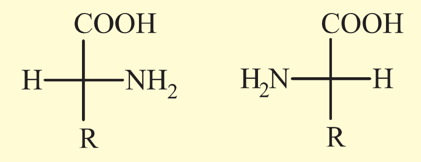
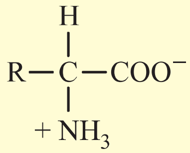
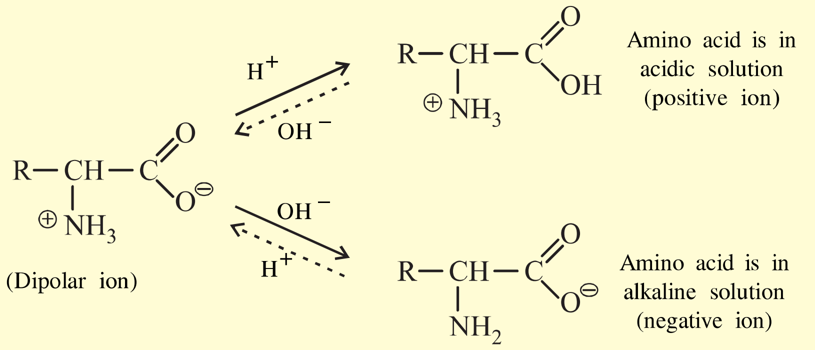

D-amino acid L-amino acid

D- and L- forms of amino acids : According to table 7.1 we can say that in all amino acids α-carbon is chiral carbon except glycine. Therefore D and L forms of all these amino acids can exist. The Fischer projection of amino acid with the –COOH group on the top and –R group at the bottom of the vertical axis is a **D-amino acid** if the $-NH_2$ group is on the right of the horizontal axis and is an **L-amino acid** if $-NH_2$ is on the left. Most of the amino acids found in nature have L-configuration.


Amino acid as dipolar molecule

Amino acid as dipolar molecule : We know that amino acids contain both the acidic group (–COOH) and basic group ($-NH_2$). In dry solid form, the amino acid exists as dipolar molecule in which carboxyl group is present as carboxylate ion (COO^-) and amino group is present as aminium ion ($\overset{+}{N}H_3$). This dipolar ion is also known as **zwitter ions.**

In acidic solution, dipolar ion of amino acid exists as a positive ion while in alkaline solution it exists as a negative ion.

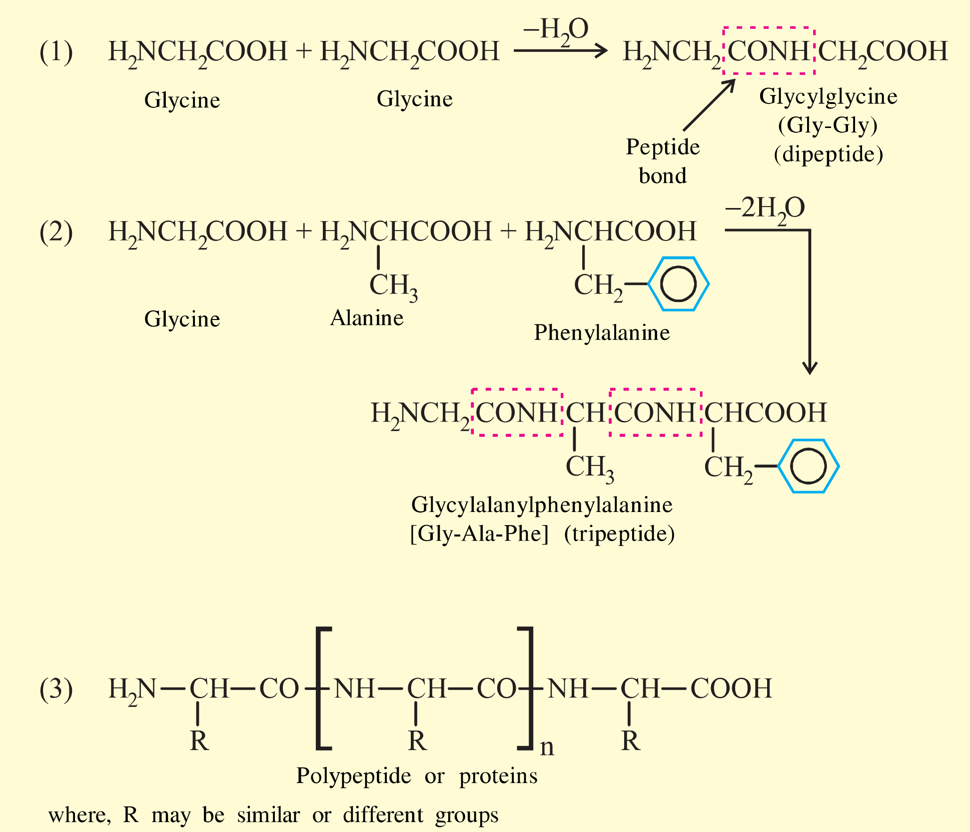


Thus, amino acids exist as positive ion (pH < 7) or negative ion (pH > 7) or dipolar ion (pH = 7) corresponding to pH of their aqueous solution. If solution of amino acid is put in an electric field then the ions present will migrate towards the specific electrode. If amino acid is present as positive ion in its solution then it will migrate towards cathode (negative electrode) and if it is present as negative ion in its solution then it will migrate towards anode (positive electrode). If amino acid is dipolar ion in its solution then it will not migrate towards anode or cathode, because of dipolar ion is neutral with respect to balancing of charge. In electric field, the pH value at which the amino acid does not migrate towards any electrode is called the **isoelectric point (pI) of amino acid.** Different amino acid have different isoelectric points.

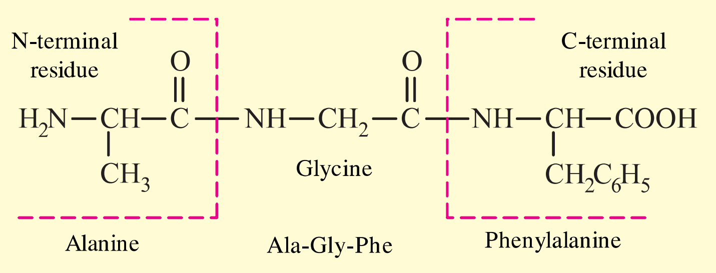
Most of the amino acids react with acid or base and form salt, so they are known as **amphoteric compounds.** A mixture of amino acids can be separated by electrophoresis and different types of chromatographic techniques.

7.7.2 Peptides :

Scientist Emil Fischer suggested that reaction between $-NH_2$ group of one amino acid and –COOH group of another amino acid loses the water molecule and forms amide. This amide bond (–CONH–) is known as **peptide bond or peptide linkage.** If two amino acids are joined by peptide bond and form a chain then it is called the **dipeptide.** If three amino acids are joined by peptide bond and form a chain is called the **tripeptide.** If four to ten amino acids are joined by peptide bond and form a long chain then it is called the **oligopeptide.** If many amino acids are joined by peptide bond and form a long chain then it is called **polypeptide or protein.** Generally peptides having molecular mass upto 10,000 are called **polypeptides** and which peptides which have molecular mass above 10,000 are called **proteins.** e.g.,



Out of two amino acids (first and last) of peptide chain, the $-NH_2$ group of one amino acid and –COOH group of another amino acid are not involved in formation of peptide bond. Thus, $-NH_2$ group at one end and –COOH group at other end are free in polypeptide chain. According to simple convention for representation of peptide structure, the free $-NH_2$ group containing end is written at left side in peptide chain. It is known as **N-terminal residue.** The free –COOH group containing end is written at right side in peptide chain. It is known as **C-terminal residue.** According to this convention tripeptide alanylglycylphenylalanine can be mentioned as follows :



The sequence of amino acids is most important in peptide chain. If amino acids are joined with different sequences then different peptides are formed. e.g., Three amino acids A, B, C are joined in different sequences to form six different types of tripeptides A–B–C, A–C–B, B–A–C, B–C–A, C–A–B, C–B–A.

7.7.3 Structures of Proteins :

Proteins can be classified into two types on the basis of their molecular shapes: (i) Fibrous proteins (ii) Globular proteins.

(i) Fibrous Proteins : When the polypeptide chains run parallel and are held together by **hydrogen and disulphide bonds,** then fibre like structure is formed. Such proteins are generally insoluble in water. e.g., Keratin (present in hair, wool, silk) and myosin (present in muscles) etc.

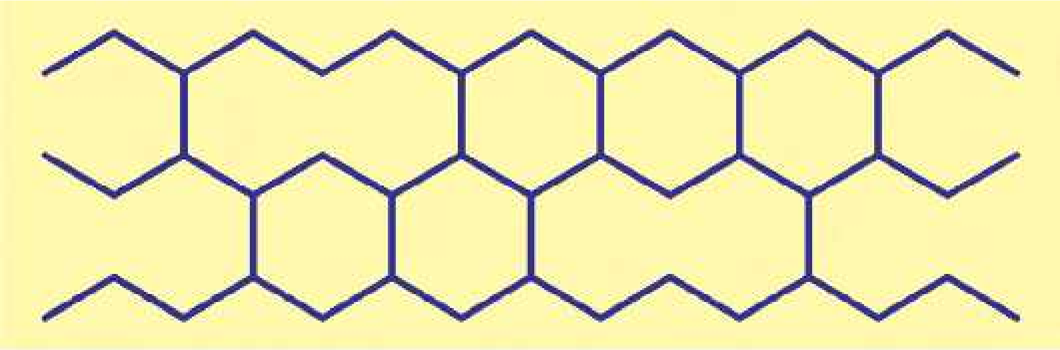


Fig. 7.1 Fibrous proteins

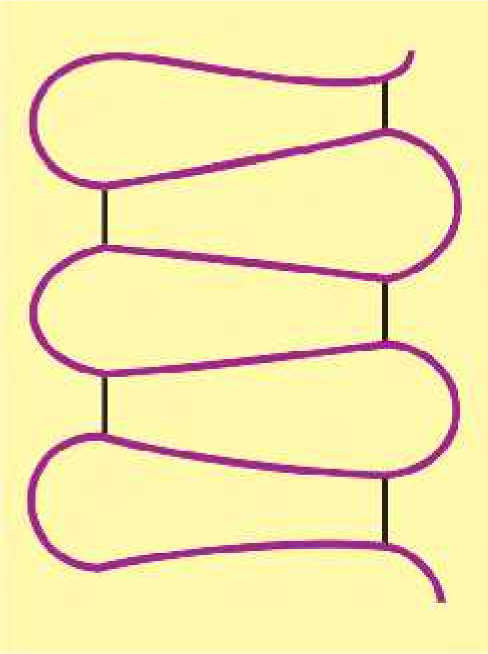


Fig. 7.2 Globular proteins

(ii) Globular Proteins : This structure results when the chains of polypeptides coil around to give a spherical shape. These are usually soluble in water. e.g., insulin, albumins etc.

Four different types of protein structures viz. primary, secondary, tertiary and quaternary have been discovered. In 1954 scientist Linus Pauling was awarded the Nobel Prize in chemistry for work on protein-structure.

(1) Primary structure of proteins : Primary structure of proteins consists of one or more chains of polypeptides. In this, the amino acids present are joined in a specific sequence. Two polypeptide chains are joined with each other by **disulphide linkage (–S–S–)** in primary structure of insulin in human.

(2) Secondary structure of proteins : This type of structure is shown in long chain of polypeptides. Secondary structure can be explained by two different types. (a) α-helix shape (b) β-pleated sheet shape (zig zag shape)

In α-helix shaped protein, polypeptide chain is coiled in helix shape. Approximate 3.6 amino acids are included per turn of the helix. In this structure, hydrogen bond is formed between oxygen atom of $>C=O$ and hydrogen atom of –NH of peptide bond. This structure is presented in Fig. 7.3.

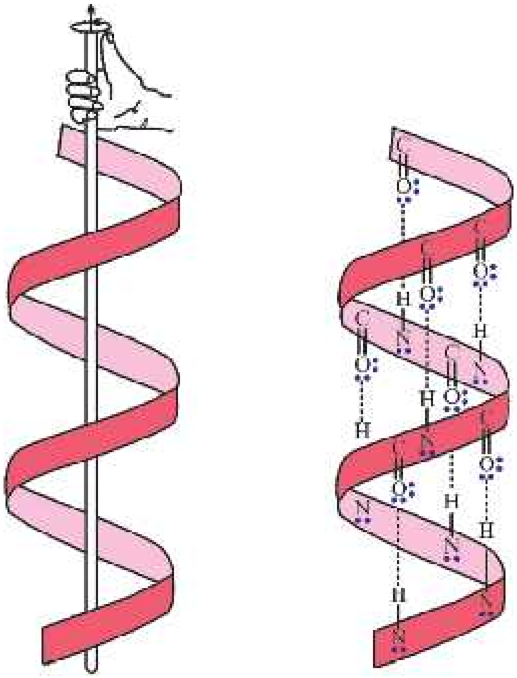
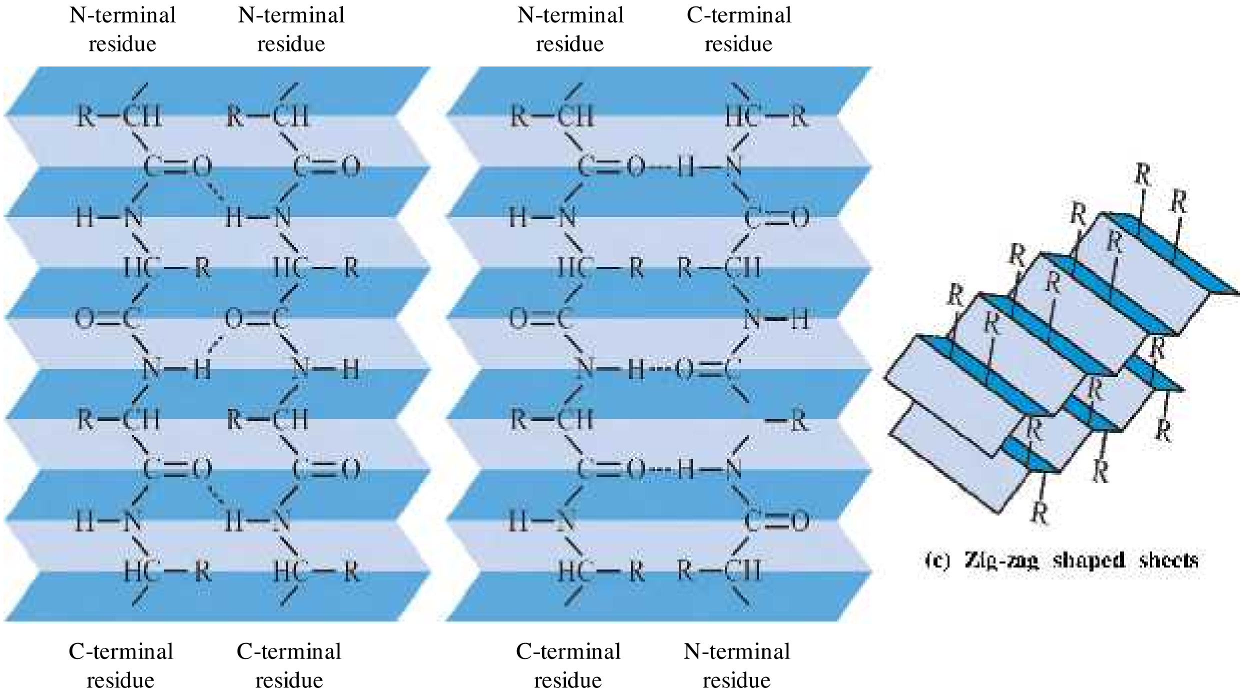


Fig. 7.3 α-Helix structure of proteins (For information only)

In β-pleated sheet shaped protein, one polypeptide chain forms intermolecular hydrogen bond (between oxygen atom of $>C=O$ and H atom of $H-N<$) with adjacent polypeptide chain. Therefore these protein chains are formed like zig zag shaped sheet. This structure is presented in Fig. 7.4.



(a) Same terminal residue containing polypeptides

(b) Different terminal residue containing polypeptides

(c) Zig-zag shaped sheets

Fig. 7.4 β-Pleated sheet structure of proteins (For information only)

(3) Tertiary structure of proteins : The tertiary structure of a protein is the three dimensional arrangement of all the atoms in the protein. In this structure, long chain of polypeptides is folded at many points and forms coil shape. Side chains of amino acids are joined to each other by van der Waals' attraction forces, hydrogen bond, ionic bond and disulphide bond. Tertiary structure of myglobin protein is presented in Fig. 7.5.

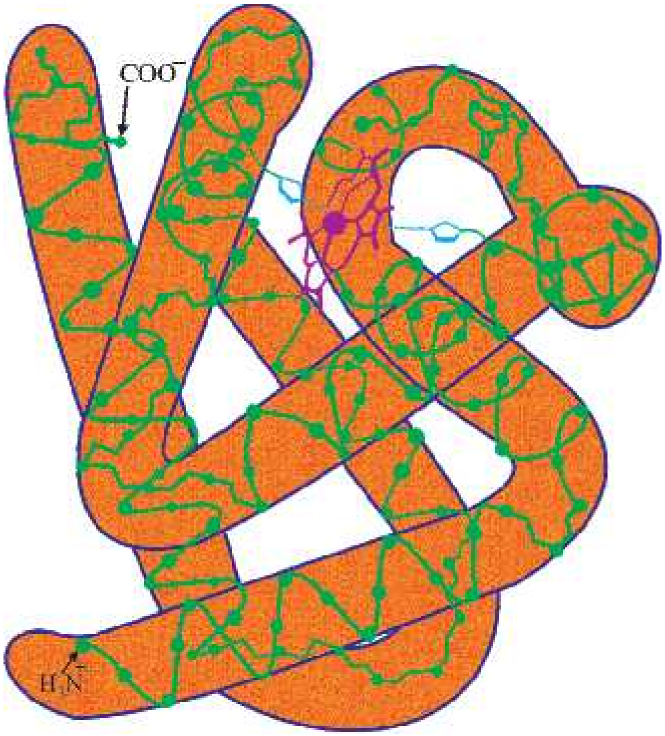


Fig. 7.5 Tertiary structure of myglobin protein (For information only)

(4) Quaternary structure of proteins : This quaternary structure is found in some complex proteins. These proteins are made up of two or more polypeptide chains. Non protein components may also be present in them. In this structure, chains of polypeptides are joined with each other by hydrogen bond, ionic bond and disulphide bond. Haemoglobin protein consists of quaternary structure, which is presented in Fig. 7.6. In this structure, two alpha chains and two beta chains are present. These four chains are arranged in a specific way as mentioned in Fig. 7.6.

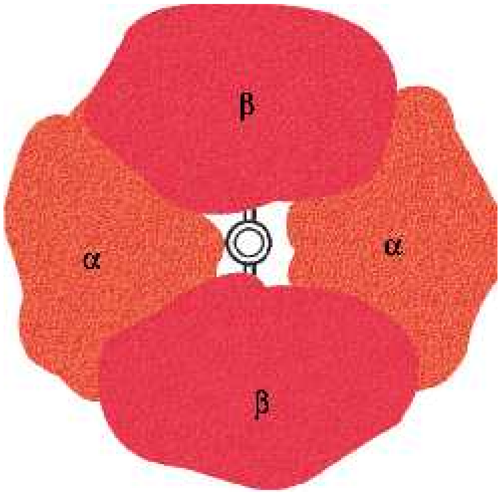


Fig. 7.6 Quaternary structure of haemoglobin protein (For information only)

7.7.4 Denaturation of Proteins :

Proteins found in living organisms are remarkably sensitive to changes in environment. Relatively small changes in pH, temperature or solvent composition, even for only a short period, may cause proteins to become denatured. In proteins, occurrence of this denaturing is known as denaturation of proteins. Due to this denaturation, proteins lose their biological activity. Reasons of denaturation of proteins are as follows :

(1) Increase in temperature : Most globular proteins become denatured when heated above 323 K - 333 K. e.g., If an egg is fried or boiled in water at 373 K or above then white protein becomes denatured, forming an insoluble mass.

(2) Changes in pH : Adding concentrated acid or alkali to a protein in aqueous solution causes changes in the characteristics of ionizable side chains in it and hydrogen bond and different types of attractions are broken down. In certain clinical chemistry tests removal of all protein material is first required. For this the trichloroacetic acid is added to sample and resulting protein is converted into precipitates by denaturation. They can be removed easily.

(3) Detergents : Detergent such as sodium dodecyl sulphate is associated with the non polar groups of proteins. It creates interference with the hydrophobic interactions in protein, due to which protein becomes denatured.

(4) Organic solvents : Organic solvents such as alcohol, acetone and ether denature the proteins by interference of hydrophobic interactions.

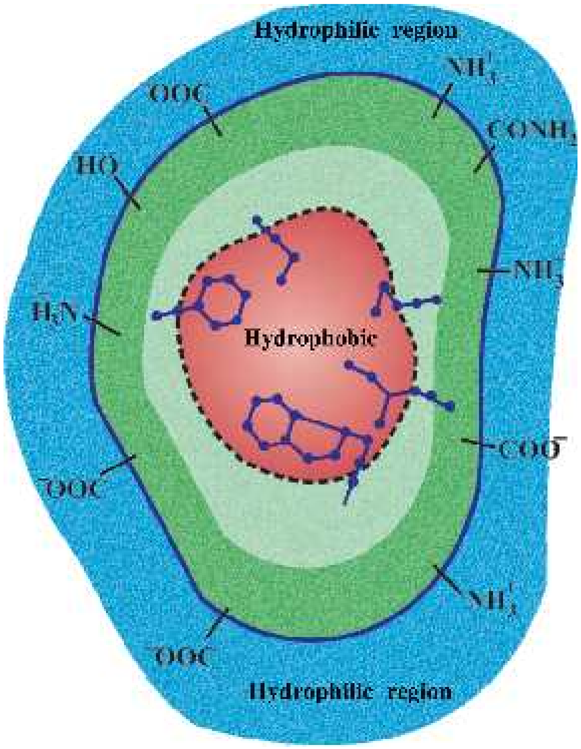


Fig. 7.7 Hydrophilic and hydrophobic regions in proteins (For information only)

7.8 Enzymes

The substance which acts as a catalyst in biochemical reactions is known as **enzyme.** Enzymes are globular proteins. Enzymes participate in biochemical reactions and increase the reaction rate. They are not utilized in reaction which means that they are obtained as such in original form at the end of the reaction. Some enzymes can increase the rate of reaction by 10^{12} times. e.g., Hydrolysis of a fat (an ester) to a carboxylic acid and an alcohol is extremely slow, but this reaction occurs rapidly in the presence of lipase enzyme. Some enzymes consist of only of proteins. Some enzymes which consist of other chemical components except proteins which are necessary for their proper functioning of them. Such a component is called a **cofactor.** Cofactors may be inorganic components such as zinc (Zn^{2+}), manganese (Mn^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+}) or copper (Cu^{2+}) metal ions. If the cofactor is organic in nature, it is called a **coenzyme.** Thus, coenzyme is a non-protein. It is necessary to note here that if inorganic component is cofactor in enzyme then it is not called coenzyme. The protein part of an enzyme is called **apoenzyme.** Both the coenzyme and the apoenzyme must be present for enzymatic activity to take place.

Coenzyme	+	**Apoenzyme**	→	**Enzyme**
(Non-protein) (inactive)		(Protein) (inactive)		(Active)

Working mechanism of enzyme : Enzyme (E) and substrate (S) combine to form an enzyme-substrate intermediate (E–S) complex. This intermediate decomposes to give product (P) and regenerate the enzyme (E).

E	+	**S**	→	**E-S**	→	**E**	+	**P**
(Enzyme)		(Substrate)		(Enzyme-substrate complex) intermediate compound		Enzyme		Product

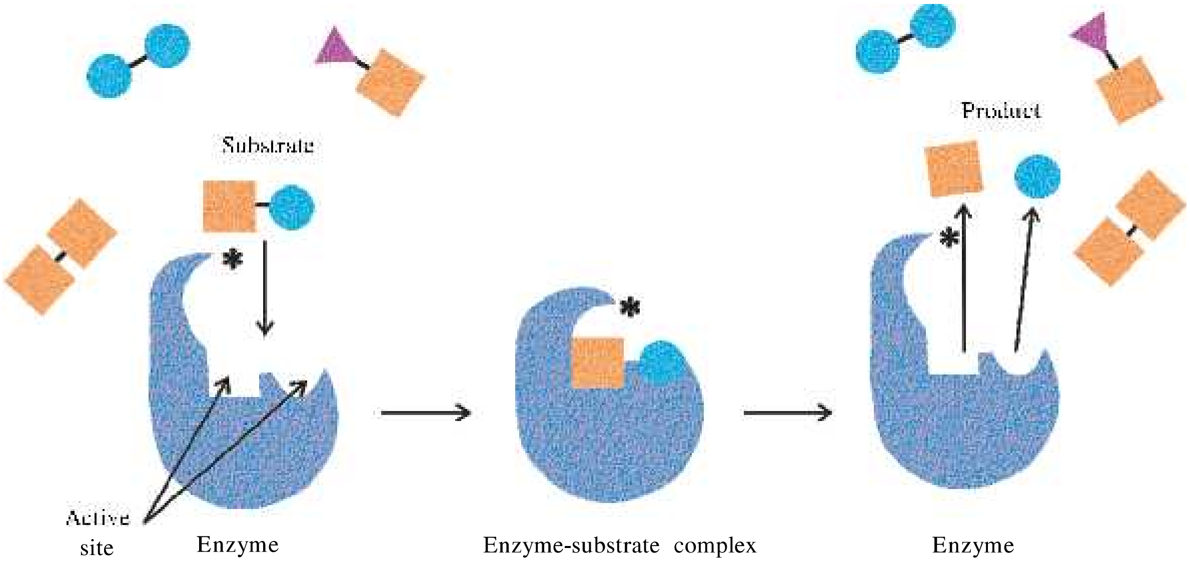


Fig. 7.8 Working mechanism of enzyme (For information only)

The substrate must fit in portion of the enzyme, called the **active site.** The specific amino acids which are present in protein part of enzyme bind the substrate. Therefore this protein part acts as an active site. Mostly an enzyme binds to specific substrate suitable with its active site. It does not bind with other substrate. For example, maltase hydrolyses the maltose but it is not useful in hydrolysis of other disaccharides-lactose or sucrose. Lactose is hydrolysed by emulsin and sucrose is hydrolysed by invertase enzyme. Thus, **each enzyme is specific for each specific reaction.** This type of working mechanism of enzyme can be explained by the lock and key model. Specific lock (substrate) is opened only by the specific key (enzyme) which is suitable for that lock. You have learnt in detail about lock and key model in unit 2 : on surface chemistry.

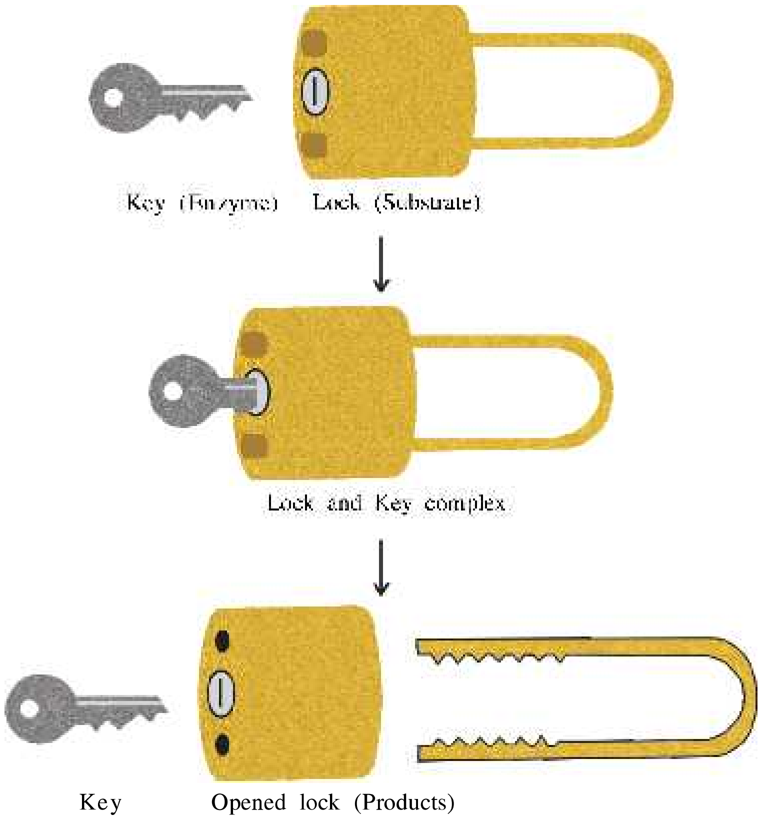


Fig. 7.9 Working mechanism of enzyme (Lock and Key model) (For information only)

Names of enzyme can be assigned in two ways. Enzyme can be named by adding the suffix ‘ase’ to the root of its substrate name. e.g., one which affects maltose is called maltase and which affects lipid is called lipase. In another way, the name of enzyme is decided by the type of reaction on which enzyme is affected. e.g., Enzyme that catalyses the hydrolysis is called hydrolase and enzyme that catalyses the oxidation is called oxidase.

7.9 Vitamins

Certain organic compounds are required in small amounts in our diet. The deficiency of these compounds causes specific diseases in our body. These organic compounds are called **vitamins.** The word vitamine was coined from the word vital + amine, because the earlier work showed that these organic compounds contained amino group. But later work showed that most of these compounds did not contain amino group, so the letter ‘e’ was dropped and the term vitamin is familiar nowadays. Most of the vitamins cannot be synthezised in our body but plants can synthesise them. Therefore vitamins are considered as essential food constituents. Vitamins are designated by alphabets A,B,C,D etc. Some of them are further named as sub-groups e.g., B_1, B_2, B_6, B_{12} etc. Human body synthezises vitamin A from carotene and it also synthezises vitamin D in skin with the help of sunlight. Vitamin B complex and vitamin K are formed by microorganism in intestine. High proportion of vitamin is harmful to us, so we should not use pills of vitamins without the advice of the doctor.

Vitamins are classified as two types **(1) Fat soluble : e.g., Vitamin A, D, E, K (2) Water soluble : e.g., Vitamin B complex, C. Vitamin H (biotin) is insoluble in both water and fat.** Important vitamins, their sources and diseases caused by their deficiency are presented in table 7.2.

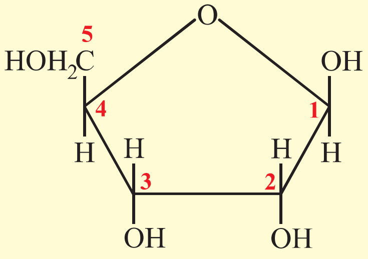
Table 7.2. Vitamins, sources and diseases caused by their deficiency

No.	Vitamin	Source	Diseases caused by their deficiency
1.	Vitamin A (Retinol)	Liver oil of fish, carrot, butter, cheese and milk	Xerophthalima
2.	Vitamin B_1 (Thiamine)	Yeast, milk, green vegetables and cereals	Beri-Beri
3.	Vitamin B_2 (Riboflavin)	Milk, egg white, liver, kidney	Dark-red tongue and skin diseases
4.	Vitamin B_6 (Pyridoxine)	Cereals, gram, milk, yeast, egg white	Skin diseases and convulsions
5.	Vitamin B_{12} (Cyanocobalamine)	Egg, fish, liver, meat (not found in plants)	Pernicious anemia
6.	Vitamin C (Ascorbic acid)	Tomato, green pepper, orange, citrus fruits and green vegetables	Scurvy
7.	Vitamin D (Calciferol)	Sunlight, fish, egg white	Bone deformation in children and soft bones and joint pain in adults
8.	Vitamin E (α-Tocopherol)	Vegetable oil, green vegetables, egg white, meat	Sterility
9.	Vitamin K (Phylloquinone)	Green vegetables	Haemorrhage
10.	Vitamin H (Biotin)	Milk, yeast, liver	Loses of hair, skin diseases, paralysis

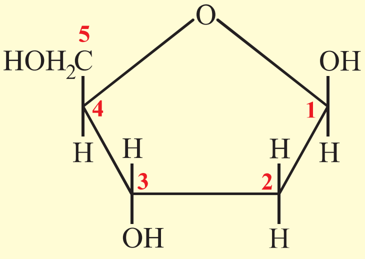
7.10 Nucleic Acids

Every generation of each and every species shows similarity with its ancestors in many ways. The process of transmission of these characteristics from one generation to the next generation is called heredity. For this, chromosomes are responsible which are present in nucleus of living cell. These chromosomes are made up of proteins and nucleic acids. Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA) are two types of nucleic acids. **Nucleic acids are long chain polymers of nucleotides, so nucleic acids are also called polynucleotides.** Complete hydrolysis of nucleic acids (DNA and RNA) forms a pentose sugar, nitrogen containing heterocyclic compounds and phosphoric acid. It indicates that nucleic acids are formed of these three constituents. Thus, it is necessary to know structure of these three constituents for understanding the structure of nucleic acid.

(1) Sugar : β-D-ribose sugar is present in RNA and β-D-2-deoxyribose sugar is present in DNA.

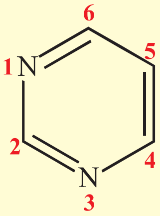


β-D-Ribose

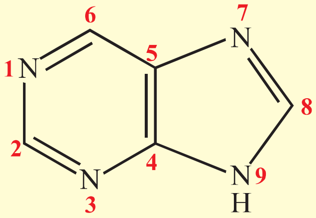


β-D-2-deoxyribose

(2) Heterocyclic base : In nucleic acids, purine and pyrimidine heterocyclic systems act as base. Pyrimidine is monocyclic compound whereas purine is dicyclic compound.



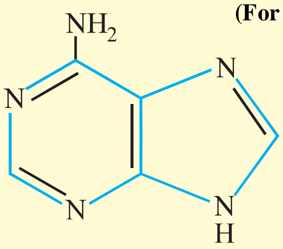
Pyrimidine



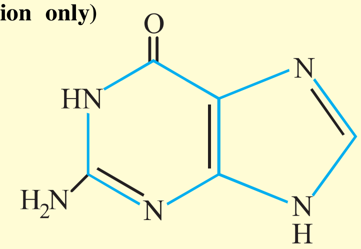
Purine

Adenine (A), guanine (G), cytosine (C), thymine (T) and uracil (U) are present in nucleic acids as heterocyclic bases. Out of them A and G are purine derivatives and C, T and U are pyrimidine derivatives, they are known as purine bases and pyrimidine bases, respectively. **DNA contains A, G, C and T bases, while RNA contains A, G, C and U bases.**

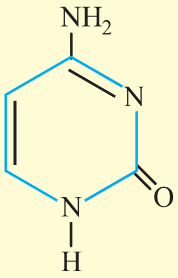
(For information only)



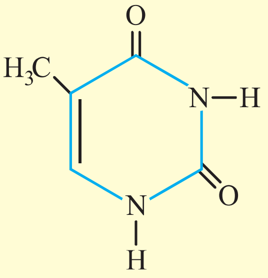
Adenine



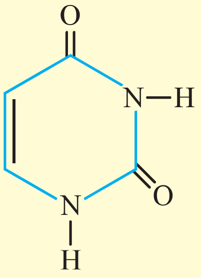
Guanine



Cytosine

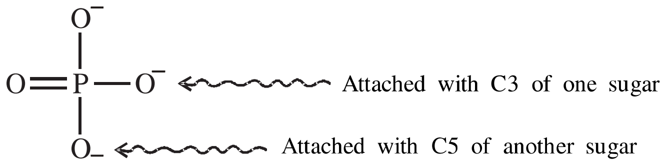


Thymine

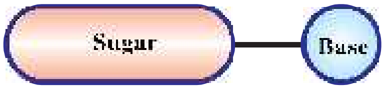


Uracil

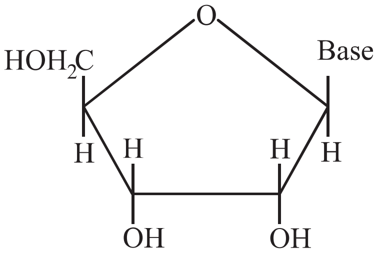
(3) Phosphoric acid : In nucleic acid, sugars are joined together by phosphate ion (PO_4^{3-}) of phosphoric acid



A unit formed by the attachment of a base to first position of sugar is known as **nucleoside.** A unit formed by the attachment of a nucleoside to phosphate ion is known as **nucleotide.**

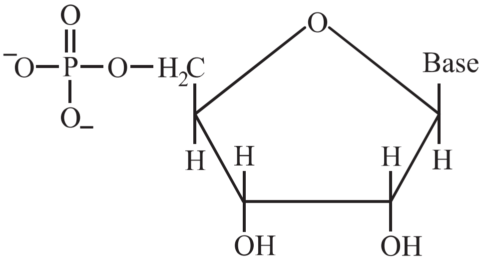


Nucleoside



Nucleoside

Nucleotide



Nucleotide

Two nucleotides are joined together by **phosphodiester linkage.** This linkage is formed between C3 of one sugar and C5 of another sugar. Formation of dinucleotide is shown in Fig. 7.10.

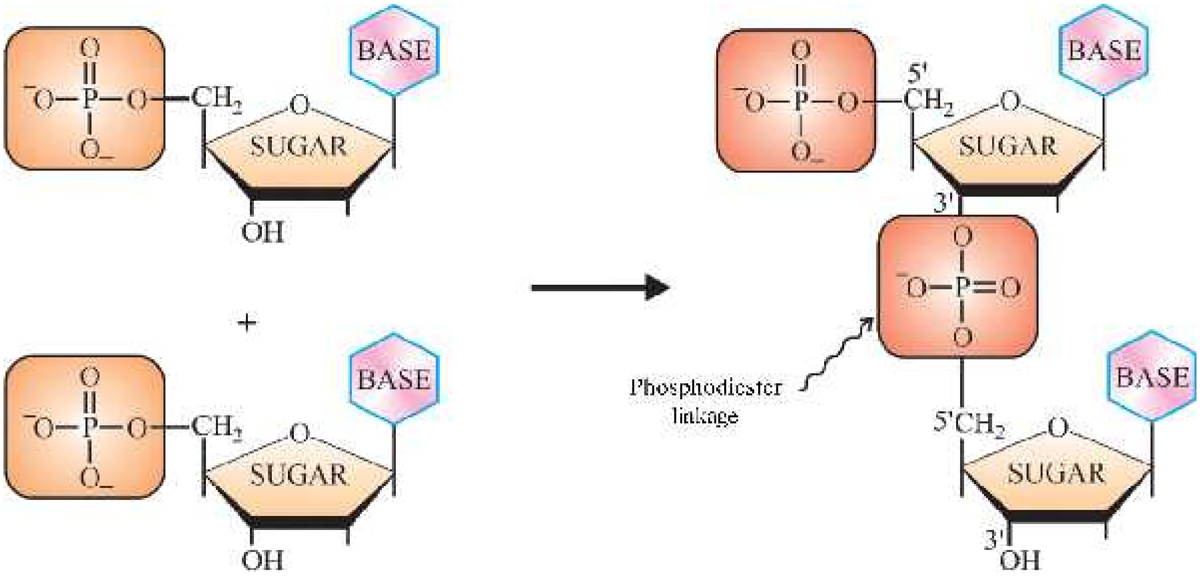
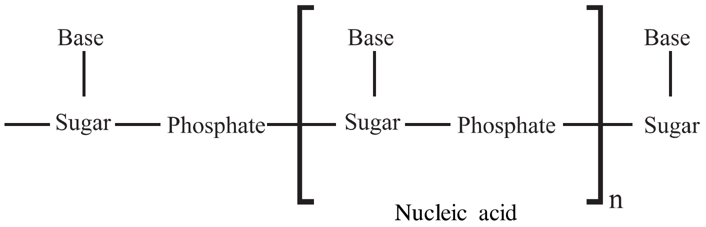


Fig. 7.10 Formation of dinucleotides (For information only)

Many nucleotides join together and form polynucleotides. It is known as nucleic acid. Structure of nucleic acid can be shown in an easy way as follows.



7.10.1 Double Helix Structure of DNA :

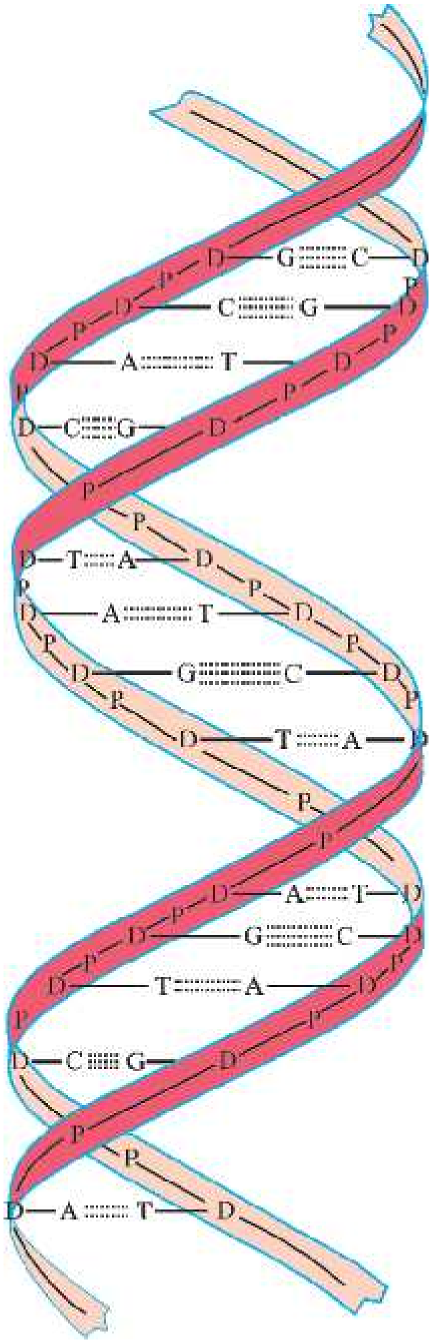


Fig. 7.11 Double helix structure of DNA
(For information only)

It is proved that the molecular shape of DNA is like a twisted rope which is shown in Fig. 7.11. It contains **phosphoric acid units on outer side and base compounds in central part.** In the nucleus of the cell, the these nucleic acids are divided, which are present in gene of chromosomes during reproduction. These nucleic acids are arranged similarly in new cell. Due to this heredity, characteristics are transmitted from one generation to next generation. In 1953 J.D. Watson and H.C. Crick proposed a double helix structure for DNA from X-ray diffraction studies of DNA. This structure looks like a spiral staircase. In connection of two polynucleotide chains, purine base of one nucleotide is joined with pyrimidine base of opposite nucleotide by hydrogen bond. In this adenine (A) base is always joined with thymine (T) and guanine (G) is always joined with cytosine (C). **A and T are joined together with two hydrogen bonds and C and G are joined together with three hydrogen bonds.**

P = Phosphate

D = Deoxyribose

A = Adenine

T = Thymine

C = Cytosine

G = Guanine

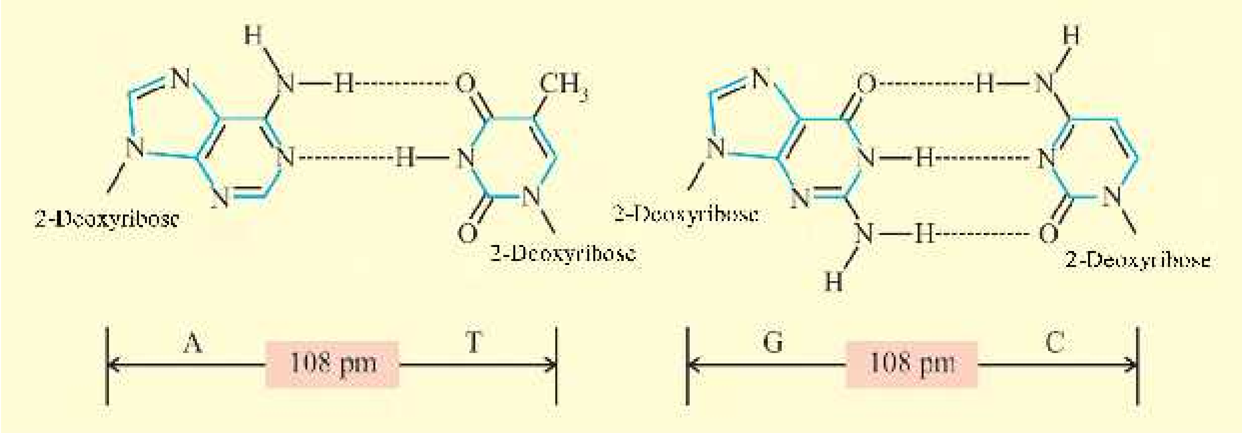


Fig. 7.12 Hydrogen bonds between A and T / G and C (For information only)

7.10.2 Biological Importance of Nucleic Acids :

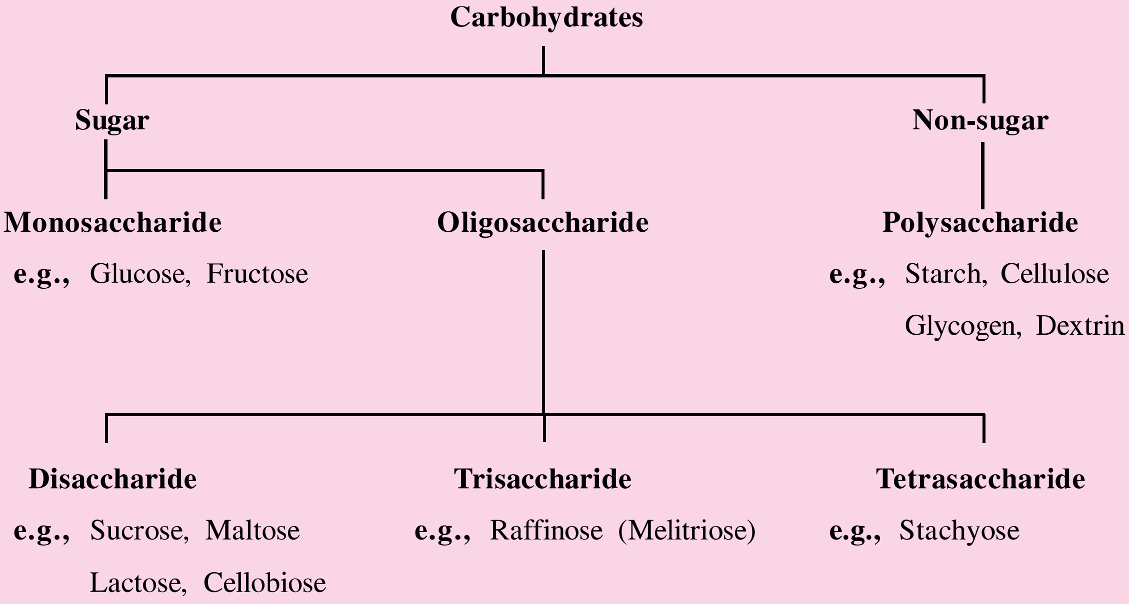
DNA is the responsible chemical for heredity. It reserves the genetic information. DNA is exclusively responsible for maintaining the identity of different species of organisms over millions of years. A DNA molecule is capable of self duplication during cell division and identical DNA strands are transferred to new cell. Another function of nucleic acids is the protein synthesis in the cell. Actually, the proteins are synthesised by various RNA molecule in the cell but the message for the synthesis of a specific protein is present in DNA.

SUMMARY

- Chemical compounds present in living systems are known as biomolecules.
- Carbohydrates, proteins, vitamins, nucleic acids enzymes and lipids are biomolecules.

Carbohydrates

- Carbohydrates are chemically polyhydroxy aldehydes or polyhydroxy ketones or such compounds which can be hydrolysed to these compounds.



Carbohydrates

Sugar

Non-sugar

Monosaccharide

e.g., Glucose, Fructose

Oligosaccharide

Polysaccharide

e.g., Starch, Cellulose
Glycogen, Dextrin

Disaccharide

e.g., Sucrose, Maltose
Lactose, Cellobiose

Trisaccharide

e.g., Raffinose (Melitriose)

Tetrasaccharide

e.g., Stachyose

Monosaccharides

Monosaccharide	**General class**	**(+) or (–)**	**Does it show mutarotation ?**	**Anomers**	**Is it reducing sugar ?**
Glucose	Aldohexose	(+)	Yes	α-D-(+)-glucose β-D-(+)-glucose	Yes
Fructose	Ketohexose	(–)	Yes	α-D-(–)-fructose β-D-(–)-fructose	Yes

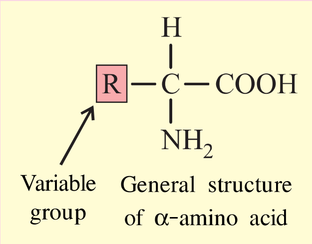
Disaccharides

Disaccharide	**(+) or (–)**	**Monosaccharide unit**	**Glycosidic linkage**	**Does it show mutarotation ?**	**Anomers**	**Is it reducing sugar ?**
Sucrose	(+)	Glucose Fructose	α-D-(+)-glucose(C1)-O-(C2)-β-D-(–)-fructose	No	No	No
Maltose	(+)	Glucose Glucose	α-D-(+)-glucose(C1)-O-(C4)-D-(+)-glucose	Yes	α-(+)-Maltose β-(+)-Maltose	Yes
Lactose	(+)	Galactose Glucose	β-D-(+)-galactose(C1)-O-(C4)-D-(+)-glucose	Yes	α-(+)-Lactose β-(+)-Lactose	Yes

Polysaccharides

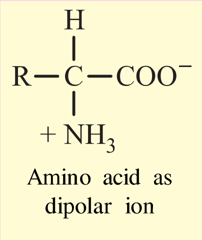
Polysaccharide	**Monosaccharide unit**	**Glycosidic linkage**
Starch		
Amylose	Glucose	α-D-(+)-glucose(C1)-O-(C4)-α-D-(+)-glucose
Amylopectin	Glucose	α-D-(+)-glucose(C1)-O-(C4)-α-D-(+)-glucose and α-D-(+)-glucose(C1)-O-(C6)-α-D-(+)-glucose
Cellulose	Glucose	β-D-(+)-glucose(C1)-O-(C4)-β-D-(+)-glucose

Amino acids



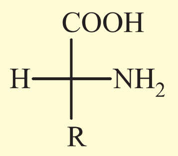
$$\mathrm{R{-}\underset{NH_2}{\overset{H}{C}}{-}COOH}$$

General structure of α-amino acid

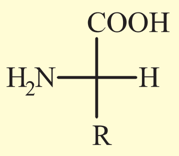


$$\mathrm{R{-}\underset{+NH_3}{\overset{H}{C}}{-}COO^-}$$

Amino acid as dipolar ion



D-amino acid



L-amino acid

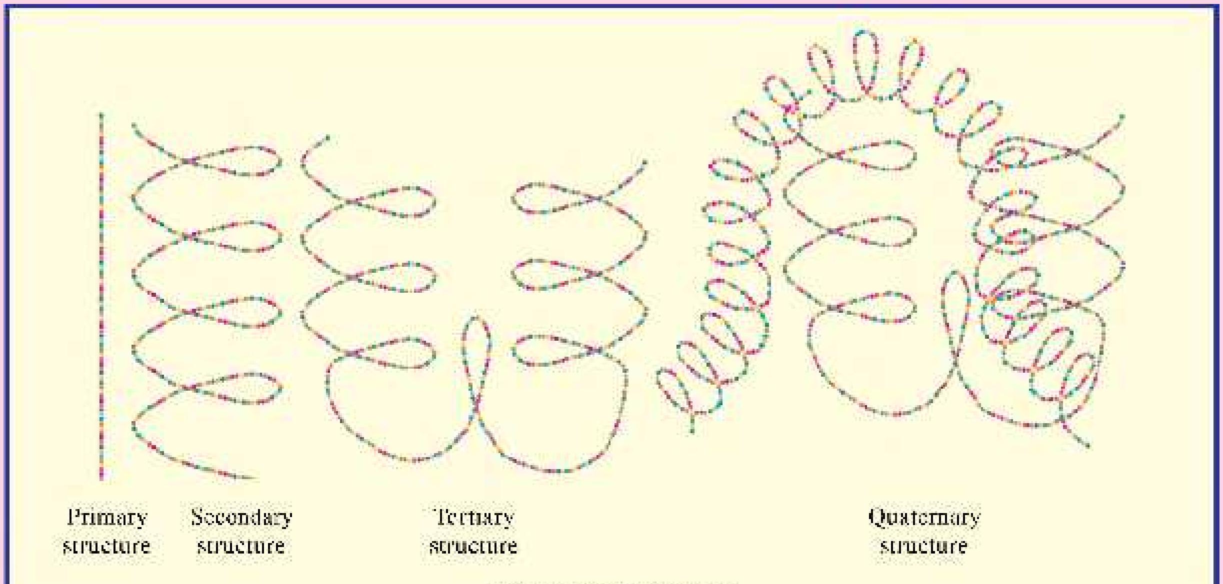
Proteins

- Proteins $\xrightarrow{\text{Hydrolysis}}$ Peptides $\xrightarrow{\text{Hydrolysis}}$ Amino acids
- Amino acid + amino acid → Dipeptide

  Amino acid + amino acid + amino acid → Tripeptide

  Amino acid + amino acid + amino acid + amino acid → Tetrapeptide

  n (Amino acid) → Polypeptide or proteins



Structures of Proteins

Enzymes

- The substance which acts as a catalyst in biochemical reaction is known as enzyme.
- **Coenzyme** + **Apoenzyme** → **Enzyme**

  (Non Protein) (inactive)   (Protein) (inactive)   (active)
- **E** + **S** → **E-S** → **E** + **P**

  (Enzyme) (Substrate) (Enzyme-substrate complex) Enzyme Product

(Working mechanism of enzyme)

Vitamins

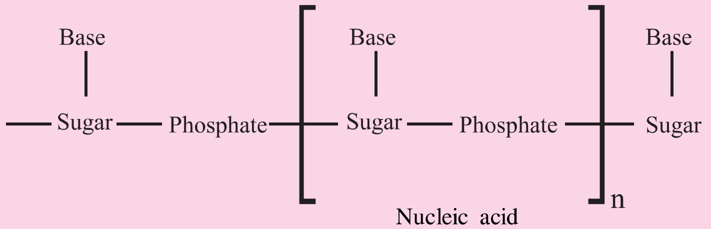
- Vitamin A, B_1, B_2, B_6, B_{12}, C, D, E, K and H are known.
- All vitamins are most important for human body. Deficiency of specific vitamin causes specific diseases.

Nucleic acids

- Two types of nucleic acids are

  (i) Deoxyribonucleic acid (DNA) and (ii) Ribonucleic acid (RNA)

- Nucleic acid means polynucleotides
- Nucleotide means nucleoside + phosphate
- Nucleoside means sugar + base
- DNA is the responsible chemical for heredity



Nucleic acid

EXERCISE

1. Select the proper choice from the given multiple choices :

(1) Which compound from the following is a disaccharide ?

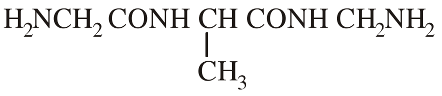
(A) Glucose (B) Fructose (C) Maltose (D) Melitriose

(2) What is the name of total four carbon atoms and one aldehyde group containing carbohydrate ?

(A) Aldotetrose (B) Aldopentose (C) Ketotetrose (D) Ketopentose

(3) Which sugar from the following is not a reducing sugar ?

(A) Glucose (B) Sucrose (C) Maltose (D) Lactose

(4) Which type of peptide chain is present in  $H_2NCH_2CONH\underset{\displaystyle CH_3}{\underset{|}{CH}}CONHCH_2NH_2$?

(A) Dipeptide (B) Tripeptide (C) Tetrapeptide (D) Polypeptide

(5) Which structure of protein is having β-pleated sheet shape?

(A) Primary (B) Secondary (C) Tertiary (D) Quaternary

(6) Which of the following statements is true ?

(A) Enzymes are carbohydrates

(B) Enzymes are not obtained at the end of reaction

(C) Enzymes are obtained in the changed form at the end of reaction

(D) Enzymes are obtained in the original form at the end of reaction.

(7) Which vitamin is insoluble in water and fat ?

(A) A (B) B complex (C) C (D) H

(8) Which of the following statements is incorrent ?

(A) A, G, C and T bases are present in DNA

(B) A and T are joined together by two hydrogen bonds in DNA

(C) A and C are purine bases.

(D) T and U are pyrimidine bases.

(9) By which linkage, two monosaccharides are joined together in disaccharide ?

(A) Peptide (B) Phosphodiester (C) Glycosidic (D) Disulphide

(10) Which of the following units are present in α-(+) -lactose ?

(A) β-(D)-(+)-galactose + α-D-(+)-glucose

(B) β-(D)-(+)-galactose + β-D-(+)-glucose

(C) α-(D)-(+)-galactose + α-D-(+)-glucose

(D) α-(D)-(+)-galactose + β-D-(+)-glucose

2. Write the answers of the following questions in brief :

(1) Write two examples of disaccharide.

(2) Write two examples of trisaccharide.

(3) Write two examples of polysaccharide.

(4) Write one example each of aldohexose and ketohexose.

(5) Write the empirical formula and molecular formula of glucose.

(6) Draw the Haworth projections of anomers of glucose.

(7) Draw the Fischer and Haworth projections of α-D-(–)-fructose.

(8) Which enzymes hydrolyse sucrose and maltose ?

(9) Mention the general structure of amino acid.

(10) Write two examples of neutral amino acids.

(11) Write two examples of acidic amino acids.

(12) Write two examples of basic amino acids.

(13) Write general structure of D- and L-amino acids.

(14) Write two names of separation techniques for amino acid mixture.

(15) Which two amino acids form glycylalanine dipeptide chain ?

(16) Based on the molecular shape which two types of protein are there ?

(17) Mention two factors for denaturation of protein.

(18) Mention the names of fat soluble vitamins.

(19) Mention the names of water soluble vitamins.

(20) At which position is the base joined with sugar in nucleoside ?

(21) By which linkage are two nucleotides joined to each other ?

(22) Which two bases are joined together with two hydrogen bonds in DNA ?

(23) Which three bases are joined together with three hydrogen bonds in DNA ?

(24) At which side N-terminal residue is written in peptide chain ?

(25) Which forms of dipolar ion of amino acids are present in acidic and basic medium ?

(26) In the following compounds, glycosidic linkage occurs between which monosaccharide molecules and at which position :

(i) Sucrose
(ii) Maltose
(iii) Lactose
(iv) Amylose
(v) Amylopectin
(vi) Cellulose

(27) Write definitions :

(i) Carbohydrate
(ii) Dextrorotatory
(iii) Levorotatory
(iv) Anomeric carbon
(v) Anomers
(vi) Mutarotation
(vii) Caramal
(viii) Zwitter ion
(ix) Isoelectric point of amino acid
(x) N-terminal residue
(xi) C-terminal residue
(xii) Enzyme
(xiii) Cofactor
(xiv) Coenzyme
(xv) Active site of enzyme
(xvi) Vitamin
(xvii) Nucleoside
(xviii) Nucleotide

3. Write the answers of the following questions :

(1) Write the formula of calculation for specific rotation of optically active compound and explain all the terms involved.

(2) Draw the open chain structure of D-(+)-glucose and L-(–)-glucose.

(3) Draw the open chain structure of D-(–)-fructose and L-(+)-fructose.

(4) What are essential amino acids ? Mention their names.

(5) Most amino acids are amphoteric in nature. Why ?

(6) Draw the structure of any dipeptide and mention the position of peptide linkage, N-terminal residue and C-terminal residue in it.

(7) Draw the simple structure of nucleic acid.

(8) Draw the structures of the following compounds. Give the proper number carbon atoms present in each monosaccharide and mention the position of glycosidic linkage in the structure of the following compounds :

(i) (+)-Sucrose
(ii) α-(+)-Maltose
(iii) β-(+)-Lactose
(iv) Amylose
(iv) Amylopectin
(vi) Cellulose

Match the following (Q.9 to 11) :

(9)

A	B
(a) Glucose	(i) Malt sugar
(b) Maltose	(ii) Cane sugar
(c) Lactose	(iii) Grape sugar
(d) Sucrose	(iv) Milk Sugar

(10)

A	B
(a) Vitamin A	(i) Biotin
(b) Vitamin B_2	(ii) Ascorbic acid
(c) Vitamin C	(iii) Riboflavin
(d) Vitamin D	(iv) Retinol
	(v) Calciferol

(11)

A	B
(a) Vitamin B_1	(i) Sterility
(b) Vitamin C	(ii) Xerophthalima
(c) Vitamin E	(iii) Scurvy
(d) Vitamin B_{12}	(iv) Beri-Beri
	(v) Pernicious anemia

(12) Encircle ◯ on the differing compound from the following groups of compounds :

(i) Starch, Cellulose, Cellobiose, Glycogen

(ii) Sucrose, Lactose, Glucose, Maltose

(iii) Cytosine, Adenine, Thymine, Uracil

(iv) Vitamin A, Vitamin C, Vitamin D, Vitamin E

Explain with reasons (Q.13 to 15)

(13) Sucrose is a non-reducing sugar.

(14) Maltose is a reducing sugar.

(15) Why lactose has anomers ?

4. Write the answers of the following questions in detail :

(1) Write classification of carbohydrates.

(2) Discuss the two methods for preparation of glucose.

(3) Describe chemical reactions for proving the open chain structure of glucose.

(4) Describe the importance of carbohydrates.

(5) Explain the primary, secondary, tertiary and quaternary structure of protein.

(6) Discuss the reasons for denaturation of proteins.

(7) Explain working mechanism of enzyme.

(8) Discuss the constituents of nucleic acid structure.

(9) Describe the double helix structure of DNA.

(10) Solve the problems :

(i) The specific rotation of 3.0 g of maltose in 20 ml of aqueous solution in a polarimeter tube 2.0 dm long is $+ 136^0$. What is the observed angle of rotation of solution of maltose ?

(ii) Fructose has a specific rotation of (-92.4^0). An aqueous solution of a fructose has an observed angle of rotation of (-27.7^0) when placed in a polarimeter tube 10 cm long. How much amount of fructose is dissolved in 100 ml of aqueous solution ?

•

Unit

8

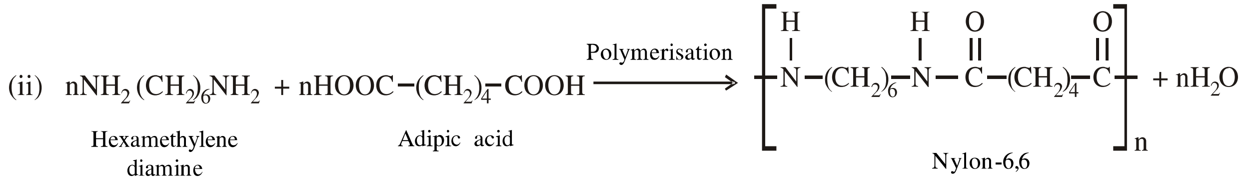
Polymers

8.1 Introduction

Polymer is part of our daily life. Daily requirement is incomplete without its usage. Thinking about universe without polymer is impossible. Polymer is a compulsory need for the physical comfort and for making our life easier. Any material of plastic, like toys for children, polythene shopping bags for purchase or synthetic clothes, tyres of vehicles or the spare parts of machines, insulated (nonconductor) wires of electric cable, or electric shock proof, devices interiors of vehicles or houses, medical field or pharmacy; in each of these polymer has established its dominance. There is a possibillity that polymer will replace the metal in future.

For daily requirement or industrial growth polymer has been used all over. In industries polymer is used in manufacturing of plastic, elastomer fiber, paint and varnish. Polymer word is formed by combination of two Greek words "poly" and "mer" in which 'poly' means many and 'mer' means unit, part or section. Polymer means huge molecule (10^3–10^7 u) containing higher molecular masses and many simple molecules combined. In general, polymer is represented by the name of macromolecules. The simple unit or molecule which is repeated many times in the polymer is known as **monomer.** Such simple units or active molecules are joined together with each other in large amount by covalent bond and form a huge molecule (polymer). This process is called **polymerisation.** The unit which is repeated several times in a huge molecule is called **repeating unit. This number of repeating unit 'n' in polymer molecule is called "degree of polymerization".** e.g., innumerable molecules of ethene monomer combined with each other by polymerisation reaction which forms a huge molecule is called polythene. Polymer molecule containing huge volume is formed by intereaction between innumerable molecules of hexamethylene diamine and adipic acid, which is called nylon-6,6.

(i) $$\underset{\text{Ethene}}{nCH_2=CH_2} \xrightarrow{\text{Polymerisation}} n\underset{\text{Repeating unit}}{\left[-CH_2-CH_2-\right]} \longrightarrow \underset{\text{Polythene}}{\left[-CH_2-CH_2-\right]_n}$$

(ii) 

$$\underset{\text{Hexamethylene diamine}}{nNH_2(CH_2)_6NH_2} + \underset{\text{Adipic acid}}{nHOOC-(CH_2)_4-COOH} \xrightarrow{\text{Polymerisation}} \underset{\text{Nylon-6,6}}{\left[-\overset{H}{\overset{|}{N}}-(CH_2)_6-\overset{H}{\overset{|}{N}}-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\right]_n} + nH_2O$$

If the value of repeating unit ‘n’ is less than 25 ($n < 25$) then that polymer is called **oligomer.** Generally oligomer is in liquid state. Liquid polymers used in fevicol like adhesives paints are oligomers. If the value of repeating unit ‘n’ is more than 25 then that polymer is called **heavy polymer.** Generally heavy polymers are in solid state.

8.2 Classification of Polymers

Classification of polymers is possible on some acceptable bases which are shown as under :

8.2.1 Classification based on source :

Polymers are classified in three types on the basis of their availability (source) :

(1) Natural Polymers : Polymers present in nature are obtained from plants or animals, e.g., protein, cellulose, starch, nucleic acids, resins, rubber, etc., are examples of natural polymers.

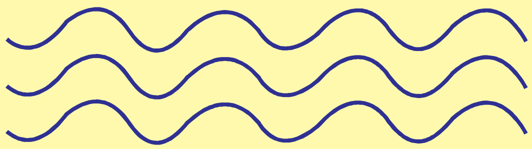
(2) Semisynthetic polymers : Polymers which are formed by chemical reaction with the polymers present in nature are called semisynthetic polymers. By changing the properties of natural polymers according to their requirement, polymers like explosive cellulose nitrate are formed by nitration of cellulose; Cellulose diacetate (rayon) is obtained by acetylation reaction of cellulose with acetic anhydride in acidic medium. Vulcanised rubber obtained by vulcanisation of natural rubber can be included in these type of polymers.

(3) Synthetic polymers : It is totally man-made polymer because synthetic polymer possesses large series of man-made polymers. In this type of polymers plastic (polythene, PVC, teflon) synthetic fibers (terylene, nylon, polyester orlon), synthetic rubber (Buna-S, Buna-N) etc are included.

8.2.2 Classification based on structures :

Polymers are classified into three types according to their structures.

(1) Linear polymers : This type of polymers contain long straight chain in their constitution. There is no branch in their straight chain. Monomer units combine with each other, forming a long straight chain and linear polymer is obtained. Fibers are included in linear polymers. Linear polymers are obtained from natural cources like cotton, silk, wool, linen whereas synthetic linear polymers are terylene, nylon, polyesters, orlon etc. Linear polymers are arranged in a long chain as shown in fig. 8.1.



Linear polymer

Fig. 8.1

(2) Branched chain polymers : This type of polymers contain branch inbetween the long straight chain in their constitution. Monomer units combine with each other, make a long straight chain and if this chain contains brachning inbetween, then it is called branched polymer. This type of thermoplastic polymer contains low density polymer (LDP). For example, polystyrene, PVC, teflon, etc are branched polymers. Branched polymers in long chain possess branches as shown in fig 8.2.

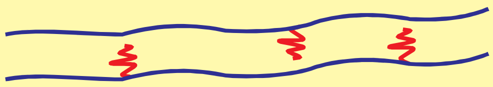

Branched polymer

Fig. 8.2

(3) Cross linked polymers : In this type of polymers, bifunctional or trifunctional monomer combines with covalent bond inbetween the long polymer chain. Long polymer chain is joined by strong covalent bond and forms a net like structure. This type of thermosetting polymer contains high density polymer. For instance, Bakelite, Melamine are crossed linked polymers. Long chain at certain distances joined by strong binding which is shown in fig 8.3.

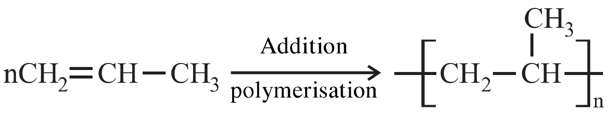

Crossed linked polymers

Fig. 8.3

8.2.3 Classification based on reaction mode of polymerisation :

On the basis of polymerisation reaction, polymers are classified into two categories

(1) Addition Polymers : Due to addition reaction, when double bond or triple bond containing innumerable monomer molecules combine with each other by chemical bond, then they form addition polymer, like polythene formed from ethene. Polypropene formed from propene and polystyrene formed from styrene are addition polymers. e.g., innumerable molecules of propene monomers are joined with each other by addition polymerisation reaction and form polypropylene polymer.



$$nCH_2{=}CH-CH_3 \xrightarrow[\text{polymerisation}]{\text{Addition}} \left[CH_2-\overset{\overset{\displaystyle CH_3}{|}}{CH} \right]_n$$

Propene monomer

Polypropene (polymers)

(a) Homopolymers : When same type of innumerable monomers combine with each other in addition polymerisation reaction, and form a polymer, it is known as Homopolymer. Polythene, polystyrene, polyvinyl chloride, teflon, orlon, butyl rubber, neoprene etc are hompopolymers. For example,

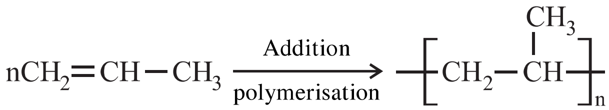
(i) When same kind of innumerable molecules of ethene monomers are joined by addition polymerisation reaction, then they form homopolymer polythene.

$$nCH_2{=}CH_2 \xrightarrow[\text{polymerisation}]{\text{Addition}} \left[CH_2-CH_2 \right]_n$$

Ethene

Polythene (homopolymer)

(ii) Innumerable molecules of propene monomer are joined by addition reaction to form polypropene.



$$nCH_2{=}CH-CH_3 \xrightarrow[\text{polymerisation}]{\text{Addition}} \left[CH_2-\overset{\overset{\displaystyle CH_3}{|}}{CH} \right]_n$$

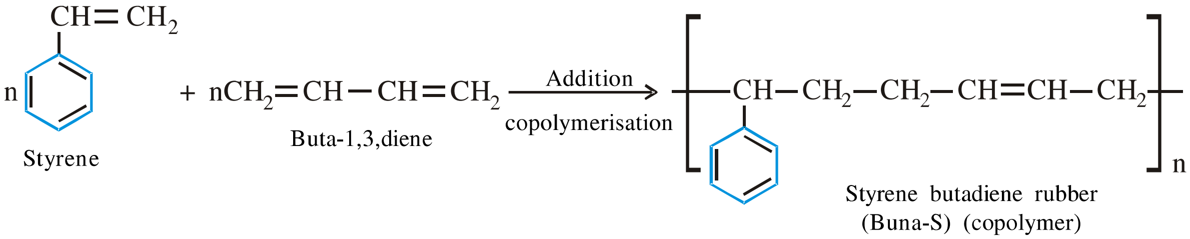
Propene

Polypropene (Homopolymer)

Here same kind of innumerable molecules (ethene or propene) combine with one another by addition reaction to form polymer, so it is called Homopolymer. In homopolymer, which is formed by the addition reaction, the repeating unit is totally based on the monomer. Naming of these homopolymers is based on the name of monomer unit.

(b) Copolymer : In addition polymerisation reaction when two or more than two different types of innumerable monomers combine with each other to form polymer then it is known as copolymer. Nylon-6,6, Terylene, Bakelite, Melamine, PHBV, etc are copolymers. For example,

Innumerable molecules of two different types of buta-1,3-diene and styrene combine by addition polymerisation reaction to form a copolymer type of rubber, Butadiene, styrene.



Here two different types of innumerable monomers of 1,3-butadiene and styrene combine with each other by addition reaction to form polymers. Hence, it is called copolymer. Repeating unit of this copolymer formed by addition reaction is dependent on the functional group of two different monomers. Names of these copolymers are represented on the basis of two different monomer units.

(2) Condensation polymer : In polymerisation reaction, two different types of innumerable monomer units containing equally bi or tri functional groups combine with each other in equal proportion by condensation reaction to form polymer. Hence, it is called condensation polymer. This type of polymerisation reaction is known as condensation polymerisation. During this condensation polymerisation reaction; water, ammonia, alcohol or hydrogen chloride molecule is released. Certain types of repeating units in condensation polymerisation depend on functional group present in two diffirent types of monomer. Its name is given by the functional group present in repeating unit. **Polyamide** condensation polymer contains –CONH– functional group and condensation polymer containing –COO– functional group is called **polyester.** For example terylene (dacron) nylon-6, nylon-6,6 are condensation polymer substances. e.g.,

Polymerisation reaction between adipic acid and hexamethylene diamine forms a condensation polymer nylon-6,6.

$$\underset{\text{Hexamethylene-diamine}}{nNH_2{-}(CH_2)_6{-}NH_2} + \underset{\text{adipic acid}}{nHOOC{-}(CH_2)_4{-}COOH} \xrightarrow[\text{polymerisation}]{\text{condensation}}$$

$$\underset{\text{Nylon-6,6}}{\left[NH{-}(CH_2)_6{-}NH{-}CO{-}(CH_2)_4{-}CO \right]_n}$$

In above reaction hexamethylenediamine monomer, contains two similar functional groups $-NH_2$. Another monomer adipic acid possesses two similar functional group –COOH. When equal proportion (n : n) of inumerable units of two monomers are combined by chemical reaction, then nH_2O

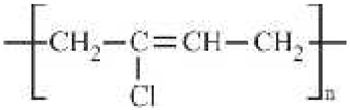
molecules are released. Due to the presence of amide (–CONH–) functional group, the obtained condensation polymer nylon-6,6 is called polyamide series polymer.

8.2.4 Classification based on molecular forces :

Polymers are used in different fields according to its characteristics. Polymers are classified by its mechanical properties, such as tensile strength, elasticity and toughness. These properties are shown with the help of intermolecular attraction forces and hydrogen bonding in polymers. Due to this attraction forces, variation is observed in long chain and branches in polymers.

It is classified on the basis of intermolecular attraction forces present in the polymer in four subcategories as under :

(1) Elastomers : This rubber is a solid substance, possessing elastic property. In elastomeric polymers, long chain of polymers are held together by weak intermolecular attraction forces. Due to weak intermolecular binding forces elastomer can be streched. A few cross linked molecules are observed in this long chain of polymers which help the polymer to retract to its original position when the force is removed. Natural rubber, Neoprene, Isoprene, Buna-S, Buna-N etc can be included in the examples of elastomers.



$$-\!\!\left[CH_2-\underset{\underset{Cl}{|}}{C}=CH-CH_2\right]\!\!-_n$$

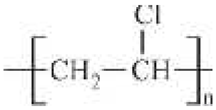
Neoprene

(2) Fibers : Those polymeric compounds which possess high tensile strength and high modulus are known as **fibers.** Because of strong intermolecular forces and hydrogen bonding, this property is seen in fibers. These strong intermolecular forces lead to close packing of long chains. As a result, crystallising property is added to it. Nylon, Terylene (polyesters) are examples of fibers.

$$-\!\!\left[NH-(CH_2)_6-NH-CO-(CH_2)_4-CO\right]\!\!-_n$$

Nylon-6,6

(3) Thermoplastic polymers : In this type of polymers slightly branched configuration is seen in long chain of huge molecule. This polymer becomes soft on heating at higher temperature than normal temperature and again becomes infusible on cooling. Its structure changes at higher temperature. In these type of polymers, intermolecular forces are more than elastomers and less than fibers. Thermoplastic polymer is soft (fusible) and less strong than thermosetting polymer. Some examples of thermoplastics are polythene, polyvinyl chloride (PVC), polystyrene etc.



$$-\!\!\left[CH_2-\overset{\overset{Cl}{|}}{CH}\right]\!\!-_n$$

Polyvinyl chloride (PVC)

(4) Thermosetting polymers : The constitution of this polymer is a large molecular structure of cross linked type of polymers, or the structure is seen like long chain containing many branches. These polymers are heated at higher temperature than normal temperature and their cross linked binding is increased, yet they do not become soft. In these polymers, even at higher temperature, there are no changes in its structure. Thermosetting polymers are hard and strong. They are resistant toward scratch. They are good insulator of electricity and heat. Bakelite and melamine are this type of polymers.

8.2.5 Classification based on growth of polymerisation reaction :

Nowadays structure of polymer molecules can be changed by changing the reaction mechanism of polymerisation. The method of polymerisation reaction can be developed by chain growth or step growth.

Types of polymerisation reactions : Mainly there are two types of polymerisation reactions : (A) Addition polymerisation or chain growth polymerisation (B) Condensation polymerisation or step growth polymerisation

(A) Addition polymerisation or chain growth polymerisation : In this type of polymerisation reaction polymer is formed by addition reaction of unsaturated monomers containing double bond combined with each other by chemical bond. Innumerable monomers containing same type of double bond or innumerable monomers containing two different types of monomers, combined with each other form a polymer. So it is called **addition polymerisation** reaction. This addition polymerisation reaction is represented in various forms based on their mechanism.

Addition homopolymerisation : Where same type of monomer, containing one or more than one double bond, are combined with each other by chemical bonding; then addition polymerisation takes place. Polythene from ethene, polypropene from propene, polystryrene from styrene, butyl rubber from isobutylene, polyvinyl chloride from vinyl chloride, polyacrylonitrile (orlon) from vinyl nitrile, polytetrafluoro ethene (Teflon) from tetrafluoro ethene etc. are the examples of polymers obtained by homopolymerisation addition reaction.

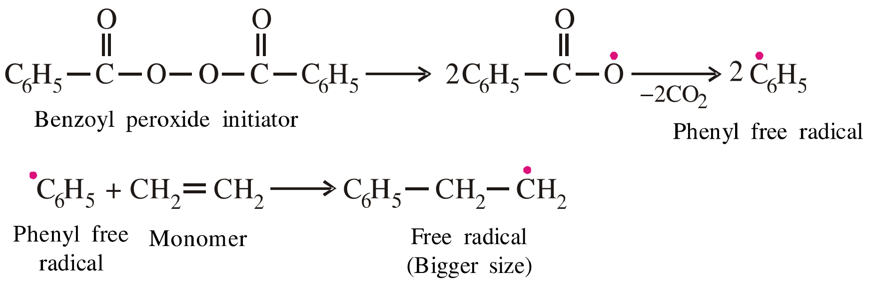
This reaction takes place by free radical or carbocation, or carbanion reactive intermediate which is produced by monomer.

Free radical addition polymerisation : Addition polymerisation reaction takes place by free radical reactive intermediate in unsaturated compounds and its derivatives, like alkene or diene.

Free radical reactive intermediate is produced by the use of initiators like benzoyl peroxide, acetyl peroxide, 3^0 butyl peroxide in the first step of this reaction with the help of proper temperature and pressure.

For example in polymerisation reaction of ethene, ethene is heated with trace amount of benzoyl peroxide as initiator at high temperature and phenyl free radical is obtained in initial stage of reaction. This phenyl free radical monomer combines with double bond of ethene molecule and forms a bigger size free radical.

First step of chain reaction :



$$C_6H_5-\overset{\overset{O}{\|}}{C}-O-O-\overset{\overset{O}{\|}}{C}-C_6H_5 \longrightarrow 2C_6H_5-\overset{\overset{O}{\|}}{C}-\dot{O} \xrightarrow[-2CO_2]{} 2\,\dot{C}_6H_5$$

$$\dot{C}_6H_5 + CH_2=CH_2 \longrightarrow C_6H_5-CH_2-\dot{C}H_2$$

This new bigger size free radical combine alternatively with many ethene molecules and at every step longer chain of new free radicals is formed.

Second step of chain reaction :

At the end, on the basis of reaction condition, long chain of free radicals combine with each other in different ways to form polythene; out of which one of the combinations is represented as below :

$$C_6H_5-CH_2-\dot{C}H_2 + CH_2=CH_2 \longrightarrow C_6H_5-CH_2-CH_2-CH_2-\dot{C}H_2$$

$$\Big\downarrow \; n\,CH_2=CH_2$$

$$C_6H_5\!-\!\!(CH_2-CH_2)_n\!-CH_2-\dot{C}H_2$$

Last step of chain reaction :

$$C_6H_5\!-\!\!(CH_2-CH_2)_n\!-CH_2-\dot{C}H_2 + C_6H_5\!-\!\!(CH_2-CH_2)_n\!-CH_2-\dot{C}H_2$$

$$\Big\downarrow$$

$$C_6H_5\!-\!\!(CH_2-CH_2)_n\!-CH_2-CH_2-CH_2-CH_2\!-\!\!(CH_2-CH_2)_n\!-C_6H_5$$

Industrial manufacturing, properties and uses of some important homo addition polymers :

(a) Polythene : According to the reaction conditions, two types of polythene can be prepared which are as under.

(i) Low Density Polythene (LDP) : Preparation : Low Density Polythene (LDP) is obtained by free radical homo addition polymerisation reaction of ethene monomer in presence of dioxygen or tertiary (3^0) butyl peroxide initiator, at 350-570 K and 1000 to 2000 bar pressure.

$$\underset{\text{Ethene}}{nCH_2=CH_2} \xrightarrow[\text{350 K to 570 K / 1000 to 2000 bar}]{\text{[Dioxygen / tertiary butyl peroxide]}} \underset{\text{Homopolymer polythene}}{\left[CH_2-CH_2\right]_n}$$

Properties :

- Low density polythene possesses branching structure.
- It is a kind of thermoplastic polymer.
- It is chemically inert.
- It is water resistant.
- It has more number of polymer molecules containing less molecular mass.
- Its boiling point and melting point are lower due to its low density.
- It is insulator towards electricity and is flexible.

Uses :

- Low density polythene is used in insulation of wires carrying electricity.
- It is useful in manufacturing of toys and packing of instruments, flexible pipes and squeeze bottles.

(ii) High Density Polythene (HDP) :

Preparation : For the preparation of high density polymer, free radical homo addition polymerisation reaction of ethene monomer in organic solvent in presence of triethyl aluminium ($(C_2H_5)_3Al$) and titanium trichloride ($TiCl_3$) or titanium tetrachloride ($TiCl_4$) (Ziegler-Natta catalyst) at 333 to 343 K temperature and under 6 to 7 bar pressure is carried out. German scientist G. Natta and Karl Ziegler were awarded the Nobel prize in 1963 for the invention of Ziegler-Natta catalyst.

$$\underset{\text{Ethene}}{nCH_2{=}CH_2} \xrightarrow[\text{333 K to 343 K, 6 to 7 bar}]{\substack{\text{Free radical homo-addition} \\ \text{polymerisation [Ziegler-Natta]}}} \underset{\text{Polythene (Homopolymer)}}{\left[CH_2-CH_2 \right]_n}$$

Properties :

- In high density polythene, the density is higher as the molecules are arranged closely packed with each other in a branch.
- It is a kind of thermoplastic polymer.
- It is chemically inert.
- It is quite hard and stronger than low density polymer.
- It has more number of molecules having higher molecular mass of polymers.
- It has higher boiling point and melting point as it has higher number of polymerisation.
- They are non-conductors of electricity.

Uses :

- High density polythene is used in preparation of unbreakable instruments.
- Buckets, dustbins, bottles and pipes are manufactured from it.

(b) Polytetrafluoroethene (Teflon) PTFE :

Preparation : On heating tetrafluoro ethene, teflon is obtained by the homo addition polymerisation reaction at high pressure and in presence of free radical or persulphate catalyst.

$$\underset{\substack{\text{Tetrafluoro} \\ \text{ethane}}}{nCF_2{=}CF_2} \xrightarrow[\Delta\text{, and High temperature}]{\substack{\text{Free radical addition polymerisation} \\ \text{[Free radical or persulphate catalyst]}}} \underset{\text{Teflon}}{\left[CF_2-CF_2 \right]_n}$$

Properties :

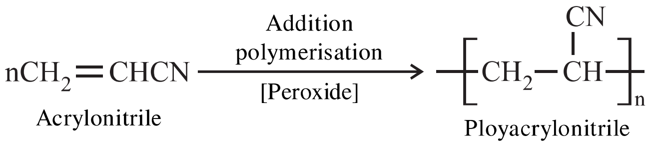
- Teflon is chemically inert.
- It is resistant towards corrosion.
- Teflon can bear high temperature so it is a type of thermoplastic and in some cases it is thermosetting.
- Teflon coating gets decomposed at temperature higher than 573 K.

Uses :

- It is used as lubricant in machines to resist scratching.
- It is used in making instruments for insulation of electricity.
- Teflon is used in munufacturing of seat and gasket.
- Teflon is used in manufacturing of non-stick kitchen vessels and tensile surface.

(c) Polyacrylonitrile (Orlon) PAN :

Preparation : Polyacrylonitrile polymer is obtained by addition polymerisation reaction of acrylonitrile monomer in presence of peroxide catalyst.



$$nCH_2{=}CHCN \xrightarrow[\text{[Peroxide]}]{\text{Addition polymerisation}} \left[CH_2-\overset{\overset{\large CN}{|}}{CH} \right]_n$$

Acrylonitrile

Ployacrylonitrile

Properties :

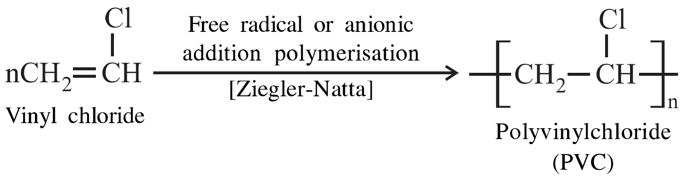
- Orlon is a branched polymer.
- It behaves like linear polymer such as natural rubber.
- It is a type of thermoplastic polymer.
- It is chemically inert.
- Acrylic fibers made out of it have good tensile strength. There is no effect of fungi and micro insects on it.

Uses :

- It is useful in making synthetic wool as a substitute of natural wool.
- Used in preparation of synthetic fibers.
- Used in making of acrylic fibers.

(d) Polyvinyl chloride (PVC)

Preparation : Polyvinyl chloride is formed by free radical addition polymerisation reaction of vinyl chloride monomer in presence of triethyl aluminium and titanium trichloride or titanium tetrachloride (Ziegler-Natta) catalyst. If reaction condition changes then ionic reactive intermediate is formed from vinyl chloride monomer. As a result polyvinyl chloride is obtained by addition polymerisation reaction.



$$nCH_2{=}\overset{\overset{\large Cl}{|}}{CH} \xrightarrow[\text{[Ziegler-Natta]}]{\text{Free radical or anionic addition polymerisation}} \left[CH_2-\overset{\overset{\large Cl}{|}}{CH} \right]_n$$

Vinyl chloride

Polyvinylchloride (PVC)

Properties :

- PVC is a branched polymer.
- It is a kind of thermoplastic polymer.
- It is water resistant.

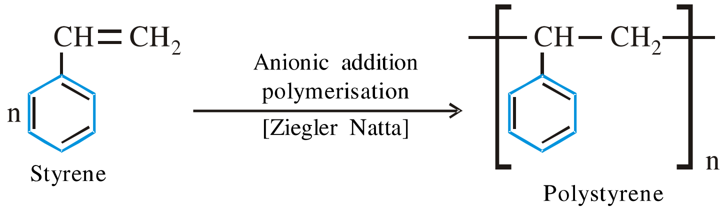
- It is resistant towards electricity.
- It is chemically inert.
- It is stronger than polythene.

Uses :

- As it is water resistant, it is useful in making rain coats, carpets, purses, etc.
- PVC is useful in making pipes, bottles, ragzin footware.

(e) Polystryrene :

Preparation : Polystyrene polymer is obtained by anionic addition polymerisation reaction of stryrene monomer in presence of triethyl aluminium and titanium trichloride titanium or tetrachloride (Ziegler-Natta) catalyst.



Properties :

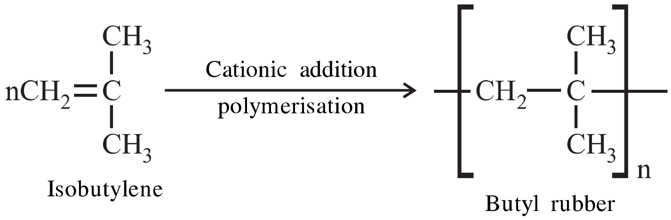
- Polystyrene is a branched polymer.
- It is a kind of thermoplastic polymer.
- It is chemically inert.
- It is lighter in weight than polythene.
- It is heat resistant and non-conductor of electricity.

Uses :

- Polystyrene is used in making cabinets of radio, friedge and T.V.
- Polystyrene is useful in making utensils as non-conductor of heat such as hot water conducting pipes, buckets, bottles etc.

(f) Butyl Rubber :

Preparation : Butyl rubber is obtained by cationic addition polymerisation reaction of iso-butylene monomer.



$$nCH_2=C(CH_3)_2 \xrightarrow[\text{polymerisation}]{\text{Cationic addition}} \left[CH_2-C(CH_3)_2 \right]_n$$

Properties :

- Butyl rubber is a branched polymer.
- It is a kind of thermoplastic polymer.

- It has a characteristic of more elasticity than natural rubber.
- It is inert towards water.

Uses :

- It is used in place of natural rubber.

Addition Copolymerisation : When polymer substance is formed by addition reaction, when two different types of monmers combine alternatively with each other, by chemical bond, then copolymer substance is formed. This reaction is called addition copolymerisation reaction. Copolymer styrene butadiene rubber is obtained from styrene and butadiene monomer whereas nitrile rubber is obtained from acrylonitrile and butadiene are polymers.

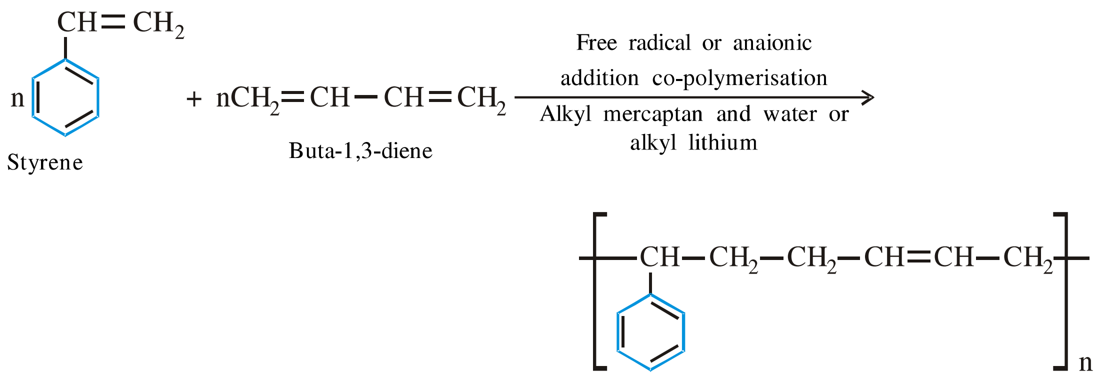
Industrial manufacturing, properties and uses of some important additon copolymer substances :

(a) Styrene Butadiene Rubber (Buna-S), SBR

Preparation : By addition reaction of two monomers-styrene and butadiene combined one by one with each other by chemical bond, styrene butadiene rubber forms a series of copolymers. Two types of products are obtained by this reaction.

(1) If addition reaction takes place between styrene and butadiene with free radical reactive intermediate alkyl mercaptan and water, then mercaptan controls the molecular mass of polymer and forms a small size and high viscosity molecules of polymer. As a result emulsion type of styrene butadiene rubber is obtained.

(2) If addition reaction takes place between styrene and butadiene at higher pressure in presence of ionic intermediate alkyl lithium and in absence of water, then ionic addition polymerisation reaction takes place where more styrene molecules combine and higher molecular mass containing hard and less flexible solution type of styrene butadiene rubber is obtained.



Styrene butadiene rubber

Properties :

- It is a synthetic rubber.
- Buna-S is reactive towards oil, waste water and ozone.
- It possesses higher viscosity than natural rubber.
- It possess high tensile strength and strong extensive property.

- Strong intermolecular H-bonding exists between their molecules.
- At higher temperature, it maintains its elastic character.
- It has higher electric capacity.

Uses :

- Its elastomer form is used in chewinggum, rubber coating and paints.
- Its solution form is used in tyres, shoes sole, gaskets etc.

(B) Condensation polymerisation or step growth polymerisation : In this type of polymerisation condensation reaction repeatedly takes place between two different types of monomers possessing two similar functional groups. As a result of this condensation polymerisation reaction, simple molecules such as water, ammonia or alcohol are removed and condensation polymer containing high molecular mass is obtained.

In condensation polymerisation reaction, repeating unit obtained in first step again reacts with bifunctional species in the second step and forms a new repeating unit. These repeating units formed possess different functional groups; then the functional group in both monomers in each step, and these repeating unit are independent from each other. Hence, this polymerisation is also called as step growth polymerisation as there is addition of repeating units.

Polymers obtained from the condensation polymerisation reaction are classified on the basis of their functional groups in repeating unit. If there is –CONH– group in repeating unit then it is called polyamide and if there is –COO– group in repeating unit, then it is called polyester. Some examples of condensation polymers are as under :

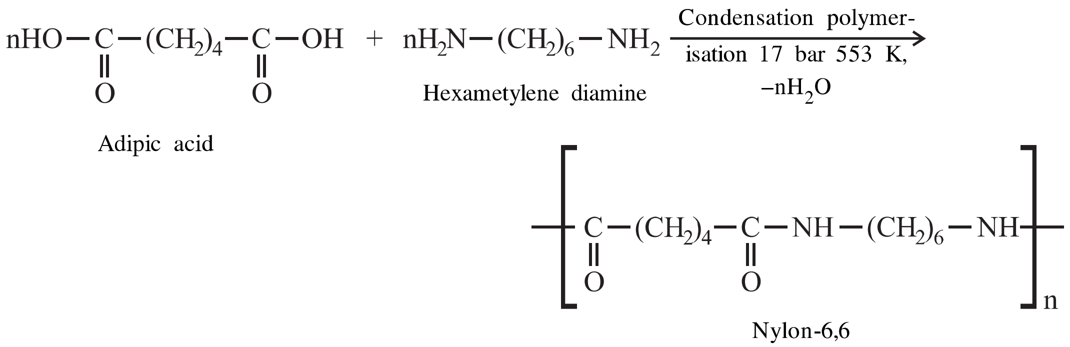
Industrial preparation, properties and uses of some important condensation polymers :

(a) Nylon 6,6 :

Preparation : Two monomers used in preparation of nylon 6,6 are (i) adipic acid containing two –COOH– functional groups and (ii) hexamethylene diamine containing two $-NH_2$ functional groups.

By condensation polymerisation reaction of mixture of two different monomers. adipic acid and hexamethylene diamine at 17 bar pressure and 553 K temperature by heating in closed vessels and on release of water molecule, Nylon-6,6 is obtained.

It is a series of polyamide polymer due to –CONH– amide group in repeating unit of nylon-6,6, and repeating units of nylon-6,6 contain 6 carbon of adipic acid and 6 carbon of hexamethylene diamine, therefore it is called nylon-6,6.



$$n\,HO-\underset{\underset{O}{\|}}{C}-(CH_2)_4-\underset{\underset{O}{\|}}{C}-OH + n\,H_2N-(CH_2)_6-NH_2 \xrightarrow[\text{isation 17 bar 553 K, } -nH_2O]{\text{Condensation polymer-}} \left[\underset{\underset{O}{\|}}{C}-(CH_2)_4-\underset{\underset{O}{\|}}{C}-NH-(CH_2)_6-NH\right]_n$$

Properties :

- Nylon-6,6 is the chief polymer of polyamide class.
- Nylon-6,6 is a linear polymer.
- –CONH– amide group is a repeating unit of nylon-6,6.
- Nylon-6,6 is a kind of thermoplasitc polymer.
- Fibers of Nylon-6,6 are hard, strong elastic and water resistant.

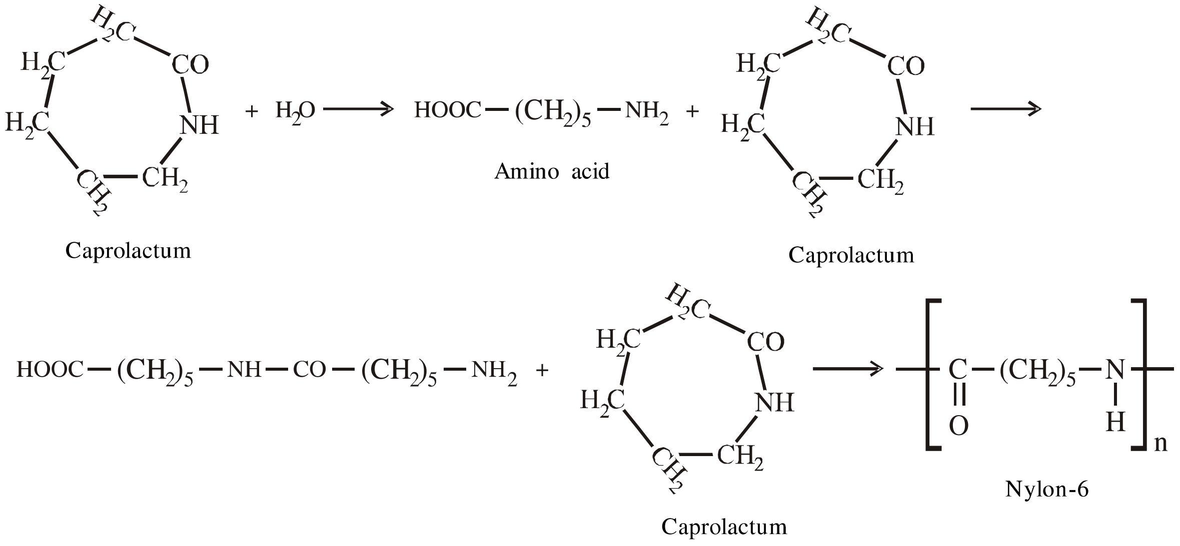
Uses :

- It is used in textile industry, preparation of fishing net, ropes and tyre industries.

(b) Nylon-6 :

Industrial preparation : On hydrolysis of one molecule of caprolactum in presence of water gives an amino acid, which reacts one by one with other caprolactum molecules by self condensation polymerisation reaction giving nylon-6.

The repeating unit of polymer nylon 6 is monomer caprolactum which contains 6 carbon atoms, therefore it is called nylon 6.



Properties :

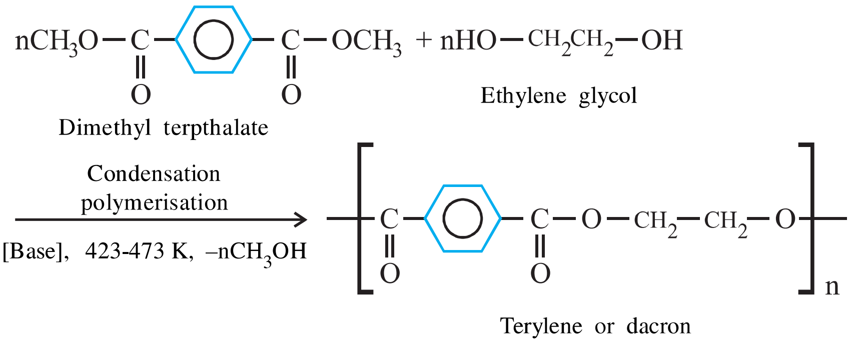
- It is the chief polymer of polyamide class.
- +CONH+ amide is repeating unit in Nylon-6
- The fibers of Nylon-6 are insoluble in common solvents and are very strong.
- It is a linear polymer.
- It is a kind of thermoplastic polymer.

Uses :

- It is useful in carpet, ropes and tyre industries.

(c) Terylene (Dacron) :

Industrial Preparation : The mixture of two different monomers dimethyl terpthalate and ethylene glycol on heating in presence of basic catalyst at 423 to 473 K temperature, by condensation polymerisation reaction gives terylene or dacron.



Properties :

- It is the chief polymer of polyester group.
- Terylene is a linear polymer.
- (–COO–) ester is a repeating unit in terylene
- Terylene is a kind of thermoplastic polymer.
- Fibers of terylene are less elastic than nylon fibers.

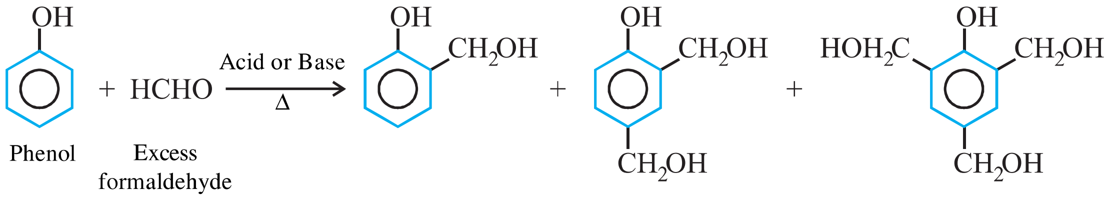
Uses :

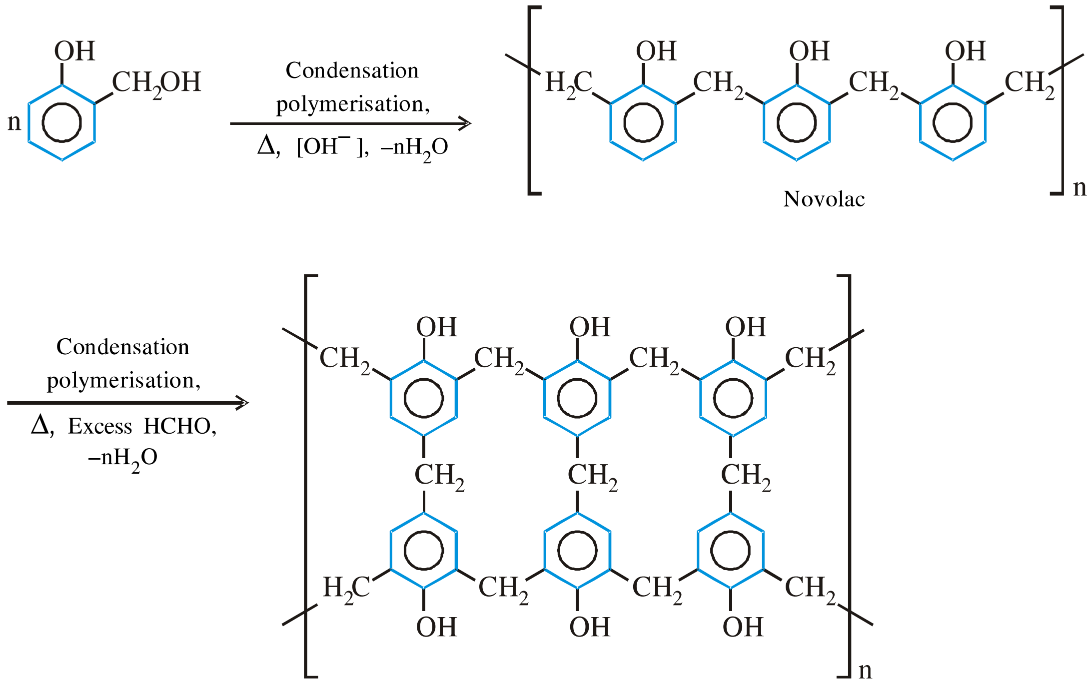
- In textile industries.
- In preparation of rope.

(d) Bakelite :

Industrial preparation :

- The mixture of phenol and formaldehyde on heating in presence of acid or base catalyst, the condensation polymerisation reaction takes place in ortho and para positions and Bakelite is obtained.
- In the begining reaction of phenol with excess formaldehyde takes place and ortho and para hydroxy methyl derivatives are obtained.
- In the begining Novolac linear polymer obtained by polymerisation reaction of hydroxy methyl phenol which on heating at higher temperature with excess of formaldehyde, the condensation takes place in p-position of Novolac and gives Bakelite.





Bakelite (cross linked polymer)

Properties :

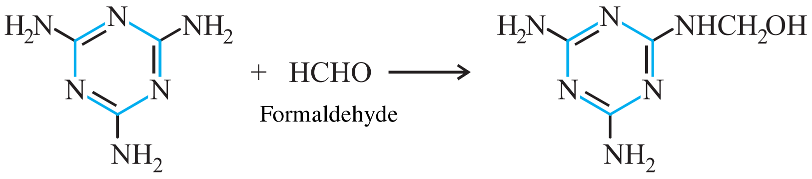
- Bakelite is a synthetic polymer of phenol formaldehyde class.
- It is a cross-linked polymer.
- It is a kind of thermosetting polymer.
- Bakelite does not fuse even on heating.
- It is water resistant, hard, brittle and scratch resistant.
- As it is brittle it cracks or breaks on striking or dropping.
- It possesses very good property as non-conductor of electricity.

Uses :

- It is used in making combs, gramophone records, handles of kitchenware and electrical appliances like plug, pin, switches.

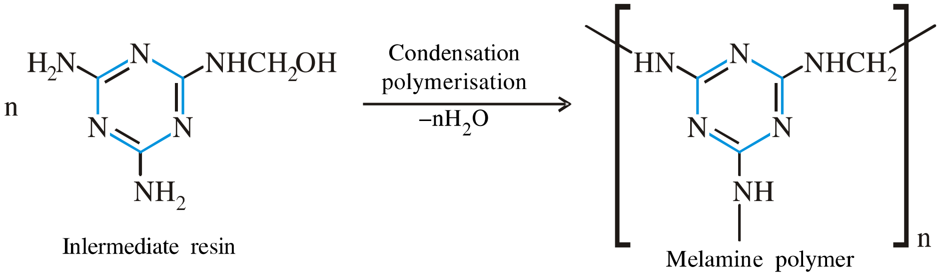
(e) Melamine :

Preparation : Melamine polymer is formed by condensation polymerisation reaction of melamine and formaldehyde on heating.



Melamine

Intermediate resin



Inlermediate resin

Melamine polymer

Properties :

- Melamine is synthetic polymer of formaldehyde class.
- It is a kind of thermosetting polymer.
- It is a cross linked polymer.
- It is hard and strong.
- It does not fuse or its structure does not change at higher temperature.
- It is resistant towards scratching.
- The melamine appliances do not crack or break on striking or dropping.

Uses :

- Melamine is useful in preparation of unbreakable crokery.

8.3 Rubber

Rubber is available in three forms : (1) Natural rubber (2) Vulcanised rubber and (3) Synthetic rubber.

8.3.1 Natural rubber :

Structure :

- Rubber trees are found in forests of India, Sri-Lanka, Indonesia, Malaysia and South Africa.
- By making incision in the trunk of rubber trees, the colloidal suspension of milky rubber in water, called latex is obtained. The natural rubber is obtained by physical and chemical processes.
- Natural rubber is linear polymer of isoprene monomer.
- Isoprene (2-methyl buta-1,3-diene) is also called a 1,4-polyisoprene.
- Its geometrical isomerism is cis due to which it is called cis-1,4-polyisoprene.
- During polymerisation reaction of innumerable molecules of isoprene monomers C1 = C2 and C3 = C4 breaks and bond between C2 = C3 is formed. Hence there is double bond between C2 = C3 in its repeating unit.
- Linear molecules of cis-1,4-polyisoprene are held together by weak van der Waals interaction forces and has a coiled structure. As a result, in natural polymer, elastic property is observed.