15 Polymers

LESSON AT A GLANCE

- **Polymers:** Polymers are high molecular masses macromolecules which consist of repeating structural units derived from the corresponding monomers. Example—Polythene, nylon 6, 6, rubber etc.
- **Addition polymerisation:** It is a polymerisation in which monomers, having one or more double bonds undergo repeated addition in a chain fashion in presence of an initiator to form a polymer. Example—Polythene, teflon, orlon etc.
- **Condensation polymerisation:** It occurs when monomers condense in a stepwise manner with or without elimination of water. The reaction proceeds by multifunctional group. Example—Nylon, bakelite, dacron etc.
- **Co-polymerisation:** A mixture of two unsaturated monomers exhibits co-polymerisation and form a copolymer containing multiple units of each monomer.
- **Natural rubber:** It is a cis 1, 4-poly-isoprene and can be made more tough by the process of vulcanization with sulphur.
- **Synthetic rubber:** It is usually obtained by copolymerisation of alkene and 1, 3 butadiene derivatives.
- **Biodegradable polymers:** PHBV and Nylon-2-Nylon-6.
- **Monomers:** Molecules that join with others in forming a dimer, trimer, or polymer. The repeating structural units are derived from some simple and reaction molecules are known as monomers. They are linked to each other by covalent bonds.
- **Polymers or (macro molecules):** A substance having large molecules consisting of repeated units (the monomers).

There are a number of natural polymers. Such as polysaccharides. Polymers do not have a definite formula since they consist of chains of different lengths. There are very high molecular mass ($10^3 - 10^7 u$) substances each molecule of which consists of a very large number of simple repeating structural units joined together through covalent bonds in a regular fashion.

- **Polymerisation.** The process by which simple molecules (monomers) are converted in polymer is called polymerisation.
- **Homopolymers.** Polymers whose repeating structural units are derived from only one type of monomer units are called homopolymers. For example, in case of polyethene (polyethylene) polymer which is obtained by polymerisation of ethene (ethylene) molecules, the repeating structural units, *i.e.* — $CH_2 - CH_2$ — is derived from only one type of monomer, *i.e.* ethene.
- **Copolymers.** Polymers whose repeating structural units are derived from two or more types of monomer units are called copolymers.

TEXTBOOK QUESTIONS SOLVED

15.1 *Explain the terms polymer and monomer.*

Ans. A polymer is a very big molecule which is made up of large number of smaller molecules. Such smaller molecules which join to form a polymer are known as monomers.

15.2 *What are natural and synthetic polymers? Give two examples of each type.*

Ans. Polymers which are obtained from natural sources (animals and plants) are classified as natural polymers. Some of the natural polymers are vital to our existence such as starch, cellulose, proteins and nucleic acids, etc. Polymers which are synthesised from monomers in the laboratory or industry are called synthetic or man-made polymers, *e.g.*, polyethylene, nylon, teflon, etc.

15.3 *Distinguish between the terms homopolymer and copolymer and give an example of each.*

Ans. When there is only one monomer unit which repeats itself in the polymer, such polymers are called homopolymers, *e.g.*, PVC, teflon, etc. Those polymers are called copolymers which

are formed by the combination of two or more types of monomers, *e.g.*, bakelite, nylon-66, etc.

15.4 *How do you explain the functionality of a monomer?*

Ans. The number of binding sites available in a monomer is called its functionality. For example, the functionality of ethene is one and that of adipic acid is two.

15.5 *Define the term polymerisation.*

Ans. Polymerisation is defined as the process in which a large number of monomers combine to form a molecule of very high molecular mass, called a polymer.

15.6 *Is $(NH—CHR—CO)_n$, a homopolymer or copolymer?*

Ans. This polymer is a homopolymer because the repeating structural unit is same. (Provided that R is same alkyl or aryl group in all monomer units).

15.7 *In which classes, the polymers are classified on the basis of molecular forces?*

Ans. On the basis of molecular forces, the polymers are classified as elastomers, fibres and plastics.

15.8 *How can you differentiate between addition and condensation polymerisations?*

Ans. In addition polymerisation, the monomers add to one another in such a way that the polymer contains all the atoms of the starting monomers. Addition polymerisation geneally occurs among molecules containing double or triple bonds. For example, the polymerisation of ethylene to polyethylene.

In condensation polymerisation, the monomer units combine with the elimination of small molecules like water, methanol, ammonia, etc. For example, the formation of nylon-66 is a condensation polymerisation.

15.9 *Explain the term copolymerisation and give two examples.*

Ans. Copolymerisation is a process which involves the combination of two or more types of monomers and the polymer, thus formed is known as a copolymer. For example, Buna-S is a copolymer of 1,3-butadiene and styrene.

15.10 *Write the free radical mechanism for the polymerisation of ethene.*

Ans. Free radical polymerisation of ethene is initiated by an initiator. The initiators are molecules which decompose to provide radicals. These radicals add to a monomer molecule

to form a free radical of larger size. This constitutes the chain initiating step.

$$\text{Initiator} \longrightarrow \text{Rad}^{\bullet}$$

$$\text{Rad}^{\bullet} + CH_2 = CH_2 \longrightarrow \text{Rad} - CH_2 - \dot{C}H_2$$

The radical so formed combines with another molecule of ethene to form still bigger radical and chain continues. These steps constitute the chain propagating steps.

$$\text{Rad} - CH_2 - \dot{C}H_2 + CH_2 = CH_2 \rightarrow \text{Rad} - CH_2 - CH_2 - CH_2 - \dot{C}H_2 \rightarrow \text{Rad} - (CH_2 - CH_2)_n - CH_2 - \dot{C}H_2$$

These chains terminate ultimately by the combination or disproportionation of two such large radicals.

Combination

$$2\,\text{Rad} - (CH_2 - CH_2)_n - CH_2 - \dot{C}H_2 \rightarrow \text{Rad} - (CH_2 - CH_2)_m \text{Rad}$$

Disproportionation

$$2\,\text{Rad} - (CH_2 - CH_2)_n - CH_2 - \dot{C}H_2 \rightarrow \text{Rad} - (CH_2 - CH_2)_n - CH = CH_2 + \text{Rad} - (CH_2 - CH_2)_n - CH_2 - CH_3$$

15.11 *Define thermoplastics and thermosetting polymers with two examples of each.*

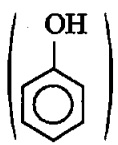
Ans. Thermoplastics are normally linear polymers in which the forces of attraction between the polymer chains are in between those of elastomers and fibres. They soften on heating and become fluid and on cooling they become hard, so they can be easily moulded into desired shapes. The common examples are polythene, polypropene, PVC, etc.

Thermosetting polymers are space-network polymers. These are highly cross-linked to form a rigid but irregular three-dimensional structure. These cannot be reused or reshaped beccause they do not soften on heating. Examples are bakelite, urea-formaldehyde resins, etc.

15.12 *Write the monomers used for getting the following polymers: (i) Polyvinyl chloride (ii) Teflon (iii) Bakelite*

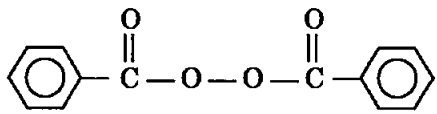
Ans. (*i*) Vinyl chloride ($H_2C = CH - Cl$)

(*ii*) Tetrafluoroethene ($F_2C = CF_2$)

(*iii*) Phenol  and formaldehyde (HCHO)

15.13 *Write the name and structure of one of the common initiators used in free radical addition polymerisation.*

Ans. One of the commonly used initiators is benzoyl peroxide.



15.14 *How does the presence of double bonds in rubber molecules influence their structure and reactivity?*

Ans. In rubber molecules, all the double bonds have *cis* configuration so the chains are not able to come close enough for effective attraction. Due to the same reason, the rubber does not exist as straight chain but has a coiled structure. Hence, the rubber can be stretched like a spring which makes it valuable for a variety of uses.

Presence of double bonds also makes rubber more reactive. It is attacked by the oxidising agents and dissolves in polar solvents. It also has a large capacity to absorb water. Although these problems are overcome by the process of vulcanisation in which rubber is treated with sulphur.

15.15 *Discuss the main purpose of vulcanisation of rubber.*

Ans. Natural rubber is very soft but it becomes hard when heated with sulphur. This process is known as vulcanisation.

Reaction of sulphur with rubber causes cross-linking of polymer chains through disulphide bonds. Thus, the individual chains which are entangled together in the rubber now get together into a giant molecule. Cross-linking prevents the polymer from being torn when it is stretched. So the vulcanised rubber has excellent elasticity, low water absorption tendency, resistance to oxidation and organic solvents.

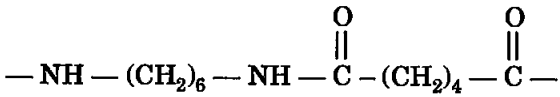
15.16 *What are the monomeric repeating units of Nylon-6 and Nylon-6,6?*

Ans. The monomer repeating unit of nylon-6 is

$$-\mathrm{NH}-(\mathrm{CH_2})_5-\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}-$$

which is obtained from caprolactam.

The repeating unit of nylon-6, 6 is



which is obtained from two monomers viz. adipic acid and hexamethylenediamine.

15.17 *Write the names and structures of the monomers of the following polymers:*

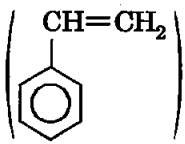
(i) Buna-S

(ii) Buna-N

(iii) Dacron

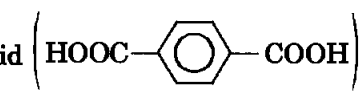
(iv) Neoprene

Ans. (*i*) 1,3-Butadiene ($CH_2 = CH - CH = CH_2$) and styrene



(*ii*) 1,3-Butadiene ($CH_2 = CH - CH = CH_2$) and acrylonitrile ($CH_2 = CH - CN$)

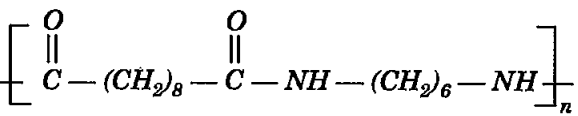
(*iii*) Ethane-1,2-diol ($HO - CH_2 - CH_2 - OH$) and terephthalic acid



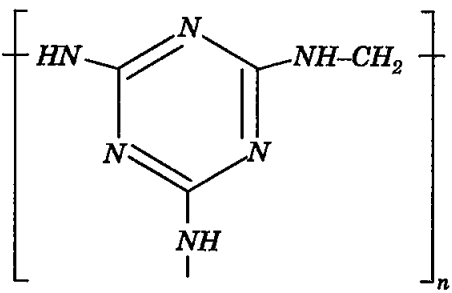
(*iv*) 2-chloro-1,3-butadiene ($CH_2 = \underset{\displaystyle Cl}{\underset{|}{C}} - CH = CH_2$). It is also known as chloroprene.

15.18 *Identify the monomer in the following polymeric structures.*

(*i*)

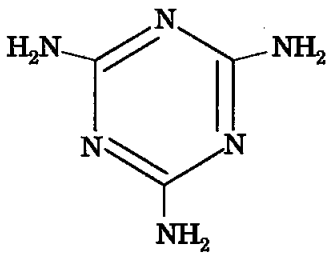


(*ii*)



Ans. (*i*) Decanoic acid ($HOOC - (CH_2)_8 - COOH$) and hexamethylene-diamine ($H_2N - (CH_2)_6 - NH_2$).

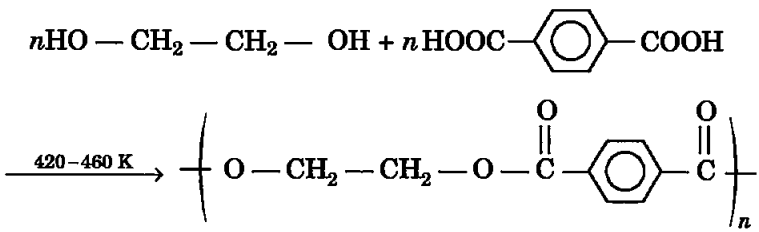
(*ii*) Melamine



and formaldehyde (HCHO).

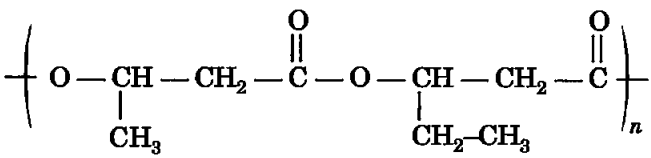
15.19 *How is dacron obtained from ethylene glycol and terephthalic acid?*

Ans. Dacron is a polymer of ethylene glycol and terephthalic acid. It is obtained by the condensation polymerisation of these two monomers with the loss of water molecules.



15.20 *What is a biodegradable polymer? Give an example of a biodegradable aliphatic polyester.*

Ans. Polymers which degrade in the environment with time are called biodegradable polymers. One example of a biodegradable aliphatic polyester is poly-β-hydroxybutyrate-co-β-hydroxyvalerate (PHBV)



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