
SAFALTA.COM
An Initiative by अमर उजाला

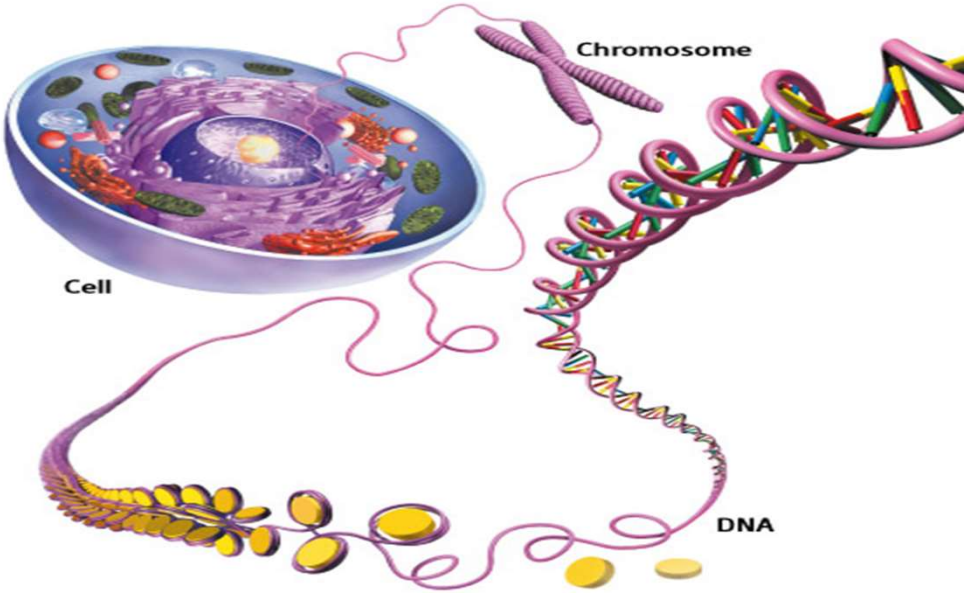
POLYMERS

INTRODUCTION TO POLYMERS

POLYMER

Mer means unit(or) part

Ex: **Biomolecules**

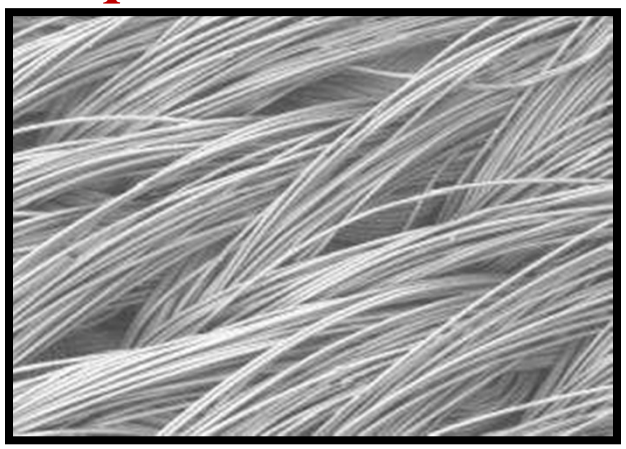


Do you know what a fiber is ?

- **A fiber is a thin thread like material (Structure) which can be *spun or woven into a fabric*.**

Thin

Thick



Short

Long

Polymers :

The term polymer is defined as very large molecule having high molecular mass(10^3-$10^7 u$). *These are also referred as* ***Macromolucles***

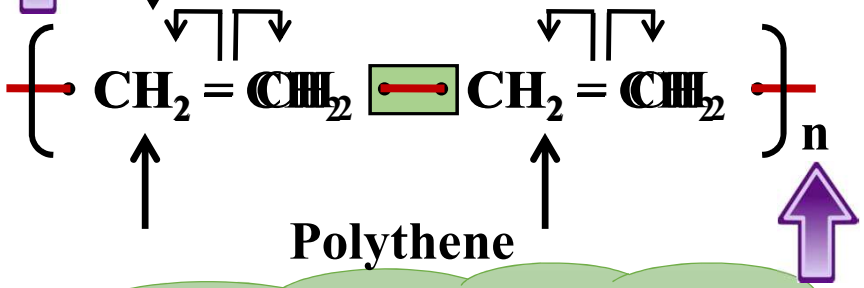
Polymers are *high molecular mass compounds* formed by joining together a large numbers of simple molecules called monomers.

Polymers : **Ex:Polythene**

Monomer **Ethene**

$n(CH_2 = CH_2)$

Molecular formula of Ethene is ---- C_2H_4



Polythene

Similarly, various molecules can be linked together

Polymers :

$n\ (CH_2 = CH_2)$ — **Ethene**

Monomer

↓

$-(CH_2 - CH_2)-_n$ — **Polyethene**

Polymer

Define polymerization if you have any idea.

The process by which *monomers are converted into polymers* is called as

Polymerization

Macromolecule:

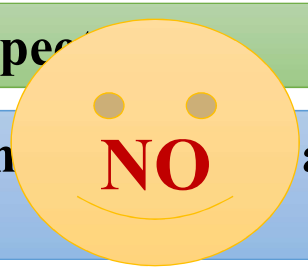
What are macro molecules?

Then what?

High molecular mass compounds are called as macromolecules.

All Polymers and macromolecules, are the same in all respe

Polymers have *essentially* a repeating structural un a macromolecule *may* or *may not possess.*



i.e. All polymers are macromolecules but all macromolecules are not polymers.

MCQs

1. **A high molecular weight molecule which does not contain a repeating structural unit(s) is called a…**

   a) Polymer

   b) Macromolecule ✓

   c) Both a & b

   d) None of these

2. Polymers are…

a) High molecular mass compounds

b) Macromolecules

c) Both a & b ✓

d) None of these

3. **A fiber is a….thread like structure which can be spun or woven into fabric**

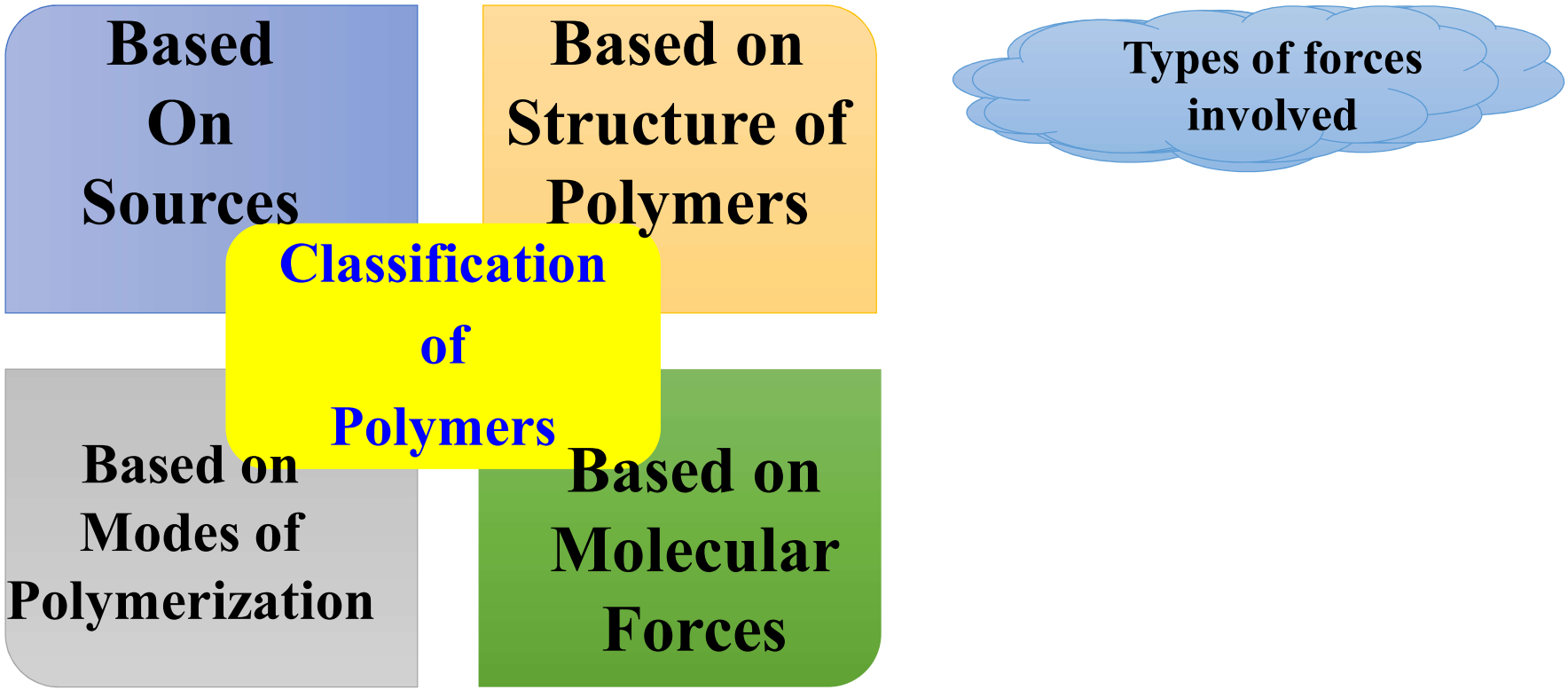
a) Thin

b) Thick

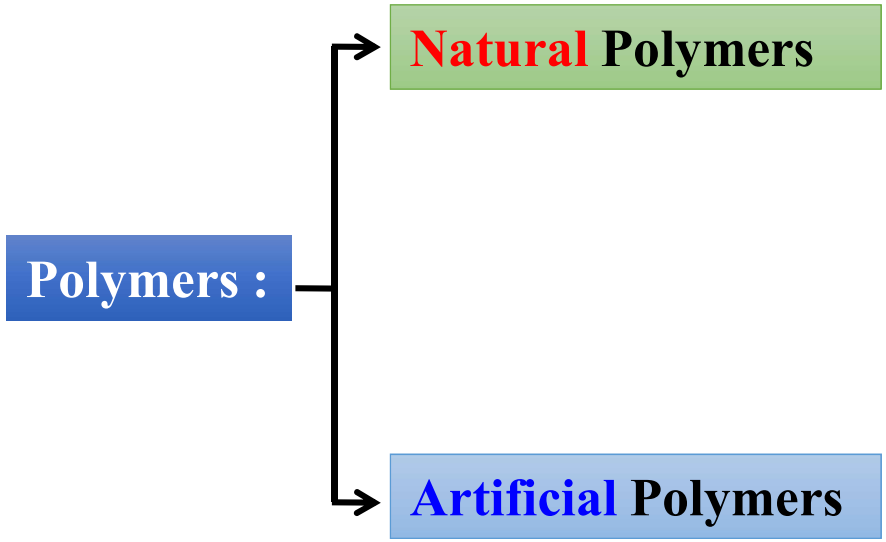
c) Both a & b

d) None of these

CLASSIFICATION OF POLYMERS BASED ON SOURCE


Based On Sources
Based on Structure of Polymers
Classification of Polymers
Based on Modes of Polymerization
Based on Molecular Forces
Types of forces involved

Classification based on Sources :



Natural Polymers

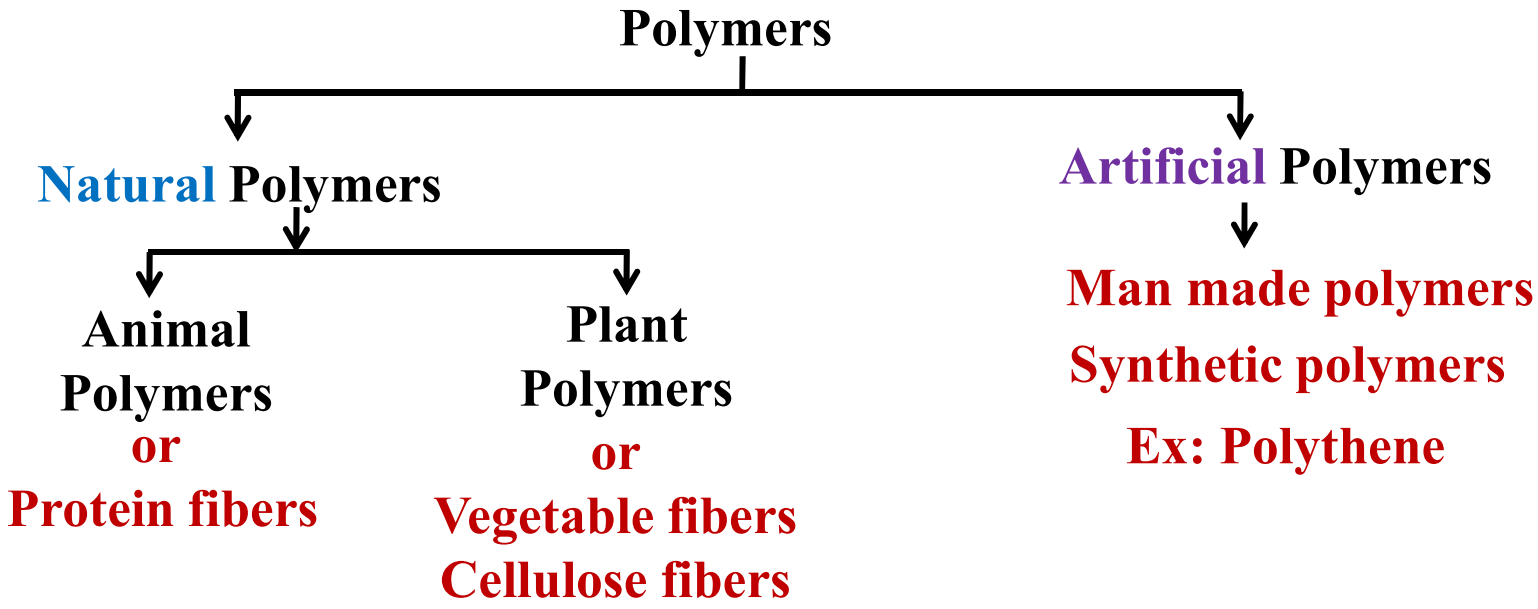
Polymers which are obtained from natural source are called as natural polymers (i.e. Plants/Animals). Examples ;proteins, cellulose, starch, some resins and rubber.

Artificial Polymers

Polymers which are made by humans are called as artificial polymers.

i.e Either made completely by humans or just by modifying the properties of natural polymers.

Classification based on Sources :



Classification based on Sources :

Animal Polymers

Polymers which are obtained form *animals* are called as Animal Polymers

Silk

(Fibrion)

Wool

(Keratin)

Classification based on Sources :

Plant Polymers

Polymers which are obtained from *plants* are called as Plant Polymers

Example :

Cotton	**Jute**	**Rubber**
Flax	**Hemp**	**Linen**
	(Paper)	**Purest Cellulose**

MCQs

1. Plant fibers are also called as…

a) Vegetable fibres

b) Cellulose fibres

c) Both a & b ✓

d) None of these

2. Animal fibers are also called as…

a) Cellulose fibers

b) Protein fibers ✓

c) Both a & b

d) None of these

3. Which of the following is a plant polymer?

a) Rayon

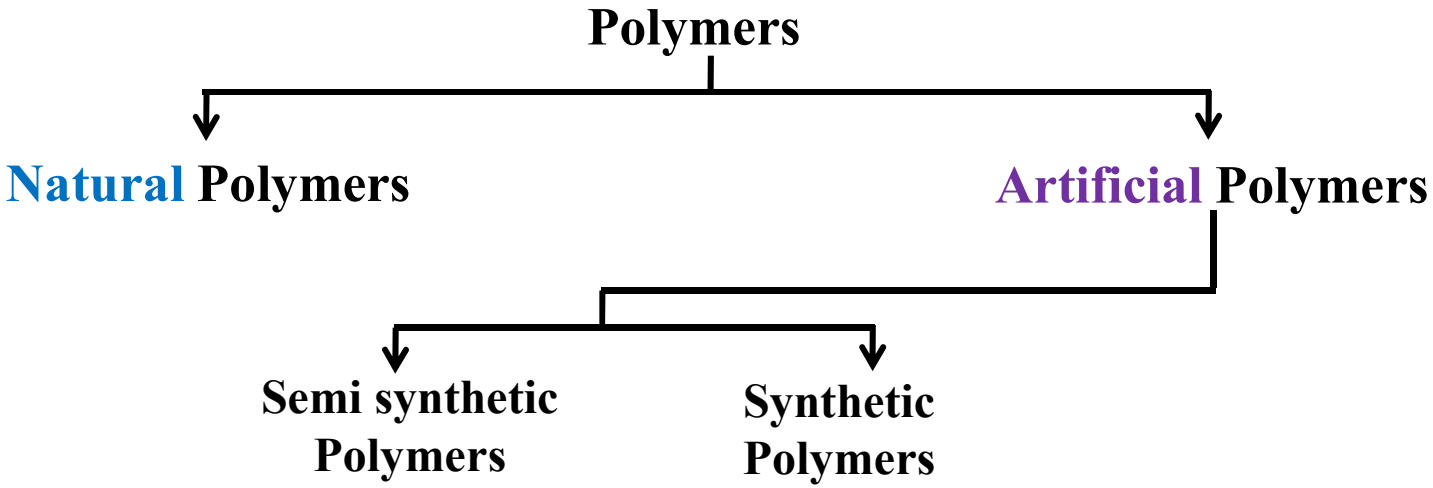
b) Silk

c) Hemp ✓

d) Wool

SYNTHETIC
&
SEMI-SYNTHETIC POLYMERS

Classification based on Sources :



Classification based on Sources :

Semisynthetic Polymers / Regenerated polymers

- **Properties of natural polymers are enhanced *by* chemical modification.**
- ***Entire* polymers are made in *factories.***

Classification based on Sources :

Semisynthetic Polymers / Regenerated polymers

Example:

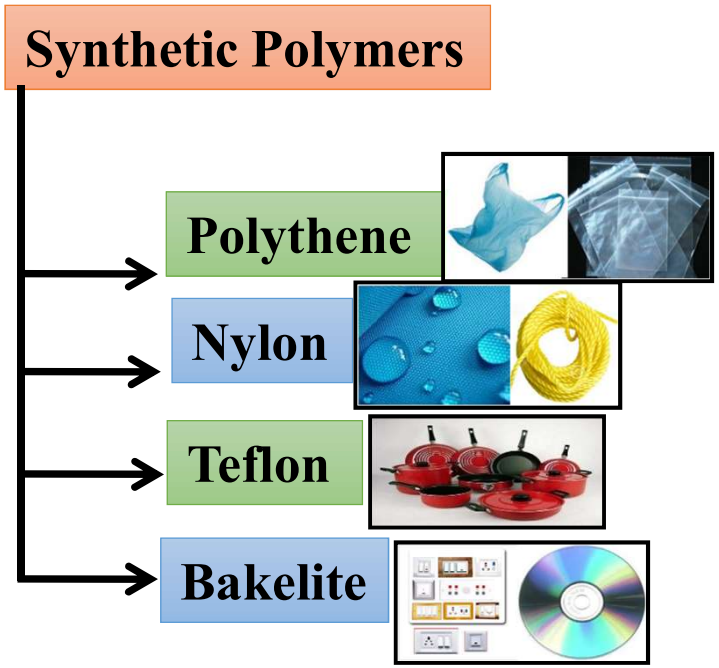
Cellulose Acetate (Rayon)

Cellulose nitrate

Buna-S

Classification based on Sources :

Synthetic Polymers :
These are man-made polymers



MCQs

1. Rayon is...

a) Natural silk

b) Natural fiber

c) Artificial silk ✓

d) None of these

2. Which of the following is a natural polymer?

a) Teflon

b) Buna-S

c) Cellulose ✓

d) None of these

3. Which of the following is used in making tyres?

a) Teflon

b) Cellulose

c) Buna-S ✓

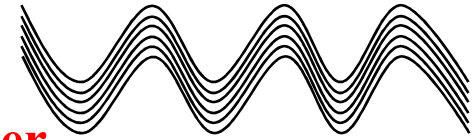
d) None of these

POLYMERS CLASSIFIED BASED ON STRUCTURE

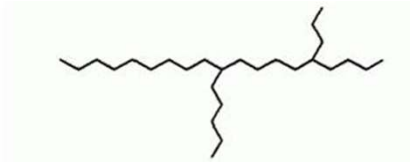
Classification based on Structure

Polymers :

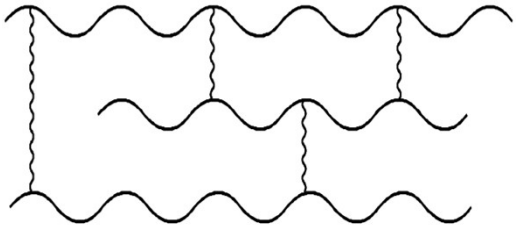
- **Linear Polymer**



- **Branched Polymer**

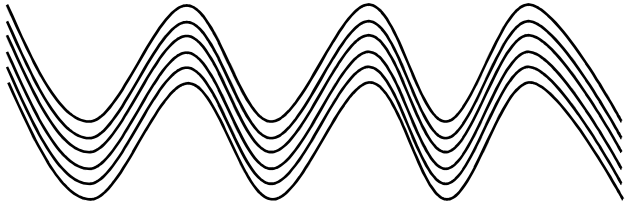


- **Cross linked / Network Polymer**



Classification based on Structure

Polymers : **1. Linear Polymer**



- **Linear polymers are *long continuous chain* polymers.**
- **They have no branching**

Classification based on Structure

Polymers : **1. Linear Polymer**

Examples :

High density polythene (HDP)

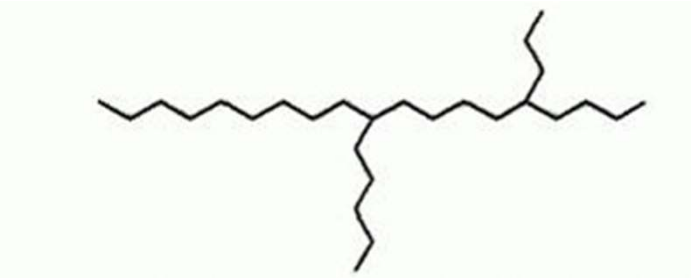
Polyvinyl chloride (PVC)

Polyesters

Nylon

Classification based on Structure

Polymers : **2. Branched Polymer**



- **Polymers have one main chain and *small side chains or branches.***
- ***Hence, they have low density.***

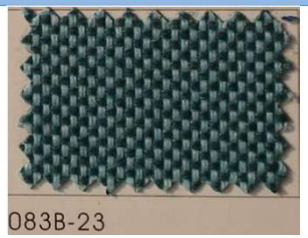
Classification based on Structure

Polymers : **2. Branched Polymer**

Examples :

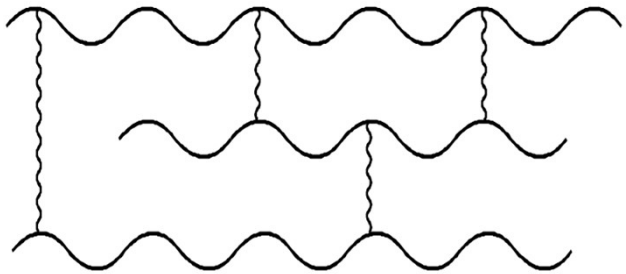
Low density polythene (LDP)

Polypropylene **etc.**



Classification based on Structure

Polymers : **3. Cross linked Polymer :**



- **These are usually formed from bi-functional and tri-functional monomers and contain *strong covalent bonds*.**
- ***Hence, leading to network nature due to cross links***

Classification based on Structure

Polymers : **3. Cross linked Polymer :**

Examples :

Bakelite

***Melamine* (Melamac)**

Rubber

1. PVC is an example of…

a) Linear polymer

b) Branched polymer

c) Network polymer

d) None of these

2. LDP (Low density polythene) is an example of …

a) Linear polymer

b) Branched polymer

c) Network polymer

d) None of these

3. Which of the following is a linear polymer?

a) Bakelite

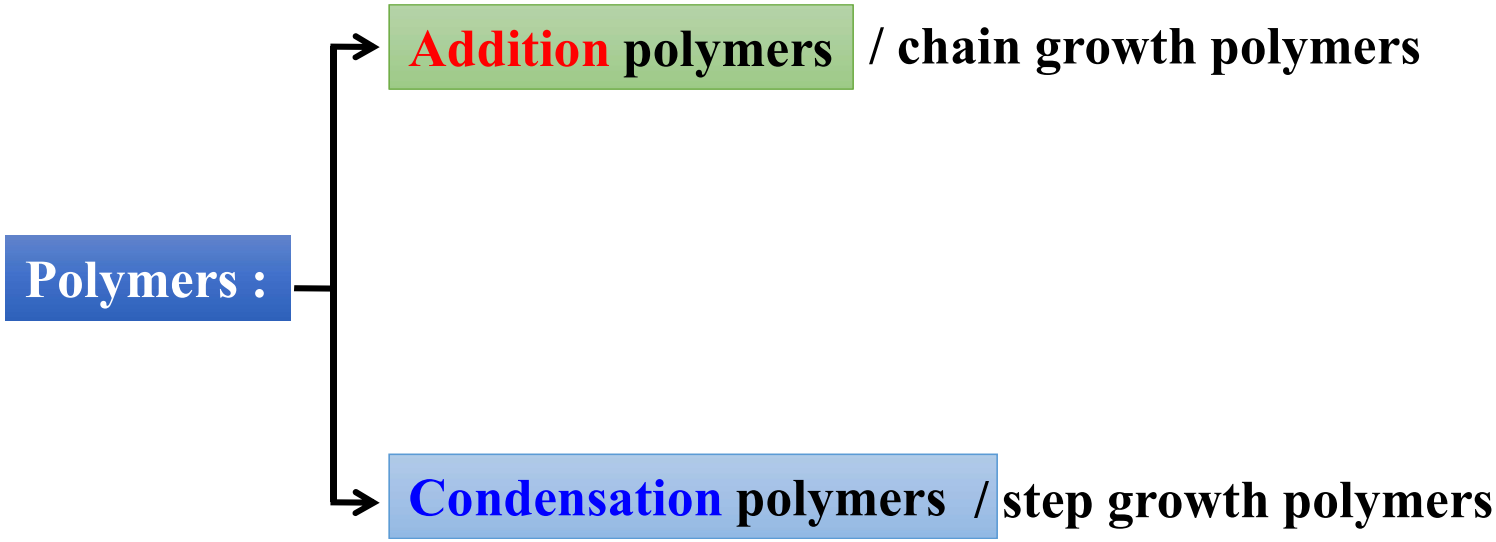
b) Melamine

c) polypropylene

d) None of these

POLYMERS CLASSIFIED BASED ON POLYMERIZATION

Classification based on mode of polymerization :



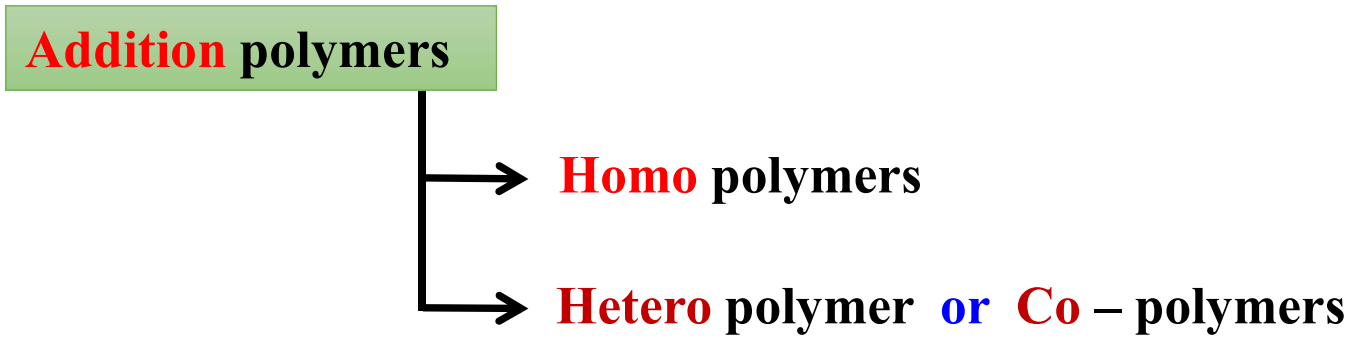
Classification based on modes of polymerization :

Addition polymers **/ chain growth polymer**

Monomers are
alkenes (ethene etc.) or
alkenylarenes(styrene) etc.

- **Polymers are formed by the *combination* of *many similar monomers or many two different monomers***
- **Generally *by-products are not* formed**

Classification based on modes of polymerization :



Classification based on modes of polymerization :

Addition polymers | **1. Homo polymer**

- ***Same type*** **of molecules (monomers) combine to form polymers.**

Ex: polythene is produced by the combination of many ethylene (C_2H_4) monomers

Addition polymers

1. Homopolymer

Examples :

Polythene

Polyvinyl chloride (PVC)

Teflon

Orlan (PAN) etc

Classification based on modes of polymerisation :

Addition polymers | **2. Heteropolymer or Co - polymer**

- ***More than one type*** **of molecules (monomers) combine to form polymers.**

Examples :

Buna – S

Monomers:
1. Styrene &
2. 1,3-butadiene

Buna – N
NBR
(Nitrile butadiene Rubber)

Monomers:
1. Vinylcyanide
or prop-2-enenitrile &
2. 1,3-butadiene

MCQs

1.Which of the following is not an addition homo-polymer?

a) PVC

b) Buna-S

c)Teflon

d) PAN

2.What are the monomers of NBR?

a) 1,3-butadiene

b) Acrylonitrile

c) Ethylene

d) a and b

CONDENZATION POLYMERS

Classification based on modes of polymerization :

Condensation polymers **/ step growth polymer**

- **Polymers are formed by the *combination of two types of monomers.***
- **A small molecule such as water or alcohol etc. is *eliminated.***

Classification based on modes of polymerization :

Condensation polymers

- **Homo polymers**
- **Hetero polymer or Co – polymers**

Classification based on modes of polymerization :

Condensation polymers | **1. Homopolymer**

- ***Same type*** **of molecules combine to form polymers.**

Examples :

Nylon – 6,
Cellulose,
Starch, etc

Classification based on modes of polymerization :

Condensation polymers | **2. Hetero polymeror or Co - polymer**

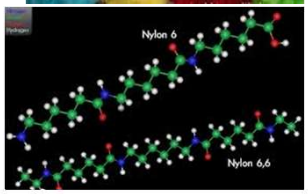
- ***More than 1 type*** **of molecules(monomers) combine to form polymers.**

Examples :

Terylene,

Bakelite, etc

Nylon – 6,6



MCQs

1. Which of the following is a copolymer?

a) Teflon

b) Polythene

c) Orlon

d) Buna - S ✓

2. Cellulose is an example of…

a) Addition homopolymer

b) Condensation homopolymer

c) Addition copolymer

d) Condensation copolymer

3. Which of the following is/are the example(s) of addition homo-polymers?

a) Polythene

b) PVC

c) Teflon

d) All of the above ✓

CLASSIFICATION BASED ON MOLECULAR FORCES

Classification based on Molecular forces :

Elastomers	Fibre
Weakest intermolecular forces	*Strongest* intermolecular forces
Vander waals Elasticity	*Hydrogen bond* High tensile strength
Buna – S, Buna – N *Neoprene* *Vulcanized Rubber*	*Nylon – 6* *Nylon – 6,6* *Terylene*

Classification based on Molecular forces:

Thermoplastic polymer	Thermosetting polymer
Force of attraction intermediate in strength between elastomers &fibers	*Polymer does not become soft on heating*
Polymer becomes soft on heating & hard on cooling	*They undergo extensive cross–linking*

Classification based on forces of attraction:

Based on heat treatment:

- A thermoplastic, or thermo-softening plastic, is a plastic material, typically a polymer, that becomes pliable or mouldable above a specific temperature and solidifies upon cooling.
- Most thermoplastics have a high molecular weight.
- The polymer chains associate through intermolecular forces, which weaken rapidly with increased temperature, yielding a viscous liquid.

Classification based on forces of attraction:

Based on heat treatment:

Thus, thermoplastics may be re-shaped by heating and are typically used to produce parts by injection moulding.

Ex: Polythene, Polystyrene, PVC, Nylon, Sealing wax

Classification based on forces of attraction:

Based on heat treatment:

Thermosetting polymers:

- A thermosetting plastic, also known as a thermoset, is petrochemical material that irreversibly cures.

The cure may be induced by heat, generally above 200 °C (392 °F), through a chemical reaction, or suitable irradiation.

Classification based on forces of attraction:

Thermosetting polymers:

Ex: Bakelite , Polysiloxanes, Urea-formaldehyde, also known as urea-methanal

- **Polyurethane (PUR and PU) is a polymer composed of a chain of organic units joined by carbamate (urethane) links.**

While most polyurethanes are thermosetting polymers that do not melt when heated, thermoplastic polyurethanes are also available.

Thermosetting polymers:

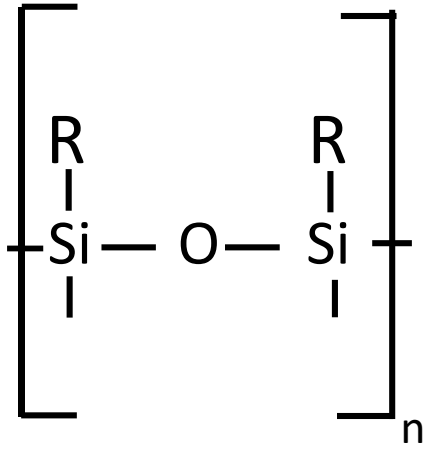
- **Polyurethane products often are simply called "urethanes", but should not be confused with ethyl carbamate, which is also called urethane. Polyurethanes neither contain nor are produced from ethyl carbamate.**
- **Polyurethanes are used in the manufacture of nonflexible, high-resilience foam seating; rigid foam insulation panels; microcellular foam seals and gaskets; durable elastomeric wheels and tyres (such as roller coaster, escalator and skateboard wheels);**

Thermosetting polymers:

- **Automotive suspension bushings; electrical potting compounds; high performance adhesives; surface coatings and surface sealants; synthetic fibers (e.g., Spandex); carpet underlay; hard-plastic parts (e.g., for electronic instruments); and houses.**

Classification based on modes of polymerisation :

Thermoplastic polymer	Thermosetting polymer
Remoulded & Recycled	*Cannot be remoulded, recycled & reused*
Polythene, PVC, Nylon, sealing wax	Bakelite, Urea-formaldehyde, Polysiloxanes



Polysiloxanes

Question

What are polymers?.

Answer:

Polymers are high molecular mass substances consisting of large numbers of repeating structural units.
They are also called as macromolecules. Some examples of polymers are Polythene, Bakelite, Rubber, Nylon 6, 6, etc.

Question

How are polymers classified on the basis of structure?

Answer:

On the basis of structure, the polymers are classified as bellow:

a) Linear polymer such as polythene, polyvinyl chloride, etc.

b) Branched chain polymers such as low density polythene

c) Cross linked polymers such as Bakelite, Melamine, etc...

MCQs

1. The polymer which can be re-cycled and re-used is…

a) Elastomers

b) Thermoplastic polymers ✓

c) Fibers

d) Thermosetting polymers

2. Weakest intermolecular forces are in…

a) Elastomers

b) Thermoplastic polymers

c) Fibres

d) Thermosetting polymers

3. Bakelite is an example of…

a) Elastomers

b) Thermoplastic polymers

c) Fibers

d) Thermosetting polymers ✓

4. Hydrogen bonding is present in…

a) Elastomers

b) Thermoplastic polymers

c) Fibres ✓

d) Thermosetting polymers

POLYTHENE

Polythene

Ethene ***Repeating unit*** ***Polythene***

Suppose we take **'n'** molecules of **ethene**

Ethene

Polythene

***Two types of Polythene* :**

Low density polythene (LDP)

High density polythene (HDP)

Low density polythene (LDP) Or ***Low Density Polyethylene (LDPE) :***

$n \quad (CH_2 = CH_2)$

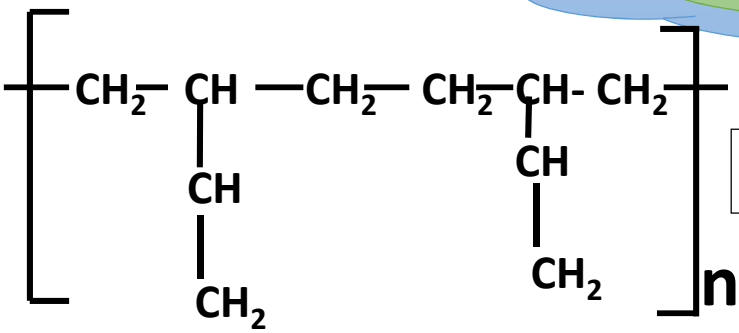
Ethene
Monomer

Monomer **used is *Ethene***

350K – 570K
1000-2000 atm

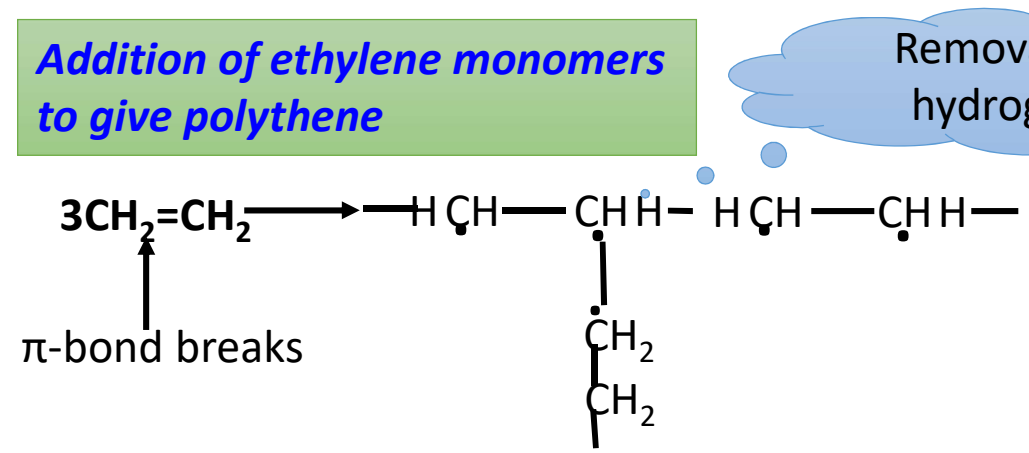
O_2/H_2O_2

The reaction requires O_2or H_2O_2 as catalyst

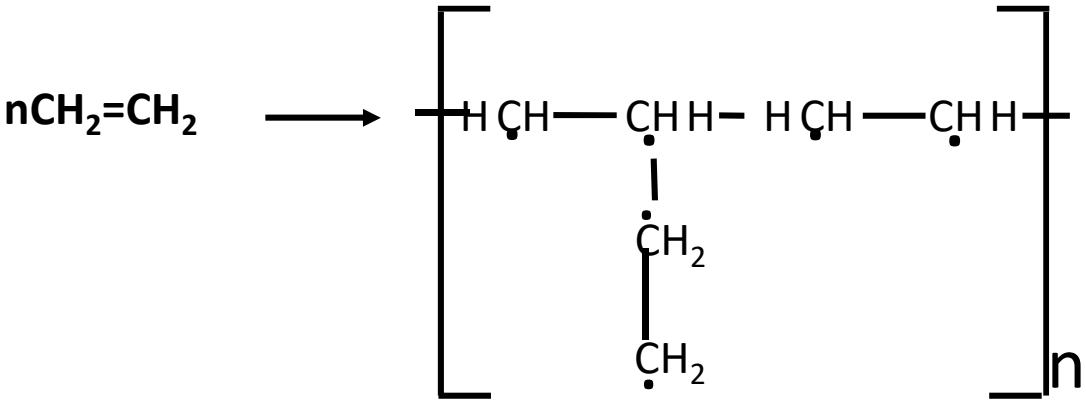


Low Density Polyethylene (LDPE) :

Addition of ethylene monomers to give polythene



Like this many molecules (monomers) unite to give polythene



Low density polythene (LDP) Or *Low Density Polyethylene (LDPE)* :

Properties :

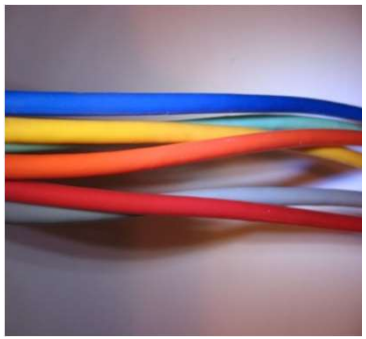
- It is *chemically inert*.
- It is *tough* (*But* ***mechanically weak***)
- It is *flexible.*
- It is a *poor conductor of electricity*.

Uses :

- It is used in manufacture of squeeze bottles, toys, flexible pipes.

Low density polythene (LDP) **Or** ***Low Density Polyethylene (LDPE) :***

Examples :

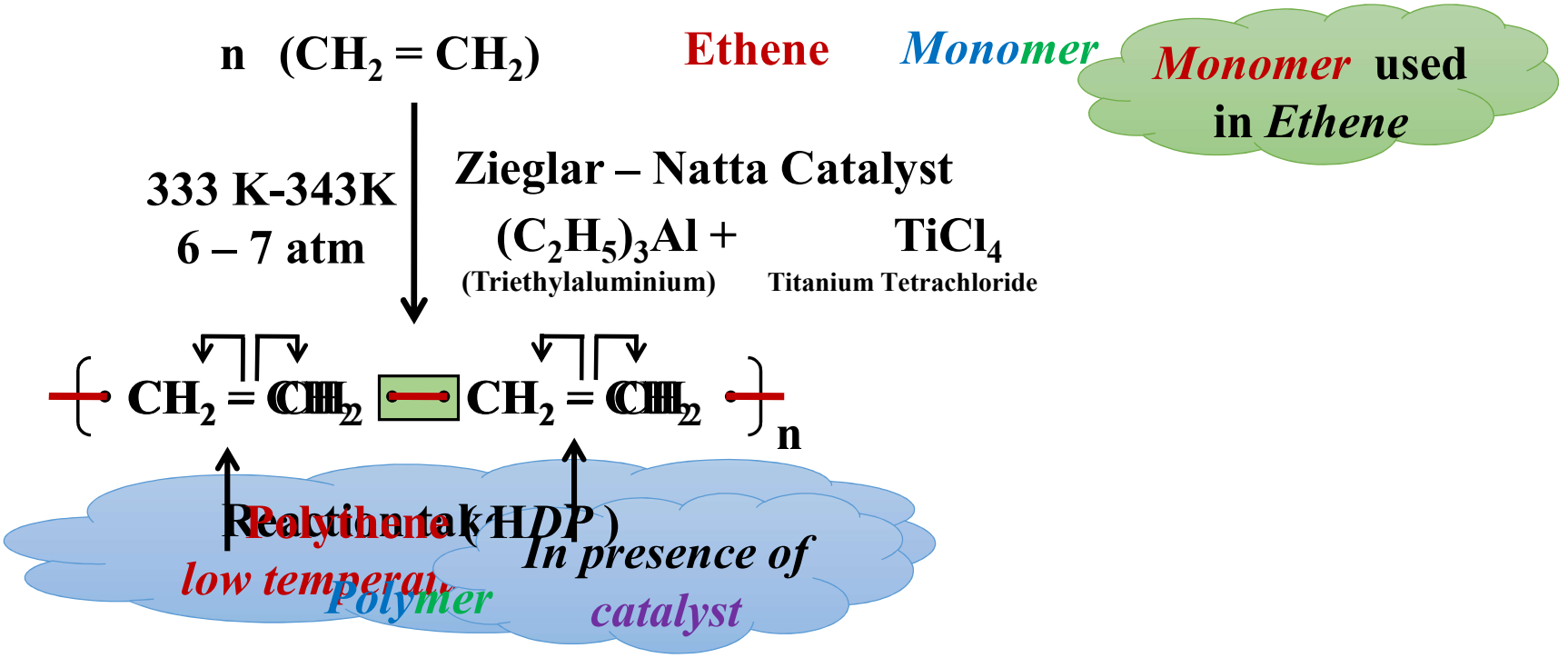


Insulations for cables

Packaging bags

Making toys

High density polythene (HDP) Or ***High Density Polyethylene (HDPE) :***



High density polythene (HDP) Or *High Density Polyethylene (HDPE)* :

Properties :

- It is a *translucent* polymers.
- It is *chemically inert*
- It is *extremely tough*

(high density & high Melting point)

Uses :

- It is used for manufacturing buckets ,dustbins ,bottles ,pipes.

High density polythene (HDP) Or ***High Density Polyethylene (HDPE)*** **:**

Examples :

Plastic bottles

Plastic containers

Plastic toys

MCQs

1. Which polymer is made at high temperature and high pressure?

a) LDP

b) HDP

c) Both a & b

d) None of these

2. *Zieglar – Natta catalyst* is used in the manufacture of…

a) LDP

b) HDP ✓

c) Both a & b

d) None of these

3. Plastic that is used as an *insulation* for cables is…

a) LDP

b) HDP

c) Both a & b

d) None of these

4. Formula of *Zeiglar – Natta catalyst* is…

a) $(C_2H_5)_2Al + TiCl_6$

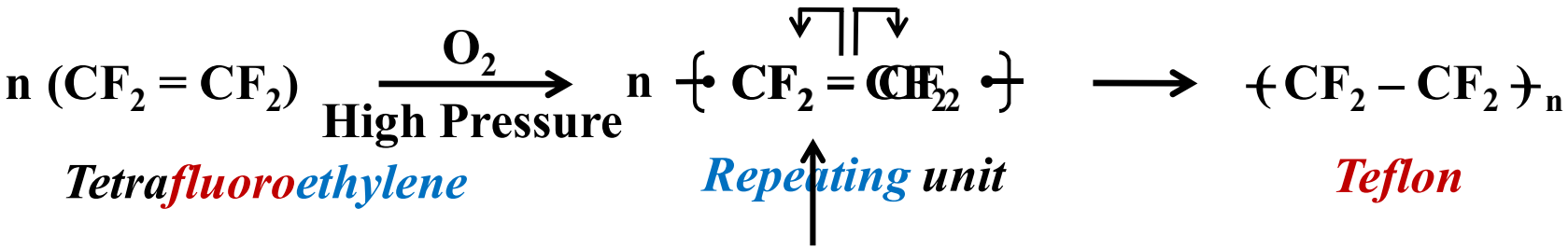
b) $(C_2H_5)_3Al + TiCl_6$

c) $(C_2H_5)_2Al + TiCl_4$

✓ d) $(C_2H_5)_3Al + TiCl_4$

TEFLON
&
POLYACRYLONITRILE

Teflon Or ***Polytetrafluoroethylene (PTFE) :***



Reaction takes place in presence of catalyst & high pressure

Teflon **Or** ***Polytetrafluoroethylene (PTFE) :***

Properties :

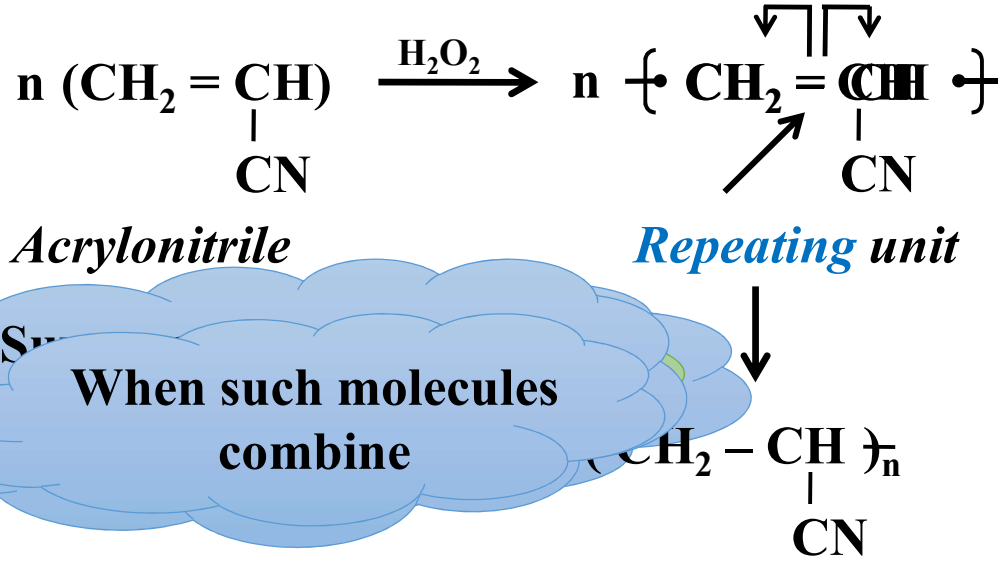
- **It is *chemically inert***

Teflon Or ***Polytetrafluoroethylene (PTFE) :***

Examples

Used as *coating* for cooking pan, oil seals, gaskets

(PAN) Polyacrylonitrile : **Or** ***Orlon*** **Or** ***Acrilan***



PAN(Polyacrylonitrile)

Polyacrylonitrile (PAN) : **Or** ***Orlon*** **Or** ***Acrilan***

Examples :

Used as *substitute* for wool *in carpets* and *blankets*.

MCQs

1. *Oil seals* and *oil gaskets* are made up of…

a) Ethene

b) HDP

c) PAN

d) Teflon ✓

2. Monomer of *teflon* is…

a) PAN

b) Tetrafluoroethylene ✓

c) Acrylonitrile

d) None of these

3. Monomer of *Orlon* is…

a) Acrilan

b) Tetrafluoroethylene

c) Acrylonitrile ✓

d) None of these

4. *Polyacrylonitrile* is also called as

a) Orlon

b) Acrilan

c) PAN

d) All of these

ADDITION POLYMERIZATION
&
IONIC POLYMERIZATION

Addition Polymerization or Chain Growth Polymerization

Mechanism :

- **Alkenes (dienes) undergo *chain growth polymerization*.**
- **The chain grows by the addition of *reactive end to* double bond of a monomer.**

Addition Polymerization or Chain Growth Polymerization

Mechanism :

The possible reaction intermediates **is**

1. ***Free radical***
2. **Carbo*cations***
3. **Carbo*anions***

Reaction intermediates are highly reactive species .

Ionic polymerization

It is of two types based on the nature of ions for the chain initiation.

1) Cationic polymerization

- **If positive ion or cation is used as the chain initiator, it is called cationic polymerization.**

2) Anionic Polymerization

- **If negative ion or anion is used as the initiator, it is called anionic polymerization.**

Cationic polymerization

- **Formation of poly vinyl compound from its monomer is an example of cationic polymerization.**
- **Lewis acids such as BF_3, $AlCl_3$, $SnCl_2$ act as chain initiators.**
- **The important general steps involved in the cationic polymerization are as follows:**

Cationic polymerization | Mechanism

(i) Chain initiation step:

$$H_2O + AlCl_3 \rightarrow H^+ + [AlCl_3\,(OH)]^-$$

$$H^+ + CH_2{=}CHR \rightarrow CH_3{-}\overset{(+)}{C}HR$$

Chain initiator Vinyl compound Chain carrier

Cationic polymerization | Mechanism

(ii) Chain propagation step:

$$CH_3 - \overset{(+)}{C}HR + CH_2{=}CHR \rightarrow CH_3 - CHR - CH_2 - \overset{(+)}{C}HR$$

Cationic polymerization | Mechanism

(iii) Chain termination step:

$$CH_3\text{-}CHR\text{-}CH_2\text{-}\overset{(+)}{C}HR + n\,(CH_2{=}CHR) \xrightarrow{[AlCl_3(OH)]^-}$$

$$CH_3\text{-}CHR\text{-}(CH_2\text{-}CHR)_n\text{-}CH{=}CHR + H^+$$

Anionic Polymerization

- **Monomers containing more electronegative i.e., electron withdrawing groups generally polymerize by anionic mechanism.**

- **Sodium in liquid ammonia, alkyl lithium compounds etc., are effective chain initiators.**

- **Formation of vinyl polymers is the best example for anionic polymerization.**

Anionic Polymerization | Mechanism

Chain initiation:

$$Na + NH_3 \rightarrow Na^+NH^-_2 + 1/2\ H_2$$

$$NH^-_2 + \underset{\text{monomer}}{M} \rightarrow NH_2M^-$$

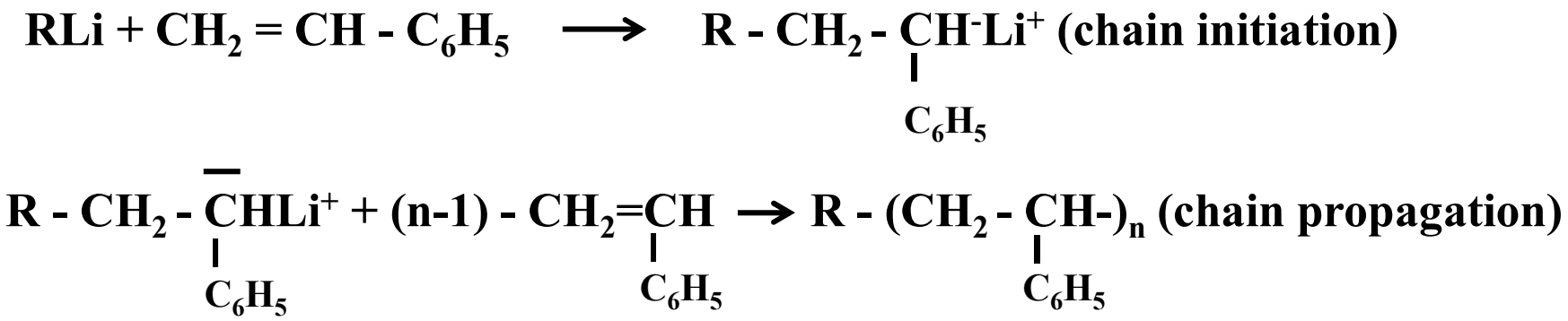
Chain propagation:

$$NH_2M^- + (n-1)\ M \rightarrow NH_2M^-_n$$

$$NH_2M^-_n + NH_3 \rightarrow NH_2M_nH + NH^-_2$$

Anionic Polymerization | Mechanism

Example:



Anionic Polymerization **Mechanism**

Example:

In anionic polymerization chain terminating step is absent.

MCQs

1. **PVC formation proceeds through which mechanism**

a) ✓ **Cationic mechanism**

b) **Anionic mechanism**

c) **Free radical mechanism**

d) **All the above mechanisms**

2. Li reacts with NH_3 to give ---gas

a) Oxygen

b) Nitrogen

c) Helium

d) Hydrogen ✓

3. The step that is need not be present or absent in anionic polymerization mechanism is --

a) Chain initiation

b) Chain propagation

c) Chain Termination ✓

d) Both a and b

SYNTHETIC RUBBER

Synthetic rubber :

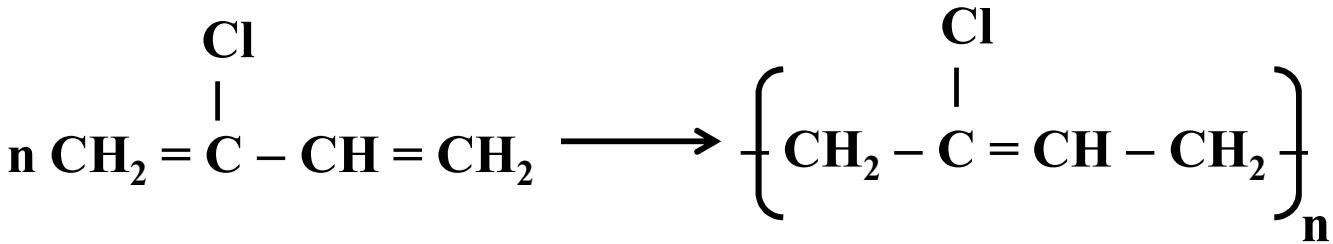
- **They are either homopolymers of 1,3- butadiene derivatives**
  (or)
  co-polymers of which one of the monomers is 1,3-butadine.

Synthetic rubber :

Examples:

1. Neoprene (or) Polychloroprene:

- **It is formed by the free radical polymerzation of chloroprene.**



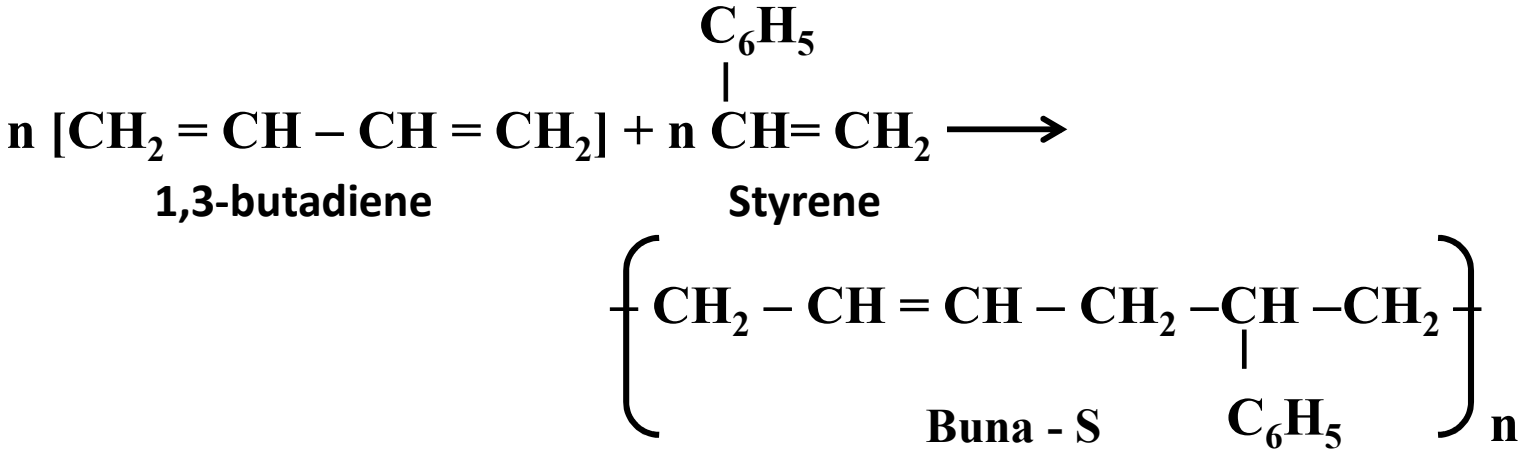
Chloroprene(2-Chloro-1,3-butadiene) **Neoprene**

Synthetic rubber :

Examples:

2. Buna - S:

- **It is obtained by the addition polymerization from 1,3-butadiene and styrene.**

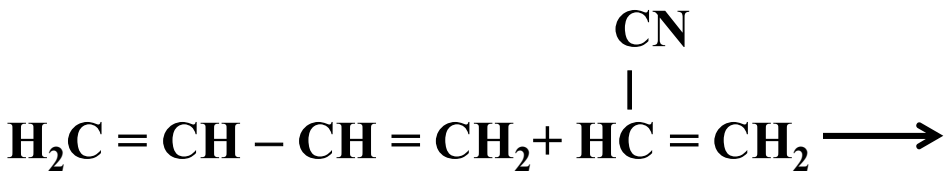


Synthetic rubber :

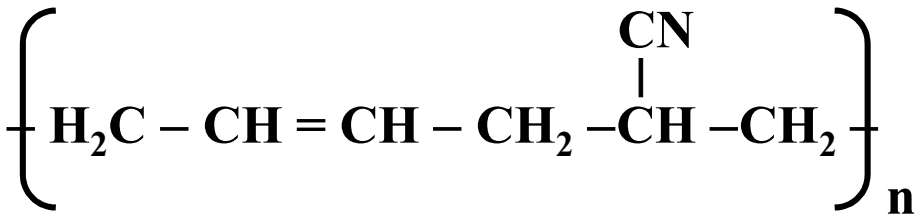
Examples:

3. Buna - N :

- **It is obtained by co-polymerization of 1,3-butadiene and acrylonitrile.**



1,3-butadiene **acrylonitrile.**



Buna - N

Difference between natural and synthetic polymers :

Natural polymers	Synthetic polymers
Prepared in nature Wool, Silk, Jute etc.	Prepared in the labs, nylon, Terylene, Bakelite etc
Not of uniform length	Can be of uniform length

Difference between natural and synthetic polymers :

Natural polymers	Synthetic polymers
Possess very high affinity for sulphur and vat dyes	Possess low affinity for sulphur and vat dyes
Fixing quality is low	Fixing quality is high

Question

Explain the difference between Buna-N and Buna-S.

Answer:

Buna-N is a copolymer of 1,3-butadiene and acrylonitrile(CH_2=CH-CN) while Buna-S is a copolymer of 1-3-butadiene and styrene (C_6H_5-CH=CH_2 (vinyl benzene))

Question

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

A. Nylon 6,6 Buna-S, polythene.

B. Nylon 6, Neoprene, Polyvinyl chloride.

Answer:

Increasing order of intermolecular forces.

Buna-S <Polythene< Nylon 6,6

Neoprene <Polyvinyl chloride <Nylon 6.

MCQs

1. Monomers of Buna – N are…

a) Butadiene only

b) Butadiene & Acrylonitrile ✓

c) Acrylonitrile only

d) Butadiene & styrene

2. Monomers of Buna – S are…

a) Butadiene only

b) Styrene only

c) Both a & b ✓

d) None of these

3. Buna – S & Buna – N are…

a) Addition linear copolymers

b) Condensation polymers

c) Both a & b

d) None of these

4. Monomer of neoprene is…

a) Ethylene

b) acrylonitrile

c) Isoprene

d) Chloroprene ✓

5. Neoprene is…

a) Addition homo-polymer

b) Addition copolymer

c) Condensation homo-polymer

d) Condensation copolymer

MOLECULAR MASS OF POLYMERS

Molecular mass of polymers:

- **Polymer properties are closely related to its molecular mass, size and structure.**
- **The polymer sample contains chains of varying length and hence its molecular mass is always expressed as an average .**

Molecular mass of polymers:

- **The average molecular mass of polymers is expressed in different ways.**
- **The most commonly expressed are …**

i) Number average molecular mass

ii) Weight average molecular mass

Molecular mass of polymers:

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

- Let the number of particles of mass M_1 each be N_1. Similarly particles of mass M_2 each be N_2 and the number of particles of mass M_i each be N_i . Then

The Total mass of the polymer

$$= M_1N_1 + M_2N_2 + \ldots\ldots\ldots + M_iN_i$$

$$= \sum_{n=1}^{i} M_iN_i$$

Molecular mass of polymers:

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

Total number of particles in the system

$$= N_1 + N_2 + \ldots\ldots\ldots + N_i$$

$$= \sum_{n=1}^{i} N_i$$

Molecular mass of polymers:

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

Number average molecular mass

$$(\bar{M}_n) = \frac{M_1N_1 + M_2N_2 + \ldots\ldots\ldots + M_iN_i}{N_1 + N_2 + \ldots\ldots\ldots + N_i}$$

$$\overline{M_n} = \frac{\sum M_iN_i}{\sum N_i}$$

The number average molecular mass ($\bar{M}n$) depends on number of molecules

Molecular mass of polymers:

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

- **The molecular mass of each type of particle is multiplied by the contribution of the species to the total weight of the sample.**
- **The product is calculated for each of the species present.**

Molecular mass of polymers:

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

- **"The sum of the products of the species present in the sample is known as weight average molecular mass".**

Molecular mass of polymers:

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

Total weight of all particles

$$= \quad N_1M_1^2 + N_2M_2^2 + \ldots\ldots\ldots + N_iM_i^2$$

$$= \quad \sum_{n=1}^{i} N_iM_i^{\,2}$$

Molecular mass of polymers:

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

Weight average molecular mass of a polymer

$$\overline{M_w} = \frac{N_1M_1^2 + N_2M_2^2 + \cdots \ldots + N_iM_i^2}{M_1N_1 + M_2N_2 + \cdots \ldots + N_iM_i}$$

$$\overline{M_w} = \frac{\sum N_iM_i^2}{\sum N_iM_i}$$

Question:

A polymer contains 10 molecules with molecular mass 10,000 and another 10 molecules with molecular mass1,00,000 . Calculate number average molecular mass($\bar{M}_n$).

Solution:

$$\bar{M}_n = \frac{\Sigma N_i M_i}{\Sigma N_i} = \frac{10 \times 10000 + 10 \times 100000}{10+10} = 55{,}000$$

Make a note

Both $(\bar{M}_n)$ & $(\bar{M}_w)$ have no units (unitless)

MCQs

1.Which of the following is correct statement?

a)Always $\bar{M}_n < \bar{M}_w$

b) Always $\bar{M}_w < \bar{M}_n$

c) Always $\bar{M}_n = \bar{M}_w$

d) Always $\bar{M}_n \leq \bar{M}_w$

2.Which of the following methods can be used to express molecular weights of polymers?

a) Number average molecular mass

b) Mass average molecular mass

c) Z-average molecular weight

d) Viscosity –Average molecular weight

3.The molecular weights of the substance can be determined by

a) Physical methods

b) Chemical methods

c) Physical and chemical methods ✓

d) Cannot be determined by physical methods

POLY DISPERSITY INDEX
&
BIODEGRADABLE POLYMERS

Poly dispersity index [PDI]:

" The ratio between weight average molecular mass ($\bar{M}_w$) and number average molecular mass ($\bar{M}_n$) of a polymer is called *poly dispersity index*"

$$\text{PDI} = \frac{(\bar{M}_w)}{(\bar{M}_n)}$$

For synthetic polymers: $(\bar{M}_n) < (\bar{M}_w)$

For Natural polymers: $(\bar{M}_n) = (\bar{M}_w)$

[i.e., PDI is 1]

NOTE: PDI value lies between 1 – 1.5

Biodegradable polymers:

- **"The polymers that degrade quickly in living systems by enzymatic chemical reactions like oxidation or hydrolysis are known as *biodegradable polymers"***
- **These polymers contain functional groups similar to the functional groups present in bio polymers and lipids.**

Biodegradable polymers:

Uses:

i) It is used in speciality packaging

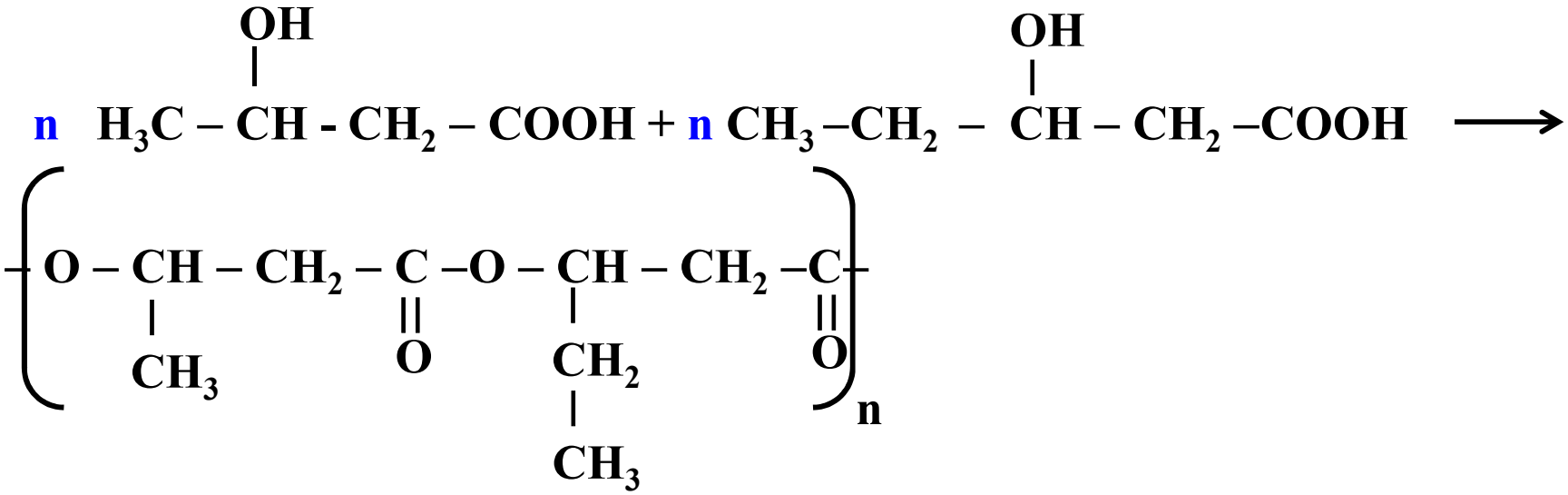
ii) Orthopedic device

iii) In the field of medicine it is used for making capsules.

Biodegradable polymers:

Example-1 :

- **Poly - β - hydroxybutyrate – co - β - hydroxyvalerate (PHBV).**
- **It is obtained by the copolymerisation of 3 – hydroxy butanoic acid and 3-hydroxy pentanoic acid.**



Biodegradable polymers:

Example -2 :

- **Nylon – 2 – Nylon – 6 :**
- **It is polyamide obtained by copolymerization of glycine and amino caproic acid**

$$n NH_2 - CH_2 - COOH + n H_2N\left(CH_2\right)_5 - COOH \longrightarrow$$

$$\left(HN - CH_2 - \underset{\underset{O}{\|}}{C} - HN\left(CH_2\right)_5 - \underset{\underset{O}{\|}}{C} \right)_n$$

MCQs

1. PDI of the polymer is given by…

a) $\frac{(\bar{M}_w)}{(\bar{M}_n)}$

b) $\frac{\bar{M}_W}{\bar{M}_n}$

c) $\bar{M}_w \times \bar{M}_n$

d) $\frac{1}{\bar{M}_w \times \bar{M}_n}$

2. PDI of a natural polymer is

a) 1

b) 2

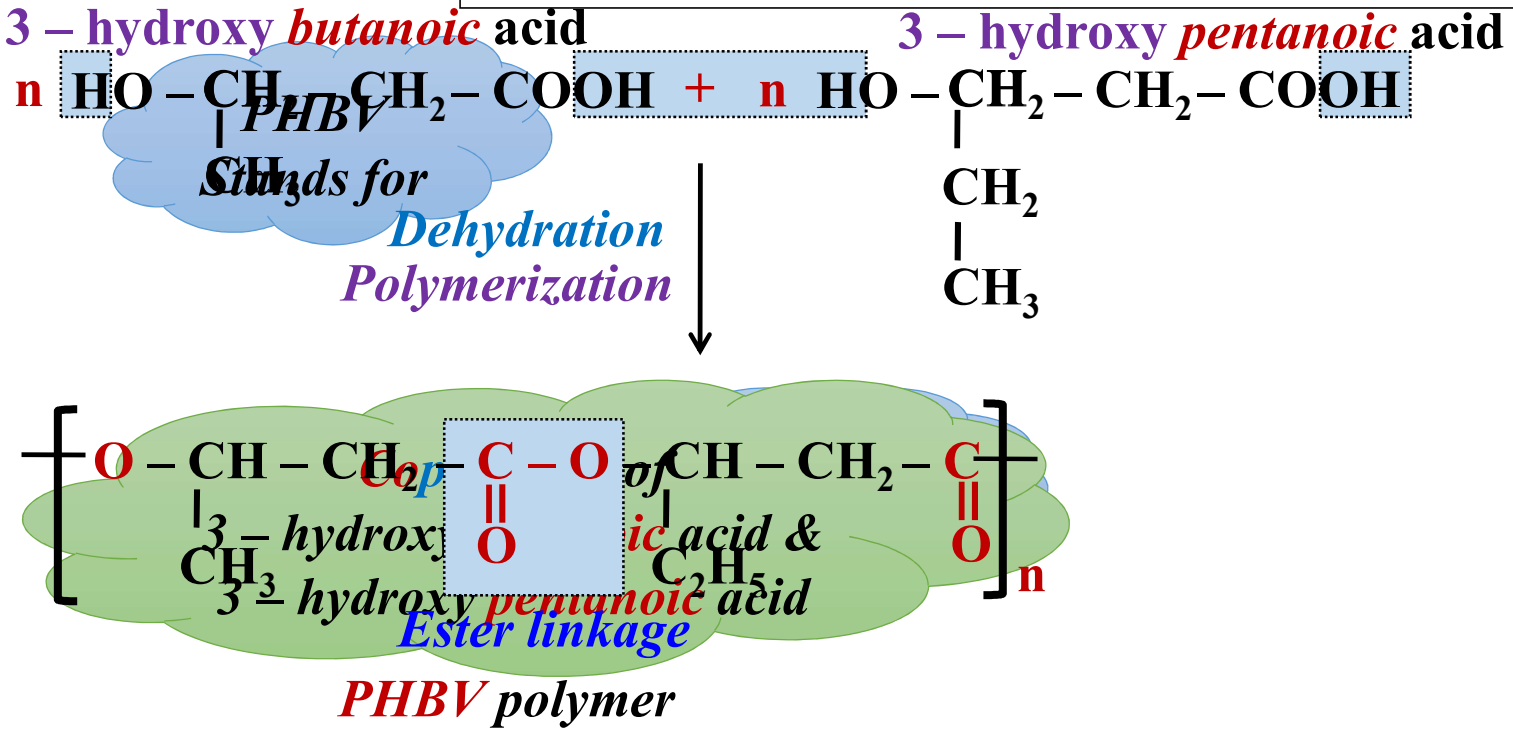
c) 3

d) 0.1

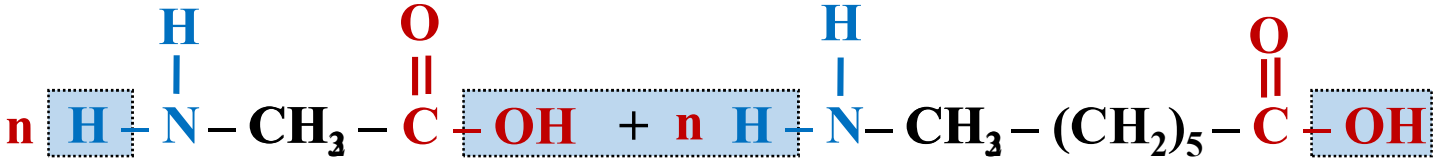
PHBV
&
NYLON - 2 – NYLON - 6

PHBV Polymer :

Poly β- hydroxy butyrate – co – β - hydroxy velarate



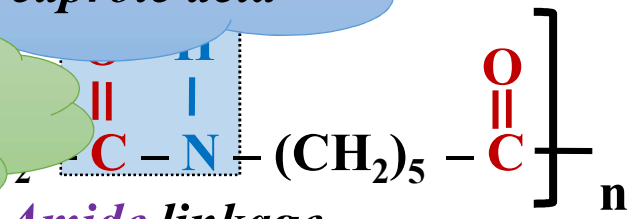
Nylon – 2 – nylon – 6 :



Dehydration Polymerization

Copolymer of Glycine & Amino caproic acid

When various such molecules combine



Amide linkage

Nylon – 2 – nylon – 6

Properties of Biodegradable polymers :

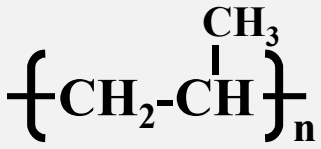
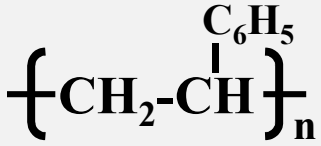
They *can undergo bacterial degradation in the environment*.

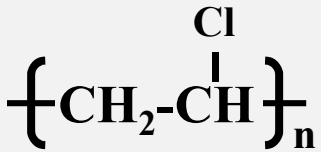
Examples **:**

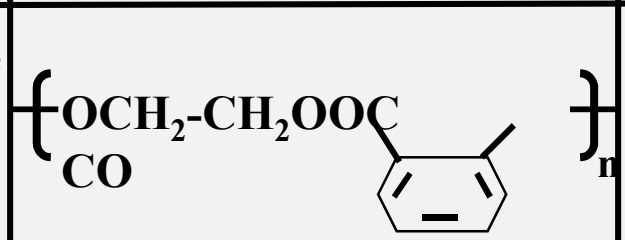
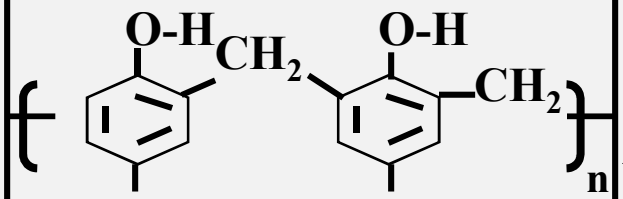
Drug release matrices

Packaging **of orthopedic devices**

Surgical suture etc.

Name of the polymer	Monomer	Structure	Uses
Polypropene	Propene		Manufacture of ropes, toys, pipes, fibres, etc.
Polystyrene	Styrene		As insulator, wrapping material, manufacture of toys, radio and television cabinets.

Name of polymer	Monomer	Structure	Uses
Polyvinyl chloride (PVC)	Vinyl Chloride $CH_2=CH-Cl$		Manufacture of rain coats, hand bags, vinyl flooring, water pipes.
Urea-formaldehyle Resin	a)Urea $CO(NH_2)_2$ b)Formaldehyde HCHO		For making unbreakable cups and laminated sheets.

Name of polymer	Monomer	Structure	Uses
Glyptal	(a) Ethylene glycol (b) Phthalic acid		Manufacture of paints and lacquers.
Bakelite	(a) Phenol (b)Formaldehyde		For making unbreakable cups and laminated sheets.

MCQs

1. Which of the following is a biodegradable polymer?

a) PHBV

b) Dextron

c) Nylon–2–nylon–6

d) All of these ✓

2. Which of the following is a polyester fibre?

a) PHBV

b) Dextron

c) Both a & b ✓

d) Nylon–2–nylon–6

3. Which of the following is a polyamide fibre?

a) PHBV

b) Nylon–2–nylon–6

c) Dextron

d) All of these

SYNOPSIS

DIFFERENCES BETWEEN NATURAL AND SYNTHETIC POLY -

Sl.No.	Distinguishing Property	Natural Polymers	Synthetic polymers
1	Source of their preparation & common example.	Prepared in nature wool, silk, jute etc.	Prepared in the lab, nylon, terylene, decron etc.
2.	Length of polymer chain.	Not of uniform length.	Can be of uniform length
3.	Affinity for sulphur and Vat dyes.	Possess very high affinity.	Posses low affinity
4.	Fixing quality	Low	High

- **The ratio of mass average molecular mass to the number if average molecular mass is called poly disparity index (PDI).**

$$PDI = \frac{\overline{M}_W}{\overline{M}_N}$$

- **PDI gives an idea about the homogeneity of a polymer**
- **For natural polymers, PDI is usually unity (Natural polymers are mono dispersed) ($\overline{M}_W$=$\overline{M}_N$)**
- **For synthetic polymers, PDI is greater than one ($\overline{M}_W > \overline{M}_N$)**

- **The osmotic pressure of each of the solution is measured.**
- **The value of π/C is plotted against C**
- **Straight line is obtained. It is extraplotted to zero concentration.**

$$Then \left(\frac{\pi}{C}\right)_0 = RT\left[\frac{1}{\overline{M}_n}\right]$$

$$\overline{M}_n = \left(\frac{C}{\pi}\right)_0 RT$$

Don’t Forget to Like / Comment & Share this video

www.Youtube.com/safaltaclass

www.Facebook.com/safaltaclass

www.Instagram.com/safaltaclass