DAY THIRTY FIVE

Polymers

Learning & Revision for the Day

- Classification of Polymers
- Methods of Polymerisation
- Some Important Polymers
- Biodegradable and Non-brodegradable Polymer

The word 'polymer' is coined from Greek words : *poly* means many and *mer* means unit or part. These are defined as very large molecules having high molecular mass (10^3-10^7 u). Polymers are formed by joining of repeating structural units, called monomers, on a large scale. The monomer units, are linked to each other by covalent bonds. The process of formation of polymer from respective monomers is called **polymerisation**.

Classification of Polymers

On the different basis the polymers are classified as follows:

1. On the Basis of Sources

- **Natural Polymers** These polymers are found in plants and animals, e.g, proteins, cellulose, starch, resins and rubber, etc.
- **Semi-synthetic Polymers** These polymers are derived from natural polymers by chemical methods, e.g. cellulose acetate (rayon), cellulose nitrate, etc.
- **Synthetic Polymers** These are man-made polymers, e.g. plastic (polythene), synthetic fibres, buna-S, etc.

2. On the Basis of Structure

- **Linear Polymers** These polymers consist of long and straight chains, e.g. high density polythene, polyvinyl chloride, etc.
- **Branched Chain Polymers** These polymers consist of linear chains with some branches, e.g. low density polythene.
- **Cross-linked or Network Polymers** These polymers are formed from bi-functional and tri-functional monomers and contain strong covalent bonds between various linear polymeric chains. e.g. bakelite, melamine, etc.

3. On the Basis of Mode of Polymerisation

- **Addition Polymers or Chain Growth Polymers** These are formed by addition reactions between monomer molecules having multiple bonds, e.g. polythene, buna-S.
- **Condensation Polymers or Step Growth Polymers** These are formed by condensation reaction between two different bi-functional or tri-functional monomeric units with the elimination of small molecules like NH_3, H_2O, etc., e.g. terylene, nylon-6 6, nylon-6, etc.

4. On the Basis of Monomers Involved

- **Homopolymers** These are formed by polymerisation of single monomeric species, e.g. polythene, polypropene, etc.
- **Copolymers** These are formed by polymerisation of two or more different monomer units, e.g. buna-S, buna-N, etc.

5. On the Basis of Molecular Forces

- **Elastomers** These are rubber-like solids with elastic properties. They have weak intermolecular forces.
  e.g. buna-S, buna-N, neoprene, etc.
- **Fibres** Fibres are the thread forming solids which possess high tensile strength, high modulus and have intermolecular hydrogen bonding, e.g. nylon-66, polyesters (terylene), etc.
- **Thermoplastic Polymers** These are the linear or slightly branched long chain molecules capable of softening on heating and hardening on cooling. These polymers possess intermolecular forces of attraction, intermediate between elastomers and fibres, e.g. polythene, polystyrene, polyvinyls, etc.
- **Thermosetting Polymers** These polymers are cross linked or heavily branched molecules which on heating undergo entensive cross linking in moulds and again become infusible. They can't be reused. e.g. bakelite, urea-formaldehyde resins, etc.

Methods of Polymerisation

The process or technique through which monomer units combine to give a polymer is known as polymerisation. The polymerisation reaction cannot be controlled easily.

These are the following methods through which monomers combine to give polymers:

1. Addition Polymerisation

It is the process in which molecules of same or different monomers combine together to give a polymer without the elimination of small molecules. Since, there is an increase in the length of chain (i.e. chain grows) by this mode of polymerisation, it is also known as chain growth polymerisation. This mode of polymerisation is observed in monomers having multiple bonds, mainly in $CH_2 = CH_y$ type molecules

(where, y may be —H, —X, —CO_2R, —CN etc.)

The addition or chain growth polymerisation can proceed by the following two mechanisms (i) By the formation of free radicals, i.e. free radical polymerisation and (ii) By the formation of ionic species, i.e. ionic polymerisation.

2. Condensation Polymerisation

In this mode of polymerisation, there is a repetitive condensation reaction between two bi-functional monomers in a controlled stepwise manner with the elimination of small molecules such as water, ammonia, alcohol, etc., as by product. This the process is also known as **step growth polymerisation**. These monomers have functional groups such as alcohol, amine or carboxylic acid groups instead of double bonds.

3. Copolymerisation

When two or more different monomer units are allowed to polymerise, a copolymer is formed which contains multiple units of each monomer used, in the same polymeric chain.

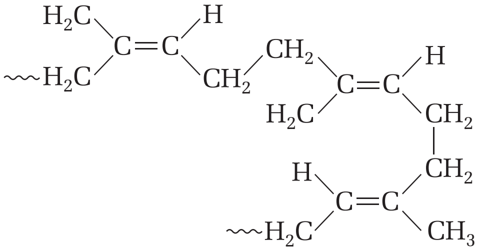
The process by which copolymers are formed is referred to as copolymerisation.

Some Important Polymers

The important examples of addition and copolymers are given below :

1. Natural Rubber

It is a natural polymer prepared from rubber latex (colloidal dispersion of rubber in water) obtained from the bark of rubber tree. It is poly *cis*-isoprene. It is very soft.



- Natural rubber becomes soft at high temperature (>335 K) and brittle at low temperature (< 283 K). It has high water absorbing capacity. It is easily attacked by oxidising agents and soluble in non-polar solvents.
- To improve these properties, vulcanisation of rubber is carried out. The process involves the heating of raw rubber with sulphur and appropriate additive at a temperature 373 - 415 K.
- Sulphur forms cross-links at reactive sites of double bonds and makes the rubber stiffened. Rubber made with 1-3% sulphur is soft and stretchy and rubber made with 3-10% S, is more rigid (used in making tyres).

2. Polythene

It's monomer is ethylene or ethene.

- **Low density polythene** (LDP)

$$n(CH_2{=}CH_2) \xrightarrow[\substack{\text{1000 to 2000 atm} \\ \text{(Traces of oxygen or a} \\ \text{peroxide initiator)}}]{\text{350 K-570 K}} \underset{\text{LDP}}{-\!\!\left(CH_2-CH_2\right)\!\!-_n}$$

It is tough, flexible, transparent, chemically inert as well as poor conductor of electricity. It has moderate tensile strength but good tearing strength.

It is used in the insulation of electricity carrying wires and manufacture of queeze bottles, toys and flexible pipes.

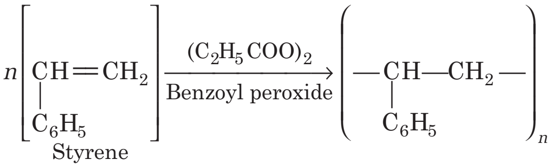
- **High density polyethylene** (HDP)

$$n(\mathrm{CH_2{=}CH_2}) \xrightarrow[\substack{\text{6 –7 atm}\\ (\textit{Ziegler-Natta}\\ \text{catalyst})}]{\text{333–343 K}} \lbrace\!\!-\mathrm{CH_2{-}CH_2}-\!\!\rbrace_n$$

It has high density due to close packing. It is also chemically inert and more tougher and harder. It is used for making containers, house wares, bottles, toys, electric insulation etc.

3. Polystyrene (styrene)

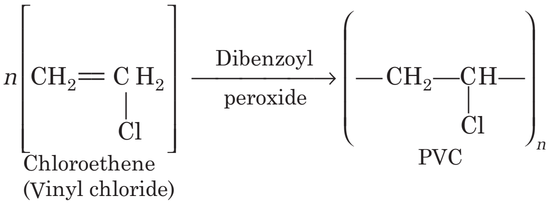
It's monomers are styrene molecules. It is thermoplastic. It is used for making toys, radio and TV cabinets.



$$n\begin{bmatrix}\mathrm{CH{=}CH_2}\\ |\\ \mathrm{C_6H_5}\end{bmatrix}_{\text{Styrene}} \xrightarrow[\text{Benzoyl peroxide}]{(\mathrm{C_2H_5COO})_2} \left(\begin{array}{c}-\mathrm{CH}-\mathrm{CH_2}-\\ |\\ \mathrm{C_6H_5}\end{array}\right)_n$$

4. Polyvinylchloride (PVC)

It's monomer is vinyl chloride.



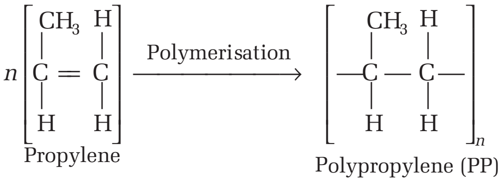
$$n\begin{bmatrix}\mathrm{CH_2{=}CH_2}\\ \quad\ |\\ \quad\ \mathrm{Cl}\end{bmatrix} \xrightarrow[\text{peroxide}]{\text{Dibenzoyl}} \left(\begin{array}{c}-\mathrm{CH_2}-\mathrm{CH}-\\ \qquad |\\ \qquad \mathrm{Cl}\end{array}\right)_n$$

Chloroethene (Vinyl chloride) PVC

It is used for making rain coats, toys, electrical insulation. It is hard and resistant to heat and chemicals.

5. Polypropylene (PP)

It is obtained by polymerising propylene in the presence of *Ziegler-Natta* catalyst.



$$n\begin{bmatrix}\mathrm{CH_3} & \mathrm{H}\\ | & |\\ \mathrm{C} = & \mathrm{C}\\ | & |\\ \mathrm{H} & \mathrm{H}\end{bmatrix} \xrightarrow{\text{Polymerisation}} \begin{bmatrix}\mathrm{CH_3} & \mathrm{H}\\ | & |\\ -\mathrm{C}- & \mathrm{C}-\\ | & |\\ \mathrm{H} & \mathrm{H}\end{bmatrix}_n$$

Propylene Polypropylene (PP)

6. Polytetrafluoroethene (Teflon)

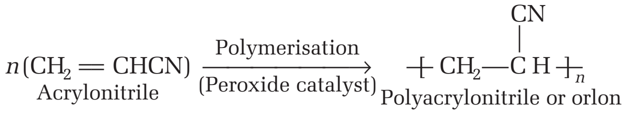
It's monomer is tetrafluoro carbon.

$$\underset{\text{Tetrafluoroethene}}{n(\mathrm{CF_2 = CF_2})} \xrightarrow[\text{High pressure}]{\text{Catalyst}} \underset{\text{Teflon}}{\lbrace\!\!-\mathrm{CF_2{-}CF_2}-\!\!\rbrace_n}$$

It is chemically inert and resistant to attack by corrosive reagent. It is used in making oil seals, gaskets and also for non-stick surface coated utensils.

7. Polyacrylonitrile

It is obtained by the polymerisation of acrylonitrile in the presence of peroxide.

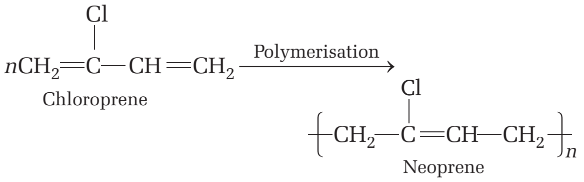


$$\underset{\text{Acrylonitrile}}{n(\mathrm{CH_2 = CHCN})} \xrightarrow[\text{(Peroxide catalyst)}]{\text{Polymerisation}} \underset{\text{Polyacrylonitrile or orlon}}{\lbrace\!\!-\mathrm{CH_2}-\overset{\overset{\mathrm{CN}}{|}}{\mathrm{C}}\mathrm{H}-\!\!\rbrace_n}$$

It is used as a substitute for wool in making commercial fibres as orlon or acrilan.

8. Neoprene

It is an addition homopolymer of chloroprene. It is fire resistant.

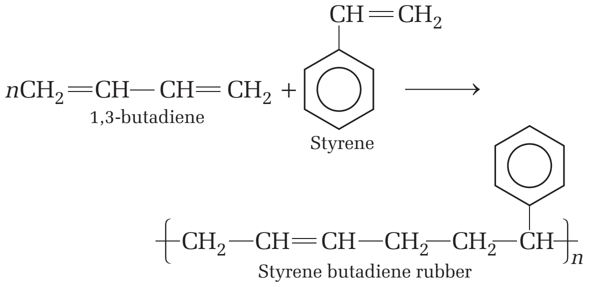


$$\underset{\text{Chloroprene}}{n\mathrm{CH_2{=}}\overset{\overset{\mathrm{Cl}}{|}}{\mathrm{C}}\mathrm{{-}CH{=}CH_2}} \xrightarrow{\text{Polymerisation}} \underset{\text{Neoprene}}{\lbrace\!\!-\mathrm{CH_2}-\overset{\overset{\mathrm{Cl}}{|}}{\mathrm{C}}\mathrm{{=}CH{-}CH_2}-\!\!\rbrace_n}$$

It is used as an insulator, making conveyor belts, gaskets, hoses and printing rollers.

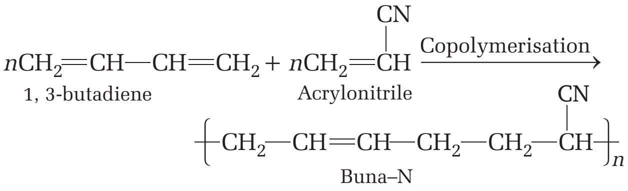
Examples of Addition Copolymers

- **Buna-S or styrene-butadiene rubber** (SBR) is addition copolymer of 1, 3-butadiene and styrene.



It is used in making automobile tyres and footwears.

- **Buna-N or nitrile rubber** It is an addition copolymer of 1, 3-butadiene and acrylonitrile.

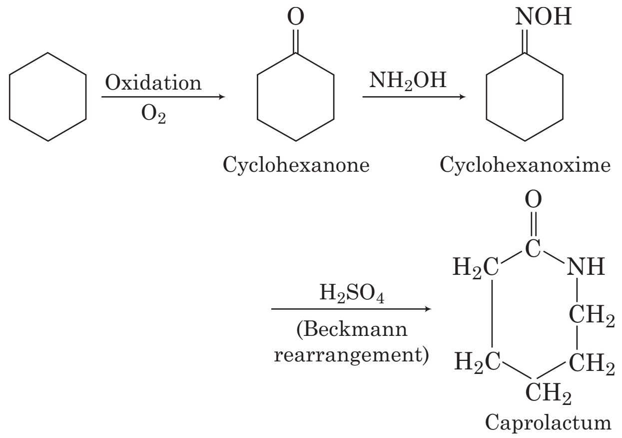


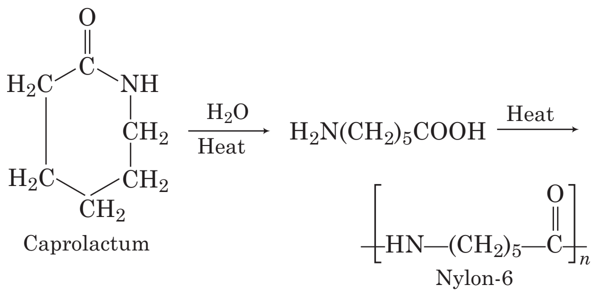
$$\underset{\text{1, 3-butadiene}}{n\mathrm{CH_2{=}CH{-}CH{=}CH_2}} + \underset{\text{Acrylonitrile}}{n\mathrm{CH_2{=}}\overset{\overset{\mathrm{CN}}{|}}{\mathrm{CH}}} \xrightarrow{\text{Copolymerisation}} \underset{\text{Buna–N}}{\lbrace\!\!-\mathrm{CH_2{-}CH{=}CH{-}CH_2{-}CH_2}-\overset{\overset{\mathrm{CN}}{|}}{\mathrm{CH}}-\!\!\rbrace_n}$$

It is used in making oil seals, manufacture of hoses and tank linings.

Examples of Condensation Homopolymers

Nylon-6 It is polyamide and obtained by heating caprolactum with water at a high temperature.

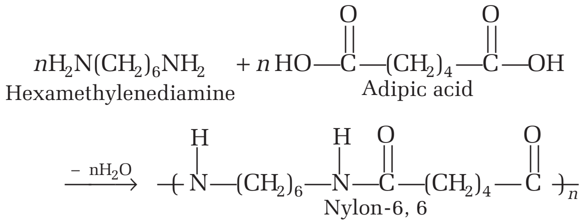




Examples of Condensation Copolymers

1. Nylon-6,6

It is polyamide (polymer which contain an amide linkage) and obtained by the condensation of adipic acid and hexamethylenediamine with the elimination of water molecule.



$$nH_2N(CH_2)_6NH_2 + n\,HO-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH \xrightarrow{-\,nH_2O} \left(\overset{H}{\overset{|}{N}}-(CH_2)_6-\overset{H}{\overset{|}{N}}-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}\right)_n$$

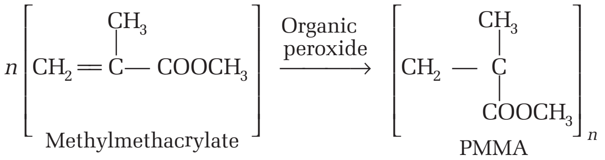
Hexamethylenediamine; Adipic acid; Nylon-6, 6

In the above case, the carbon atoms are 6 in each case, therefore the product is described as nylon-6,6.

It is a linear polymer and has very high tensile strength. It shows good resistance to abrasion. Nylon-66 is usually fabricated into sheets. It is used in bristles for brushes and in textile.

2. Polymethylmethacrylate (PMMA)

It is a polyester (polymer which contain ester linkage) and prepared by the polymerisation of methylmethacrylate in the presence of suitable organic peroxide.



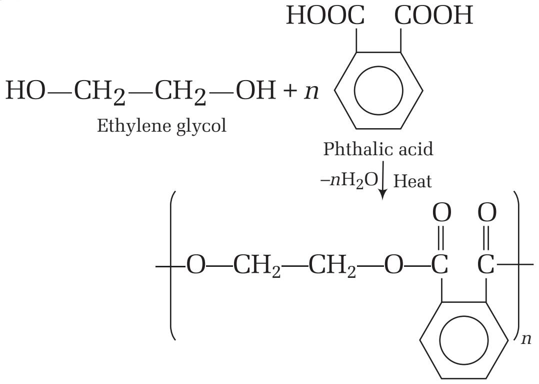
$$n\left[CH_2=\overset{CH_3}{\overset{|}{C}}-COOCH_3\right] \xrightarrow{\text{Organic peroxide}} \left[CH_2-\underset{COOCH_3}{\underset{|}{\overset{CH_3}{\overset{|}{C}}}}\right]_n$$

Methylmethacrylate; PMMA

The polymer is known by several commercial names such as lucite, acrylite, plexiglass and perspex. It is a hard and transparent polymer and is quite resistant to the effect of light, heat and ageing. It is used, in the manufacture of unbreakable lights, protective coatings, dentures, and in making windows for aircrafts.

3. Glyptal

It is a polyester having crosslinks. It is a thermosetting plastic. It is obtained by condensation of ethylene glycol and phthalic acid or glycerol.

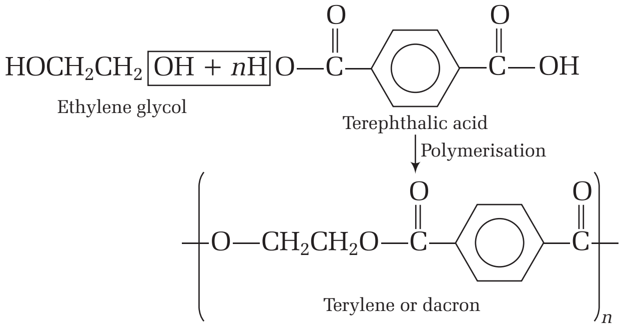


Glyptal

When its solution in a suitable solvent is evaporated, it leaves a tough but non-flexible film. It is, therefore, used in the manufacture of paints and lacquers.

4. Terylene (Dacron)

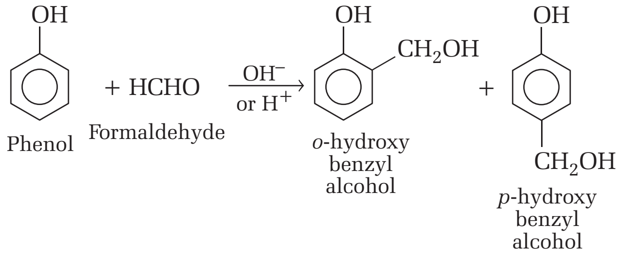
It is a condensation product of ethylene glycol and terephthalic acid. Polymerisation is carried out at 420 to 460 K in the presence of catalytic mixture of zinc acetate and antimony trioxide.



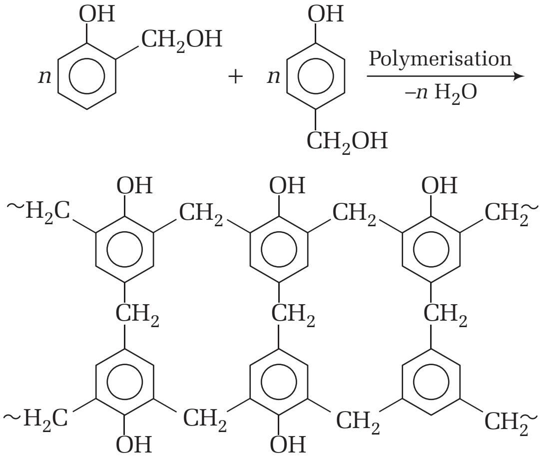
- It is highly resistant to the action of chemical and biological agents. Its fibres are quite strong and durable. It can also be blended with wool or cotton to obtain fabrics of desired composition.
- It is used in the manufacture of a variety of clothes such as terycot, terywool and terysilk as a result of blending with other yerns. It is also used for preparing magnetic recording tapes, conveyer belts, aprons for industrial workers etc.

5. Phenol-formaldehyde polymer (Bakelite)

It's monomers phenol (C_6H_5OH) and formaldehyde (HCHO).



The *ortho* and *para* substituted phenols undergo polymerisation to produce bakelite.

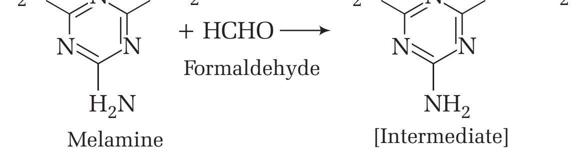


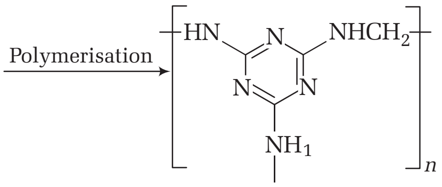
Bakelite (Cross-linked polymer)

It is used for making combs, phonograph records, electrical switches, and handles of various utensils.

6. Melamine-formaldehyde Polymer

It's monomers are melamine and formaldehyde (HCHO).





(Melamine-formaldehyde polymer)

It is used in the manufacture of unbreakable crockery.

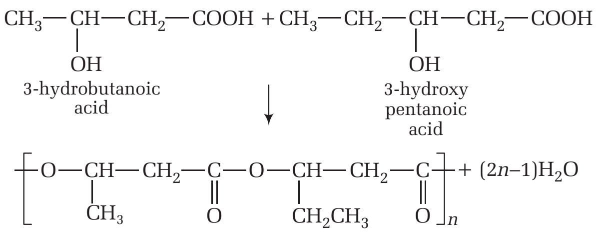
7. Urea-formaldehyde Resin

It's monomers are urea (NH_2CONH_2) and formaldehyde (HCHO).

It is used for making unbreakable cups and laminated sheets.

Biodegradable and Non-biodegradable Polymers

- **Biodegradable polymers** are the polymers which are degraded by micro-organisms with in a suitable period so that these polymers and their degraded products do not cause any serious affect on the environment e.g.,
- **Poly β - hydroxybutyrate-co - β - Hydroxy Valerate** (PHBV) It's monomers are 3-hydroxy butanoic acid. and 3-hydroxy pentanoic acid.



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

3-hydrobutanoic acid 3-hydroxy pentanoic acid

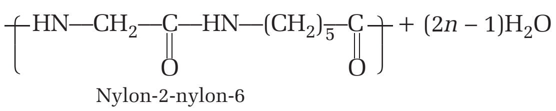
$$\downarrow$$

$$\left[-O-\underset{CH_3}{\underset{|}{CH}}-CH_2-\underset{O}{\underset{\|}{C}}-O-\underset{CH_2CH_3}{\underset{|}{CH}}-CH_2-\underset{O}{\underset{\|}{C}}-\right]_n + (2n\text{–}1)H_2O$$

It is used in the speciality packaging, orthopaedic devices and in controlled release of drugs.

- **Nylon-2-nylon-6** It's monomers are glycine ($H_2N—CH_2—COOH$) and amino caproic acid [$H_2N—(CH_2)_5COOH$].

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



$$\left(-HN—CH_2—\underset{O}{\underset{\|}{C}}—HN—(CH_2)_5—\underset{O}{\underset{\|}{C}}-\right) + (2n-1)H_2O$$

Nylon-2-nylon-6

The polymers that do not degraded by microorganisms within a suitable period of time are known as **non-biodegradable polymers**.

e.g. polystyrene, polypropene, polythene etc.

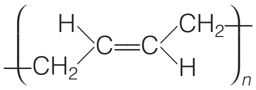
DAY PRACTICE SESSION 1

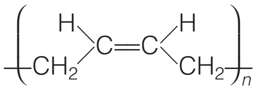
FOUNDATION QUESTIONS EXERCISE

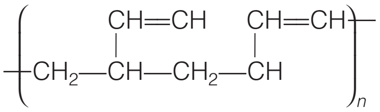
1 Polymer formation from monomers starts by

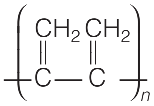
(a) hydrolysis of monomers
(b) conversion of monomer to monomer ions by protons
(c) condensation reaction between monomers
(d) coordination reaction between monomers

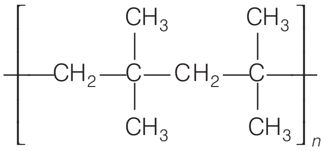
2 Mark out the most unlike form of polymerisation of $CH_2{=}CH{-}CH{=}CH_2$

(a) 

(b) 

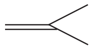
(c) 

(d) 

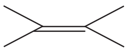
3 

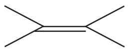
$$\left[-CH_2-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-CH_2-\underset{CH_3}{\overset{CH_3}{\underset{|}{\overset{|}{C}}}}-\right]_n$$

is a polymer having monomer units.

(a) 

(b) 

(c) 

(d) 

4 Regarding cross-linked or network polymers, which of the following statements is incorrect? **→ NEET 2018**

(a) Examples are bakelite and melamine
(b) They are formed from bi- and tri-functional monomers
(c) They contain covalent bonds between various linear polymer chains
(d) They contain strong covalent bonds in their polymer chains

5 Cellulose acetate is a

(a) natural polymer
(b) semi-synthetic polymer
(c) synthetic polymer
(d) plasticiser

6 Three dimensional molecules with cross links are formed in the case of a

(a) thermoplastic
(b) thermosetting plastic
(c) Both (a) and (b)
(d) None of the above

7 Which one of the following is a chain growth polymer?

(a) Starch (b) Nucleic acid
(c) Polystyrene (d) Protein

8 Teflon, PVC and neoprene are all

(a) copolymers (b) condensation polymers
(c) homopolymers (d) monomers

9 Teflon polymer is formed by the polymerisation of

(a) $CH_2{=}CH{-}CN$ (b) $Cl_2C{=}CH_2$
(c) $F_2C{=}CF_2$ (d) $H_2C{=}CHCl$

10 The process involving heating of rubber with sulphur is called

(a) galvanisation (b) vulcanisation
(c) bessemerisation (d) sulphonation

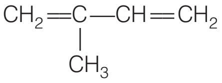
11 Which of the following organic compounds polymerises to form the polyester dacron? **→ CBSE-AIPMT 2014**

(a) Propylene and *para* $HO-(C_6H_4)-OH$
(b) Benzoic acid and ethanol
(c) Terephthalic acid and ethylene glycol
(d) Benzoic acid and *para* $HO-(C_6H_4)-OH$

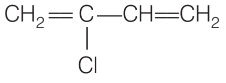
12 Natural rubber has **→ NEET 2016, Phase I**

(a) All *trans*-configuration
(b) Alternate *cis* - and *trans*-configuration
(c) Random *cis* - and *trans*-configuration
(d) All *cis*-configuration

13 Which of the monomer of neoprene in the following? **→ NEET 2013**

(a) 

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

(b) 

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

(c) $CH_2{=}CH{-}C{\equiv}CH$

(d) $CH_2{=}CH{-}CH{=}CH_2$

14 Which of the following is used to make non-stick cookware?

(a) PVC
(b) Polystyrene
(c) Polyethylene
(d) Polytetrafluoroethylene

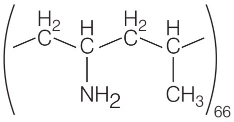
15 The catalyst used in the manufacture of polythene by *Ziegler-Natta* method is

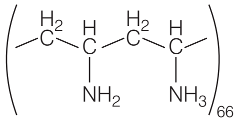
(a) titanium tetra chloride and triethyl aluminium
(b) titanium oxide
(c) lithium tetrachloride and triphenyl aluminium
(d) titanium *iso*-peroxide

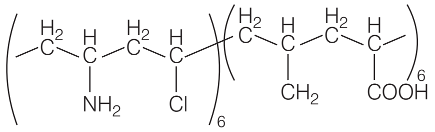
16 Which of the following is an addition polymer?

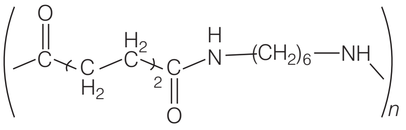
(a) Buna-S (b) Bakelite
(c) Nylon-6 (d) Malamac

17 Which one of the following structures represents nylon-6, 6 polymer? **→ NEET 2016, Phase II**

(a)


(b)


(c)


(d)


18 The monomers of buna-S rubber are

(a) vinyl chloride and sulphur
(b) butadiene
(c) styrene and butadiene
(d) isoprene and butadiene

19 Inter-particle forces present in nylon-6, 6 are

(a) van der Waals' forces
(b) dipole-dipole interactions
(c) H-bonding
(d) None of the above

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

(a) Hydrogen bonding (b) Covalent bonding
(c) Ionic bonding (d) All of the above

21 For the formation of terylene, the number of moles of ethylene glycol required per mole of terephthalic acid is

(a) 1 (b) 2
(c) 3 (d) 4

22 Nylon is an example of **→ NEET 2013**

(a) polysaccharide (b) polyamide
(c) polythene (d) polyester

23 Glyptal polymer is obtained from glycol by reacting with

(a) malonic acid (b) phthalic acid
(c) maleic acid (d) terephthalic acid

24 Thermosetting polymer, bakelite is formed by the reaction of phenol with

(a) CH_3CH_2CHO (b) CH_3CHO
(c) HCHO (d) HCOOH

25 Of the following which one is classified as polyester polymer? **→ CBSE-AIPMT 2011**

(a) Bakelite (b) Melamine
(c) Nylon-6, 6 (d) Terylene

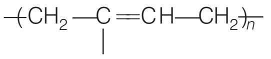
26 Which one of the following is not a condensation polymer? **→ CBSE-AIPMT 2012**

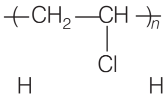
(a) Melamine (b) Glyptal
(c) Dacron (d) Neoprene

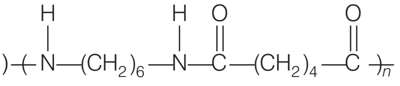
27 Which of the following represents the example of homopolymer?

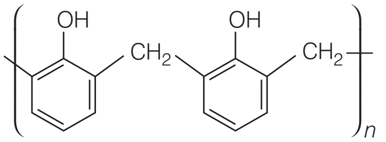
(a) PMMA (b) Nylon-6, 6
(c) Dacron (d) Bakelite

28 Which one of the following is an example of thermosetting polymer? **→ CBSE-AIPMT 2014**

(a)

$-\!\!\left(CH_2-\underset{|}{C}=CH-CH_2\right)_n\!\!-$

(b)

$-\!\!\left(CH_2-\underset{\underset{Cl}{|}}{CH}\right)_n\!\!-$

(c)

$-\!\!\left(\overset{\overset{H}{|}}{N}-(CH_2)_6-\overset{\overset{H}{|}}{N}-\overset{\overset{O}{\|}}{C}-(CH_2)_4-\overset{\overset{O}{\|}}{C}\right)_n\!\!-$

(d)


29 Which of the following polymers can have strong intermolecular forces?

I. Nylon II. Polystyrene
III. Rubber IV. Polyesters

The correct answer is

(a) I and IV (b) II and III
(c) I and III (d) All of these

30 Copolymer is

(a) nylon-6,6 (b) nylon-6
(c) PMMA (d) polythene

31 Among cellulose, polyvinyl chloride, nylon and natural rubber, the polymer in which the intermolecular force of attraction is weakest is

(a) nylon (b) polyvinyl chloride
(c) cellulose (d) natural rubber

32 Which of these is not a monomer for a high molecular mass silicone polymer? **→ NEET 2013**

(a) Me_2SiCl_2 (b) Me_3SiCl
(c) $PhSiCl_3$ (d) $MeSiCl_3$

33 Which of the following is a biodegradable polymer?

(a) Cellulose (b) Polythene
(c) Polyvinyl chloride (d) Nylon-6

34 Which of the following monomers form biodegradable polymers?

I. 3-hydroxybutanoic acid + 3-hydroxypentanoic acid
II. Glycine + amino caproic acid
III. Ethylene glycol + phthalic acid
IV. Caprolactam

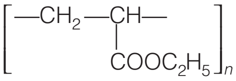
The correct answer is

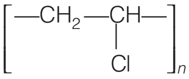
(a) I and II (b) II and III
(c) I, II and III (d) All of these

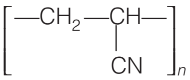
DAY PRACTICE SESSION 2

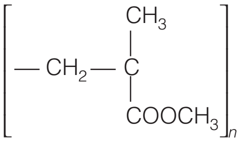
PROGRESSIVE QUESTIONS EXERCISE

1 Acrilan is a hard, horny and a high melting material. Which of the following represents its structure?

(a) 
$\left[-CH_2-\underset{COOC_2H_5}{\underset{|}{CH}}-\right]_n$

(b) 
$\left[-CH_2-\underset{Cl}{\underset{|}{CH}}-\right]_n$

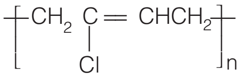
(c) 
$\left[-CH_2-\underset{CN}{\underset{|}{CH}}-\right]_n$

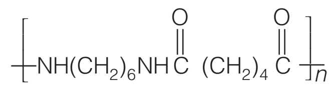
(d) 
$\left[-CH_2-\underset{COOCH_3}{\underset{|}{\overset{\overset{CH_3}{|}}{C}}}\right]_n$

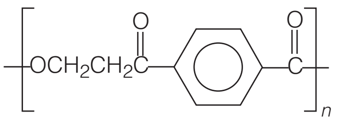
2 Which one of the following statements is not true?

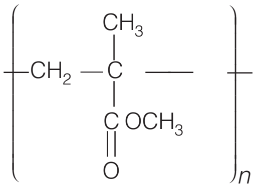
(a) Natural rubber has the *trans*–configuration at every double bond
(b) Buna-S is a copolymer of butadiene and styrene
(c) Natural rubber is a 1,4-polymer of isoprene.
(d) In vulcanisation, the formation of sulphur bridges between different chains make rubber harder and stronger.

3 Which one of the following is not correctly matched?

(a) Neoprene 
$\left[CH_2\ \underset{Cl}{\underset{|}{C}}=CHCH_2\right]_n$

(b) Nylon-6, 6 
$\left[NH(CH_2)_6NH\overset{O}{\overset{\|}{C}}\ (CH_2)_4\overset{O}{\overset{\|}{C}}\right]_n$

(c) Terylene 

(d) PMMA 
$\left(CH_2-\underset{\underset{\underset{O}{\|}}{C\ OCH_3}}{\underset{|}{\overset{\overset{CH_3}{|}}{C}}}-\right)_n$

4 Name the polymer which obtained from $CHCl_3$ as follows,

$$CHCl_3 \xrightarrow[SbF_3]{HF} X \xrightarrow{800°C} Y \xrightarrow{\text{Polymerisation}} \text{Plastic}$$

(a) bakelite (b) teflon
(c) polythene (d) nylon-6,6

5 Which of the following process is adopted for the industrial manufacture of high density polyethylene?

(a) Free radical liquid phase polymerisation
(b) Free radical gas phase polymerisation
(c) Anionic polymerisation
(d) *Zeigler-Natta* or oxide catalysed polymerisation

6 In which of the following polymers, empirical formula resembles with monomer?

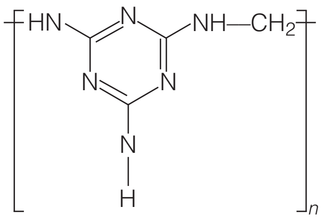
(a) Bakelite (b) Teflon
(c) Nylon-6,6 (d) Dacron

7 Given the polymers,
A = Nylon 6 6; B = Buna-S; C = Polythene.

Arrange these in increasing order of their intermolecular forces (lower to higher).

(a) $A < B < C$ (b) $B > C > A$
(c) $B < C < A$ (d) $A < C < B$

8 The monomers of the following polymer are

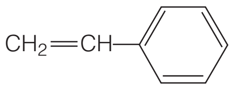


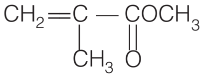
(a) hexamethylene diamine and decanedioic acid
(b) hexamethylene diamine and methanal
(c) melamine and methanal
(d) melamine and ethanal

9 Polystyrene, dacron and orlon are classified respectively as

(a) chain growth; step growth; step growth
(b) chain growth; chain growth; step growth
(c) chain growth; step growth; chain growth
(d) step growth; step growth; chain growth

10 Head-to-tail addition takes place in chain-growth polymerisation when monomer is

(a) 
(b) $CH_2{=}CH{-}CH{=}CH_2$

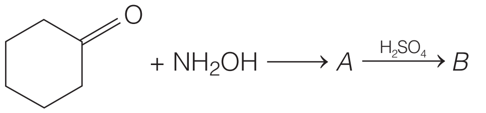
(c) 
$CH_2{=}\underset{CH_3}{C}{-}\underset{O}{\overset{\|}{C}}OCH_3$
(d) $CH_2{=}CH{-}C{\equiv}N$

11 The rubber used for manufacturing types is vulcanised with

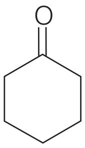
(a) 3% S
(b) 7% S
(c) 1% S
(d) All of these can be used

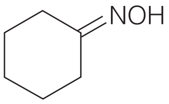
12 The polymer used in Orthopaedic devices and in controlled drug release is

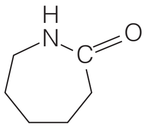
(a) Orlon (b) PTFE (c) SBR (d) PHBV

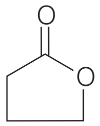
13 

The product B is

(a) 

(b) 

(c) 

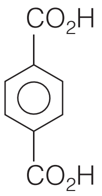
(d) 

14. The bakelite is made from phenol and formaldehyde. The initial reaction between the two compounds is an example of

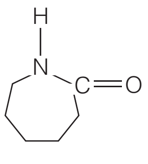
(a) aromatic electrophilic substitution
(b) aromatic nucleophilic substitution
(c) free radical reaction
(d) aldol reaction

15. Identify from the following monomers, which will undergo condensation polymerisation.

I. $H_2C = CH{-}CH = CH_2$

II. 

III. $H_2C = CHCl$

IV. 

V. $F_2C = CF_2$ VI. $(H_3C)_2C = CH_2$

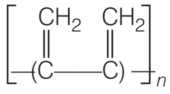
(a) Both III and V
(b) Both I and III
(c) Both I and VI
(d) Both II and IV

ANSWERS

SESSION 1	1 (c)	2 (d)	3 (a)	4 (d)	5 (b)	6 (b)	7 (c)	8 (c)	9 (c)	10 (b)
	11 (c)	12 (d)	13 (b)	14 (d)	15 (a)	16 (a)	17 (d)	18 (c)	19 (c)	20 (a)
	21 (a)	22 (b)	23 (b)	24 (c)	25 (d)	26 (d)	27 (a)	28 (d)	29 (a)	30 (a)
	31 (d)	32 (b)	33 (a)	34 (a)						
SESSION 2	1 (c)	2 (a)	3 (c)	4 (b)	5 (d)	6 (b)	7 (c)	8 (c)	9 (c)	10 (d)
	11 (b)	12 (d)	13 (c)	14 (a)	15 (d)					

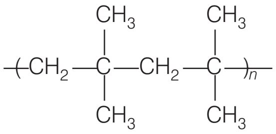
Hints and Explanations

1 Formation of polymer takes place as a result of condensation reaction between monomers.

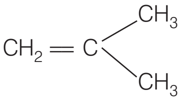
2 

$$\left[-(\overset{\overset{CH_2}{\|}}{C}-\overset{\overset{CH_2}{\|}}{C})-\right]_n$$

It suggests polymerisation on the lost of vinylic hydrogen atom, which is not possible.

3 

$$-(CH_2-\underset{CH_3}{\overset{CH_3}{\overset{|}{\underset{|}{C}}}}-CH_2-\underset{CH_3}{\overset{CH_3}{\overset{|}{\underset{|}{C}}}}-)_n-$$

is a polymer having monomer units,  $CH_2=C(CH_3)_2$

4 Cross-linked or network polymers are formed from bi-functional and tri-functional monomers and contain strong covalent bonds between various linear polymer chains. These are hard, rigid and brittle due to cross-links e.g. bakelite, melamine etc. Thus, option (d) is incorrect.

5 Cellulose acetate is a semi-synthetic polymer.

6 Thermosetting plastics have three dimensional cross linked structure.

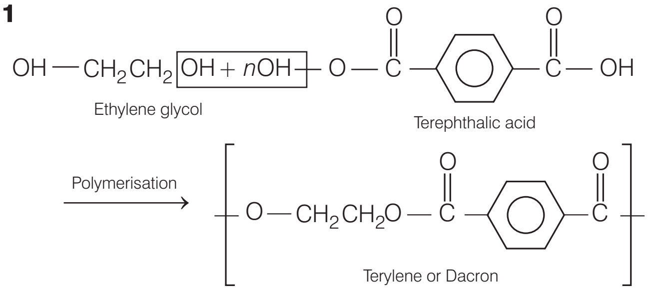
7 Chain growth polymerisation requires an initiator to produce a free radical to which the monomers are added in a chain fashion.

Initiators are added in small quantities. Polystyrene is an example of chain growth polymer because in it, styrene molecules are associated in the form of monomer.

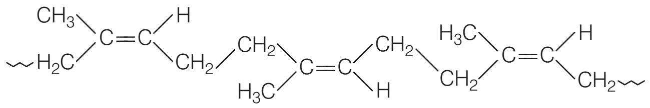
8 Teflon, PVC and neoprene are examples of homopolymers.

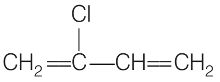
9 (a) $CH_2=CH-CN$ (acrylonitrile) polymerises to form PAN.
(b) $CH_2=CHCl$ (vinyl chloride) polymerises to form PVC.
(c) $F_2C=CF_2$ (tetrafluoroethylene) polymerises to form teflon.

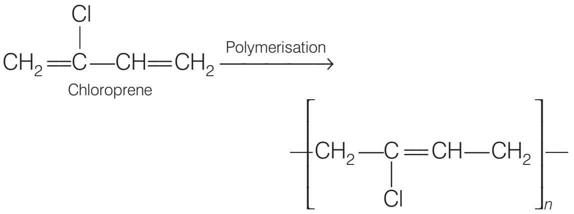
10 Vulcanisation is a process of heating the rubber with sulphur.

11 

12 The repeating unit in natural rubber has the *cis*-configurations with chain extensions on the same side of the ethylene double bond, which is essential for elasticity.



13  $CH_2=\overset{\overset{Cl}{|}}{C}-CH=CH_2$ is the monomer of neoprene

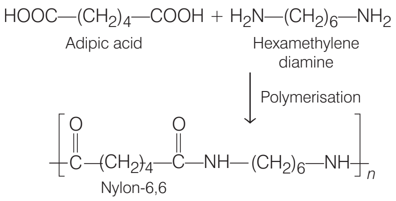


14 Teflon (polytetrafluoroethylene) is used to make non-stick cookwares.

15 The catalysts $TiCl_4$ and $(C_2H_5)_3Al$ are used in the manufacture of polythene by *Ziegler-Natta* method.

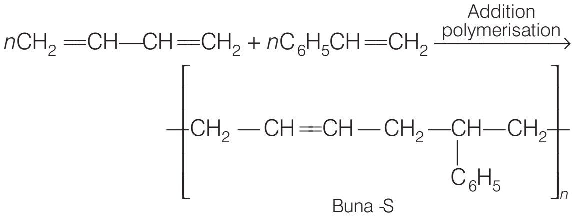
16 Buna-S is an example of addition polymer.

17 Nylon-6, 6 polymer is formed as



Thus, option (d) is correct.

18 Buna-S rubber is a polymer of buta-1, 3-diene and styrene.



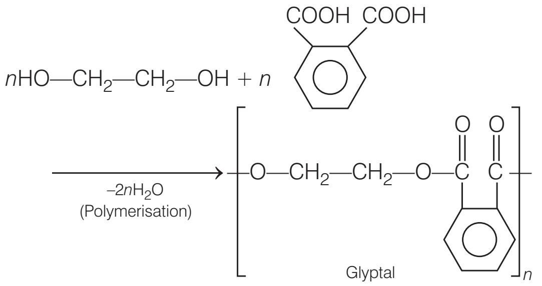
19 In nylon-6,6 there is H-bonding as inter particle forces.

20 Strong intermolecular forces like hydrogen bonding lead to close packing of chains that imparts crystalline character.

21 Terylene is a condensation product of ethylene glycol and terephthalic acid. So, one mole of terephthalic acid is required for the formation of terylene.

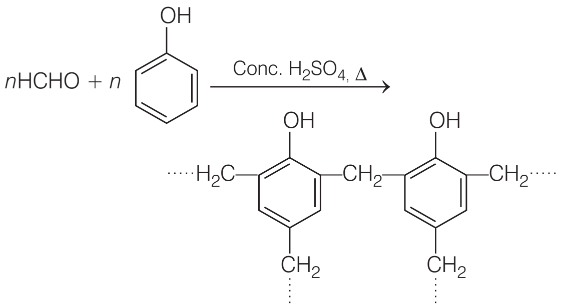
22 Nylon is a polyamide polymer.

23 Glyptal or alkyd resin is a polymer of ethylene glycol and phthalic acid.



Glyptal

24 Bakelite is a thermosetting plastic formed by reaction of phenol with HCHO in the presence of conc. H_2SO_4.



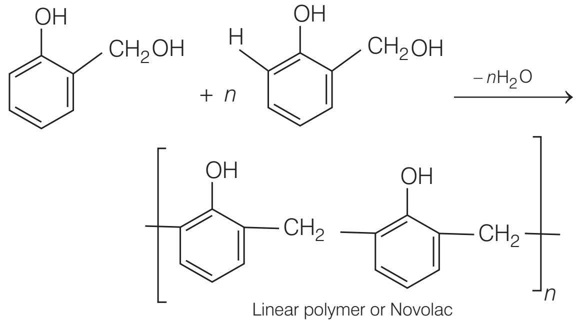
It is thus cross-linked polymer, condensation taking place at *o*- and *p*-positions. Thus, HCHO is the correct choice.

25 Terylene is a polyester polymer because it is formed by the monomer units terephthalic acid and ethylene glycol.

26 Condensation polymers are obtained by bifunctional molecules (monomers) with the elimination of smaller molecules whereas additional polymers are obtained from multiple bond containing monomers. Neoprene is a polymer of chloroprene ($CH_2{=}C(Cl){-}CH{=}CH_2$) so it is an addition polymer, instead condensation polymer.

27 Polymethyl methacrylate (PMMA) is a homopolymer.

28 Novolac is thermosetting polymer. When *o*-hydroxy benzyl alcohol undergo self condensation to give a linear polymer, called novolac.



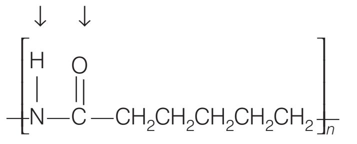
Linear polymer or Novolac

29 Nylon and polyesters have strong intermolecular forces (i.e., hydrogen bonding)

30 Nylon-6, 6 is an example of copolymer.

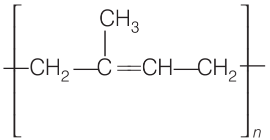
31 Nylon has amide linkage capable of forming intermolecular H-bonding as

Sites capable of forming H-bonding



Nylon-6

Due to H-bonding, nylon has strong intermolecular attraction. Cellulose is a polyhydroxy compound, also capable of forming strong intermolecular H-bonding; polyvinylchloride is a polar polymer due to carbon chlorine bond and it possess strong dipole-dipole attraction. Natural rubber is polyisoprene, a hydrocarbon, possess weak van der Waals' attraction.

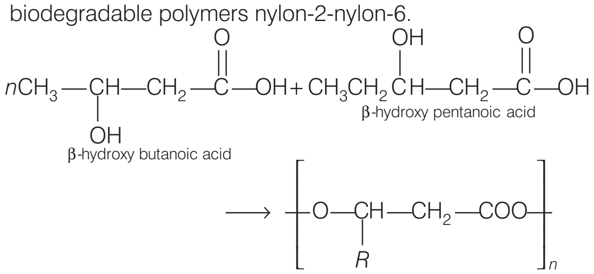


cis-poly (isoprene)
Natural rubber

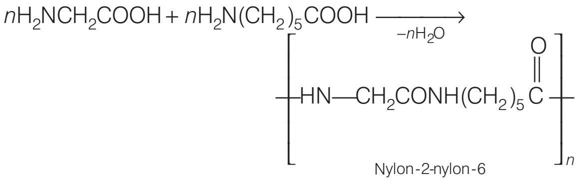
32 It can form only dimer.

33 Cellulose is a biodegradable polymer. Different enzymes secreted by bacteria digest it.

34 Monomers 3-hydroxy butanoic acid and 3-hydroxy-pentanoic acid react each other and form biodegradable, PHBV polymer. Glycine and amino caproic acid also react to form biodegradable polymers nylon-2-nylon-6.



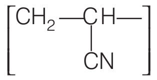
PHBV



Nylon-2-nylon-6

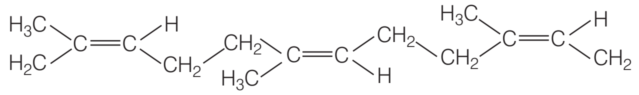
SESSION 2

1 Acrilan (or acrylonitrile) is monomer unit of polyacrylonitrile (PAN). Its structure is

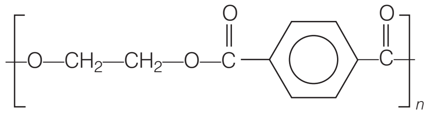


$$\left[CH_2-\underset{CN}{CH}- \right]$$

2 Natural rubber is *cis*-1, 4-polyisoprene and has all *cis*-configurations about the double as shown below. It is prepared from latex which is obtained in *cis* form.



3 Terylene is formed by the condensation of dimethyl terephthalate and glycol. Its structure is



Terylene (Dacron)

Hence, the structure of terylene given in question is incorrect.

4 $$CHCl_3 \xrightarrow[SbS_5]{HF} \underset{(X)}{CHF_3} \xrightarrow[-HF]{800°C} \underset{(Y)}{F_2C=CF_2}$$

$$\xrightarrow{\text{Polymerisation}} \underset{\text{Teflon (Plastic)}}{-(F_2C=CF_2)_n-}$$

5 *Zeigler-Natta* or oxide catalysed polymerisation is done for the industrial manufacture of high density polyethylene.

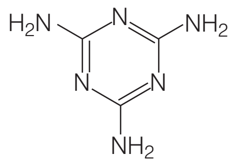
6 In addition homopolymers such as teflon, empirical formula resembles with monomer.

7 Buna-S is an elastomer, thus has weakest intermolecular forces. Nylon-66, is a fibre, thus has strong intermolecular forces like H-bonding. Polythene is a thermoplastic polymers, thus the intermolecular forces present in polythene are in between elastomer and fibres. Thus, the order of intermolecular forces of these polymers is

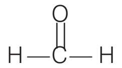
buna-S < polythene < nylon-6,6

8 Break—NH—CH_2 bond and add H_2O to get the structure of monomers.

(a) 2, 4, 6-triamino-1, 3, 5-triazine or melamine



(b) Formaldehyde or methanal (HCHO)



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

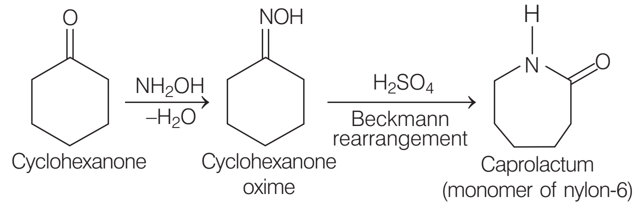
9 Polystyrene and orlon, being vinyl derivative are chain growth polymers while dacron is a step growth polymer.

10 Vinyl derivatives containing electron releasing group readily undergo head to tail addition polymerisation.

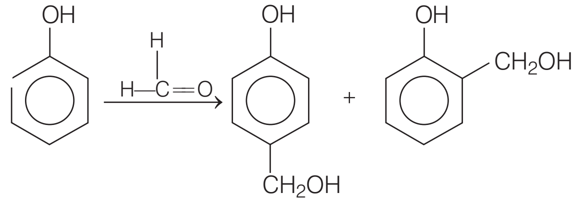
11 Rubber vulcanised with 3-10% sulphur is more rigid and hence, used for manufacturing tyres. While the rubber vulcanised with 1-3% sulphur is soft and stretchy, so used to make rubber band.

12 PHBV (Poly-β-hydroxybutyrate –CO-β-hydroxy valerate), a copolymer of 3-hydroxy butanoic acid and 3-hydroxypentanoic acid is used in orthopaedic devices and in controlled drug release.

13



14 The initial reaction between phenol and formaldehyde is aromatic electrophilic substitution.



15 In condensation polymerisation, molecules of same or different monomers are combined in a controlled stepwise manner with elimination of small molecules such as water, ammonia, alcohols, etc.