15 Polymers

Facts that Matter

Classification of Polymers

	Types	Properties
(A) Based on Source	(*i*) Natural Polymers	Found in plants and animals, *e.g.* proteins, cellulose, natural rubber, silk, wool.
	(*ii*) Synthetic Polymers	Man-made, *e.g.* nylon, polyester, neoprene, bakelite, teflon, PVC, polystyrene.
(B) Based on Structure	(*i*) Linear Polymers	They consist of long and straight chain repeating units, *e.g.* High density polythene (HDPE), PVC, nylon, polyester.
	(*ii*) Branched Polymers	They contain linear chains having some branches, *e.g.* amylopectin, glycogen, etc.
	(*iii*) Cross linked Polymers	Strong covalent bond are present between various linear polymer chains. E.g. bakelite, urea-formaldehyde polymer, melamine, etc.
(C) Based on Mode of Polymerisation	(*i*) Addition Polymers	These are formed by the repeated addition of monomer units possessing multiple bonds, *e.g.* polythene, polypropene, polystyrene, PMMA (polymethylmethacrylate).
	(*ii*) Condensation Polymers	These are formed by the repeated condensation reaction of different bifunctional or trifunctional monomers, with the elimination of small molecules like water, HCl, NH_3, alcohol, etc. *E.g.* Bakelite, nylon, polyester, urea-formaldehyde resin, etc.
(D) Based on Molecular Forces	(*i*) Elastomers	Forces of interaction between polymer chains are weakest, *e.g.* natural rubber, neoprene and vulcanised rubber.
	(*ii*) Fibres	Strong hydrogen bond are present between the polymer chains. They have high tensile strength, *e.g.* nylon, polyester, silk, wool, orlon, rayon, etc.
	(*iii*) Thermoplastics	They are linear/slightly branched chain molecules, capable of repeated softening on heating and hardening on cooling, *e.g.* polythene, PVC, polystyrene, polypropene etc.

(E) Based on growth of Polymerisation	(*i*) Addition Polymers or Chain growth Polymers	They mostly follow free radical mechanism.
	(*ii*) Condensation Polymers or Step growth Polymers	They are named because they are formed in gradual steps.

- **Polymers:** They are macromolecules of high molecular masses formed by the combination of a large number of simple molecules (monomers).

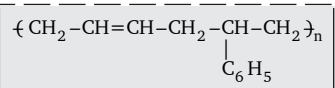
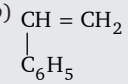
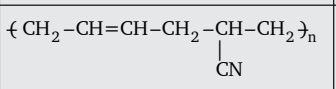
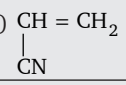
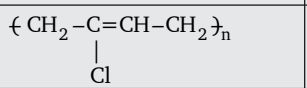
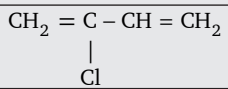
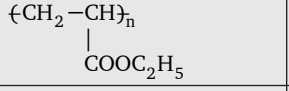
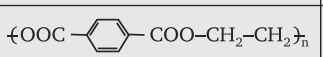
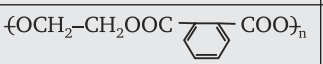
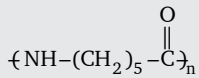
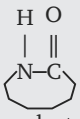
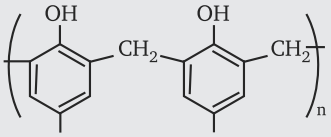
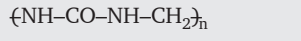
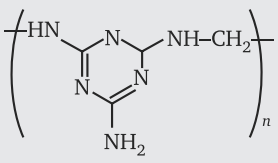
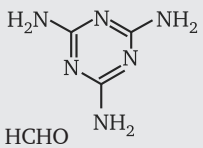
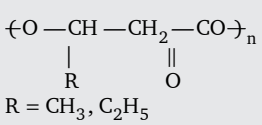
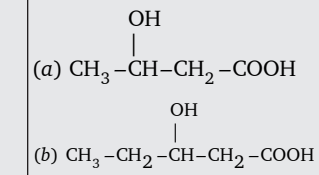
$$\text{Monomers} \xrightarrow[\text{Polymerisation}]{\Delta} \text{Polymer}$$

- **Homopolymers:** They are formed by the polymerisation of only one type of monomers. *Examples:* polythene, PVC
- **Copolymers:** They are formed by the polymerisation of two or more types of monomers. *Examples:* nylon-6, 6; Buna-S.
- **Natural polymers:** They are formed in nature by plants and animals. *Examples:* natural rubber, starch
- **Synthetic polymers:** They are formed artificially by using certain chemical compounds. *Examples:* nylon-6, 6; PVC.
- **Linear polymers:** In these polymers, the monomer units are linked together to form straight chains, these chains are present over one another to give a well packed structure. *Examples:* polythene, nylon-6, 6.
- **Branched chain polymers:** In these polymers, monomer units are linked to give long chains with side chain of different lengths. *Examples:* amylopectin, glycogen.
- **Cross-linked polymers:** In these polymers, monomer units are linked to give a three dimensional solid network with cross-linking. *Examples:* bakelite, melamine.
- **Addition polymers:** In these polymers, monomer units are added to form long chains without the elimination of any by-product. *Example:* polythene.
- **Condensation polymers:** In these polymers, monomer units are added to form long chains, with the elimination of some by-products. *Example:* nylon-6, 6.
- **Chain growth polymers:** In these polymers, monomer units get converted into some active intermediate by some initiator molecule. So monomer units are added one by one to this active intermediate by a chain process. *Example:* polythene.
- **Step growth polymers:** In these polymers, monomer units are condensed stepwise through independent reactions. Each independent reaction involves a condensation process by the loss of some by-products. *Example:* nylon-6, 6.
- **Elastomers:** These are the polymers in which the polymeric chains are held together by weak attractive forces, due to which they can be stretched.
  When stress is applied on these polymers, the polymeric chains become straight and the polymer is said to be stretched. After removing the stress, the polymers regain their original form. *Example:* rubber.
- **Fibres:** These are the polymers which have some strong interparticle forces. They are thread like polymers. *Example:* nylon-6, 6.

- **Thermoplastics:** These are the polymers in which the interparticle forces are in between the elastomers and fibres. These polymers can be easily changed into any shape by heating because they become soft upon heating and become hard upon cooling. They can be remoulded again and again. *Example:* polythene.
- **Thermosetting polymers:** These are the polymers which become permanently hard after heating and cannot be remoulded again and again because various cross links are present in them. *Example:* bakelite.
- **Plasticisers:** Those plastics which do not soften upon heating but can be easily made soft by the addition of some organic compounds are called plasticisers. *Examples:* dialkyl phthalates or cresyl triphosphates.
- **Addition polymerisation:** The process of addition of monomer units one by one to the chain having an active intermediate like free radical, carbocation and a carboanion is called addition polymerisation. *Example:* polymerisation of ethene.
- **Condensation polymerisation:** The process in which polymers are formed in stepwise process is called condensation polymerisation. In this type of polymerisation, various independent reactions are carried out through condensation reactions. *Examples:* polymerisation of adipic acid and hexamethylene diamine.
- **Copolymerisation:** When two or more different monomer units polymerise together, the product so formed is called copolymer and the process is called copolymerisation. *Examples:* polymerisation of styrene and buta-1, 3-diene.
- **Biopolymers:** These are the polymers which control our various biological processes. *Examples:* starch, protein.

Some Important Synthetic Polymers, their Monomer Units and Uses:

S.No.	Name of Polymer	Structure	Monomer	Uses
1.	Polythene	$\left(CH_2–CH_2\right)_n$	$CH_2 = CH_2$	As insulator, anti-corrosive, packing material, household and laboratory wares.
2.	Polystyrene	$\left(CH(C_6H_5)–CH_2\right)_n$	$CH(C_6H_5)=CH_2$	As insulator, wrapping material, manufacture of toys and household articles.
3.	Polyvinylchloride (PVC)	$\left(CH(Cl)–CH_2\right)_n$	$CH_2 = CHCl$	In the manufacture of raincoats, hand bags, vinyl flooring and leather clothes.
4.	Polytetrafluoro-ethylene (PTFE)	$\left(CF_2–CF_2\right)_n$	$CF_2 = CF_2$	As lubricant, insulator and making cooking wares.
5.	Polymethyl methaacrylate (PMMA) or Plexi glass	$\left(CH_2–C(CH_3)(COOCH_3)\right)_n$	$CH_2 = C(CH_3)(COOCH_3)$	As substitute of glass and for making decorative materials.
6.	Polyacrylonitrile (Orlon)	$\left(CH_2–CH(CN)\right)_n$	$CH_2 = CHCN$	In making synthetic fibres and synthetic wool.

7.	Styrene butadiene rubber (SBR or Buna-S)		(*a*) $CH_2 = CH - CH = CH_2$ (*b*) 	In making automobile tyres and footwear.
8.	Nitrile rubber (Buna-N)		(*a*) $CH_2 = CH — CH = CH_2$ (*b*) 	In making oil seals, manufacture of hoses and tank linings.
9.	Neoprene			As insulator, making conveyor belts and printing rollers.
10.	Polyethyl acrylate		$CH_2=CH–COOC_2H_5$	In making films, hose pipes and finishing fabrics.
11.	Terylene		 (*b*) $HO–CH_2–CH_2–OH$	For making fibres, safety belts, tyre cords, tents, etc.
12.	Glyptal		 (*b*) $HO–CH_2–CH_2–OH$	As binding material in preparation of mixed plastics and paints.
13.	Nylon-6		 (Caprolactam)	In making fibres, plastics, tyre cords and ropes.
14.	Nylon-66	$\{NH(CH_2)_4NHCO(CH_2)_4CO\}_n$	(*a*) $HOOC–(CH_2)_4–COOH$ (*b*) $H_2N–(CH_2)_6–HN_2$	In making brushes, synthetic fibres, parachutes, ropes and carpets.
15.	Bakelite		(*a*) HCHO (*b*) C_6H_5OH	For making gears, protective coating and electrical fittings.
16.	Urea formaldehyde resin		(*a*) HCHO (*b*) NH_2CONH_2	For making non-break able cups and laminated sheets.
17.	Melamine formaldehyde resin (Melmac)		(*a*)  (*b*) HCHO	In making plastic crockery, non-breakable cups and plates.
18.	Poly-β-hydroxy -butyrate-co-βhydroxy valerate (PHBV)			As packaging material, in making ortho-paedic devices and in controlled drug release.

NCERT IN-TEXT QUESTIONS SOLVED

15.1. What are polymers?

Ans. Polymers are high molecular mass (10^3–$10^7 u$) substances consisting of a very large number of simple repeating structural units called monomers.
Some examples are: polythene; nylon 6, 6; bakelite; rubber; etc.

15.2. How are polymers classified on the basis of structure?

Ans. On the basis of structure, polymers are classified as follows:

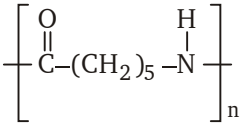
(*i*) **Linear polymers:** These polymers consist of long and straight chain, e.g. high density polythene, polyvinyl chloride, etc.

(*ii*) **Branched chain polymers:** These polymers contain linear chains having some branches, e.g. L.D.P. E.

(*iii*) **Cross linked or Network polymers.** These are formed from bifunctional and trifunctional monomer units and strong covalent bond between varying linear polymer chains, e.g. bakelite, melamine, etc.

15.3. Write the names of monomers of the following polymers:

(*i*) 

(*ii*) 

(*iii*) $\{CF_2 - CF_2\}$

Ans. (*i*) Hexamethylenediamine $H_2N–(CH_2)_6– NH_2$ and adipic acid $HOOC(CH_2)_4COOH$.

(*ii*) Caprolactam

(*iii*) Tetrafluoroethene, $F_2C = CF_2$

15.4. Classify the following as addition and condensation polymers:
Terylene, Bakelite, Polyvinyl chloride, Polythene.

Ans. Addition polymers: Polyvinyl chloride, Polythene

Condensation polymers: Terylene, Bakelite

15.5. Explain the difference between Buna–N and Buna–S.

Ans. Both are copolymers, but Buna–N is a copolymer of 1, 3–butadiene & acrylonitrile and Buna–S is a copolymer of 1, 3–butadiene and styrene.

15.6. Arrange the following polymers in increasing order of their intermolecular forces.

(*i*) Nylon 6, 6, Buna–S, Polythene.

(*ii*) Nylon 6, Neoprene, Polyvinyl chloride.

Ans. (*i*) Buna–S < Polythene < Nylon 6, 6.

(*ii*) Neoprene < Polyvinyl chloride < Nylon 6.

NCERT TEXTBOOK QUESTIONS SOLVED

15.1. Explain the terms polymer and monomer.

Ans. Polymers: Polymers are defined as high molecular mass macromolecules which consists of repeating structural units derived from the corresponding monomers.
Monomers. Simple and reactive molecules from which the polymers are prepared either by addition or condensation reaction are called monomers. For example: ethene, vinyl chloride, acrylonitrile, etc.

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

Ans. Natural polymers: Polymers which are found in nature, *i.e.* in animal and plants are called natural polymers. For example, proteins, starch, cellulose, etc.

Synthetic polymers: Man-made polymers are called synthetic polymers. For example plastics, synthetic fibres.

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

Ans. **Homopolymers:** Polymers whose repeating structural units are derived from only one type of monomer units are called homopolymers. For example, polythene, PVC, PAN, etc.

Copolymers. Polymers whose repeating units are derived from two or more types of monomer molecules are called co-polymers. For example, Buna–S; Buna–N; Nylon 6, 6; etc.

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

Ans. Functionality of a monomer is the number of bonding sites in a molecule.
For example, the functionality of ethene, propene, styrene, acrylonitrile is one.

15.5. Define the term polymerisation.

Ans. The process of formation of polymers from their respective monomers is called polymerisation.

15.6. Is $-(NH-CHR-CO)-_n$ a homopolymer or copolymer?

Ans. It is a homopolymer.

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

Ans. On the basis of molecular forces polymers are classified as follows:

(*i*) Elastomers (*ii*) Fibres

(*iii*) Thermoplastics (*iv*) Thermosetting polymers

15.8. How can you differentiate between addition and condensation polymerisation?

Ans. **Addition polymerisation.** In this type of polymerisation, a large number of molecules of same or different monomers simply add to the other unit, leading to the formation of a macromolecule. Addition polymerisation generally occurs among molecules containing double and triple bonds.

Condensation polymerisation. In this type of polymerisation two or more bifunctional molecules undergo a series of independent condensation reactions usually with the elimination of simple molecules like water, alcohol, ammonia, etc.

15.9. Explain the term copolymerisation and give two examples.

Ans. When two or more different monomers are allowed to polymerise together, the product formed is called a copolymer and the process is called copolymerisation. For example, Buna–S and Buna–N.

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

Ans. The polymerisation of ethene to polythene consists of heating or exposing to light a mixture of ethene with a small amount of benzoyl peroxide initiator. Mechanism can be shown as:

Chain Initiation Step:

$$\underset{\text{Benzoyl peroxide}}{C_6H_5-\overset{O}{\overset{\|}{C}}-O-O-\overset{O}{\overset{\|}{C}}-C_6H_5} \longrightarrow 2C_6H_5-\overset{O}{\overset{\|}{C}}-\dot{O} \longrightarrow 2\dot{C}_6H_5 + 2CO_2$$

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

Chain Propagation Step:

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

$$\downarrow n CH_2=CH_2$$

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

Chain Termination Step:

$$C_6H_5 \left(CH_2 - CH_2 \right)_n CH_2 - \dot{C}H_2 + C_6H_5 \left(CH_2 - CH_2 \right)_n CH_2 - \dot{C}H_2 \longrightarrow \underset{\text{Polythene}}{C_6H_5 \left(CH_2 - CH_2 \right)_n CH_2 - CH_2 - CH_2 - CH_2 \left(CH_2 - CH_2 \right)_n C_6H_5}$$

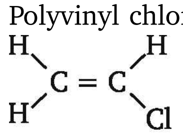
15.11. Define thermoplastics and thermosetting polymers with two examples of each.

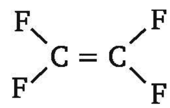
Ans. **Thermoplastic polymers:** These are linear or slightly branched long chain molecules capable of repeatedly softening on heating and hardening on cooling. These polymerses possess intermolecular forces of attraction intermediate between elastomers and fibres. Some common thermoplastics are polythene, polystyrene.

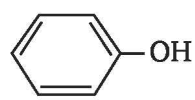
Thermosetting polymers: These polymers are cross linked or slightly branched molecules. These cannot be reused. Examples: bakelite, urea formaldehyde resins

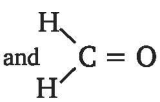
15.12. Write the monomers used for getting the following polymers.

(*i*) Polyvinyl chloride (*ii*) Teflon (*iii*) Bakelite

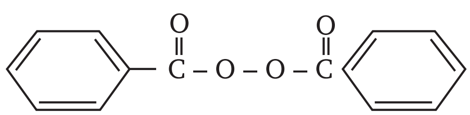
Ans. (*i*) 
Vinyl chloride

(*ii*) 
Tetrafluoroethene

(*iii*) 
Phenol

and 
Formaldehyde

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

Ans. Benzoyl peroxide: 

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

Ans. In this polymer, double bonds are located between C_2 and C_3 of each isoprene unit. These *cis*-double bonds does not allow the polymer chains to come closer for effective interactions and hence intermolecular forces are quite weak. As a result natural rubber has a randomly coiled structure.

15.15. Discuss the main purpose of vulcanisation of rubber.

Ans. (*i*) To improve the physical properties of rubber like hardness and elasticity.

(*ii*) After vulcanisation, rubber becomes resistant to the action of organic solvents and oxidising agents.

15.16. What are the monomeric repeating units of Nylon–6 and Nylon–6, 6.

Ans. Nylon–6 — Carprolactam

Nylon–6, 6 — Adipic acid and Hexamethylenediamine

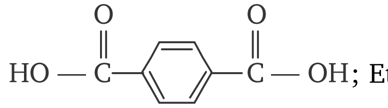
15.17. Write the names and structure of the monomers of the following polymers:

(*i*) Buna–S (*ii*) Buna–N (*iii*) Dacron (*iv*) Neoprene

[*AI*, *Delhi CBSE* 2017]

Ans. (*i*) Butadiene, $CH_2 = CH—CH = CH_2$; Styrene, $C_6H_5—CH = CH_2$

(*ii*) Butadiene, $CH_2 = CH—CH = CH_2$; Acrylonitrile, $CH_2 = \underset{\displaystyle CN}{\underset{|}{CH}}$

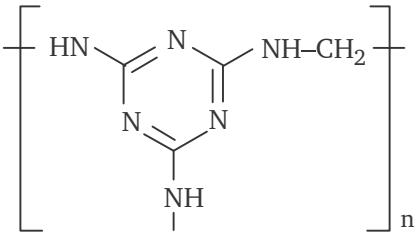
(*iii*) Terephthalic acid,  ; Ethylene glycol (Ethane-1, 2-diol)

$$\begin{array}{l} CH_2OH \\ | \\ CH_2OH \end{array}.$$

(*iv*) Chloroprene, $CH_2 = \underset{\underset{Cl}{|}}{C} - CH = CH_2$; 2-Chloro-1, 3-butadiene is the monomer of neoprene.

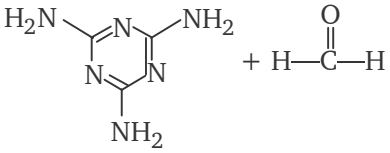
15.18. Identify the monomer in the following polymeric structures.

(*i*) $+\left[\overset{O}{\overset{\|}{C}}-(CH_2)_8-\overset{O}{\overset{\|}{C}}-NH-(CH_2)_6-NH\right]_n$ (*ii*)



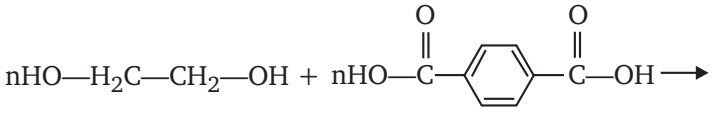
Ans. (*i*) $HO-\overset{O}{\overset{\|}{C}}-(CH_2)_8-\overset{O}{\overset{\|}{C}}-OH$ and $H_2N-(CH_2)_6-NH_2$

(*ii*)

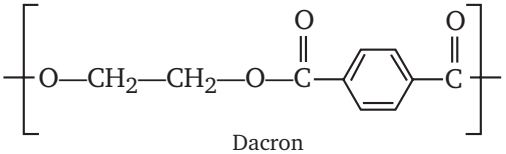


15.19. How is dacron obtained from ethylene glycol and terephthalic acid?

Ans. Dacron is obtained by condensation polymerisation of ethylene glycol and terephthalic acid with the elimination of water molecules:



Ethylene glycol Terephthalic acid



Dacron

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

Ans. Polymers which disintegrate by themselves over a period of time due to environmental degradation by bacteria, etc. are called biodegradable polymers.

Example: PHBV (poly hydroxy butrate-co-β hydroxyvalerate).

ADDITIONAL QUESTIONS SOLVED

I. Very Short Answer Type Questions

(1 Mark)

Q1. Name the monomer of nylon 2 or nylon 6 polymer. [*CBSE* 2009]

Ans. Caprolactam

Q2. What is the difference between the two notations: nylon-6 and nylon-6, 6 [*AI Set–I* 2008]

Ans. Nylon 6 — $+\left[\overset{O}{\overset{\|}{C}}-(CH_2)_5-\overset{O}{\overset{\|}{N}}-\right]_n$

Nylon 6

Nylon 6, 6 — $+\left[\overset{H}{\underset{|}{N}}-(CH_2)_6-\overset{H}{\underset{|}{N}}-\overset{O}{\overset{\|}{C}}-(CH)_2-\overset{O}{\overset{\|}{C}}-C_4\right]_n$

Nylon 6, 6

Q3. Define the term polymerisation. [*AI* 2008]

Ans. It is a process of formation of a high molecular mass polymer from one or more monomers by linking together a large number of repeating structural units through covalent bonds.

Q4. Which of the following is a fibre? Nylon, Neoprene, PVC [*CBSE* 2014]

Ans. Nylon

II. Short Answer Type Questions

(2 or 3 Marks)

Q1. Distinguish between homopolymers and copolymers and give an example of each class. [*AI* 2008]

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

Example—PVC, Teflon, Nylon 6, etc.

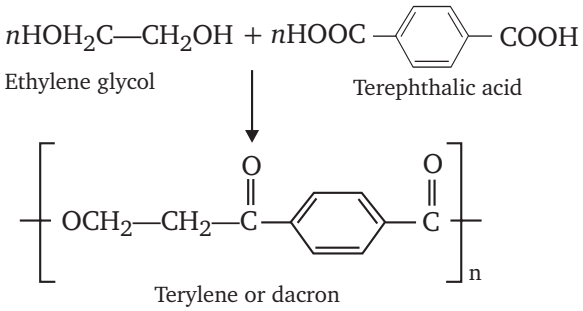
Copolymers: Polymers whose repeating structural units are derived from two or more type of monomer units are called copolymers.

Example—Bakelite, Buna–S, Nylon 6, 6; etc.

Q2. What is step growth polymerisation? Explain the steps involved in this process. [*AI* 2008]

Ans. Condensation occurs in gradual steps with the loss of small molecules.

For example, adipic acid and hexamethylene diamine undergoes step growth polymerisation. Terylene is synthesised by condensation of terephthalic acid and ethylene glycol:



Q3. What is the difference between elastomers and fibres? Give one example of each. [*AI* 2008]

Ans.

Elastomers	Fibres
(*i*) These are rubber like solids with elastic properties.	(*i*) These are the thread forming solids which possesses high tensile strength and high modulus.
(*ii*) These are held by the weak intermolecular forces. **Example:** Buna–S and Buna–N.	(*ii*) These are held together by strong intermolecular forces like hydrogen bonding. **Example:** Nylon 6, 6 and polyesters (terylene)

Q4. What are thermoplastics and thermosetting polymers? Give one example of each. [*AI* 2008, 2014]

Ans. Thermoplastics: Thermoplastics are linear polymers which can be repeatedly softened on heating and hardened on cooling and hence can be used again and again without any change in chemical composition and mechanical strength.

Example—Polythene and polypropene.

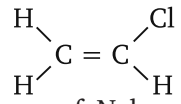
Thermosetting polymers : Thermosetting polymers, are permanently setting polymers. On heating in a mould, they get hardened and set and cannot be softened again. This hardening on heating is due to cross linking between different polymeric chains which give rise to a three dimensional network solid. Example—Bakelite.

Q5. Draw the structure of monomer of each of the following polymers:

(*i*) Polyvinyl chloride (PVC)

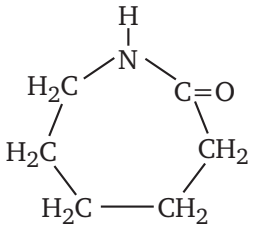
(*ii*) Nylon–6 [*AI* 2007]

Ans. (*i*) Monomer of PVC is vinyl chloride. Structure:



(*ii*) Monomer of Nylon–6 is caprolactum.

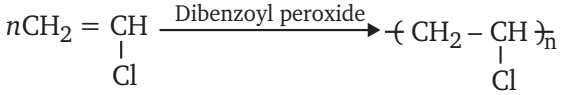
Structure:



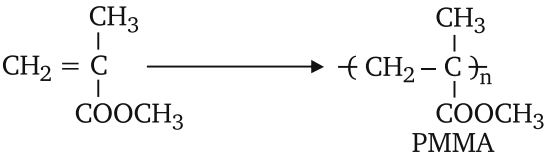
Caprolactum

Q6. Write the names of monomers used for getting the polymers PVC and PMMA. State one use for each of these polymers. [*AI* 2006]

Ans. For PVC, the monomer unit is vinyl chloride:



PVC is used in the manufacture of raincoats, hand bags, vinyl flooring, etc. The momer unit for PMMA is methylmethacrylate.



PMMA

PMMA is used as a substitute of glass and in making decorative materials.

Q7. Write the structures of monomers used and one use of each of the following polymers:

(*a*) Teflon

(*b*) Buna–N [*AI* 2006]

Ans. (*a*) Teflon — Monomer:

$CF_2 = CF_2$

Tetrafluoroethylene

Uses: In making non sticky cooking utensils and in making of seals and tank linings.

(*b*) Buna–N — Monomer:

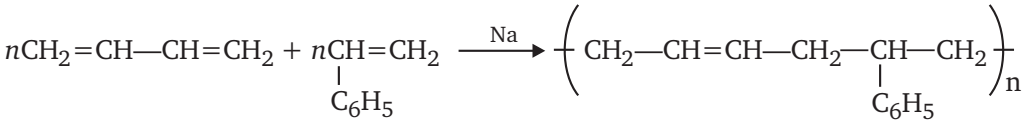
1, 3-Butadiene

Acrylonitrile

Uses: It is resistant to the action of petrol, lubricating oil and organic solvents. It is used in making oil seals, tank lining, etc.

Q8. What are elastomers? Give the chemical equation for the preparation of Buna–S. [*AI* 2006]

Ans. Elastomers: Polymers in which the intermolecular forces of attraction between the polymer chains are weakest are called elastomers. These polymers consist of randomly coiled molecular chains of irregular shape having a few cross links.



Buta-1,3-diene Styrene Buna–S

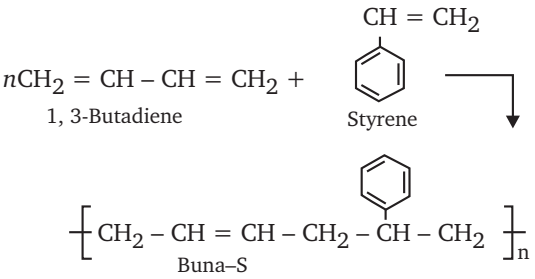
Q9. How is bakelite made and what is its major use? Why is bakelite a thermosetting polymer? [*AI CBSE* 2005]

Ans. Bakelite is formed by the condensation polymerisation reaction of phenol with formaldehyde in the presence of an acid or a base catalyst. Bakelite is chiefly used in making electrical goods.

Bakelite is a thermosetting plastic because it cannot be reshaped on heating due to high degree of cross-linking between the different polymer chains.

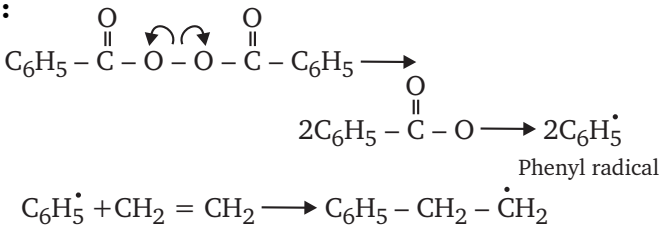
Q10. What is meant by copolymerisation? Give one example of such a polymer. [*AI* 2004]

Ans. Copolymerisation: When the polymers are synthesised by polymerisation of two or more than two different monomers, then they are called copolymers. For example, when styrene and butadiene are poly-merised, we get a copolymer called butadiene-styrene copolymer or Buna-S rubber.

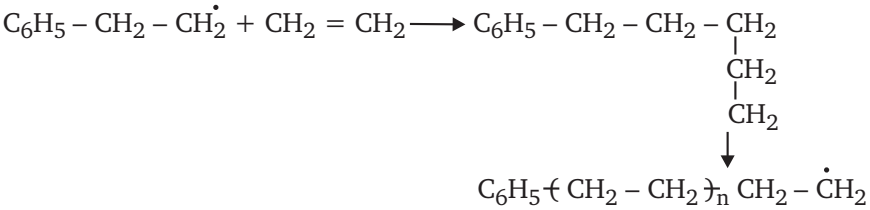


Q11. Write the mode of free radical polymerisation of an alkene. [*AI* 2004]

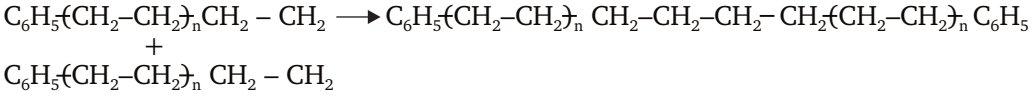
Ans. Chain Initiation step:



Chain propagating step:



Chain termination step:



Q12. Differentiate between addition and condensation polymers based on the mode of polymerisation. Give one example of each type. [*AI* 2004]

Ans.

Addition Polymers	Condensation polymers
(*i*) They are formed by adding monomers to a growing polymer chain without loss of any molecule.	(*i*) They are formed by combining monomers together with the loss of small molecules like H_2O, NH_3, CO_2, etc.
(*ii*) They are formed from unsaturated compounds. **Example:** Polyethene, polypropene	(*ii*) Monomers have di or polyfunctional groups. **Example:** Nylon–6, 6, Nylon–6, Terylene.

Q13. Write formulae of the monomers of polythene and teflon. [*AI* 2007]

Ans. Polythene — $CH_2 = CH_2$
Teflon — $CF_2 = CF_2$

Q14. (*a*) How does vulcanisation changes the character of natural rubber?
(*b*) Why are the numbers 6, 6 and 6 put in the names of nylon 6, 6 and nylon 6?

Ans. (*a*) The process involving more cross-links in a rubber and altering its structure so that it becomes less plastic and sticky, more resistant to swelling by organic liquids and thus rubber has enhanced elasticity.

(*b*) Nylon–6,6 is a polymer of adipic acid and hexamethylene diamine, *i.e.* both the monomers having 6 carbon atoms each.

Nylon–6 is a polymer of carpolactam which contains 6 carbon atoms.

Q15. What are biodegradable polymers? Give two examples: [*AI* 2006]

Ans. Biodegradable polymers are those which are decomposed by micro-organisms.
e.g., PHBV (poly β-hydroxybutyrate–co–β-hydroxyvalerate), poly-glycolic acid and poly-lactic acid.

Q16. Can a copolymer be formed both in addition and condensation polymerisation? Explain with examples. [*AI* 2006 *C*, 2005 *C*]

Ans. Yes a copolymer can be made by addition as well as in condensation polymerisation. For example, Buna–S is an addition copolymer of 1, 3 Butadiene and styerene, whereas Nylon–6, 6 is a condensation copolymer of adipic acid and hexamethylene diamine.

$$n\mathrm{CH_2=CH-CH=CH_2} + n\mathrm{CH(C_6H_5)=CH_2} \longrightarrow \left(\mathrm{CH_2-CH=CH-CH_2-CH(C_6H_5)-CH_2}\right)_n$$

1, 3-Butadiene — Styrene — Buna–S

$$n\mathrm{H_2N(CH_2)_6NH_2} + n\mathrm{HOOC(CH_2)_4COOH} \longrightarrow \left(\mathrm{NH(CH_2)_6NHCO(CH_2)_4CO}\right)_n$$

Hexamethylene diamine — Adipic acid — Nylon 6, 6

Q17. How are polymers classified on the basis of forces operating between their molecules? To which of these classes does nylon–6, 6 belong? [*AI* 2005]

Ans. Polymers are classified in the following four subgroups on the basis of magnitude of intermolecular forces present in them:

(*i*) **Elastomers:** The polymer chains are held together by weak intermolecular forces.
Example—Buna–S, Buna–N, Neoprene.

(*ii*) **Fibres.** They have strong forces of attraction. Example—Polyamides, (Nylon 6, 6), polyesters.

(*iii*) **Thermoplastics:** They are long chain molecules capable of repeatedly softening on heating and hardening on cooling. Example—Polythene, polystyrene.

(*iv*) **Thermosetting Plastics:** They do not become soft on heating and cannot be remoulded. Example—Bakelite.
Nylon-6, 6, belong to fibres.

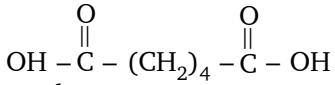
Q18. Distinguish between 'chain growth polymerisation and step growth polymerisation' and give one example of each. [*Foreign* 2005]

Ans.

Chain growth polymerisation	Step growth polymerisation
1. Only one repeating unit is added at a time.	1. Any two species present can react.
2. Reaction is fast and polymer is formed at once. Example—polythene.	2. Polymer is formed in gradual steps. Example—Nylon–6, 6.

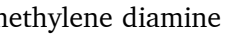
Q19. Write the structural formula for the monomers of following polymers:
(*i*) Nylon-6 (*ii*) Natural rubber.
[*Delhi* 2012]

Ans. (*i*) Adipic acid –



and

Hexamethylene diamine –

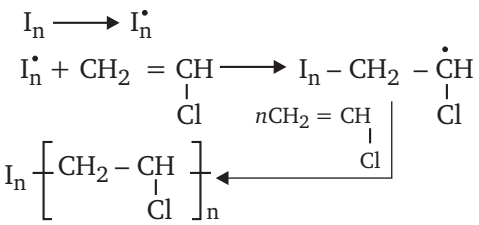


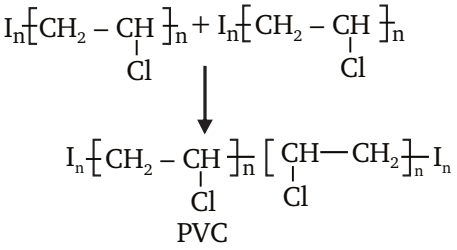
(*ii*) Isoprene

Q20. What are the different ways of initiating addition polymerisation. Describe one of them for polymerising vinyl chloride.
[*Foreign* 2005]

Ans. Different ways of initiating addition polymerisation:
(*i*) Free radical polymerisation using peroxide as an initiator.
(*ii*) Cationic polymerisation using H^+ as the initiator.
(*iii*) Anionic polymerisation using KNH_2 as the initiator.

Free radical polymerisation:





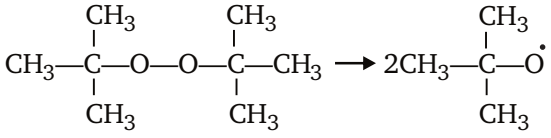
PVC

Q21. Name the four categories in which polymers have been classified on the basis of magnitude of forces present in them.
[*CBSE* 2005 *C*]

Ans. (*i*) Elastomers
(*ii*) Fibres
(*iii*) Thermoplastics
(*iv*) Thermosetting

Q22. Write the structure of a reagent used for initiating a free radical chain reaction. How does it act? [*Foreign* 2004]

Ans.

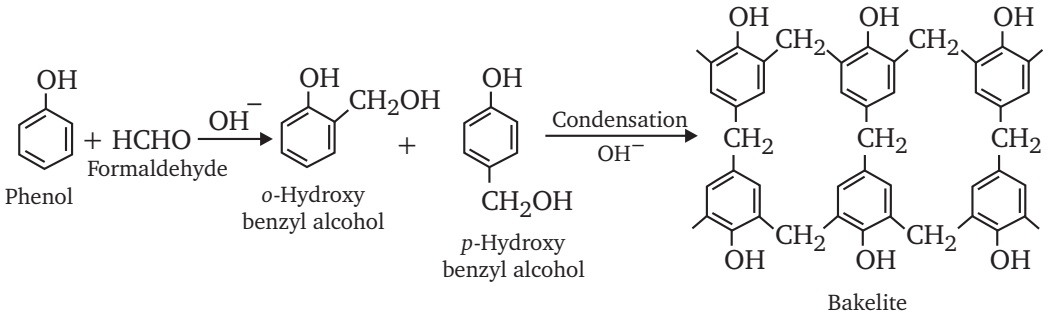


Tert.butyl peroxide

It undergoes homolytic fission to generate free radical which initiates chain reaction.

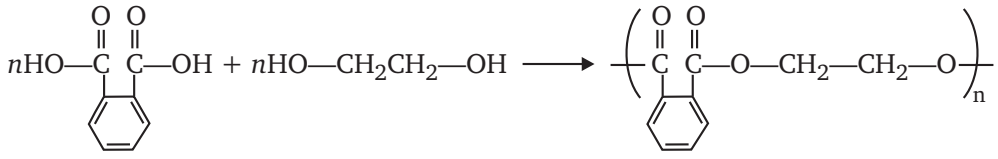
Q23. (*a*) How is the following prepared: Bakelite [*AI* 2004]
(*b*) Write equations for the synthesis of the following: Glyptal. [*AI* 2003]

Ans. (*a*) **Bakelite:** It is prepared by the condensation of phenol and formaldehyde—



Phenol + Formaldehyde → *o*-Hydroxy benzyl alcohol + *p*-Hydroxy benzyl alcohol (Condensation, OH^-) → Bakelite

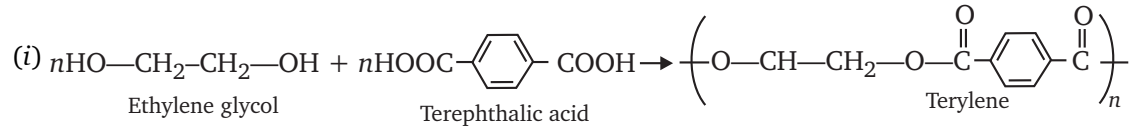
(*b*) **Glyptal.** It is prepared by condensation of ethylene glycol and phthalic acid.



Phthalic acid Ethylene glycol Glyptal

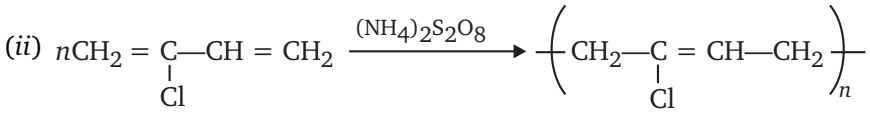
Q24. Write equations used for the synthesis of (*i*) terylene, (*ii*) neoprene. [*AI* 2003]

Ans. (*i*)



Ethylene glycol Terephthalic acid Terylene

(*ii*)



Chloroprene Neoprene

Q25. Classify the following as addition and condensation polymers:
Terylene, Bakelite, Polyvinyl chloride, Polythene.

Ans. Addition polymers — PVC, Polythene.
Condensation polymers — Terylene, Bakelite.

Q26. Differentiate the following pair of polymers based on the property mentioned against each.
(*i*) Novolac and Bakelite (Structure)
(*ii*) Buna–S and Terylene (intermolecular forces of attraction) [*AI* 2009]

Ans. (*i*) Novolac is a straight chain linear polymer but bakelite is cross linked Polymer.
(*ii*) Buna–S is an elastomer having weak van der Waals' intermolecular forces whereas Terylene is a fibre having strong intermolecular forces–hydrogen bonding.

Q27. Write names of monomers of the following polymers and classify them as addition or condensation polymer.
(*a*) Teflon
(*b*) Bakelite
(*c*) Natural rubber [*AI* 2009]

Ans. (*a*) Tetraflouroethene, addition polymer,
(*b*) Phenol and formaldehyde,condensation polymer, and
(*c*) Isoprene, addition polymer

Q28. (*a*) What is the role of Benzoyl peroxide in the polymerisation of ethene?
(*b*) What are LDPE and HDPE? How are they prepared? [*AI* 2009]

Ans. (*a*) Benzoyl peroxide is the initiator. It forms the free radical to initiate polymerisation.
(*b*) **LDPE:** (Low density polyethylene). It is obtained by the polymerisation of ethene under high pressure of 1000 to 2000 atm. at 350 K to 570 K temperature in the presence of an initiator.
HDPE: (High density polyethylene) It is obtained when polymerisation of ethene is done in the presence of **Ziegler Natta Catalyst** at 333 K to 343 K under 6–7 atm. pressure.

Q29. Write the name of monomers used for getting the following polymers:
(*i*) Teflon (*ii*) Buna–N [*CBSE* 2014]

Ans. (*i*) $CF_2 = CF_2$ (Tetrafluoroethylene)

(*ii*) $\underset{\text{(Butan– 1, 3–di–ene)}}{CH_2 = CH - CH = CH_2} + CH_2 = \underset{\text{(Acrylonitrile)}}{\underset{\displaystyle CN}{\underset{|}{CH}}}$

Q30. Write the names and strucutres of the monomers of the following polymers:

(*a*) Nylon-6, 6 (*b*) PHBV (*c*) Neoprene [*CBSE* 2015]

Ans. (*a*) $CF_2 = CF_2$ (Tetrafluoroethylene)

(*b*) $\underset{\beta\text{-hydroxy butyrate}}{H_3C - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_2COOH}$ and $\underset{\beta\text{-hydroxyvalerate}}{H_3C - CH_2 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_2 - COOH}$

(*c*) $\underset{\text{2-chloro-buta–1, 3–diene (monomer)}}{H_2C = \underset{\displaystyle Cl}{\underset{|}{C}} - CH = CH_2}$

Q31. (*i*) What is the role of benzoyl peroxide in the polymerisation of ethene? [*CBSE* 2016]

(*ii*) Identify the monomers in the following polymer:

$$\left(\begin{array}{l} H \\ | \\ N - (CH_2)_6 - NH - \underset{\displaystyle O}{\underset{\|}{C}} - (CH_2)_4 - \underset{\displaystyle O}{\underset{\|}{C}} \end{array} \right)_n$$

(*iii*) Arrange the following polymers in the increasing order of intermolecular forces:

Polythene; Nylone 6, 6; Buna – S.

Ans. (*i*) Benzoyl peroxide is free radical initiator. In the presence of benzoyl peroxide, phenyl free radical is formed which is responsible for the chain initiating step.

(*ii*) (*a*) $H_2N - (CH_2)_6 - NH_2 \rightarrow$ (Hexamethydiamine) and adipic acid $\rightarrow$ $COOH - (CH_2)_4 - COOH$

(*iii*) Polythene < Buna – S < Nylon 6,6

Q32. Write the mechanism for free radical polymerization of ethene. [*CBSE* 2016]

Ans. Free radical mechanism:–

(*i*) Chain initiation step–

$$\underset{\text{Benzoyl peroxide (initiator)}}{C_6H_5 - \overset{\displaystyle O}{\overset{\|}{C}} - O - O - \overset{\displaystyle O}{\overset{\|}{C}} - C_6H_5} \longrightarrow 2C_6H_5 - C - \overset{\bullet}{O} \longrightarrow \underset{\text{phenyl radical}}{2C_6\overset{\bullet}{H}_5}$$

(*ii*) Chain propagating step:

$$C_6H_5 + mCH_2 = CH_2 \longrightarrow C_6H_5 - (CH_2 - CH_2)_m$$

(*iii*) Chain terminating step:

$$C_6H_5CH_2 - CH_2 + CH_2 = CH_2 \longrightarrow C_6H_5 - CH_2 - CH_2 - CH_2^{\bullet}$$

$$\downarrow \text{ Chain termination}$$

$$\underset{\text{Polythene}}{C_6H_5(CH_2 - CH_2)_n CH_2 - CH_2 - CH_2(CH_2 - CH_2)_n C_6H_5}$$

III. Value-Based Questions

Q1. Ram's mother always follow very traditional way of cooking using earthen wares, copper utensils. He replaced all the kitchen utensils with Teflon coated ones.

(*a*) In your opinion who is correct in the present life situation?

(*b*) What is the monomer of Teflon? What is its structure?

(*c*) What are the values involved?

Ans. (*a*) Ram

(*b*) Tetrafluoroethene, $-(CF_2-CF_2)-_n$.

(*c*) Scientific attitude and Self awareness

Q2. The Government order that directs the shopkeepers to charge their customers for the polythene bags, to take the items that they purchase.

(*a*) Name the different types of polythene available.

(*b*) Why does the Government impose such an order?

(*c*) What are the values involved in the Government order?

Ans. (*a*) LDPE (low density polyethylene) and HDPE (high density polyethylene).

(*b*) Polythene is non-biodegradable and is becoming a big problem for disposal as garbage.

(*c*) Social responsibility and Environmental conservation.

Q3. Two shopkeepers are using LDP (Low Density Polythene) and HDP (High Density Polythene) polymers, respectively for packaging of materials.

(*i*) Name the polythene preferred for packaging.

(*ii*) Name the catalyst used in the synthesis of HDP.

(*iii*) Mention the values associated with the use of a specific polymer.

Ans. (*i*) LDP is preferred for packaging.

(*ii*) Ziegler-Natta catalyst.

(*iii*) Critical thinking and Self awareness.

Q4. PHBV (Poly-β-hydroxybutyrate-co-β-hydroxyvalerate) is a biodegradable polymer. It is a copolymer of 3-hydroxy valeric acid and 3-hydroxypentanoic acid.

(*a*) How PHBV has found utility in medicines as capsules?

(*b*) Write the name of polymer used in artificial limb, popularly known as Jaipur foot.

(*c*) Mention the value associated with the use of such polymers.

Ans. (*a*) When a drug is put in a capsule of PHBV, it is released only after the degradation of this polymer. Hence, it controls the release of drug.

(*b*) PHBV.

(*c*) Environmental conservation.

Q5. How are biopolymers more beneficial than synthetic polymers?

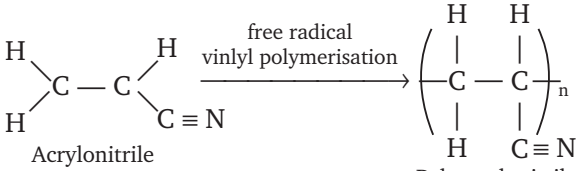
Ans. Durability of synthetic polymers is advantageous, however it presents a serious waste disposable problem. In renewal of the disposable problem, biodegradable polymers are useful to us.

Biopolymers are safe in use. They disintegrate by themselves in biological system during a certain period of time by enzymatic hydrolysis and to some extent by oxidation and hence, are biodegradable. As a result, they do not cause any pollution.

IV. HOTS Questions

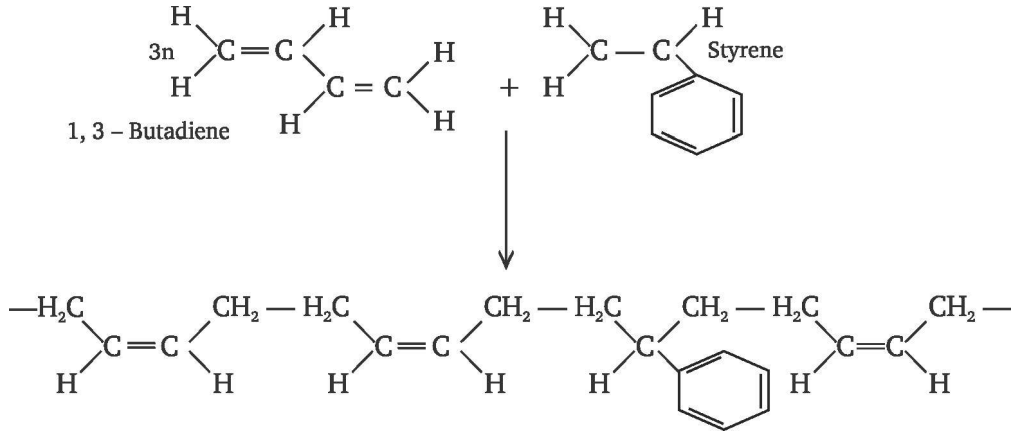
Q1. Give the method of preparation of polyacrylonitrile?

Ans. The addition polymerisation of acrylonitrile in the presence of a peroxide catalyst leads to the formation of polyacrylonitrile. It is used as a substitute for wool in making fibres such as orlon or acrilan.



Q2. Define copolymerisation? Give chemical reaction showing formation of a copolymer.

Ans. Copolymerisation is a polymerisation reaction in which a mixture of more than one monomeric species is allowed to polymerise together to form a copolymer. For example, a mixture of a 1, 3–butadiene and styrene forms a copolymer as:



Styrene-Butadiene Rubber

Q3. Describe the method for the preparation of neoprene?

Ans. Neoprene or poly chloroprene is formed by the free radical polymerisation of chloroprene monomeric unit as:

$$n\,CH_2 = \underset{\displaystyle Cl}{\underset{|}{C}} - CH = CH_2 \xrightarrow{\text{Polymerisation}} -\!\left[\,CH_2 - \underset{\displaystyle Cl}{\underset{|}{C}} = CH - CH_2\,\right]_n -$$

Chloroprene (2–chlorobutadiene) → Neoprene (synthetic rubber)

Q4. Differentiate between Addition and Condensation polymers?

Ans.

S.No.	Addition Polymers	Condensation Polymers
1.	They are formed by the repeated addition of molecules possessing double or triple bonds.	They are formed by repeated condensation reaction between two different bi-functional bi-functional and tri-functional monomeric units.
2.	E.g. polythene	E.g. nylon 6, 6

Q5. Differentiate between Homopolymers and Copolymers with example.

Ans. Homopolymers: The addition polymers formed by the repeated addition of monomer molecules possessing double or triple bonds, are known as hompolymers.

$$\underset{\text{Ethene}}{n\,CH_2 = CH_2} \longrightarrow \underset{\text{Polythene}}{-\!\left(CH_2 - CH_2\right)-}$$

Copolymers: The polymers formed by addition polymerisation of two different monomers are termed as copolymers.

E.g. $n\,CH_2{=}CH{-}CH = CH_2 + n\,C_6H_5CH = CH_2 \longrightarrow -[CH_2{-}CH = CH{-}CH_2{-}CH(C_6H_5)-]_n$

Q6. Define the term polyesters? How is it manufactured?

Ans. Polyesters are the condensation products of dicarboxylic acids and diols, *e.g.* Dacron or Terylene.

It is manufactured by heating a mixture of ethylene glycol and terephthalic acid at 420 to 460 K in the presence of zinc acetate-antimony trioxide as catalyst.

Q7. Explain vulcanisation of rubber?

Ans. Natural rubber becomes soft at high temperatures and brittle at low temperature. It has high water absorption capacity. It is also soluble in non-polar solvents and is non-resistant to attack by oxidising agents.

To improve upon these physical properties, the process of vulcanisation is carried out. It consists of heating a mixture of raw rubber with sulphur within a temperature range of 373 K to 415 K. On vulcanisation, sulphur form cross links at reactive sites of double bonds and thus the rubber gets stiffened.

Q8. Give two examples of biodegradable polymers?

Ans. (*i*) PHBV (*ii*) Nylon 2–nylon 6

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