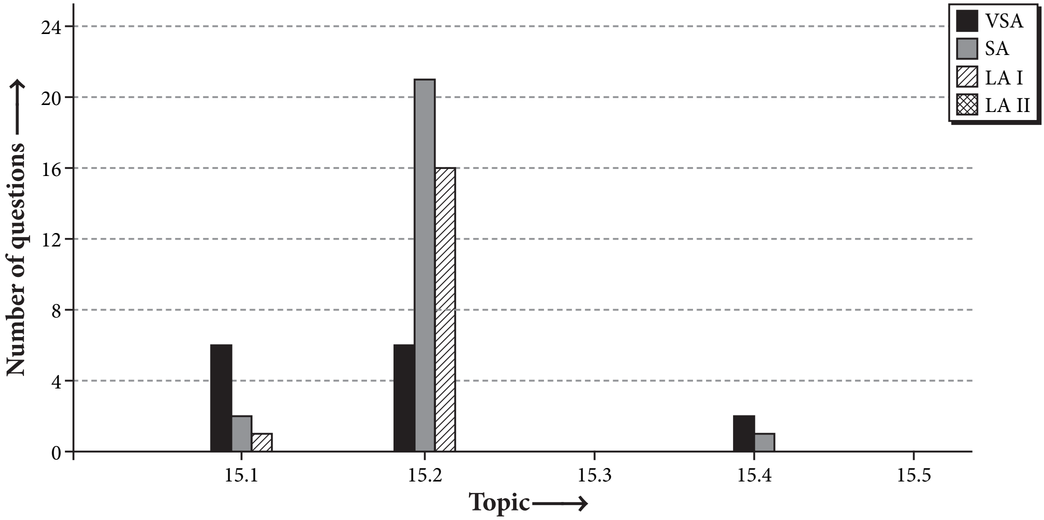
CHAPTER

15

Polymers

Topicwise Analysis of Last 10 Years' CBSE Board Questions (2020-2011)



- Maximum total weightage is of *Types of Polymerisation Reactions.*
- Maximum VSA type questions were asked from *Classification of Polymers* and *types of Polymerisation Reactions.*
- Maximum SA and LA I type questions were asked from *Types of Polymerisation Reactions.*

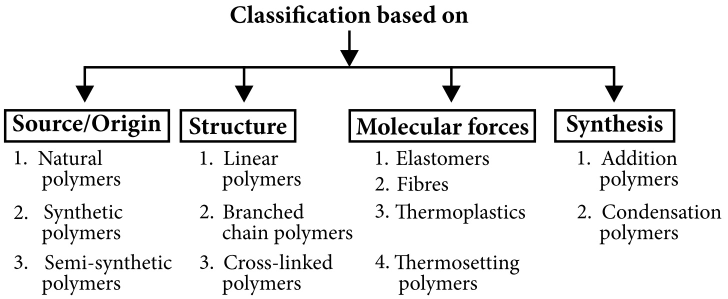
QUICK RECAP

- **Polymers :** They are macro-sized, high molecular mass compounds, formed by the combination of a large number of simple molecules or repeating units.
- **Monomers :** The simple molecules or repeating units which combine to give polymers are called *monomers*.
- The process of joining together of a large number of the monomers is termed as *polymerisation*.
- A polymer formed from one type of monomers is called *homopolymer*, *e.g.*, polyethene, PVC, polyacrylonitrile, etc.

- A polymer formed from two or more different monomers is called *copolymer, e.g.*, nylon-6,6, polyester, bakelite, etc.

- The number of times a monomer unit is repeated in a polymer, is called its *degree of polymerisation*.

- **Classification of polymers :**

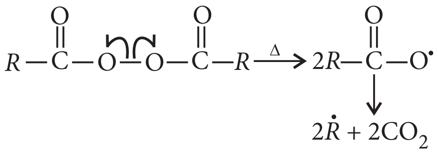


- **Natural polymers :** These are substances of natural origin and are mainly found in plants and animals, *e.g.*, starch, cellulose, proteins, etc.
- **Synthetic polymers :** These polymers are prepared in the laboratories, they are also called *man-made polymers*, *e.g.*, teflon, terylene, synthetic rubber, etc.
- **Semi-synthetic polymers :** They are mostly derived from naturally occurring polymers by chemical modifications, *e.g.*, vulcanised rubber, cellulose nitrate, etc.
- **Linear polymers :** In these polymers, the monomers are linked together to form linear chains, *e.g.*, polyethene, polyester, nylon, etc.
- **Branched chain polymers :** In these polymers, the monomers are joined to form long chains or branches of different lengths, *e.g.*, glycogen, starch, etc.
- **Cross-linked polymers :** In these polymers, the monomer units are cross-linked together to form a three-dimensional network polymers, *e.g.*, bakelite, melamine, etc.
- **Elastomers :** These are the polymers having very weak intermolecular forces between the polymer chains. The weak forces permit the polymer to be stretched. Elastomers, thus, possess elastic character, *e.g.*, vulcanised rubber.
- **Fibres :** These are the polymers which have strong intermolecular forces between the chains. These forces are either hydrogen bonds or dipole-dipole interactions, *e.g.*, nylon-6,6.
- **Thermoplastics :** These are the polymers in which the intermolecular forces of attraction are intermediate between those of elastomers and fibres. These polymers do not have any cross-links between the chains, they can be easily moulded on heating *i.e.*, thermoplastics soften on heating and become hard on cooling, *e.g.*, polythene, polystyrene, PVC, etc.
- **Thermosetting polymers :** They have extensive cross-links formed between polymer chains on heating. They undergo a permanent change on heating, *e.g.*, bakelite, melamine, etc.
- **Addition polymerisation :** A polymer formed by direct addition of repeated monomers without the elimination of by-product molecules is called *addition polymer* and the phenomenon is known as *addition polymerisation*, *e.g.*, polythene.
- **Condensation polymerisation :** A polymer formed by the condensation of two or more than two monomers with the elimination of simple molecules like water, ammonia, alcohol, etc. is called *condensation polymer* and the phenomenon is known as *condensation polymerisation*, *e.g.*, terylene.

- **Types of polymerisation reactions :**

- **Addition or chain growth polymerisation :** Depending upon the reactive particles formed, it is of three types :
  - **Free radical polymerisation :** It takes place in three steps :

- **Chain initiating step :** This step requires initiators which are free radicals produced on heating, *e.g.*, benzoyl peroxide, acetyl peroxide, dioxygen, etc.



$$R-\overset{O}{\overset{\|}{C}}-O-O-\overset{O}{\overset{\|}{C}}-R \xrightarrow{\Delta} 2R-\overset{O}{\overset{\|}{C}}-\dot{O} \longrightarrow 2\dot{R} + 2CO_2$$

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

- **Chain propagating step :** The free radical thus formed adds to the double bond of the monomer to form larger free radical.

$$RCH_2\dot{C}H_2 \xrightarrow{CH_2=CH_2} RCH_2CH_2CH_2\dot{C}H_2 \longrightarrow R-(CH_2-CH_2)_n-CH_2-\dot{C}H_2$$

- **Chain terminating step :** The growing free radical chain consumes free radicals either by combination or by disproportionation to get polymer.

Combination :

$$2R-(CH_2-CH_2)_n-CH_2-\dot{C}H_2 \longrightarrow R-(CH_2CH_2)_n-CH_2CH_2CH_2CH_2-(CH_2CH_2)_n-R$$

Disproportionation :

$$2R-(CH_2-CH_2)_n-CH_2-\dot{C}H_2 \longrightarrow \underset{\text{Alkene}}{R-(CH_2-CH_2)_n-CH=CH_2} + \underset{\text{Alkane}}{R-(CH_2-CH_2)_n-CH_2-CH_3}$$

– **Cationic polymerisation :** Initiated by the use of strong Lewis acids such as HF, $AlCl_3$, H_2SO_4, etc.

$$H_2SO_4 \longrightarrow H^+ + HSO_4^-$$

$$H^+ + CH_2=CH_2 \longrightarrow \underset{\text{Carbocation}}{CH_3-CH_2^+}$$

e.g., polyvinylether, polyisobutylene, polystyrene, etc.

– **Anionic polymerisation :** Initiated by strong bases such as $NaNH_2$, C_4H_9Li and Grignard reagent, etc.

$$B: + CH_2=CH_2 \longrightarrow \underset{\text{Carbanion}}{B-CH_2-CH_2^-}$$

e.g., polyacrylonitrile, polyvinyl chloride and polymethylmethacrylate, etc.

► **Condensation or step growth polymerisation :** In this type of polymerisation reactions, monomers are bifunctional and form bond with the loss of simple molecule of water, alcohol, ammonia, etc.

Differences between LDPE and HDPE :

Polyethylene

Low density polyethylene (LDPE)

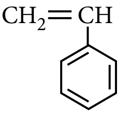
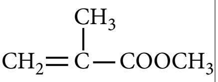
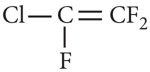
- Addition or chain growth homopolymer.
- By heating ethylene under high pressure (1000-2000 atm) at temperature of 350-570 K in presence of traces of oxygen or peroxide.
- Free radical addition polymerisation.
- Highly branched polymer.
- Low density (0.92 g/cm^3), low melting point (384 K)
- Transparent, moderate tensile strength.
- Chemically inert, tough but flexible.
- Used for packing, insulation and manufacturing squeeze bottles, pipes, toys, etc.

High density polyethylene (HDPE)

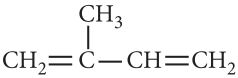
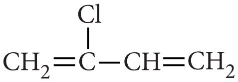
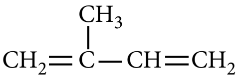
- Linear addition or chain growth homopolymer.
- By heating ethylene at 333-343 K and 6-7 atm in presence of Ziegler-Natta catalyst.
- Coordination polymerisation.
- Linear molecules, closely packed.
- High density (0.97 g/ cm^3), high melting point (403 K).
- Translucent.
- Chemically inert, quite harder, greater tensile strength.
- Used for manufacturing containers, housewares and pipes, etc.

Preparation of some important addition homopolymers :

Polyolefins

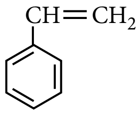
Polymer	Structure of monomers
Polythene	$CH_2{=}CH_2$ Ethylene
Polypropylene	$CH_3{-}CH{=}CH_2$ Propylene
Polytetrafluoroethene (Teflon) (PTFE)	$CF_2{=}CF_2$ Tetrafluoroethene
Polyacrylonitrile (Orlon) (PAN)	$CH_2{=}CHCN$ Acrylonitrile (Vinyl cyanide)
Polyvinyl chloride (PVC)	$CH_2{=}CHCl$ Chloroethene (Vinyl chloride)
Polystyrene (Styron)	
Polymethylmethacrylate (PMMA)	 $CH_2{=}C(CH_3){-}COOCH_3$ Methylmethacrylate
Polymonochlorotrifluoroethylene (PCTFE)	 $Cl{-}CF{=}CF_2$ Chlorotrifluoroethylene

Polydienes

Polymer	Structure of monomers
Natural rubber (*cis*-1, 4-polyisoprene)	 $CH_2{=}C(CH_3){-}CH{=}CH_2$ Isoprene (2-Methyl-1, 3-butadiene)
Neoprene (synthetic rubber)	 $CH_2{=}C(Cl){-}CH{=}CH_2$ Chloroprene (2-chloro-1, 3-butadiene)
Gutta-percha (*trans*-polyisoprene)	 $CH_2{=}C(CH_3){-}CH{=}CH_2$ Isoprene (2-Methyl-1, 3-butadiene)

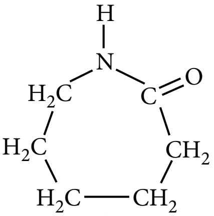
Preparation of some important addition copolymers :

Polydienes

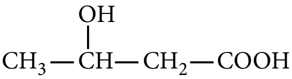
Polymer	Structure of monomers
Buna-S (Styrene Butadiene Rubber) (SBR)	$CH_2{=}CH{-}CH{=}CH_2$ 1,3-Butadiene  Styrene
Buna-N (Nitrile rubber)	$CH_2{=}CH{-}CH{=}CH_2$ 1,3-Butadiene $CH_2{=}CH{-}CN$ Acrylonitrile

Preparation of some important condensation homopolymers :

Polyamides

Polymer	Structure of monomers
Nylon-6 (Perlon-L)	 Caprolactam

Polyesters

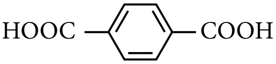
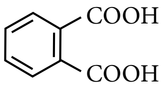
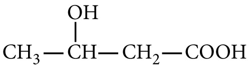
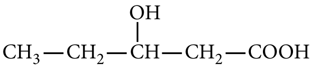
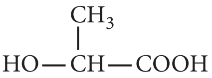
Polymer	Structure of monomers
Polyhydroxy butyrate (PHB)	 $CH_3{-}CH(OH){-}CH_2{-}COOH$ 3-Hydroxybutanoic acid

Preparation of some important condensation copolymers :

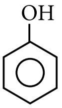
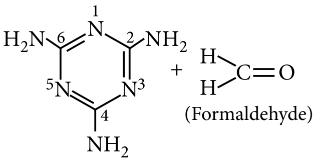
Polyamides

Polymer	Structure of monomers
Nylon-6, 6	$HOOC{-}(CH_2)_4{-}COOH$ Adipic acid $H_2N{-}(CH_2)_6{-}NH_2$ Hexamethylenediamine
Nylon-6, 10	$HOOC{-}(CH_2)_8{-}COOH$ Sebacic acid $H_2N{-}(CH_2)_6{-}NH_2$ Hexamethylenediamine
Nylon-2, 6	$H_2N{-}CH_2{-}COOH$ Glycine $H_2N{-}(CH_2)_5{-}COOH$ 6-Aminohexanoic acid

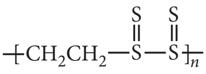
Polyesters

Polymer	Structure of monomers
Terylene (Dacron)	$HOCH_2-CH_2OH$ Ethylene glycol (Ethane-1,2,-diol)  Terephthalic acid (Benzene-1, 4-dicarboxylic acid)
Glyptal (Alkyd resin)	$HOCH_2-CH_2OH$ Ethylene glycol  Phthalic acid (Benzene-1, 2-dicarboxylic acid)
Poly-β-hydroxy butyrate-co-β-hydroxy valerate (PHBV)	 $CH_3-\overset{OH}{\overset{\vert}{CH}}-CH_2-COOH$ 3-Hydroxybutanoic acid  $CH_3-CH_2-\overset{OH}{\overset{\vert}{CH}}-CH_2-COOH$ 3-Hydroxypentanoic acid
Poly (glycolic acid) poly(lactic acid) (Dextron)	$HO-CH_2-COOH$ Glycolic acid  $HO-\overset{CH_3}{\overset{\vert}{CH}}-COOH$ Lactic acid

Formaldehyde resins

Polymer	Structure of monomers
Phenol-formaldehyde resin (Bakelite)	 Phenol + HCHO Formaldehyde
Melamine-formaldehyde resin (Melmac)	 (Formaldehyde) Melamine (2, 4, 6-Triamino-1,3,5-triazine)
Urea-formaldehyde resin	NH_2CONH_2 + HCHO Urea Formaldehyde

Polysulphide

Polymer	Structure of monomers
Thiokol  $\left[CH_2CH_2-\overset{S}{\overset{\Vert}{S}}-\overset{S}{\overset{\Vert}{S}}\right]_n$	$Cl-CH_2-CH_2-Cl$ Ethylene dichloride Na_2S_4 Sodium tetrasulphide

Differences between natural rubber and vulcanized rubber :

	Natural rubber	Vulcanized rubber
1.	Natural rubber is soft and sticky.	Vulcanized rubber is hard and non-sticky.
2.	It has low tensile strength.	It has high tensile strength.
3.	It has low elasticity.	It has high elasticity.
4.	It can be used over a wide narrow range of temperature (from 10°C to 60°C).	It can be used over a wide range of temperature (– 40°C to 100°C).
5.	It has low wear and tear resistance.	It has high wear and tear resistance.
6.	It is soluble in solvents like ether, carbon tetrachloride, petrol, etc.	It is insoluble in all the common solvents.

Molecular mass of polymers

There are two ways of expressing molecular mass of a polymer :

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

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

(i) **Number average molecular mass $(\bar{M}_n)$:** $\bar{M}_n$ is generally determined by osmotic pressure method. It is obtained by the expression.

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

where N_i = number of molecules and M_i = molecules mass

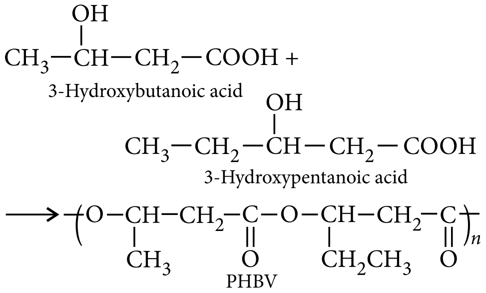
(ii) **Weight average molecular mass $(\bar{M}_w)$:** $\bar{M}_w$ is generally determined by using methods such as light scattering, ultracentrifuge, etc. It is obtained by the expression.

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

where N_i = number of monomer molecules and M_i = molecular mass.

Biodegradable polymers : Aliphatic polyesters are one of the most important class of biodegradable polymers. Some important examples are given below :

- **Poly β-hydroxybutyrate-co-β-hydroxy valerate (PHBV) :** PHBV is used in speciality packaging, orthopaedic devices and in controlled release of drugs. PHBV undergoes bacterial degradation in the environment.



$$CH_3-\overset{OH}{\overset{|}{CH}}-CH_2-COOH + CH_3-CH_2-\overset{OH}{\overset{|}{CH}}-CH_2-COOH$$

3-Hydroxybutanoic acid

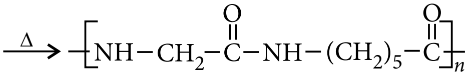
3-Hydroxypentanoic acid

$$\longrightarrow \left(O-\underset{CH_3}{\underset{|}{CH}}-CH_2-\underset{O}{\underset{||}{C}}-O-\underset{CH_2CH_3}{\underset{|}{CH}}-CH_2-\underset{O}{\underset{||}{C}} \right)_n$$

PHBV

- **Nylon-2-nylon-6 :** It is an alternating polyamide copolymer of glycine (H_2NCH_2COOH) and amino caproic acid [$H_2N(CH_2)_5COOH$] and is biodegradable.

$$nH_2N-CH_2-COOH + nH_2N-(CH_2)_5-COOH$$



$$\xrightarrow{\Delta} \left[NH-CH_2-\overset{O}{\overset{||}{C}}-NH-(CH_2)_5-\overset{O}{\overset{||}{C}} \right]_n$$

Nylon-2-nylon-6

Previous Years' CBSE Board Questions

15.1 Classification of Polymers

VSA (1 mark)

1. Arrange the following polymers in the increasing order of their intermolecular forces :
Polystyrene, Terylene, Buna-S. *(1/3, Delhi 2016)*

2. Arrange the following polymers in the increasing order of their intermolecular forces :
Terylene, Polythene, Neoprene. *(1/3, AI 2016)*

3. Which of the following is a natural polymer?
Buna-S, Proteins, PVC *(AI 2014)*

4. Based on molecular forces what type of polymer is neoprene? *(AI 2014)*

5. Which of the following is a fibre?
Nylon, Neoprene, PVC *(AI 2014)*

6. Explain the following term giving a suitable example :
Elastomers *(1/3, AI 2012)*

SA (2 marks)

7. Define thermoplastic and thermosetting polymers. Give one example of each. *(2/3, AI 2013)*

8. How are thermosetting polymers different from thermoplastic polymers? *(2/3, Delhi 2013C, 2012C)*

LA I (3 marks)

9. Differentiate between thermoplastic and thermosetting polymers. Give one example of each. *(AI 2012)*

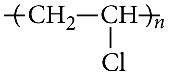
15.2 Types of Polymerisation Reactions

VSA (1 mark)

10. Give the structure of the monomer of PVC. *(One word , 2020)*

11. Write the structure of the monomers used for getting the following polymer :
Nylon-6, 6 *(1/3, AI 2017)*

12. Write the name and structure of the monomers of the following polymer :
Buna-S *(1/3, Delhi 2015C, 2013)*

13. Is  $\left[\!-\mathrm{CH_2}-\underset{\displaystyle\mathrm{Cl}}{\underset{|}{\mathrm{CH}}}-\!\right]_n$ a homopolymer or a copolymer? *(AI 2013)*

14. Name the polymer which is used for making non-stick cooking utensils. *(1/3, Delhi 2013C)*

15. Define the term, 'homopolymerisation' giving an example. *(Delhi 2012)*

SA (2 marks)

16. Write the names and structures of monomers in the following polymers :
(a) Bakelite (b) Neoprene *(2020)*

17. Write the name and structures of monomers in the following polymers :
(i) Nylon 6, 6 (ii) Terylene *(2/3, 2020)*

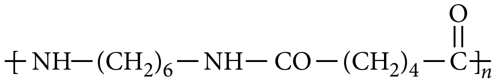
18. Classify the following as addition and condensation polymers giving reason :
(a) Teflon (b) PHBV *(AI 2019)*

19. Write the structures of monomers of the following polymers.
(a) Terylene
(b) Buna-N *(AI 2019)*

20. Write the structures of the monomers used for getting the following polymers :
(i) Dacron
(ii) Buna-N *(2/3, 2018C, Delhi 2017)*

21. Write the structures of the monomers used for getting the following polymers :
(i) Nylon-6
(ii) Teflon *(2/3, Delhi 2017)*

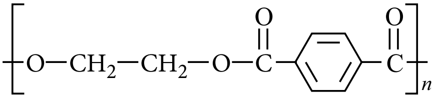
22. (i) What is the role of *t*-butyl peroxide in the polymerisation of ethene?
(ii) Identify the monomers in the following polymer :



$$\left[\!-\mathrm{NH}-(\mathrm{CH_2})_6-\mathrm{NH}-\mathrm{CO}-(\mathrm{CH_2})_4-\overset{\displaystyle\mathrm{O}}{\overset{\|}{\mathrm{C}}}-\!\right]_n$$

(2/3, Delhi 2016)

23. (i) What is the role of sulphur in the vulcanisation of rubber?
(ii) Identify the monomers in the following polymer :



(2/3, AI 2016)

24. Write the names and structures of the monomers of the following polymers :
(i) Nylon-6, 6
(ii) Neoprene *(2/3, Delhi 2015, 2013)*

25. Write the names and structures of the monomers of the following polymers :
(i) Neoprene
(ii) Teflon *(2/3, Delhi 2015C)*

26. Explain the term 'copolymerisation' and give two examples of copolymerisation.
(2/3, AI 2015C)

27. Write the name of monomers used for getting the following polymers :
(i) Bakelite
(ii) Neoprene *(AI 2014)*

28. Write the name of monomers used for getting the following polymers :
(i) Terylene
(ii) Nylon-6,6 *(AI 2014)*

29. Write the name of monomers used for getting the following polymers :
(i) Teflon (ii) Buna-N
(AI 2014)

30. Give names of the monomers of the following polymers :
(i) Neoprene (ii) Polystyrene
(iii) Polypropene *(Delhi 2014C)*

31. Write the names and structures of monomers used for getting the following polymers :
(i) Buna-S
(ii) Nylon-6, 6 *(AI 2014C)*

32. Distinguish between homopolymers and copolymers. Give one example of each.
(AI 2013)

33. Draw the structure of the monomer for each of the following polymers.
(i) Nylon-6
(ii) Polypropene *(Delhi 2012)*

34. Explain the following terms giving a suitable example for each :
(i) Condensation polymers
(ii) Addition polymers *(AI 2012)*

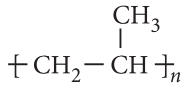
35. Write down the structure of monomer and one use of the polymer polystyrene.
(2/3, Delhi 2012C)

36. Mention two important uses of each of the following :
(i) Bakelite
(ii) Nylon-6 *(2/3, Delhi 2011)*

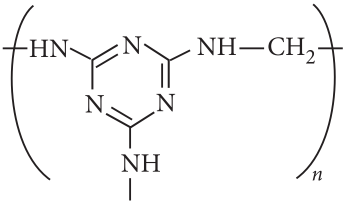
LA I (3 marks)

37. Write the names and structures of the monomers in the following polymers :
(i) Buna-S
(ii) Nylon-6, 6
(iii) Bakelite *(2020)*

38. Write the structures of monomers used for getting the following polymers :
(i) Nylon-6,6 (ii) Glyptal
(iii) Buna-S. *(Delhi 2019)*



39. (i) Is $\left[\!-CH_2-\underset{}{\overset{CH_3}{\overset{|}{C}H}}-\!\right]_n$ a homopolymer or copolymer? Give reason.
(ii) Write the monomers of the following polymer :



(iii) What is the role of sulphur in vulcanization of rubber? *(Delhi 2019)*

40. Write the structures of the monomers used for getting the following polymers:
(i) Neoprene
(ii) Melamine-formaldehyde polymer
(iii) Buna-S *(Delhi 2017)*

41. Write the mechanism of free radical polymerisation. *(Delhi 2016)*

42. Write the names and structures of the monomers of the following polymers :
(i) Buna-S (ii) Glyptal
(iii) Polyvinyl chloride *(AI 2015)*

43. Write the names and structures of the monomers of the following polymers :
(i) Terylene (ii) Bakelite
(iii) Buna-S *(Foreign 2015)*

44. Write the name of the monomers of the following polymers :
(i) Polythene
(ii) Polyvinyl chloride
(iii) Bakelite *(Delhi 2014C)*

45. Write the names and structures of the monomers of the following polymers :
(i) Bakelite
(ii) Nylon-6
(iii) Polythene *(Delhi 2013)*

46. (a) Differentiate between copolymerisation and homopolymerisation. Give one example of each.
(b) What is the role of benzoyl peroxide in preparation of polythene? *(Delhi 2013C)*

47. Write the monomers of the following polymers and classify them as addition or condensation polymers :
Teflon, Bakelite and Natural rubber *(AI 2013C)*

48. Explain the term copolymerization and give two examples of copolymers and the reactions for their preparations. *(AI 2012C)*

49. Draw the structure of the monomers of the following polymers :
(i) Polythene (ii) PVC
(iii) Teflon *(AI 2011)*

50. What are addition polymers? How are the two types of addition polymers different from each other? Give one example of each type. *(Foreign 2011)*

51. Mention two important uses for each of the following polymers :
(i) Bakelite
(ii) Nylon 6,6
(iii) PVC *(Foreign 2011)*

52. Distinguish between addition polymers and condensation polymers. Classify the following into addition and condensation polymers :
(i) Polythene
(ii) PTFE
(iii) Polybutadiene
(iv) Bakelite *(AI 2011C)*

15.4 Biodegradable Polymers

VSA (1 mark)

53. Write the name and structures of monomers in the following polymers :
PHBV *(1/3, 2020, Delhi 2015)*

54. What are biodegradable polymers? Give one example. *(1/3, AI 2013C, Delhi 2011)*

SA (2 marks)

55. What is a biodegradable polymer? Give an example of a biodegradable aliphatic polyester. *(2/3, AI 2013)*

Detailed Solutions

1. The intermolecular forces are least in case of elastomers like Buna-S while strongest in case of fibres like terylene and in case of thermoplastics like polystyrene the intermolecular forces are intermediate in between elastomers and fibres.

Thus, the increasing order of their intermolecular forces is Buna-S < Polystyrene < Terylene

2. Neoprene < Polythene < Terylene

3. Proteins are natural polymers.

4. Elastomer

5. Nylon is a fibre.

6. Elastomers are the polymers in which polymer chains are held by weakest intermolecular forces. *e.g.*, Buna-S, Buna-N.

7. **Thermoplastics :** Thermoplastics are linear or slightly branched 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 polystyrene.

Thermosetting Polymers : Thermosetting polymers on heating in a mould get hardened and set and cannot be softned again. This hardening on heating is due to cross-linking between different polymer chains to give a three-dimensional network solid.

Example : Bakelite.

8. *Refer to answer 7.*

9. *Refer to answer 7.*

10. $\underset{\text{(Vinyl chloride)}}{H_2C{=}CHCl}$

11. Monomers used for getting nylon–6,6, are $HOOC(CH_2)_4COOH$ (adipic acid) and $H_2N(CH_2)_6NH_2$ (hexamethylenediamine).

12. Buna-S :

$\underset{\text{1,3–Butadiene}}{CH_2{=}CH-CH{=}CH_2}$ and $\underset{\text{Styrene}}{C_6H_5CH{=}CH_2}$

13. Homopolymer

14. Teflon $+\!CF_2-CF_2\!+_n$

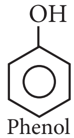
15. A polymer made by polymerisation of a single monomer is known as homopolymer and the process is known as homopolymerisation *e.g.*, polythene made by polymerisation of ethene molecules.

$$\underset{\text{Ethene}}{nCH_2 = CH_2} \longrightarrow \underset{\text{Polythene}}{+\!\left(CH_2-CH_2\right)\!+_n}$$

16. (a) **Bakelite :** Monomers are phenol and formaldehyde.

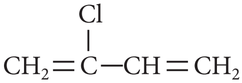
$$H-\overset{\overset{\displaystyle O}{\|}}{C}-H$$

Formaldehyde



Phenol

(b) **Neoprene :** Neoprene or polychloroprene is formed by the polymerisation of chloroprene.



$$CH_2{=}\overset{\overset{\displaystyle Cl}{|}}{C}-CH{=}CH_2$$

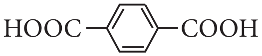
Chloroprene

(2-Chloro-1,3-butadiene)

17. (i) *Refer to answer 11.*

(ii) Monomers of terylene :

$\underset{\text{Ethylene glycol}}{HO-CH_2-CH_2-OH}$ and



Terephthalic acid

18. (a) Teflon is an addition polymer as it is made by addition of large number of tetrafluoroethylene molecules.

$$nCF_2{=}CF_2 \longrightarrow \underset{\text{Teflon}}{+\!CF_2-CF_2\!+_n}$$

(b) PHBV (poly-β-hydroxybutyrate-co-β-hydroxy valerate) is a condensation polymer because it is formed by repeated condensation reaction between two bifunctional (3-hydroxybutanoic acid and 3-hydroxypentanoic acid) monomer units with the elimination of water molecules.

19. (a) *Refer to answer 17(ii).*

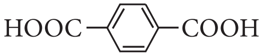
(b) **Monomers of Buna–N :**

$\underset{\text{1,3-Butadiene}}{CH_2{=}CH-CH{=}CH_2}$

$\underset{\text{Acrylonitrile}}{H_2C{=}CH-CN}$

20. (i) **Monomers of of terylene or dacron :**

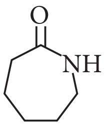
$\underset{\text{Ethylene glycol}}{HOCH_2-CH_2-OH}$ and



Terephthalic acid

(ii) *Refer to answer 19(b).*

21. (i) **Monomer of nylon-6 :** Caprolactam;



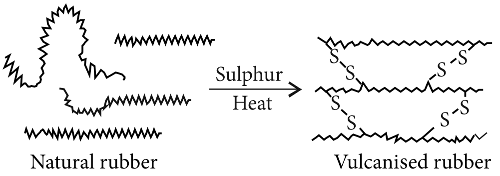
(ii) **Monomer of teflon :** Tetrafluoroethene; $(CF_2{=}CF_2)$

22. (i) Polymerisation of ethene requires an initiator to start the polymerisation with free radical mechanism. Thus, peroxide like *t*-butyl peroxide decomposes to give free radical that initiates the reaction.

(ii) Hexamethylenediamine and adipic acid.

23. (i) Vulcanisation is a process of heating natural rubber with sulphur and an appropriate additive to modify its properties.

It gives greater elasticity and ductility. Sulphur forms cross linked network which gives mechanical strength to the rubber.

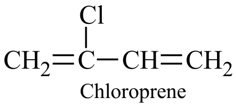


(ii) Terephthalic acid and ethylene glycol.

24. (i) **Nylon-6, 6 :** $\underset{\text{Adipic acid}}{HOOC\text{—}(CH_2)_4\text{—}COOH}$

and $\underset{\text{Hexamethylenediamine}}{H_2N\text{—}(CH_2)_6\text{—}NH_2}$

(ii) **Neoprene :**



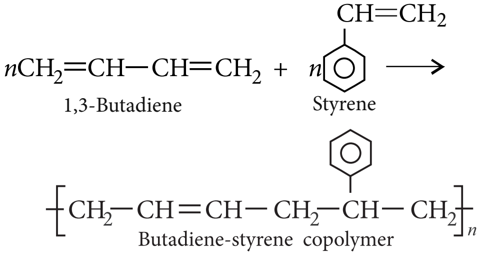
$$\underset{\text{Chloroprene}}{CH_2{=}\overset{\overset{Cl}{|}}{C}{-}CH{=}CH_2}$$

25. (i) *Refer to answer 24(ii).*

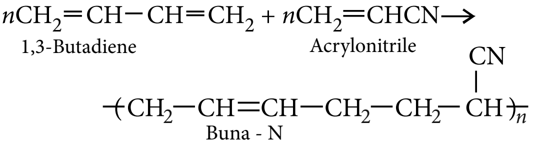
(ii) *Refer to answer 21(ii)*

26. **Copolymerisation :** When the polymers are synthesised by polymerization of two or more than two different monomers then this process is called as copolymerisation. Example,

(i) **Styrene butadiene rubber (SBR) :**



(ii) **Buna–N :**



$$\underset{\text{1,3-Butadiene}}{nCH_2{=}CH{-}CH{=}CH_2} + \underset{\text{Acrylonitrile}}{nCH_2{=}CHCN} \longrightarrow$$

$$\underset{\text{Buna - N}}{\left(CH_2{-}CH{=}CH{-}CH_2{-}CH_2{-}\overset{\overset{CN}{|}}{CH}\right)_n}$$

27. (i) *Refer to answer 16.*

28. (i) *Refer to answer 17(ii).*

(ii) *Refer to answer 24(i).*

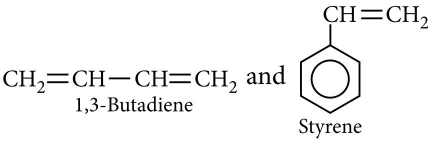
29. (i) *Refer to answer 25(ii).*

(ii) *Refer to answer 19(b).*

30.

Name of polymer	Monomer
(i) Neoprene	Chloroprene
(ii) Polystyrene	Styrene
(iii) Polypropene	Propene

31. (i) **Buna–S :**

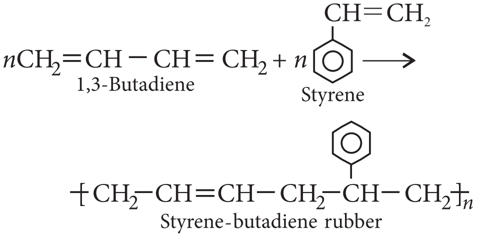


(ii) *Refer to answer 24(i).*

32. **Homopolymer :** A polymer made by polymerisation of a single monomer is known as homopolymer and the reaction is called homopolymerisation. *e.g.,* Polythene made by ethene molecules.

$$\underset{\text{Ethene}}{nCH_2{=}CH_2} \rightarrow \underset{\text{Polythene (homopolymer)}}{\left(CH_2{-}CH_2\right)_n}$$

Copolymer : A polymer made by polymerisation of two or more different monomers is called copolymer and the reaction is called copolymerisation. When styrene and butadiene are polymerised together, a polymer called styrene-butadiene rubber is formed.



33. (i) *Refer to answer 21(i)*

(ii) **Polypropene :** $\underset{\text{Propene}}{CH_3{-}CH{=}CH_2}$

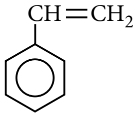
34. (i) **Condensation polymers :** The polymers formed by the condensation of two or more bifunctional monomers are called condensation polymers.

For example : Nylon 6,6, Bakelite.

(ii) **Addition polymers :** The polymers formed by the addition reaction of a large number of unsaturated monomers are called addition polymers.

For example : Polythene, polystyrene.

35. Monomer of polystyrene :



Styrene

Used to make transparent drinking cups.

36. (i) Bakelite is used for making combs, electrical switches, handles of various utensils and phonograph records.

(ii) Nylon–6 is used for making tyre cords, ropes and fabrics.

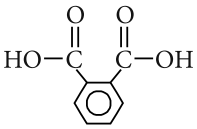
37. (i) *Refer to answer 31(i).*

(ii) *Refer to answer 24(i).*

(iii) *Refer to answer 16(a).*

38. (i) *Refer to answer 24(i).*

(ii) **Glyptal :**



and $HO-CH_2-CH_2-OH$

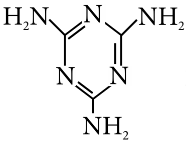
Ethylene glycol

Phthalic acid

(iii) *Refer to answer 31(i).*

39. (i) It is a homopolymer because it is made up of one type of monomer propylene.

(ii) Melamine-formaldehyde polymer is formed by condensation polymerisation of melamine and formaldehyde.

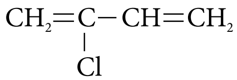


Melamine

+ HCHO
Formaldehyde

(iii) *Refer to answer 23(i).*

40. **(i)** Neoprene is formed by the free radical polymerisation of chloroprene.



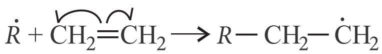
$$CH_2=\underset{\displaystyle Cl}{\underset{|}{C}}-CH=CH_2$$

2-Chloro-1,3-butadiene

(ii) *Refer to answer 39(ii).*

(iii) *Refer to answer 31(i).*

41. **Chain initiation :**



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

Chain propagation :

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

Chain termination :

$$R-CH_2-CH_2-CH_2-\dot{C}H_2+\dot{R}\longrightarrow R-(CH_2)_4-R$$

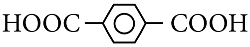
42. (i) *Refer to answer 31(i).*

(ii) *Refer to answer 38(ii).*

(iii) *Refer to answer 10.*

43. (i) HOH_2C-CH_2OH and

Ethylene glycol



Terephthalic acid

(ii) *Refer to answer 16(a).*

(iii) *Refer to answer 31(i).*

44. (i) Monomer of polythene is ethene.

(ii) Monomer of PVC is vinyl chloride.

(iii) Monomers of bakelite are formaldehyde and phenol.

45. (i) *Refer to answer 16(a).*

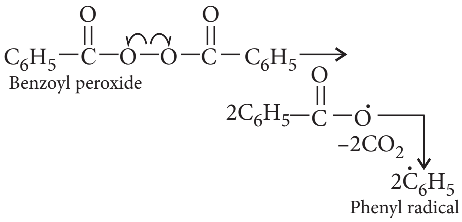
(ii) *Refer to answer 21(i).*

(iii) **Polythene :** $CH_2=CH_2$

Ethene

46. (a) *Refer to answer 32.*

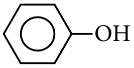
(b) In the preparation of polythene from ethene, benzoyl peroxide acts as an initiator or free radical generator.



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

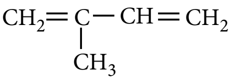
47. **Teflon :** $CF_2=CF_2$: Addition polymer

Bakelite : HCHO +



: Condensation polymer

Natural rubber :



$$CH_2=\underset{\displaystyle CH_3}{\underset{|}{C}}-CH=CH_2$$

: Addition polymer.

48. *Refer to answer 26.*

49. (i) *Refer to answer 45(iii).*

(ii) *Refer to answer 10.*

(iii) *Refer to answer 25(ii).*

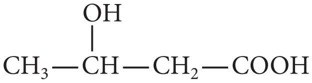
50. Polymers which are formed by the repeated addition reaction of unsaturated monomer molecules are called the addition polymers.

Refer to answer 32.

51. (i) **Bakelite** – (1) In electrical switches.
(2) In making handles of various utensils.
(ii) **Nylon-6,6** – (1) In Fabrics.
(2) In tyre cords.
(iii) **PVC** – (1) In handbags.
(2) In water pipes.

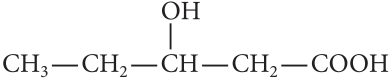
52. *Refer to answer 34.*
(i) Polythene – addition polymer
(ii) PTFE – addition polymer
(iii) Polybutadiene – addition polymer
(iv) Bakelite – condensation polymer

53. Monomers of PHBV (poly-β-hydroxybutyrate-co-β-hydroxy valerate) are



$$CH_3-\overset{\overset{\displaystyle OH}{|}}{CH}-CH_2-COOH$$

3-hydroxybutanoic acid



$$CH_3-CH_2-\overset{\overset{\displaystyle OH}{|}}{CH}-CH_2-COOH$$

3-hydroxypentanoic acid

54. Biodegradable polymers : The natural polymer, which disintegrates by itself or by micro-organisms within certain period of time is called biodegradable polymer, *e.g.*, PHBV (poly–β–hydroxybutyrate–co–β–hydroxyvalerate), Nylon 2–nylon 6.

55. *Refer to answer 54.*