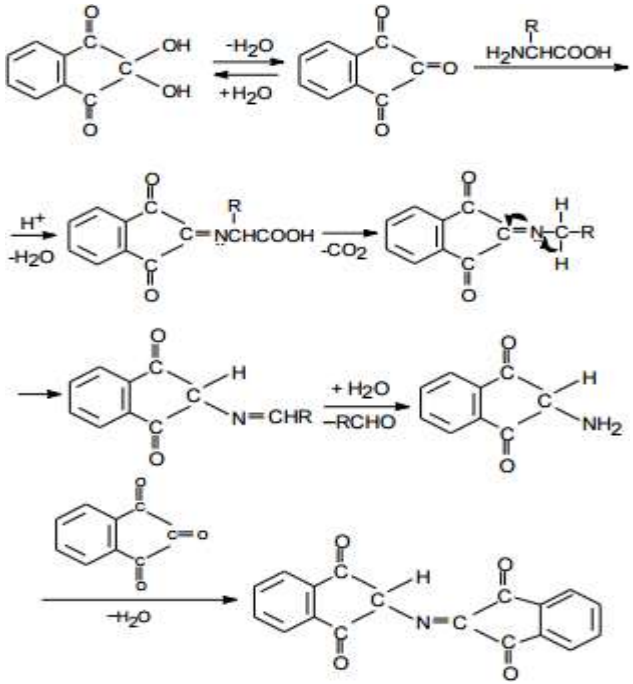
Food Chemistry: Amino Acids

Chemical properties of amino acids
Reactions of the amino group

Acylation



Ninhydrin reaction

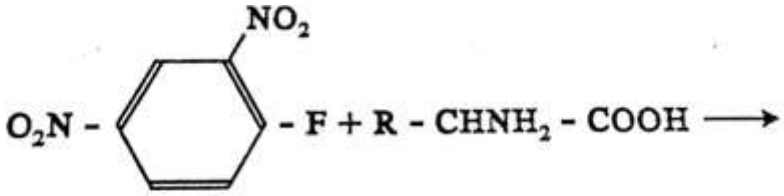


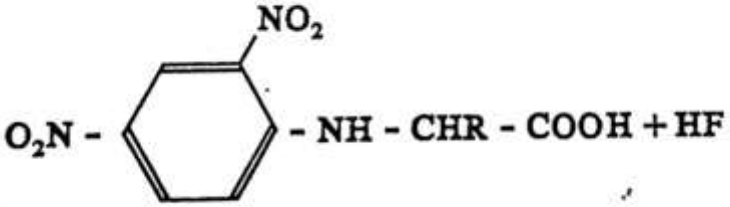
Used to detect and quantify amino acids

Food Chemistry: Amino Acids

Chemical properties of amino acids
Reactions of the amino group

Alkylation





Identification of N- terminal amino acids in peptides

Reaction with HNO_2

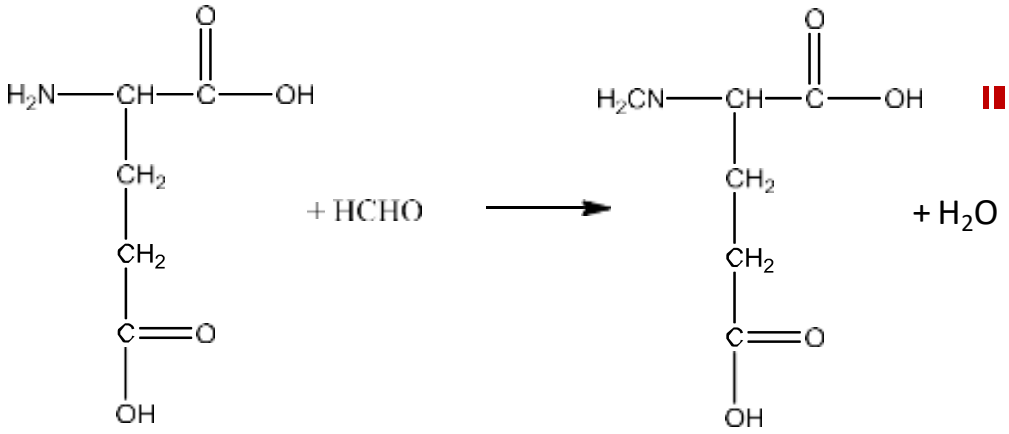
$$R\text{-}CHNH_2\text{-}COOH + HNO_2 \longrightarrow R\text{-}CHOH\text{-}COOH + N_2 + H_2O$$

Quantitative determination of amino acids

Food Chemistry: Amino Acids

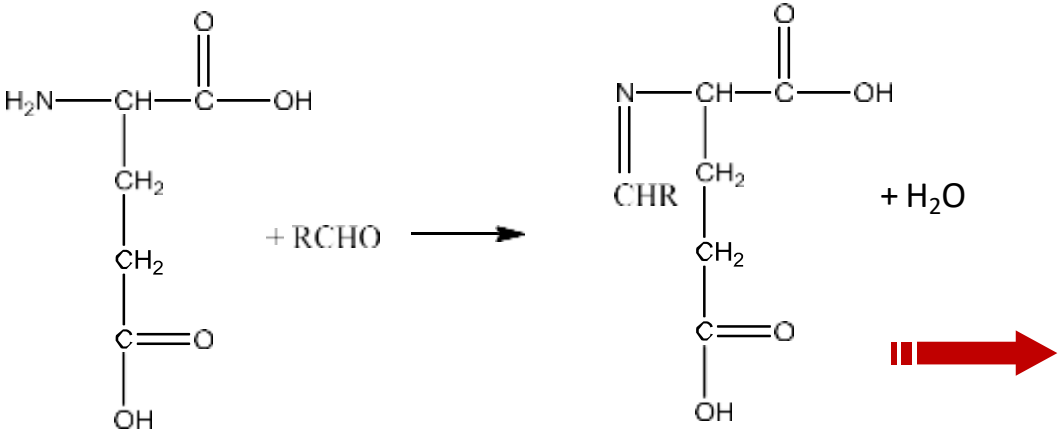
Chemical properties of amino acids
Reactions due to amino group

Formaldehyde reaction



Determining amino acids in solutions

Schiff Base Formation

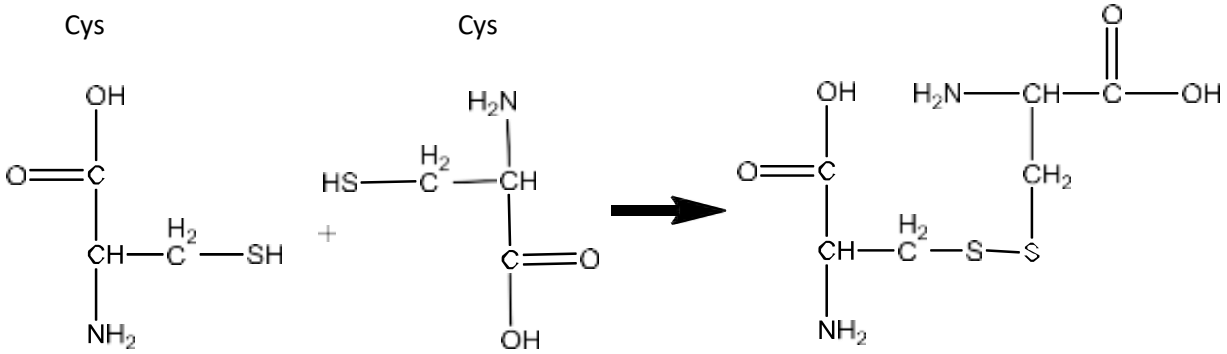


Non-enzymic food browning

Food Chemistry: Amino Acids

Chemical properties of amino acids
Reactions from other groups

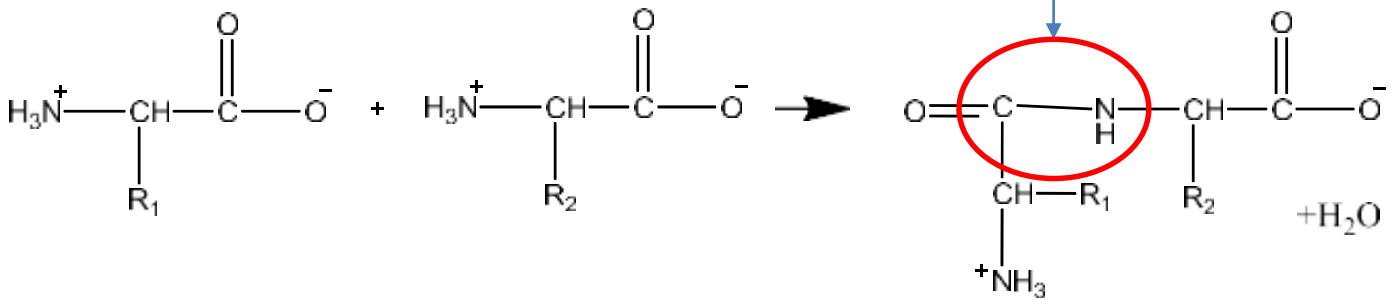
Sulfhydryl group



Improvement of flour baking ability

Food Chemistry: Proteins

Peptides: → Compounds consisting of amino acids joined together as amides (peptide bond)



Proteins: →

- Essential components of every living cell
- Linked to every physiological function

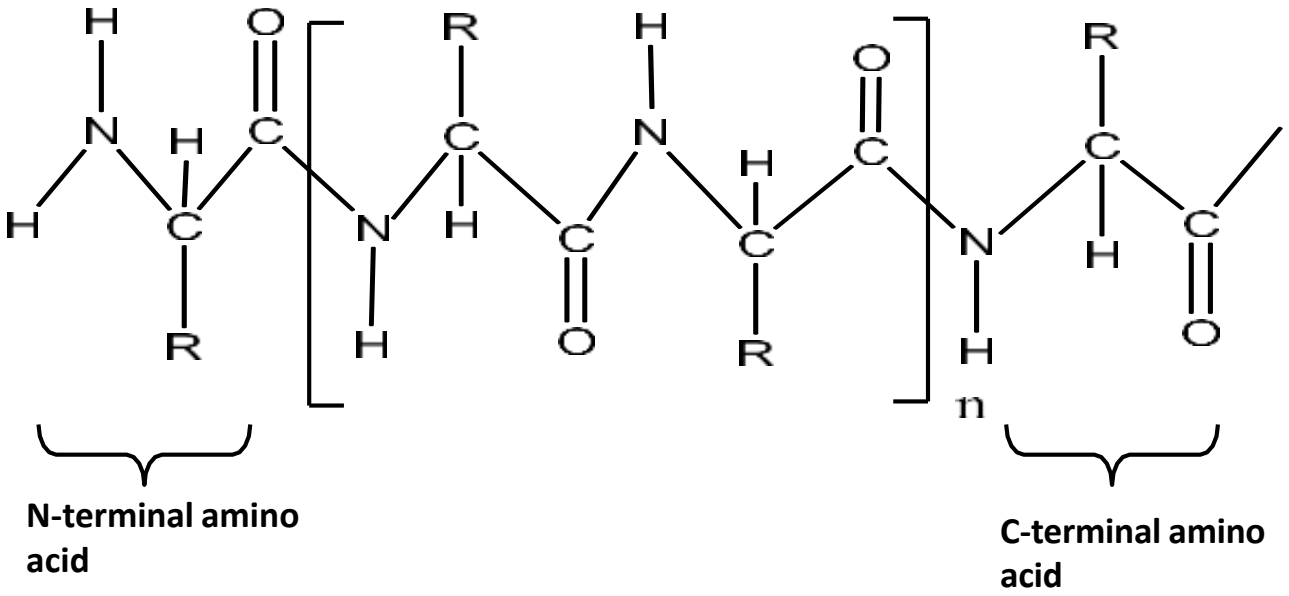
Contain
H ~ 7%
O_2 ~22%
N_2 ~16%
C ~50%
and less of
S, P, Zn,
Fe,
Cu

- Plants synthesize proteins from mineral sources
- Animals and humans depend on plants

Food Chemistry: Proteins

Proteins: → An infinite number of proteins can be synthesized by the 21 amino acids. There are 2000 proteins in our natural environment.

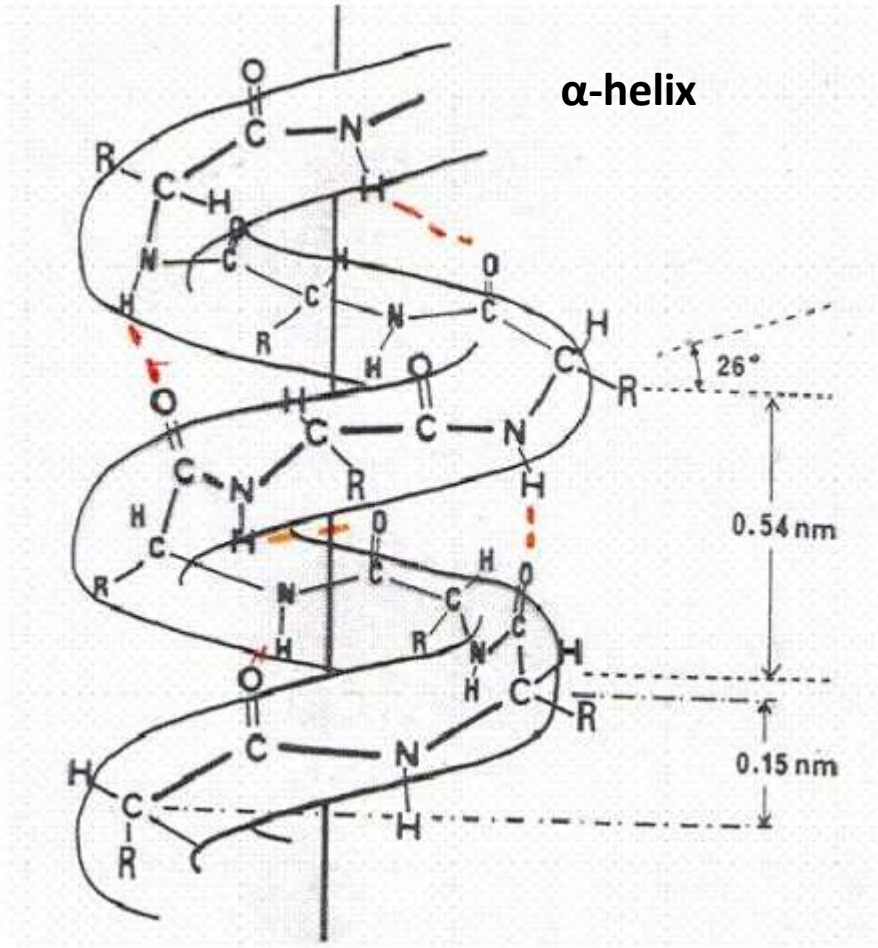
Primary structure:



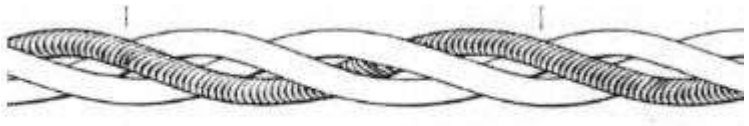
The linear sequence and number of amino acids that form the protein

Food Chemistry: Proteins

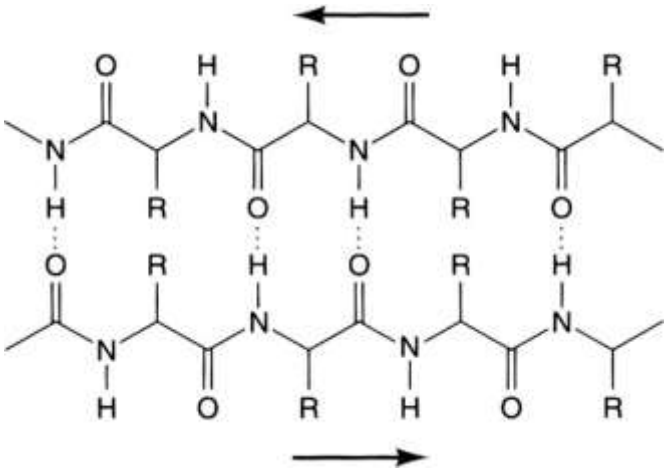
Secondary structure:



Three-dimensional axis layout

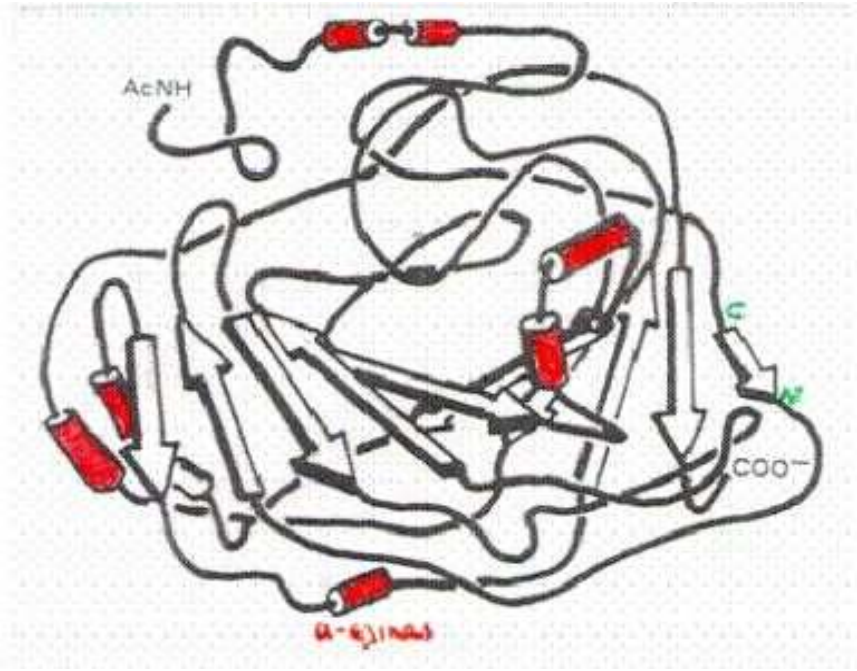


Triple helix of collagen



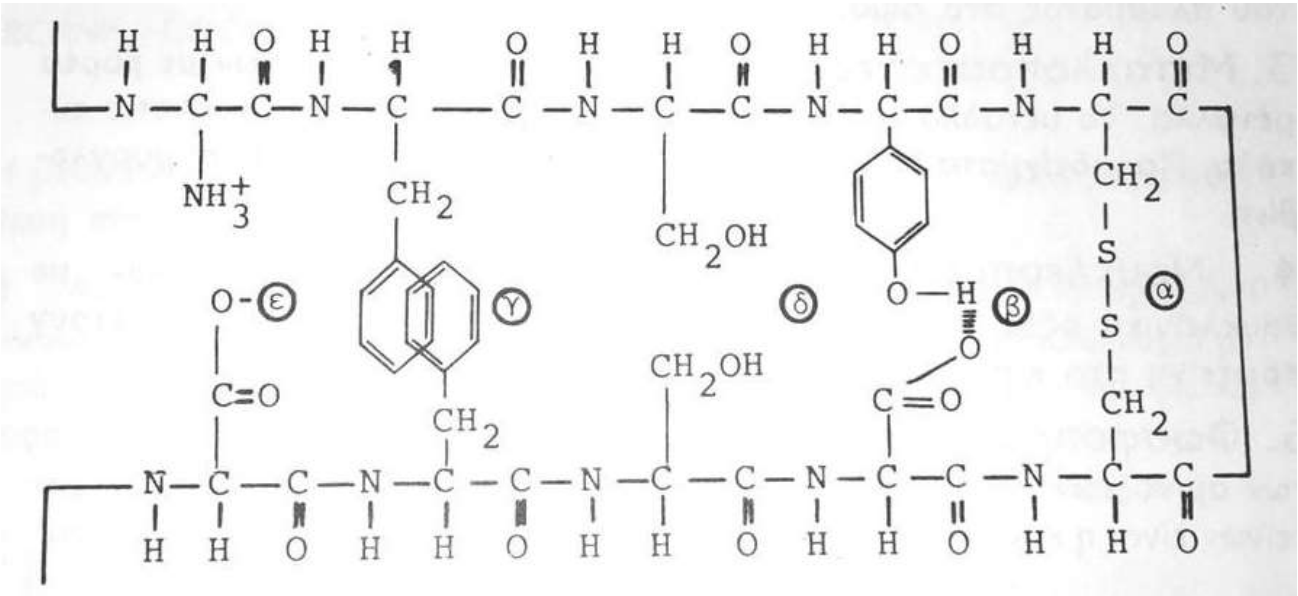
Pleated sheet structure

Tertiary structure:



Portraiture of the tertiary structure of a spherical protein. It is the folding of the helical or pleated chain in space so that it acquires a defined form. (The cylinders symbolize α-helix segments and the arrows pleated leaves.)

Tertiary structure:



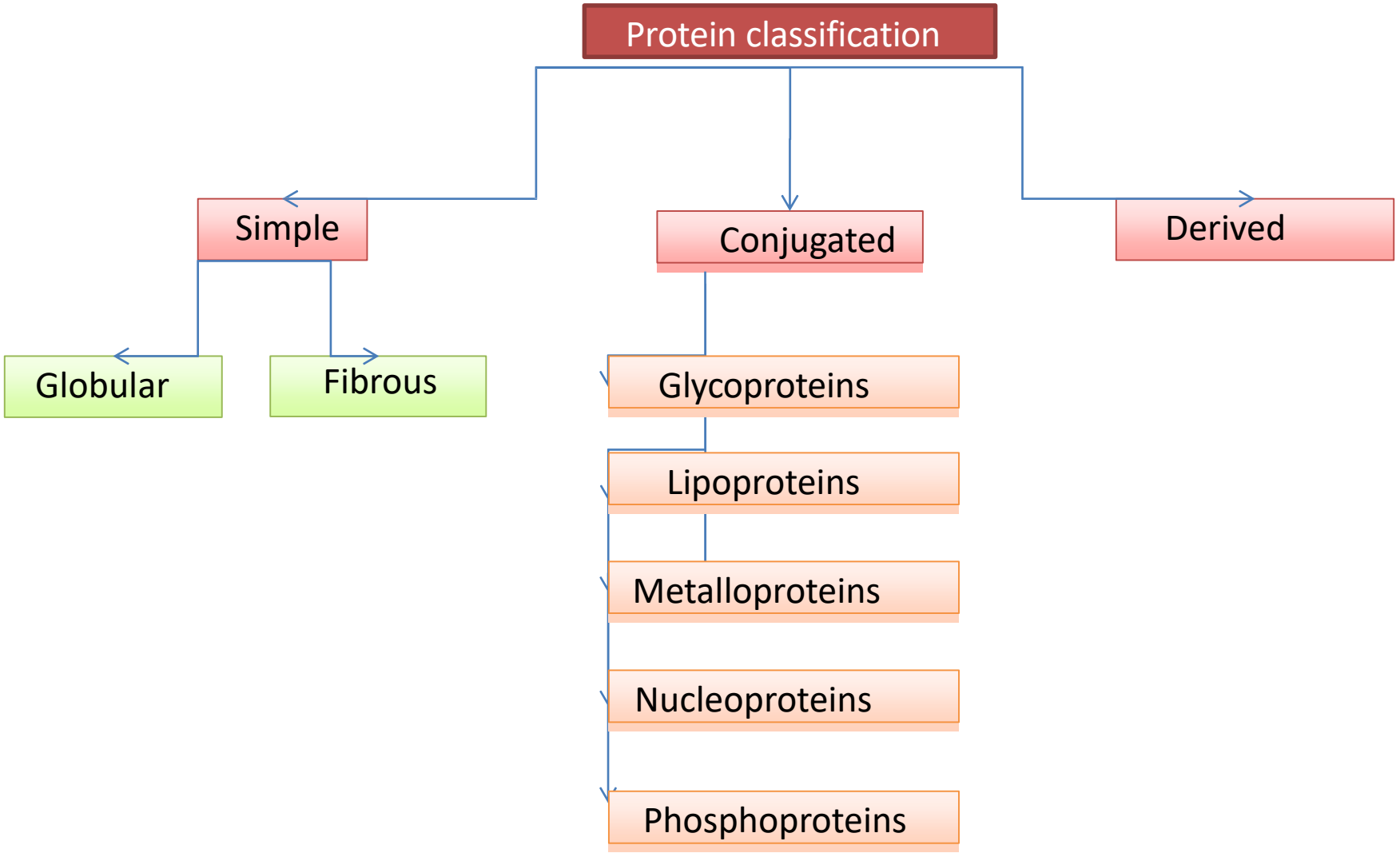
α= disulfide bond (covalent bond)
β= hydrogen bond
γ= hydrophobic interaction
δ= instantaneous dipole
ε= electrostatic attraction (ionic or electrovalent bond)

The quaternary structure of a protein is the association of several protein chains

Quaternary structure:

- The quaternary structure of a protein is the association of several protein chains or subunits into an arrangement.
- Hemoglobin is a heme-protein consisting of four peptide chains that are each bound to a heme molecule.
- Heme iron is found in the reduced bivalent form and remains bivalent during both oxygen binding and release.
- The adult hemoglobin consists of two α chains and two β chains, symbolised α2β2.

Food Chemistry: Proteins



Food Chemistry: Proteins

1. Simple proteins

With hydrolysis they form amino acids or their derivatives

1.a. Globular proteins

1.a.1) Globulins → Soluble in neutral salt solutions
e.g. serum globulin in blood serum, beta-galactoglobulin in milk, actin and myosin in meat

1.a.2) Albumins → Soluble in water and salt solutions
e.g. ovalbumin, and cereal leucosine

1.a.3) Glutelins → Soluble in dilute solutions of acids or bases,
Insoluble in neutral solutions
e.g. Wheat glutenin, rice oryzenin

1.a.4) Prolamines → Soluble in alcohol 0-80%, insoluble in water
e.g. maize zein, wheat gliadin, barley chordine

Food Chemistry: Proteins

1.b. Fibrous proteins

1.b.1. Collagen

It is located in the connective tissue. In mammals it consists 1/3 its proteins or 6% of the body weight. By boiling in the presence of acids or bases it is converted to a soluble protein, gelatin.

1.b.2. Elastin

It is found in the connective tissue of vertebrates.

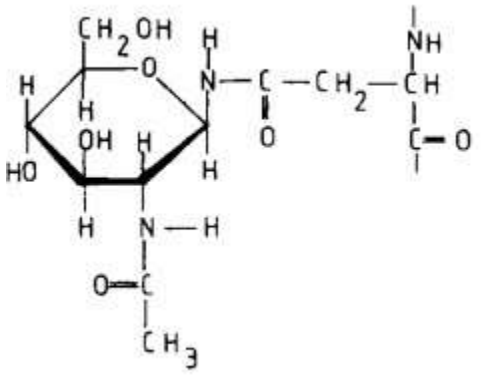
1.b.3. Keratin

Component of corneal tissues (hair, skin, horns, etc.)

2. Complex or Conjugated Proteins

2a.) Glycoproteins

With hydrolysis they form amino acids and carbohydrates



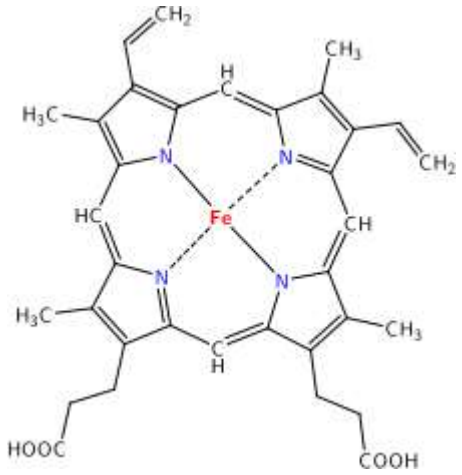
2b.) Lipoproteins

With hydrolysis they form amino acids and lipids [triglycerides, phospholipids (lecithin), cholesterol]

2. Complex or Conjugated Proteins

2c.) Metalloproteins

With hydrolysis they form amino acids and metals
(e.g. hemoglobin, ferritin)



2d.) Nucleoproteins

Protein and nucleic acid complexes

2. Complex or Conjugated Proteins

2d.) Phosphoproteins

With hydrolysis they form amino acids and phosphate compounds (e.g. milk casein)

3.Derived proteins

Proteins that form from protein modifications by chemical means or enzymes (e.g. denatured proteins, peptones, proteoses)

Food Chemistry: Proteins

Protein solubility

Effect:

1. pH, charge
2. Percentage of hydrophilic (polar) and hydrophobic (non-polar)
3. Neutral salts

Low concentration → Increase of protein solubility (salting in → solvation)

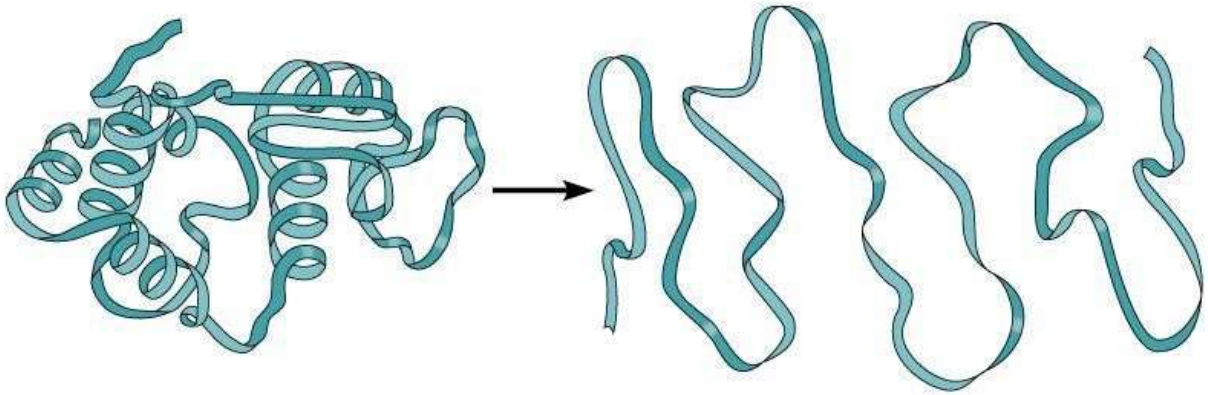
High concentration → Reduction of solubility (salting out)

4. Organic solvents (acetone, ethanol)
5. Temperature. Increase from 0-40 ◦C

Food Chemistry: Proteins

Protein Denaturation

Change of protein structure **without** change in the primary structure (unfolding) with gentle means



Natural Protein

Denatured Protein

Natural Factors

- ✓ Temperature
- ✓ Moisture
- ✓ Type of ions
- ✓ High Pressure
- ✓ Radiation
- ✓ Foaming

Chemical Factors

- ✓ pH
- ✓ Concentration
- ✓ Synthetic detergents
- ✓ Organic solvents

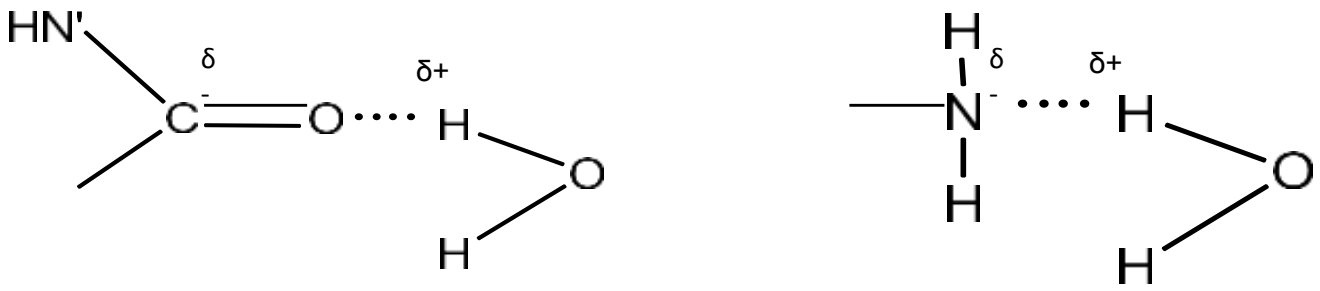
Protein Denaturation

Consequences of denaturing:

1. Reduction of solubility (due to exposure of hydrophobic groups)
2. Change in H_2O sorption capacity
3. Loss of biological activity (enzymatic or immunological).
4. Increased vulnerability to proteolytic enzymes.
5. Increased viscosity.
6. Loss of crystallization ability.

Protein Hydration

Binding water to proteins and thus hydrating them through hydrogen bonds



Protein hydration through hydrogen bonding with water

The percentage of hydration depends on:

Protein concentration

Ionized forms of proteins (not in the neutral point) favor hydration

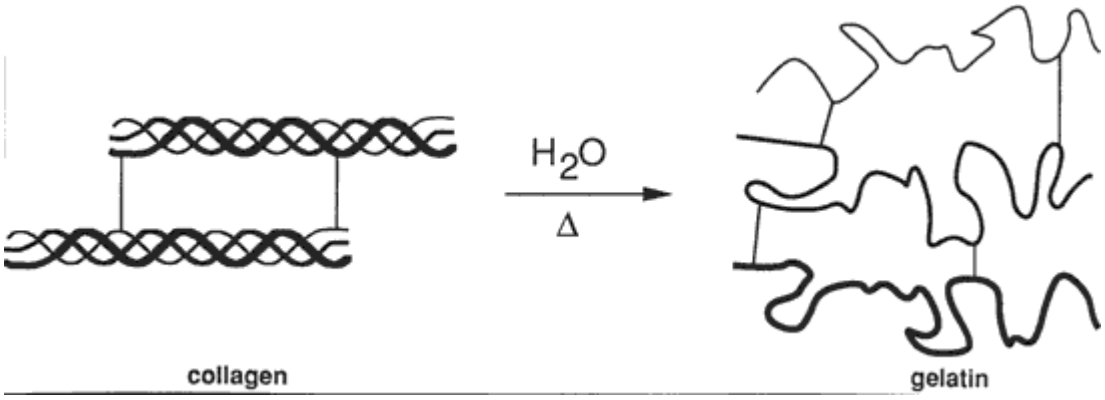
1. In presence of other water-binding compounds e.g. sugars
2. Temperature etc.

Food Chemistry: Proteins

Protein Hydration

Gelatinization

Proteins and carbohydrates form (gels): Colloidal solutions where large volumes water bound by a small amount of solid



Collagen by heating and adding water forms gelatin

Food Chemistry: Proteins

Foam formation and stabilization

Proteins act as components of foam formation and stabilization in delicacies, sweets, desserts and beer

This varies from protein to protein. Foam is gas dispersion in liquid. By beating the egg white, air bubbles bind and proteins adhere to them through its hydrophobic regions, causing denaturation of the protein. The unfolded protein molecules are intertwined with each other, thus contributing to the stability of the foam. Egg white globulin is suitable for foaming.

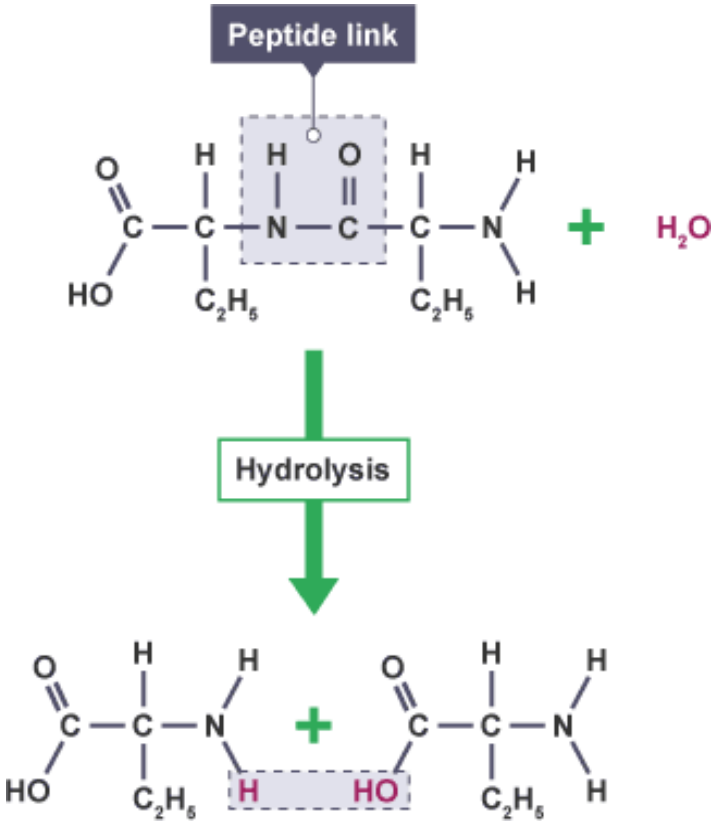
Foam destruction

Lipids:
prevent protein fusion in order to form a foam stabilization film

Organic solvents:
e.g. Higher alcohols: due to hydrophobicity
They displace proteins from the surface of air bubbles without being able to form stable films

Food Chemistry: Proteins

Protein hydrolysis



Made with acids, bases, enzymes

Essential for the study of amino acid composition

Food Chemistry: Proteins

Functions of proteins in food

1. **Water retention ability** (taste and tenderness of meat)

2. **Emulsifying ability** (egg yolk (lipoproteins) for mayonnaise, dressings, etc.)

3. **Milk coagulation** (casein thrombosis → production of yoghurt and cheese)

4. **Foaming ability** (e.g. egg white)

5. **Gelatinisation** (e.g. meat collagen converted to gelatin in boiling water when making soups)

6. **Baking ability** (hydrated gluten in preparation bread)

Effect of various processes on structural and thermal properties of proteins

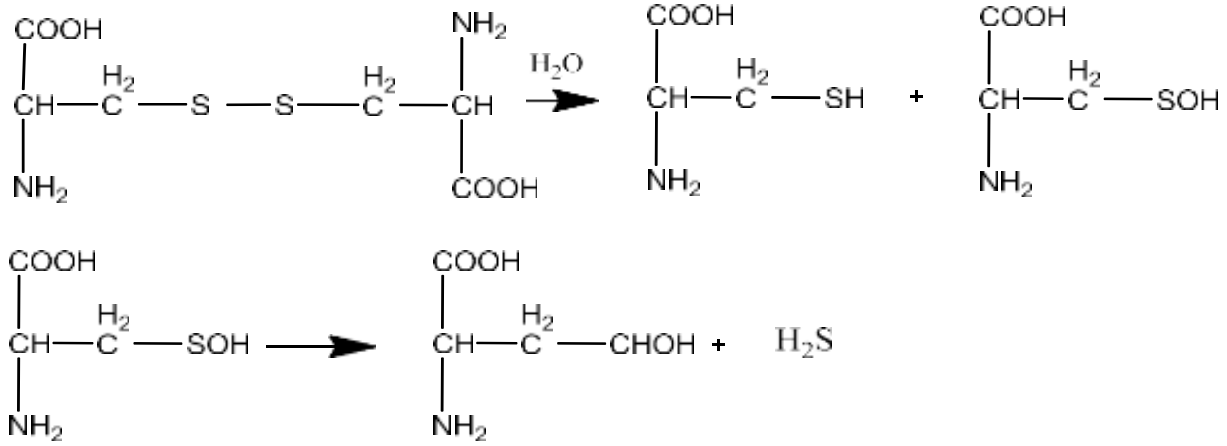
Medium heating

- **Greater bioavailability** of amino acids due to protein denaturation and further easier enzymatic hydrolysis
- **Deactivation of factors**: Deactivation of the enzyme thiaminase prevents the destruction of thiamine (vitamin B1, neurological disease Beriberi. Denaturation of avidin (egg protein) prevents the denaturation of the vitamin biotin of the B complex.

Increased intense heat processing → Opposite results → Reduction of nutritional value of proteins due to undesirable changes

Non-enzymatic browning or Maillard reaction: Reduction of biological value of proteins by heating, Loss of part of amino acids.

Protein heating in the absence of air: Heat process → May cause losses in the non-essential amino acid cystine



Effect of various processes on structural and thermal properties of proteins

2. Refrigeration-freezing

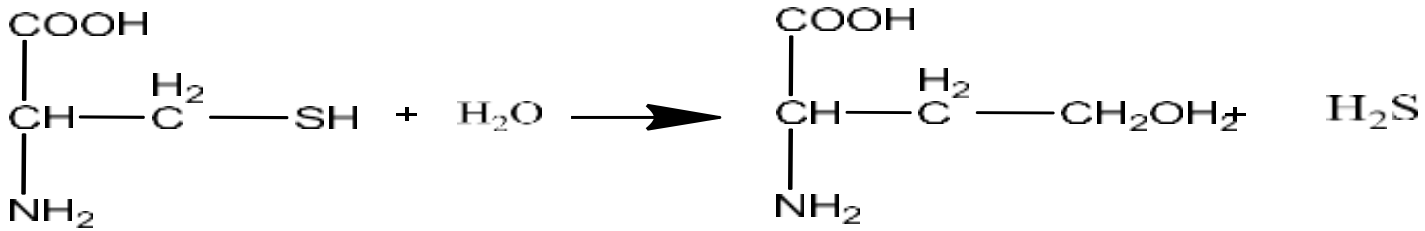
Freezing affects the organoleptic characteristics (texture) of proteins rather than the nutritional value

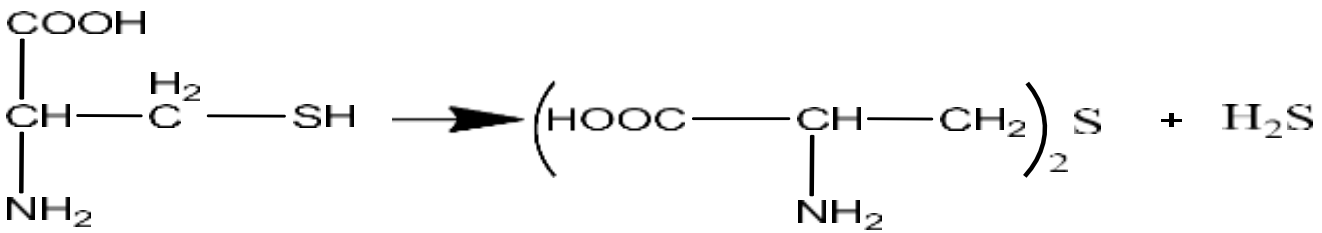
3. Dehydration

- ✓ Freeze drying
- ✓ Spray drying

4.Pasteurization

72◦C for 15sec for milk





Styles of exam questions on lipids – proteins – water

1. What is called **autoxidation** of fatty substances? What factors cause it? How is it developing? Describe and provide chemical reactions.
2. Relation of **water activity (a_w)** of a food and its stability against from a microbial, enzymatic, and chemical point of view.
3. Is **hydrogenation** or **transesterification** preferable from a nutritional point of view for making margarine? Explain and provide chemical reactions.
4. Give the general **formula** of amino acids, their structures in acidic, neutral and alkaline environments as well as the amino acid titration curve by an alkaline and explain it.
5. What are **essential** amino acids? How are amino acids linked to give peptides? Write the **structure** of a tripeptide.
6. Explain the formation and retention of beer **foam** when transferred to the glass.
7. If autoxidation has started in a fatty substance, does the addition of antioxidants (BHA, BHT) inhibit it? Can a fatty substance with $\alpha_w<0.2$ be oxidized? Explain.