

UNIT – V

ENGINEERING MATERIALS

3.5 ALUMINIUM:

Aluminium is the most abundant metal in the earth's crust and is obtained mainly from bauxite. Its resistance to corrosion, lightness, and strength have led to widespread use in domestic utensils, engineering parts, and aircraft construction. It is a silver white metal. Aluminium alloy elements are Si, Mg, Cu, Ni, Zn, Mn, Fe and Ti.

Composition:

Zinc → 12.5% to 14.5% Copper → 2.5 % to 3% Nickel → upto 1% Magnesium → 3%
Remaining → Aluminium.

Properties:

Light weight.

High thermal conductivity.

Good corrosion resistance.

Soft and ductile.

Low specific gravity.

Good tensile strength.

Non – magnetic.

Good formability.

It is brittle.

Application:

Making Aero plane parts, house hold items, electric wires, furniture, surgical Instruments.
Chemical plants, food processing equipment.

3.17 AL – CU ALLOYS (ALUMINIUM – COPPER ALLOYS):

They are :

1. Wrought alloy (Duralumin).
2. γ - alloy (cast alloy).

1. Wrought alloy (Duralumin) :

Duralumin is a hard, light alloy of aluminium with copper and other elements.

Composition:

Copper (Cu) \rightarrow 3.5 to 4.5 %, Manganese (Mg) \rightarrow 0.4 to 0.7%, Magnesium (Mn) \rightarrow 0.4 to 0.7%, Remaining \rightarrow Aluminium 94.5%.

Properties:

- Good strength after age hardening.
- Good mechanical properties.
- Good corrosion resistance.
- High shock resisting.

Applications:

Aircraft industry, Automobile industry, Surgical Instruments.

2. γ - alloy (Cast alloy) :

γ alloy is a nickel-containing aluminium alloy.

Composition:

Al \rightarrow 92.5% Cu \rightarrow 4% Ni \rightarrow 2% Mg \rightarrow 1.5%.

Properties:

- High strength.
- Low thermal expansion.
- High corrosion resistance.
- It can be easily cast and rolled.

Application:

Pistons, cylinder heads of I.C engines, gearbox, blade etc.

3.18 AGE HARDENING (OR) PRECIPITATION HARDENING:

The strength and hardness of non-ferrous alloys may be increased by the formation of small particles within the original solid solution. They are refined and distributed uniformly throughout the matrix by heat treatment. This process is called as Age hardening. Age hardening is also used to mention this because there is a increase in hardness at room temperature.

They are three stages:

Solution heat treatment

Quenching

Aging

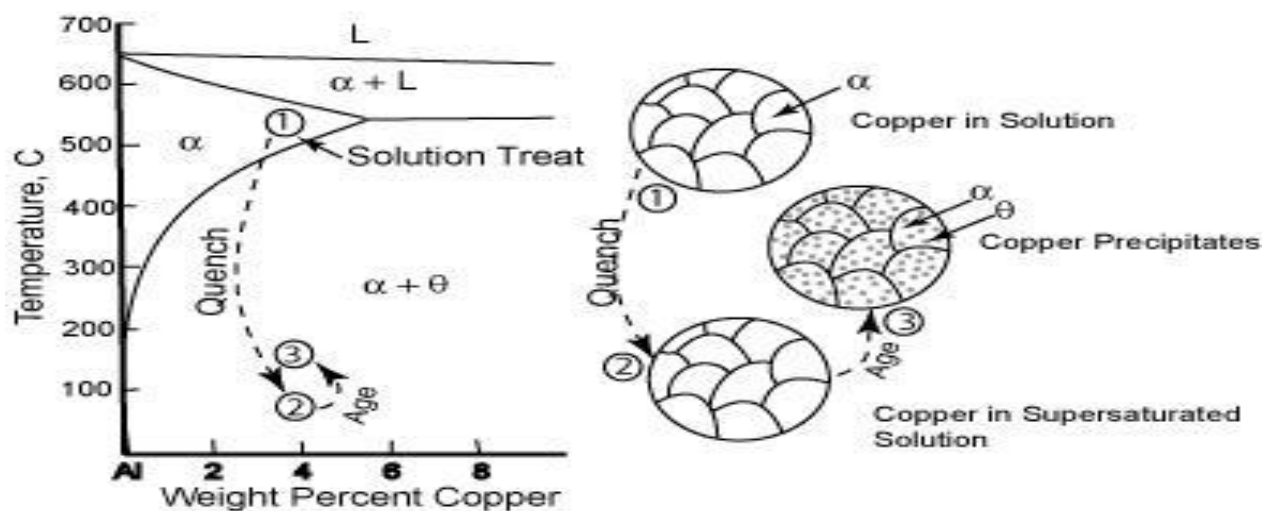


Fig 3.1 Precipitation hardening

Examples of alloys that are age hardened by Aluminum – copper, copper – Beryllium, Copper – tin and Magnesium – Aluminum. The phase diagram of Al – Cu alloy. The Maximum solubility of Cu is 5.65% at 548°C. The solubility of Cu goes on decreasing with decreasing temperature.

(a) Solution heat treatment:

The alloy is heated above the solvus line at around 500°C. It is soaked at this temperature for sufficient time such that the α phase dissolves to form a homogeneous α solid solution.

(b) Quenching:

The heated alloy is rapidly cooled in water to around room temperature. The micro structure obtained is super-saturated (α_{ss}). α_{ss} contains excess Cu in the Al – base Matrix and hence is not a stable phase.

(c) Aging:

The Unstable super – saturated solid solution (α_{ss}) is heated below the solvus temperature. After sufficient time period at aging temperature, following structural change occurs:

unstable	stable	CuAl ₂
Super saturated →	Saturated +	Age hardenings
(α_{ss})	(α)	(θ)

The CuAl₂ (θ) Aluminium alloy elements are Si, Mg, Cu, Ni, Zn, Mn, Fe and Ti. Age is hard and thus provides hardness and strength to the Al – Cu alloy system.

3.19 BEARING ALLOYS:

They are anti-Friction alloys.

Properties:

- It should be hard to provide longer life.
- High wear resistance.
- High compressive strength.
- High fatigue strength.

Good plasticity.
High thermal conductivity.
High corrosion resistance.
Good machinability.
Low melting point.

Types of bearing alloys:

White metal alloys (Babbitts)

(a) Tin based bearing alloys.

(b) Lead based bearing alloys.

Copper – lead alloys.

Aluminium alloys.

Silver – lead alloys.

Gray cast iron.

Porous self lubricating bearing.

Non – Metallic bearing.

White metal alloys (Babbitts) :

(a) Tin based bearing alloys:

Sn → 90%, Sb → 5%, Cu → 5%.

Applications:

steam turbines, turbo–supercharger.

(b) Lead based bearing alloys:

Pb → 80%, Sn → 10%, Sn → 10%.

Applications:

I.C engine, lathe and milling machines, fans, electric motors.

2. Copper – lead alloys:-

Pb → 20 to 40%, Cu → 60 to 80%.

Applications:

Automobile and aircraft industry.

3. Aluminum alloys:

It contains alloying elements such as Sn, Cu, Ni, Fe, Si and Mn.

Applications:

Connecting rod and main bearings of engine.

4. Silver – lead alloy:

Plated with silver and coating of Lead.

Applications:

Heavy load bearings for air craft industry.

5. Grey cast iron :

C → 3 to 4%, Fe → 91%, remaining → Si, S, P, Mn.

Applications:

Bearings for refrigerators, compressors, railways coaches etc.

6. Porous self – lubricating Bearing:

Copper – Based (Cu → 90%, Sn → 10%).

Iron – Based (Fe → 96%, C → 4%).

Applications:

Food, paper and textile industry.

7. Non – metallic bearing:

Teflon (Poly tetra fluoroethylene), nylon, graphite, Molybdenum disulphide.

Applications:

Food, paper and textile industry.

Bearing are classified as:

- 1.Sliding bearing.
- 2.Rolling bearing.
- 3.Thrust bearing.

3.20 MAGNESIUM ALLOYS (Mg – Alloys):

Magnesium alloys are mixtures of magnesium with other metals (called an alloy), often aluminum, zinc, manganese, silicon, copper, rare earths and zirconium. Magnesium is the lightest structural metal. Magnesium alloys have a hexagonal lattice structure, which affects the fundamental properties of these alloys.

Composition:

Al → 94.5%, Mg → 5%, Mn → 0.5 %.

Properties:

- High corrosion resistance.
- Good Mach inability.
- Poor cast ability.
- Better finish.

Applications:

Marine, Aircraft, automobile components, Dairy equipment, Architectural work.

3.21 NICKEL ALLOYS (NI ALLOYS) :

Nickel alloys are alloys with nickel as principal element. Complete solid solubility exists between nickel and copper. Wide solubility ranges between iron, chromium, and nickel make possible many alloy combinations.

Properties:

It has F.C.C. structure.

Good ductility.

Good corrosion resistance.

Good electrical conductivity.

Better formability.

High tensile strength.

Applications:

It is used for electroplating.

It is used in production of stainless steel, nickel alloys, permanent Magnets etc.

It is used in radio industries and lamp.

It is used as thermocouple Material.

Low current electrical applications..

Types of Nickel Alloys:

1, Monel Metal → 68% Ni, 30% Cu, 1% Fe, 1% Mn.

Invar → Ni 36%, Fe 64%.

Inconel → Ni 77%, Cr 15%, Fe 8%.

Nichrome → 80% Ni, 20% Cr.

Constantine → Ni 45%, Cu 55%.

Hastelloy A → Ni 57%, Mo 20%, Fe 20%.

3.22 SUPER ALLOYS:

A super alloy, or high-performance alloy, is an alloy that exhibits several key characteristics: excellent mechanical strength, resistance to thermal creep deformation, good surface stability, and resistance to corrosion or oxidation.

Properties:

High hardness and strength.

High wear resistance.

High creep resistance.

High oxidation resistance.

3.23 TITANIUM ALLOYS:

Titanium alloys are metals that contain a mixture of titanium and other chemical elements. Such alloys have very high tensile strength and toughness. They are light in weight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures. It is a highest carbide of all the alloying elements. It improves hardenability. It is added to stainless steels.

Properties:

Light weight and strong.

High corrosion resistant.

High strength to weight ratio.

High Melting point.

Low thermal conductivity.

Low thermal coefficient of expansion.

Good weld ability and formability.

Applications:

Valves, tanks, pipe, aircraft parts, steam turbine, sheet metal parts, forgings.

Types of Titanium alloys:

1. Alpha alloys.

2. Beta alloys.

3. Alpha and beta alloys.

1. Alpha alloys :

Ti → 92%, Al → 5%, Sn → 2.5%.

2. Beta alloys:

Ti → 73%, Al → 3%, V → 13%, Cr → 11%.

3. Alpha – Beta Alloys:-

Ti → 90%, Al → 6%, V → 4%.

3.24 HIGH SPEED TOOL STEELS (H.S.S) :

High-speed tool steels are so named primarily because of their ability to machine materials at high cutting speeds. High speed steel has unusually high resistance to softening at temperatures up to 600°C. It is called, red hardness. It is known as Tungsten High speed Tool steel.

Composition:

C → 0.7%, W → 18%, Cr → 4%, V → 1%

Properties:

High hardness.

High wear resistance.

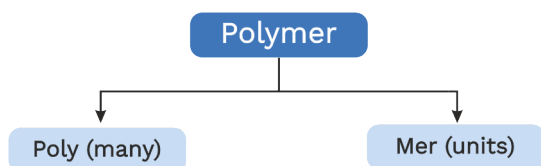
High cutting ability.

Temperature upto 600⁰C

Applications:

Cutting tools, dies, blanking tools, gears.

Polymers



Definition

Polymers which are obtained from animal and plants are known as natural polymers.

Macromolecules

- Individual molecule of very high molecular weight. e.g., Hemoglobin, Chlorophyll etc.

Monomer

- Monomer is the molecule that forms the basic unit for Polymer. e.g., Propene, Styrene, Vinyl chloride etc.

Polymer

- Natural, semisynthetic and synthetic compounds consisting of number of molecules (monomers) called Polymer. e.g., Polypropene, Polystyrene, PVC, Nylon-6 etc.

Concept Ladder



The number of monomers which are joined together in a polymer constitutes the degree of polymerization.

Classification of Polymers

Based upon source	Based upon Structure	Based upon Molecular Force	Based upon Polymerization
Natural	Linear	Elastomers	Addition polymers
Semisynthetic	Branched	Fibres	Condensation polymers
Synthetic	Cross linked or three dimensional	Thermoplastic	
		Thermosetting	

I. Classification Based upon source

(1) Natural polymers

Polymers which are found in nature. eg. Starch, cellulose and natural rubber, Silk, Proteins, Nucleic acid. ...etc.

(2) Semisynthetic polymers

It is obtained from naturally occurring polymers by chemical treatment. Most of the semisynthetic polymers are prepared

Rack your Brain



Why all polymers are macromolecules but all macromolecules are not polymers.



from cellulose. eg. cellulose acetate, cellulose nitrate, cellulose xanthate and rayon.

(3) Synthetic polymers

Man made polymers are known as synthetic polymer. eg. PVC, polyethylene, polystyrene, nylon-6, nylon-6,6; nylon-6,10; terylene, synthetic rubbers etc.

Classification Based upon structure

1. Linear polymers

Monomers are joined together to form long straight chains. The various linear polymeric chains are stacked over one another to give a well packed structure close packed in nature, having high densities, high melting point and high tensile (pulling) strength.

Note:

All fibers are linear polymers. eg. cellulose, silk, nylon, terylene etc.

2. Branched chain polymers

Polymers in which the monomeric units constitute a branched chain. Branched chain polymers have lower melting point low densities and tensile strength as compared to linear polymers.

Examples are amylopectin, glycogen, low density polyethylene and all vulcanized rubbers.

3. Cross linked or Three-Dimensional network polymers

When linear polymeric chains are joined together to form a three dimensional network structure. These polymers are hard,

Concept Ladder



Polymers in which repeating units are derived from two or more types of monomers units are called copolymers. eg. nylon-6,6; Buna-S; Buna-N; Polyesters.

Definition

Man-made polymers, i.e. polymers prepared in laboratory are known as synthetic polymers.

Previous Year's Question



Which compound forms linear polymer due to H-bond?

[AIPMT]

- (1) H_2O
(3) HF

- (2) NH_3
(4) HCl

rigid and brittle. Cross linked polymers are always condensation polymers. Resins are cross linked polymers.

Classification Based upon molecular force

1. Elastomers

Polymers in which the intermolecular forces of attraction between the polymer chains are the weakest (weak van der Waals forces of attraction) these polymers consist of randomly coiled molecular chains of irregular shape having a few cross links.

Examples are natural rubber, Buna-S, Buna-N etc.

2. Fibres

Those polymers in which the intermolecular forces of attraction are the strongest are called fibers. These polymers held together by H-bonding or dipole-dipole interaction. Fibres have high tensile strength, least elasticity having high melting point and low solubility.

3. Thermoplastics

In thermoplastics intermolecular forces of attraction are in between those of elastomers and fibres. Thermoplastics become soft and viscous on heating and rigid on cooling.

Examples are polythene, nylon-6, nylon-6,6 etc.

4. Thermosetting polymers

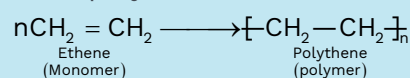
These polymers have low molecular masses and are semi-fluid substances. These polymers are hard and infusible.

Examples are melamine-formaldehyde, bakelite (phenol-formaldehyde) etc.

Concept Ladder



Polymers whose repeating structural units are derived from only one type of monomer units are called homopolymers.



Rack your Brain



Why branched chain polymers do not pack well?

Concept Ladder



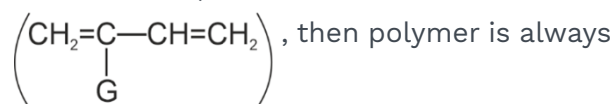
Linear polymers may be condensation as well as addition polymers. Examples are cellulose, polypeptide, nucleic acid, nylon, terylene etc.



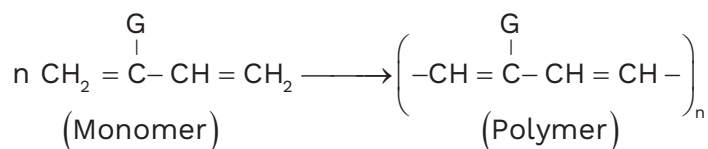
Classification based upon polymerisation

1. Addition polymerization

- (a) Addition polymers are those in which addition reaction takes place
- (b) If monomer is ethylene, then addition polymer may be either linear polymer or branched chain polymer. Examples are polystyrene, polytetrafluoroethylene, polyacrylonitrile etc.
- (c) If monomer is 1,3-butadiene or 2-substituted-1, 3-butadiene



branched chain polymer.



	Monomer	Polymer
(a)	G = H : 1,3-Butadiene	(i) Polybutadiene
(b)	G-CH ₃ : 2-Methyl-1, 3-butadiene or isoprene	(ii) Polyisoprene
(c)	G=Cl; 2-Chloro-1, 3-butadiene or chloroprene	(iii) Polychloroprene (Neoprene)

- (d) Addition polymers are also known as chain growth polymers.

Concept Ladder



Addition polymerization takes place in three steps: Initiation, chain propagation and chain termination.

Previous Year's Question



Regarding cross-linked or network polymers, which of the following statements is incorrect? **[NEET]**

- (1) They contain covalent bonds between various linear polymer chains.
- (2) They are formed from bi- and tri-functional monomers.
- (3) Examples are bakelite and melamine.
- (4) They contain strong covalent bonds in their polymer chains.



Types of Addition Polymerisation

(a) Free Radical Polymerisation

(i) Free radical polymerisation takes in the presence of radical initiators. Such as dioxygen, benzoyl peroxide, acetyl peroxide etc.

For example, polymerization of ethene is carried out at high temperatures (350-570K) and at high pressure (1000-2000 atm) in presence of dioxygen or a small amount of benzoyl peroxide as radical initiator.

Previous Year's Question



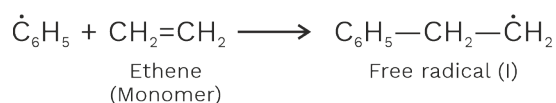
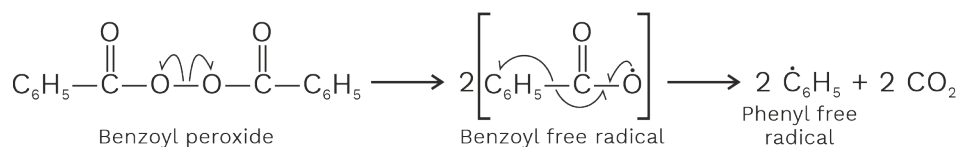
Which can absorb over 90% of its own mass of water and does not stick to wound?

[AIPMT]

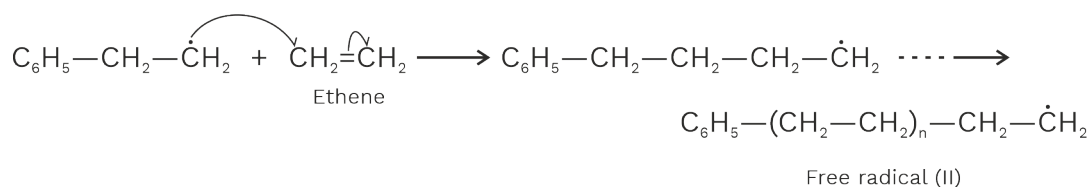
- (1) Rayon (2) Gun cotton
(3) Thiokol (4) Saran

Mechanism

Chain initiating steps:

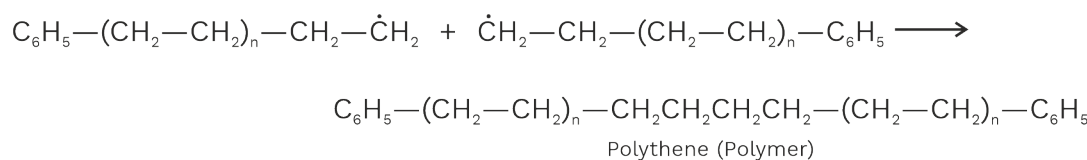


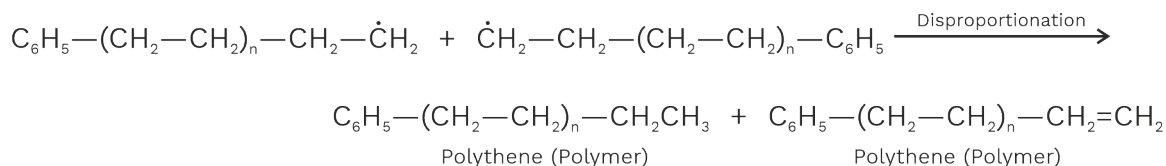
Chain propagating steps:



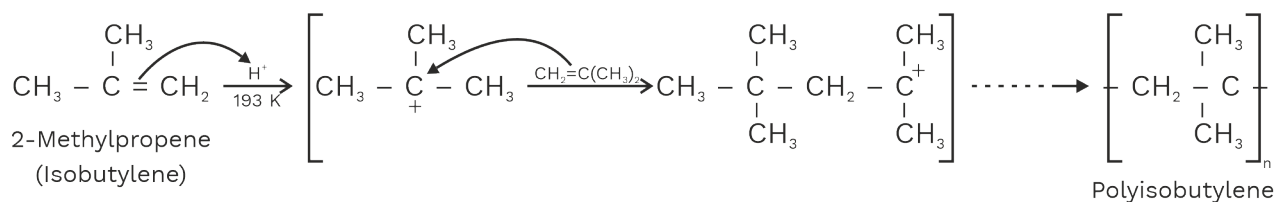
Chain terminating steps:

Step 1 : By combination of free radicals (II)

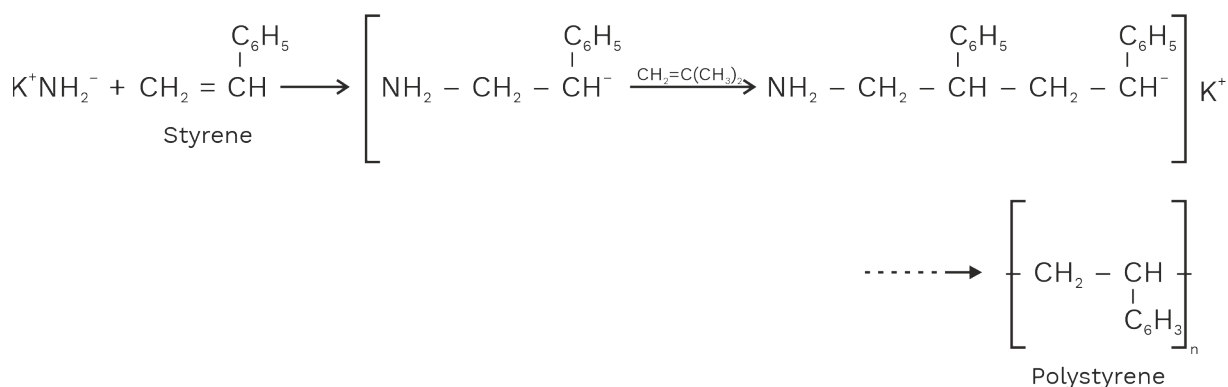


**Step 2 : By disproportionation of free radicals (II)****(b) Cationic Polymerisation**

Cationic polymerisation takes place in the presence of strong protonic acids such as H_2SO_4 , AlCl_3 , BF_3 etc.

**(c) Anionic Polymerization**

In anionic polymerisation, it takes place in the presence of strong bases such as KNH_2 , NaOH , KOH , some organometallic compounds etc.

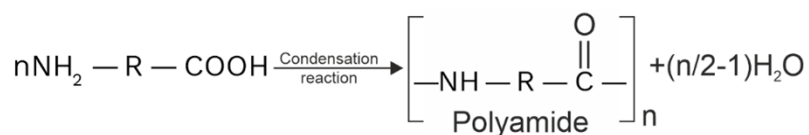
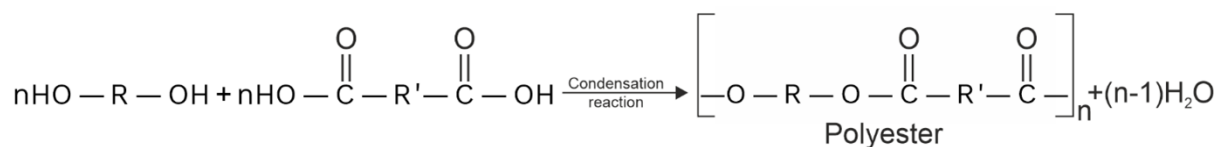
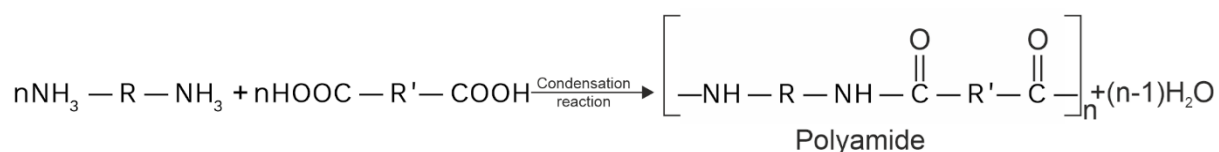
**2. Condensation polymerization**

(a) They are formed due to condensation reactions.

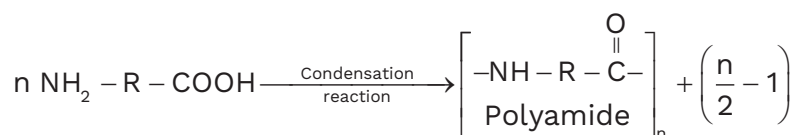


- (b) Condensation polymerization is also known as step growth polymerization.
- (c) For condensation polymerization, monomers should have at least two functional groups. (functional groups may be same or different).

For example,



- (d) During condensation elimination of small molecules like ammonia, alcohol, water, HCl takes place.



- (e) Monomer having three functional groups always gives cross linked polymer. Examples are : Urea formaldehyde resin, phenol-formaldehyde resin.

Previous Year's Question



Which one of the following is not a condensation polymer?

[AIPMT]

- (1) Melamine (2) Glyptal
(3) Dacron (4) Neoprene

Concept Ladder



Monomers having only two functional group always give linear polymer.

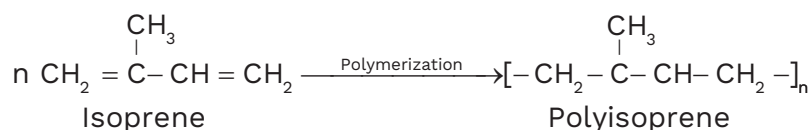


Natural Rubber

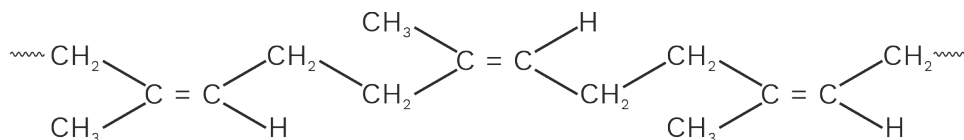
The main source of natural rubber is *braziliensis* tree. Natural rubber is obtained from latex. Again latex is coagulated with acetic acid and formic acid and coagulated mass is then squeezed.

Natural rubber is a sticky, gummy & soft and insoluble in water, alkalies & dilute acids. Natural rubber soluble in non-polar solvents. It has low elasticity and low tensile strength.

Example : Polyisoprene.



Structure of Natural Rubber (cis-polyisoprene)

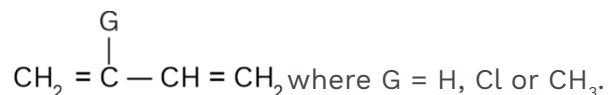


Synthetic Rubber or Polymerisation of Dienes

Polymers of 1,3-butadienes are called synthetic rubbers because they have some properties of natural rubber. Synthetic rubber are water proof and great elasticity.

1. Homopolymers

Monomer of this class is 2-substituted



Ziegler-Natta catalyst is used for polymerisation which gives stereo regular polymers.

Concept Ladder



Natural rubber is a polymer of 2-methyl-1, 3-butadiene (isoprene). On average, molecules of rubber contain 5000 isoprene units held together by head to tail. All the double bonds in rubber are cis, hence natural rubber is cis-polyisoprene.



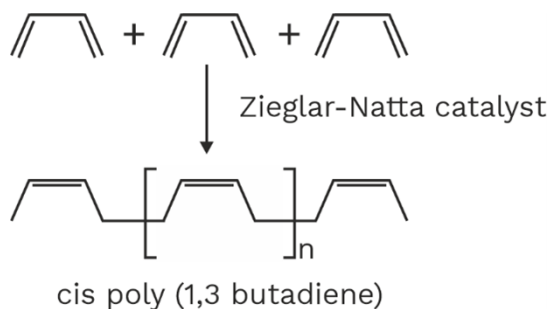
Previous Year's Question



natural rubber is a polymer of

[AIPMT]

- | | |
|---------------|--------------|
| (1) Styrene | (2) Ethyne |
| (3) Butadiene | (4) Isoprene |



Dieprene (Neoprene) was the first synthetic rubber manufactured on large scale. It is the monomer of chloroprene (2-chlorobutadiene).

2. Copolymers

Copolymers are derived from two or more types of monomer units. Example of copolymers are :

1	Buna-S, SBR (Styrene-Butadiene rubber)	$\text{C}_6\text{H}_5 - \underset{(25\%)}{\text{CH} = \text{CH}_2} + \underset{(75\%)}{\text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2}$
2	Buna-N, NBR (Nitrile-Butadiene rubber)	$\text{CH}_2 = \underset{(25\%)}{\text{CH} - \text{CN}} + \underset{(75\%)}{\text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2}$
3	Butyl rubber	$\text{CH}_3 - \underset{\substack{ \\ \text{CH}_3 \\ (98\%)}}{\text{C} = \text{CH}_2} + \underset{(2\%)}{\text{Butadiene}}$
4	ABS; Acrylonitrile, Butadiene, Styrene	$\text{CH}_2 = \text{CH} - \text{CN} + \text{CH}_2 = \text{CH}_2 = \text{CH} - \text{CH} = \text{CH}_2 + \text{C}_6\text{H}_5\text{CH} = \text{CH}_2$

(a) Buna-S (SSR : Styrene-butadiene rubber)

Buna-S rubber is a copolymer of three moles of butadiene and one mole styrene. Buna-S is generally compounded with

Concept Ladder



Synthetic rubbers have some improved properties. They are more flexible, tougher and more durable than natural rubber.



Rack your Brain

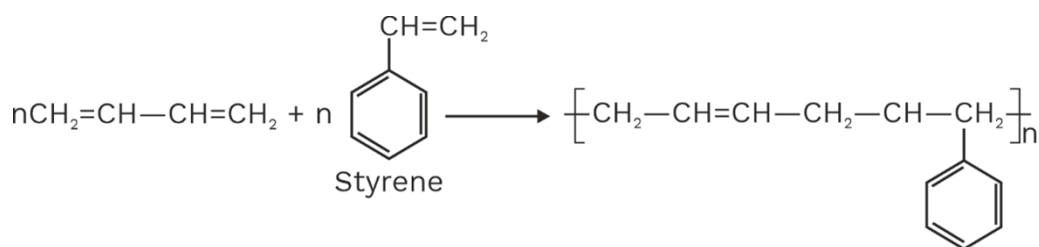


Which polymer is used to make 'non-stick' cookware?

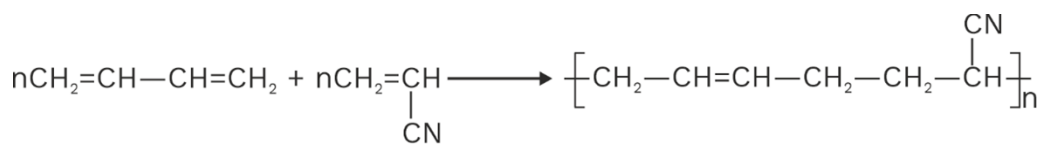
carbon black and vulcanised with sulphur. It is extremely resistant to tear & wear and therefore used in the manufacture of tyres and other mechanical rubber goods. It is obtained as a result of free radical copolymerisation of its monomers.

(b) Buna -N

Buna-N is obtained by copolymerisation of butadiene and acrylonitrile (General purpose Rubber acrylonitrile or GRA)



Buna-N is rigid and resistant to the action of organic solvents, lubricating oil and petrol. It is also used for making fuel tanks.



Concept Ladder



In Buna-S, 'Bu' stands for butadiene, 'na' for symbol of sodium (Na) which is a polymerizing agent and 'S' stands for styrene. It is an elastomer (General purpose styrene Rubber or GRS).

Q1 Buna-S is also called _____?

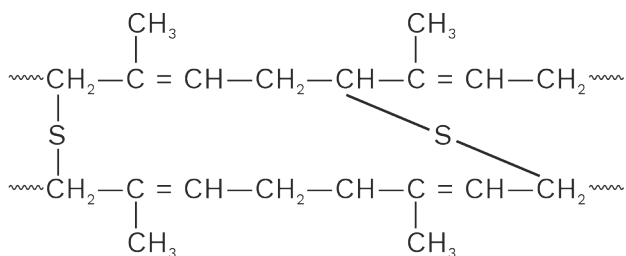
- | | |
|------------------|--------------|
| (1) Polyurethane | (2) SBR |
| (3) Teflon | (4) Bakelite |

Sol. (2)
SBR is known as styrene butadiene.



Vulcanisation of rubber

Natural rubber soft & sticky and becomes even more so at high temperatures and brittle at low temperatures. Therefore, rubber is generally used in the temperature range 283-335 K where its elasticity is maintained. It has a large water absorption capacity, has low tensile strength and low resistance to abrasion. It is also not-resistant to the action of organic solvents and is also easily attacked by oxidising agents. These properties can be improved markedly by a process called vulcanization.



It consists of heating raw rubber with sulphur at 373-415 K. Since this process is slow, therefore, additives like zinc oxide, are used to accelerate the rate of vulcanization. The vulcanized rubber thus obtained has excellent elasticity, low water absorption tendency and is resistant to the action of organic solvents and oxidising agents. During vulcanization, sulphur bridges or cross-links between polymer chains are introduced either at reactive allylic positions or at the sites of the double bonds.

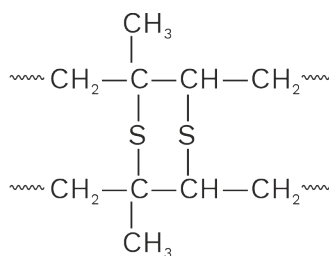
Nylon

Nylons are prepared by the condensation polymerisation of dibasic acids with diamines. Nylon contains amide linkages having a protein like structure.

Concept Ladder



Synthetic rubbers are either homopolymers of 1, 3-butadiene or its derivatives or are copolymers of 1, 3-butadiene or its derivatives with another unsaturated monomer.



Rack your Brain



How does rubber get stiffness?

Previous Year's Question



Nylon is an example of

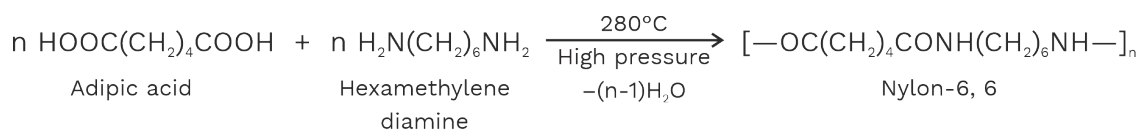
[NEET]

- (1) polyamide (2) polythene
(3) polyester (4) polysaccharide



(1) Nylon-6,6 (Nylon-six, six)

It is obtained by condensation polymerisation of a diamine with six carbon atoms (hexamethylenediamine) and a dibasic acid having 6 carbon atoms (adipic acid).



(2) Nylon-6,10 (Nylon-six, ten)

It is obtained by condensation polymerisation of six carbon atoms (hexamethylenediamine) and a dibasic acid with 10 carbon atoms (sebacic acid).

These fibres are light, very strong, flexible and elastic having retain creases and drip dry property. These polymers are inert towards biological and chemicals agents. These polymers can be blended with wool to make carpets, garments, tyre cords, ropes, etc.

(3) Nylon-6 (Perlon L)

A polyamide closely related to nylon is known as perlon L (Germany) or Nylon-6 (USA). During prolonged heating of caprolactam at 260–270°C. It is formed by self condensation of a large number of molecules of amino caproic acid. Since, caprolactam is more easily available, it is used for polymerization, with is carried out in the presence of H₂O that first hydrolysis the lactam to amino acid. Subsequently, the amino acid can react with the lactam and the process goes on and onto formed by polyamide polymer.

Caprolactam is obtained by Backman

Concept Ladder



Nylon fibres are stronger than natural fibres and so are used in making cords and ropes.

Previous Year's Question



Nylon-6, 6 is a polyamide obtained by the reaction of

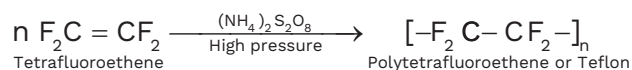
[AIPMT]

- (1) $\text{COOH(CH}_2)_4\text{COOH} + \text{H}_2\text{NC}_6\text{H}_4\text{NH}_2$ (p)
- (2) $\text{COOH(CH}_2)_4\text{COOH} + \text{NH}_2(\text{CH}_2)_6\text{NH}_2$
- (3) $\text{COOH(CH}_2)_4\text{COOH} + \text{NH}_2(\text{CH}_2)_4\text{NH}_2$
- (4) $\text{COOHC}_6\text{H}_4\text{COOH}$ (p) + $\text{NH}_2(\text{CH}_2)_6\text{NH}_2$

rearrangement of cyclohexanone oxime.

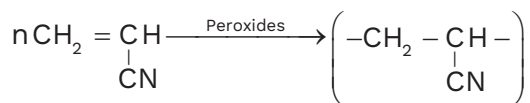
Polytetrafluoroethene (PTEE) or Teflon

Teflon is manufactured by heating tetrafluoroethene in presence of peroxides or ammonium persulphate catalyst at high pressures.



Polyacrylonitrile (PAN) or Orlon

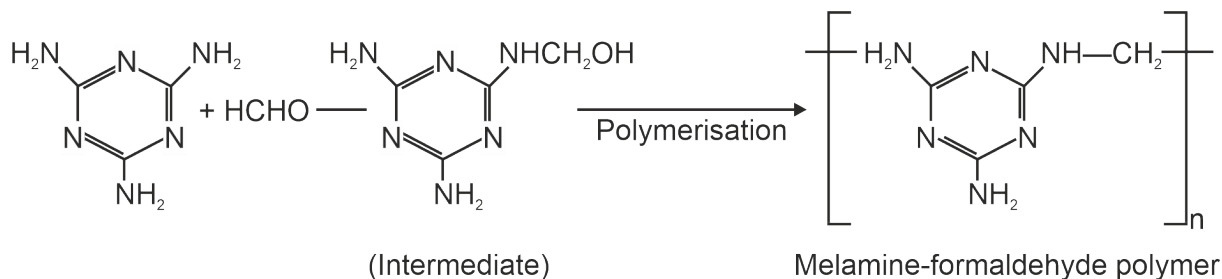
During Polymerisation of acrylonitrile in the presence of a peroxide catalyst gives polyacrylonitrile.



Melamine-formaldehyde resin

This resin is formed by condensation polymerization of melamine and formaldehyde.

It is a quite hard polymer and is used widely for making plastic crockery under the name melamine. The articles made from this polymer do not break even when dropped from considerable height.



Q2 What is the monomer of bakelite?

Sol. Bakelite is a polymer formed by the monomers of phenol and formaldehyde. This phenol-formaldehyde resin is a thermosetting polymer.

Rack your Brain



Why the articles made from melamine do not break even if they fall from several heights?

Concept Ladder

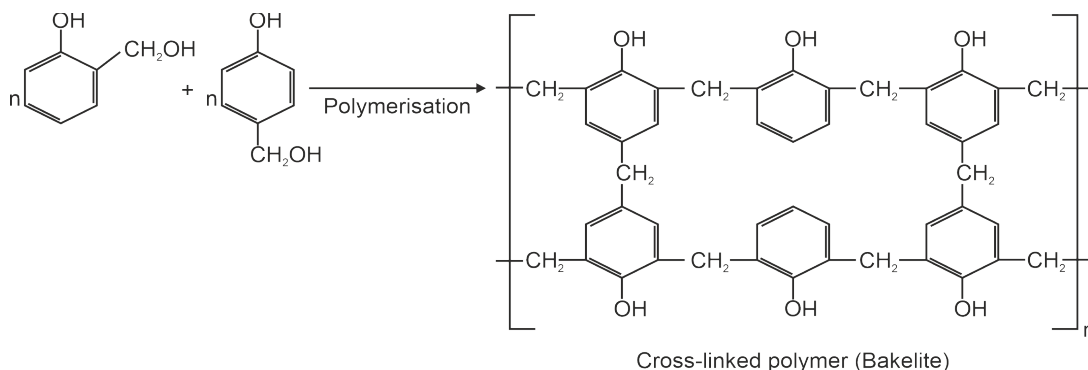
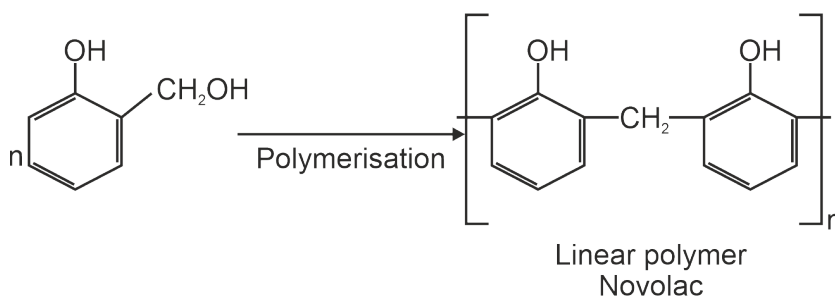
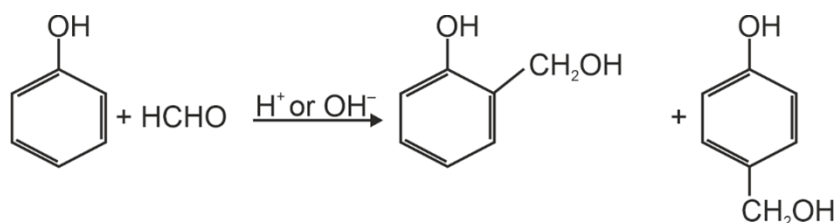


PAN is used as a substitute for wool in the manufacture of orlon and acrilan fibres which are used for making clothes, carpets and blankets.



Bakelite

Phenol-formaldehyde resins are obtained by the reaction of phenol and formaldehyde in the presence of either an acid or a basic catalyst. It starts with the initial formation of ortho and para hydroxymethyl phenol derivatives, which further react with phenol to form compounds where rings are joined to each other with $-\text{CH}_2$ groups. This reaction involves the formation of methylene bridges in ortho, para or both ortho and para positions. Linear or cross-linked materials are obtained depending on the condition of the reaction.



Previous Year's Question



The bakelite is prepared by the reaction between

[AIPMT]

- (1) Phenol and formaldehyde
- (2) Tetramethylene glycol
- (3) Urea and formaldehyde
- (4) Ethylene glycol



Polyesters

Dacron is a common polyester, prepared using ethylene glycol and terephthalic acid. The reaction is carried out at 140°C to 180°C in the presence of zinc acetate and Sb_2O_3 as catalyst.

The dacron is crease resistant and has low moisture absorption. It has high tensile strength. It is mainly used in making wash and wear garments, in blending with wood to provide better crease and wrinkle resistance.

Molecular mass of polymer.

Normally, a polymer contains chains of varying lengths and therefore, its molecular mass is always expressed as an average. In contrast, natural polymers such as protein contains chain of identical length and hence, have definite molecular mass.

Number average molecular mass (\bar{M}_n)

$$\bar{M}_n = \frac{\sum N_i M_i}{\sum N_i}$$

Here N_i is the number of molecules of molecular mass M_i



Previous Year's Question

Of the following which one is classified as polyester polymer?

[AIPMT]

- (1) Terylene
- (2) Bakelite
- (3) Melamine
- (4) Nylon-6, 6



Definition

The ratio of the weight and number average molecular masses (\bar{M}_w / \bar{M}_n) is called Poly Dispersity Index (PDI).

Q3

The number average molecular mass and mass average molecular mass of a polymer are 30,000 and 40,000 respectively. the PDI of the polymer is :

Sol.

PDI (Polydispersity Index) is the ratio of the mass average molecular mass to the number average molecular mass.

$$\text{Therefore, PDI} = \frac{40000}{30000} = 1.33$$

Thus, PDI of the polymer is >1 .



Here N_i is the number of molecules of molecular mass M_i . Methods such as light scattering and ultracentrifuge depend on the mass of the individual molecules and yield weight as average molecular masses. \bar{M}_n is determined by osmotic pressure measurement (colligative properties).

Some natural polymers, which are generally monodispersed, the PDI is unity (i.e. $\bar{M}_w = \bar{M}_n$).

In synthetic polymers, which are always polydisperse, $\text{PDI} > 1$ because \bar{M}_w is always higher than \bar{M}_n .

Biodegradable Polymers:

Many polymers are quite resistant to the environmental degradation processes and are thus responsible for the accumulation of polymeric solid waste materials (environmental pollution). These solid wastes cause acute environmental and health problems and remain undegraded for quite a long time (100 — 1000 years). For general awareness and concern, the problems created by the polymeric solid wastes, certain new biodegradable synthetic polymers have been designed and developed. These polymers contain functional groups similar to the functional groups present in biopolymers.

Concept Ladder



Weight average molecular mass (\bar{M}_w)

$$\bar{M}_w = \frac{\sum N_i M_i^2}{\sum N_i m_i}$$

Previous Year's Question



Which of the following is a biodegradable polymer?

[AIIMS]

- (1) Cellulose
- (2) Polythene
- (3) Polyvinyl chloride
- (4) Nylon-6

Q4 Identify the type of polymer.
—A—A—A—A—A—A—

Sol. Here the monomer is —A—. Since the same or identical monomer is being repeated to form this above polymer, so this is a homopolymer. ('Homo' means same or identical)

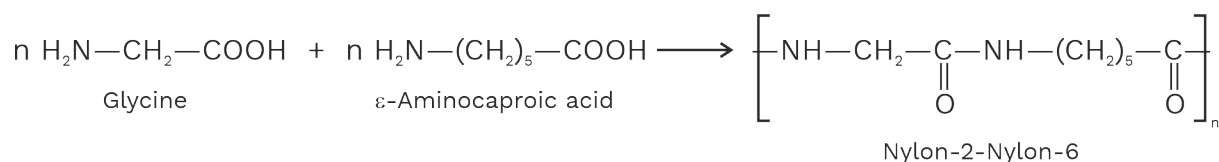


By far the most important class of biodegradable polymers are aliphatic polyesters and polyamides.

Some of these are discussed below :

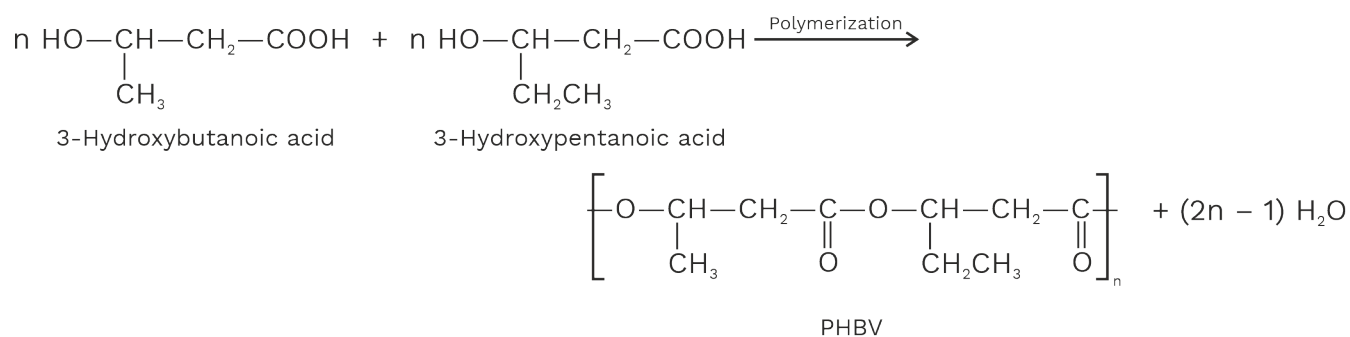
(i) Nylon-2-Nylon-6

It is an alternating polyamide of glycine (containing two carbon atoms) and ϵ -aminocaproic acid or 6-aminohexanoic acid. (containing six carbon atoms)



(ii) PHBV

It is a thermoplastic co-polymer of 3-hydroxy-butanoic acid and 3-hydroxypentanoic acid in which the two monomer units are connected by ester linkages.





Q5 Identify the type of polymer.



Sol. Monomers 'A' and 'B' are being joined in a random manner in the same polymer chain. It is the example of a copolymer. Copolymers are formed by the mixture of two or more unsaturated monomers reacts to each other.

Q6 Why are rubbers called elastomers?

Sol. Rubbers can be stretched by applying mechanical forces and come back to its original position after the removal of applied force. So they are called elastomers.

Q7 Can the enzyme be called a polymer?

Sol. The enzyme are the catalysts which enhances the biological (bio-chemical) reactions. Enzymes are made up of proteins (monomeric units are amino acids). Thus, enzymes are also polymers.

Q8 Can nucleic acids, proteins and starch be considered as step growth polymers?

Sol. Step growth polymers are condensation polymers. Proteins, starch and nucleic acids can be considered as step-growth polymers. Those polymers in which monomers possess bifunctional or trifunctional functional groups can combine by the loss of a simple molecule.

Q9 To have practical applications why are cross-links required in rubber?

Sol. In order to increase the quality of rubber, cross-linking is done which helps to increasing elastomeric properties and thermal stability.



Q10 Why does cis-polyisoprene possess elastic property?

Sol. cis-polyisoprene has a coiled structure and does not have a straight chain. It can be stretched like a spring. On stretching, the molecules become partially aligned with respect to each other and on withdrawing the force, the chains come back to their original coiled state.

Q11 What is the structural difference between HDP and LDP? How does the structure account for different behaviour and nature, hence the use of a polymer?

Sol. Low density polymer is a low density structure which has branched structure and high density polymer is a high-density polymer which has a linear structure. Low density polymer has a lower melting point and is flexible whereas high density polymer is chemically inert and has a higher melting point.

Q12 **Assertion:** Rayon is a semi-synthetic polymer and is taken as a better choice than cotton fabric.
Reason: Mechanical and aesthetic properties of cellulose can be improved by acetylation.

Sol. Assertion and reason both are correct statements and reason explains the assertion.

Q13 Which factor imparts crystalline nature to a polymer like nylon?

Sol. One molecule of Nylon can join another by intermolecular H-bonding which is present between two terminal groups $-C=O$ and $-NH$. Since intermolecular H-bonding is relatively strong, it can lead to close packing of chains that impacts the crystalline character of Nylon.

Q14 Name the polymers used in laminated sheets and give the name of monomeric units involved in its formation.

Sol. Urea-formaldehyde resin is used in laminated sheets. For the formation of laminated sheets, urea and formaldehyde are the monomeric units.

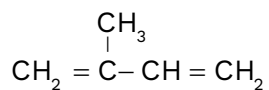


Q15 Which of the following polymer is stored in liver of animals?
(1) Amylose (2) Cellulose (3) Amylopectin (4) Glycogen

Sol. (4)
Glycogen is a multibranched polysaccharide of glucose that serves as a form of energy storage in animals.
Glycogen is the analogue of starch, a glucose polymer in plants, having a similar structure of amylopectin, but more extensively branched and compact than starch. Starch is polymer of α -glucose and consist of two components amylose and amylopectin.
Amylose is water soluble component which constitutes about 15-20% of starch. Amylose and amylopectin is insoluble in water and constitutes about 80-85% of starch.
Amylose and amylopectin are the main storage polysaccharide of plants. Cellulose occurs exclusively in plants and it is the most abundant organic substance in plant kingdom. It is a predominant constituent of cell wall of plants cells.

Q16 Natural rubber is a polymer of
(1) cis-isoprene (2) trans-isoprene
(3) both (1) and (2) (4) None of the above

Sol. (1)
Natural rubber is a polymer of cis-isoprene, [2-methyl-1, 3-butadiene].



Q17 A condensation polymer among the following polymers is
(1) teflon (2) polystyrene
(3) PVC (4) dacron

Sol. (4)
The polymer formed by the condensation polymerisation is known as condensation polymer. Dacron (terylene) is a condensation polymer. It is formed by the condensation polymerisation of terephthalic acid and ethylene glycol.



Chapter Summary

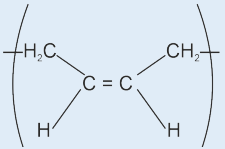


1. Have high molecular mass and formed by union of monomers.
2. **Chain growth polymers or addition polymers** are formed by successive addition of monomers without loss of simple molecules like H_2O , NH_3 etc.
3. **Step growth or condensation polymers :**
these are formed through series of independent steps. Each step involves condensation between two monomers leading to formation of polymers. More than one monomer unit is involved.
4. **Homopolymers :**
Polymers made of same monomer.
5. **Copolymers :**
Polymers made of different types of monomers.
6. **Elastomers :**
The strands of polymer are held together by weak inter molecular forces (van der wall's). e.g. - **Vulcanised rubber.**
7. **Fibres** are held together by hydrogen bonds. e.g. - **nylon, polyester, polyamide.**
8. **Thermoplastics** can be easily moulded on heating. They don't have cross-links, e.g.- **polyethene.**
9. **Thermosetting polymers** have cross links, cannot be remolded on heating. e.g. - Bakelite.
10. **Plastisizer** are high boiling esters which are added to plastic to make it soft and rubber like.

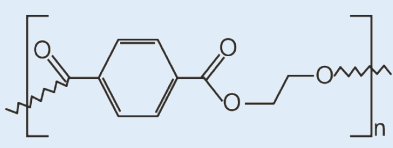
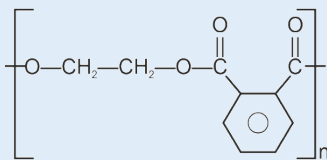


SOME COMMON ADDITION POLYMERS/ CHAIN GROWTH POLYMER (HOMOPOLYMERS)				
S. No.	Name(s)	Formula	Monomer	Uses
1.	Polyethylene (low density (LDPE))	$-(\text{CH}_2-\text{CH}_2)_n-$	$\text{CH}_2=\text{CH}_2$ (ethylene)	film wrap, plastic bags
2.	Polyethylene (high density (HDPE))	$-(\text{CH}_2-\text{CH}_2)_n-$	$\text{CH}_2=\text{CH}_2$ (ethylene)	electrical insulation bottles, toys
3.	Polypropylene (PP) different grades	$\begin{array}{c} \text{CH}_3 \\ \\ \text{---}[\text{CH}-\text{CH}_2]_n\text{---} \end{array}$	$\text{CH}_2=\text{CHCH}_3$ (propylene)	similar to LDPE carpet, upholstery
4.	Poly vinyl chloride (PVC)	$\begin{array}{c} \text{Cl} \\ \\ \text{---}[\text{CH}-\text{CH}_2]_n\text{---} \end{array}$	$\text{CH}_2=\text{CHCl}$ (vinyl chloride)	pipes, siding, flooring
5.	Poly(vinylidene chloride) (Saran A)	$\begin{array}{c} \text{Cl} \\ \\ \text{---}[\text{CH}-\text{CH}_2]_n\text{---} \\ \\ \text{Cl} \end{array}$	$\text{CH}_2=\text{CCl}_2$ (vinylidene chloride)	seat covers, films
6.	Polystyrene (PS) (Styron)	$\begin{array}{c} \text{---}[\text{CH}-\text{CH}_2]_n\text{---} \\ \\ \text{C}_6\text{H}_5 \end{array}$	$\text{CH}_2=\text{CHC}_6\text{H}_5$ (styrene)	toys, cabinets packaging (foamed)
7.	Polyacrylonitrile (PAN, Orlon, Acrilan)	$\begin{array}{c} \text{N} \\ \\ \text{C} \\ \\ \text{---}[\text{CH}-\text{CH}_2]_n\text{---} \end{array}$	$\text{CH}_2=\text{CHCN}$ (acrylonitrile)	rugs, blankets clothing
8.	Polytetrafluoroethylene (PTFE, Teflon)	$-(\text{CF}_2-\text{CF}_2)_n-$	$\text{CF}_2=\text{CF}_2$ (tetrafluoroethylene)	non-stick surfaces electrical insulation



9.	Poly(methyl methacrylate) (PMMA, Lucite, Plexiglas, perspex)	$-\text{[CH}_2\text{C(CH}_3\text{)CO}_2\text{CH}_3\text{]}_n-$	$\text{CH}_2=\text{C(CH}_3\text{)CO}_2\text{CH}_3$ (methyl methacrylate)	lighting covers, signs skylights
10.	Poly(vinyl acetate) (PVAc)	$-\text{(CH}_2-\text{CHOC(O)CH}_3\text{)}_n-$	$\text{CH}_2=\text{CHOC(O)CH}_3$ (vinyl acetate)	latex paints, adhesives
11.	<p style="text-align: center;">Polyisoprene</p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p>cis form (Natural rubber) (1,1-addition)</p>  </div> <div style="text-align: center;"> <p>Trans-form gutta-purca</p> </div> </div>	$-\text{[CH}_2-\text{CH=C(CH}_3\text{)-CH}_2\text{]}_n-$	$\text{CH}_2=\text{CH-C(CH}_3\text{)=CH}_2$ (isoprene)	requires vulcanization for practical
12.	Polychloroprene (cis + trans) (Neoprene)	$-\text{[CH}_2-\text{CH=CCl-CH}_2\text{]}_n-$	$\text{CH}_2=\text{CH-CCl=CH}_2$ (chloroprene)	synthetic rubber oil resistant

Some Condensation POLYMERS (Step Growth Polymers)

S. No.	Name(s)	Formula	Monomer	Uses
1.	Polyester/ Dacron/ Terylene/Mylar		$\text{HO}_2\text{C-C}_6\text{H}_4\text{-CO}_2\text{H}$ (Terephthalic acid) $\text{HO-CH}_2\text{CH}_2\text{-OH}$ Ethylene glycol	Copolymer Step growth, Linear Polymer
2.	Glyptal or Alkyds resin		$\text{HO}_2\text{C-C}_6\text{H}_4\text{-CO}_2\text{H}$ (Phthalic acid) $\text{HO-CH}_2\text{CH}_2\text{-OH}$	Copolymer Step growth, Linear Polymer



3.	Polycarbonate Lexan		$(\text{HO}-\text{C}_6\text{H}_4-)_2$ $\text{C}(\text{CH}_3)_2$ (Bisphenol A) $\text{X}_2\text{C}=\text{O}$ (X = OCH_3 or Cl)	Copolymer Step growth, linear Polymer
4.	Polyamide (Nylon 6,6)	$\sim[\text{CO}(\text{CH}_2)_4\text{CO}-\text{NH}(\text{CH}_2)_6\text{NH}]_n\sim$	$\text{HO}_2\text{C}-(\text{CH}_2)_4-$ CO_2H $\text{H}_2\text{N}-$ $(\text{CH}_2)_6-\text{NH}_2$	Copolymer Step growth, Linear Polymer
5.	Nylon 6,10		$\text{HOOC}-(\text{CH}_2)_8-$ COOH $\text{H}_2\text{N}-(\text{CH}_2)_6-\text{NH}_2$	Copolymer Step growth, Linear Polymer
6.	Bakelite		$\text{PhOH} + \text{HCHO}$ in (excess)	Copolymer Cross-linked polymer Step growth
7.	Urea- formaldehyde resin	$(-\text{NH}-\text{CO}-\text{NH}-\text{CH}_2-)_n$	$\text{H}_2\text{N}-\text{CO}-\text{NH}_2$ (Urea) HCHO (Formaldehyde)	Copolymer Step growth Cross-linked polymer
8.	Melamine formaldehyde resin		Melamine + Formaldehyde	Cross-linked polymer



Some Useful Copolymers

Monomer A	Monomer B	Copolymer	Uses
$\text{H}_2\text{C}=\text{CHCl}$	$\text{H}_2\text{C}=\text{CCl}_2$	Saran	films & fibers
$\text{H}_2=\text{CH}-\text{CH}=\text{CH}_2$ 1, 3-Butdiene		Buna Rubber (Homo-polymer)	In manufacture of tyres, hoses, etc.
$\text{H}_2\text{C}=\text{CHC}_6\text{H}_5$	$\text{H}_2\text{C}=\text{CH}-$ $\text{CH}=\text{CH}_2$	SBR styrene butadiene rubber (Buna-S)	Tires
$\text{H}_2\text{C}=\text{CHCN}$	$\text{H}_2\text{C}=\text{CH}-$ $\text{CH}=\text{CH}_2$	Nitrile Rubber (Buna-N)	Adhesives hoses
$\text{H}_2\text{C}=\text{CHCN}$	$\text{H}_2\text{C}=\text{CH}-$ $\text{CH}=\text{CH}_2 +$ $\text{H}_2\text{C}=\text{CHC}_6\text{H}_5$	ABS rubber	Fuel tanks