

CHEMISTRY

CHAPTER 15: POLYMERS



Polymers

Introduction

➤ Polymer

- The word 'polymer' is coined from two Greek words.
- Poly = Many and Mer = unit or part
- They are also called as macromolecules which are formed by joining of repeating structural units on a large scale.

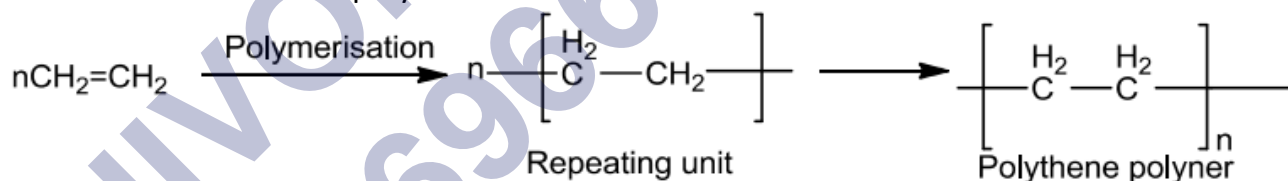
➤ Monomer

The repeating structural units which are derived from some simple and reactive molecules are known as monomers. They are linked to each other by covalent bonds.

➤ Polymerisation

The process of formation of polymers from respective monomers is called polymerisation. Examples:

i) Conversion of ethene to polyethene

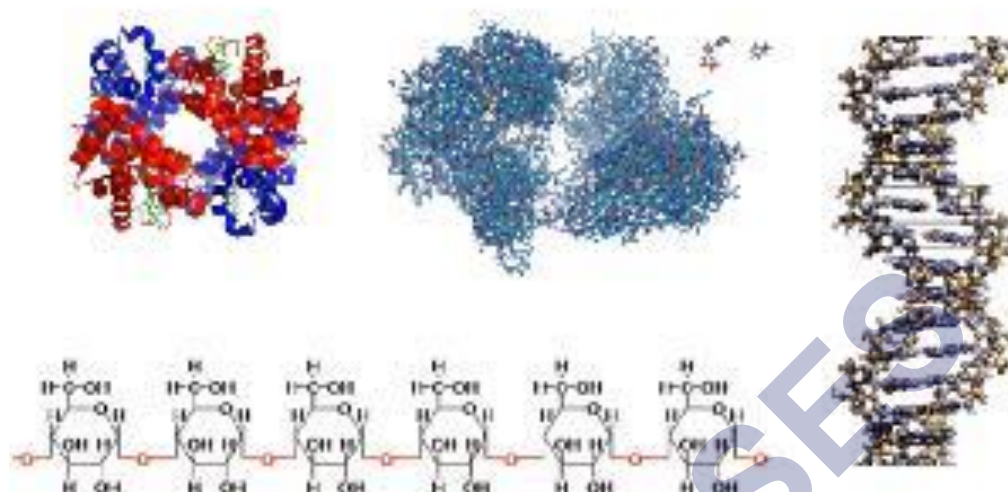


Define the terms: Monomers, Polymers & Polymerization

Define the terms: Monomers, Polymers & Polymerization

The term polymer is defined as a chemical substance of a very high molecular mass (10³-10⁷u) formed by combination of a simple molecule, called monomers.

Polymers are also known as macromolecules, which are formed by repeating structural units on a large scale.



This process of formation of polymers from respective monomers is called polymerisation.

For example:- $n \text{CH}_2 = \text{CH} \rightarrow n[-\text{CH}_2 - \text{CH} -] \rightarrow [-\text{CH}_2 - \text{CH}_2 -]_n$
 Ethene Repeating Unit Polythene polymer

Classification of Polymers

Classification of Polymers

There are several ways of classification of polymers based on some special considerations.

The following are some of the common classifications of polymers:

Source

Structure

Mode of polymerization

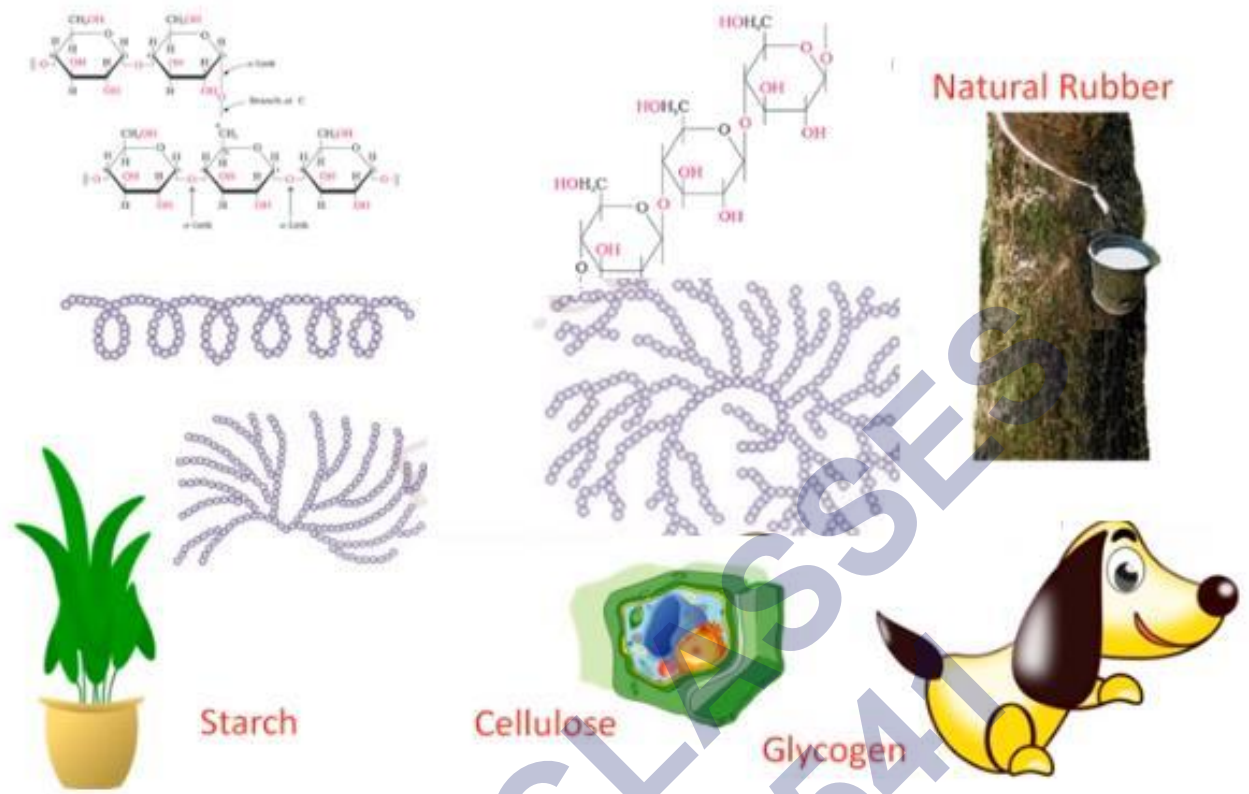
Molecular Force

Source

Under this type of classification, there are three sub categories.

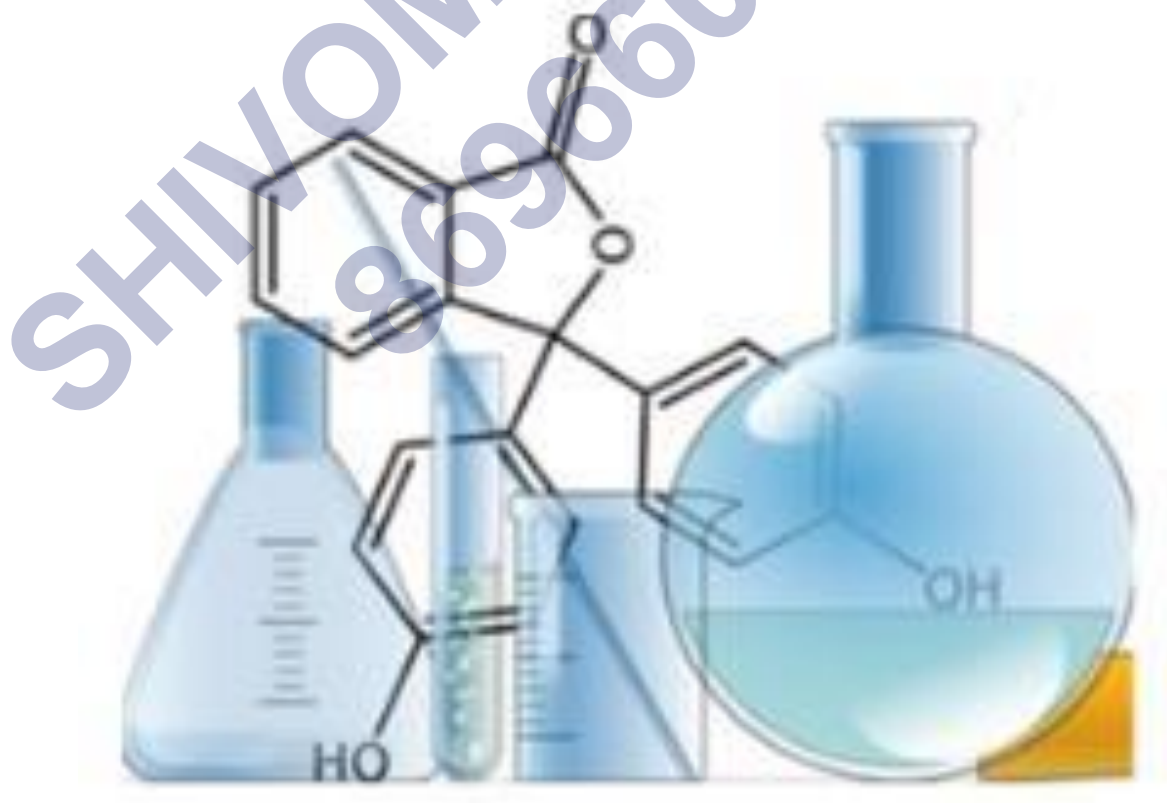
Natural polymers

These polymers are found in plants and animals. Examples are proteins, cellulose, starch, some resins and rubber.



Semi-synthetic polymers

b) Cellulose derivatives as cellulose acetate (rayon) and cellulose nitrate, etc. are the some examples.



Synthetic Polymers

A variety of synthetic polymers as plastic (polythene), synthetic fibres. Examples: - (nylon 6, 6) and synthetic rubbers (Buna - S) are polymers extensively used in daily life as well as in industry.



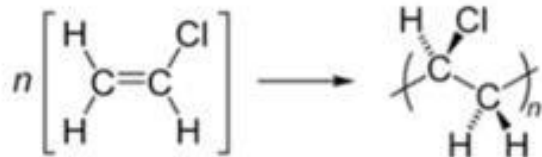
Structure

There are three different types based on the structure of the polymers.

Linear Polymers: -

These polymers consist of long and straight chains. The examples are high density polythene, polyvinyl chloride, etc. These are represented as:





Vinyl Chloride

After polymerization
changes to PVC

Branched chain polymers:-

b) These polymers contain linear chains having some branches, e.g. low density polythene. These are depicted as follows:

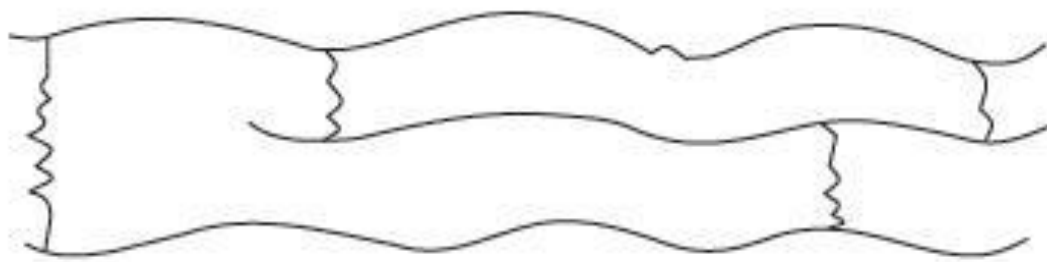


Glycogen



Cross linked or Network polymers:-

c) These are usually formed from bi-functional and tri-functional monomers and contain strong covalent bonds between various linear polymer chains, e.g. Bakelite, melamine, etc. These polymers are depicted as follows:



Mode of Polymerization

Polymers can also be classified on the basis of mode of polymerisation into two sub groups.

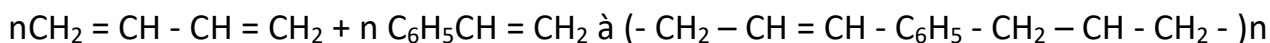
Addition polymers: -

- The addition polymers are formed by the repeated addition of monomer molecules possessing double or triple bonds.
- For example: - The formation of polythene from Ethene and polypropene from propene.
- However, the addition polymers formed by the polymerisation of a single monomeric species are known as homopolymers.
- For example: - polythene.



Ethene Polythene

The polymers made by addition polymerisation from two different monomers are termed as copolymers, e.g., Buna-S, Buna-N, etc.



1,3 – Butadiene

Styrene

Butadiene-styrene copolymer

(Buna-S)



Condensation polymers

- The condensation polymers are formed by repeated condensation reaction between two different bi-functional or tri-functional monomeric units.
- In these polymerisation reactions, the elimination of small molecules such as water, alcohol, hydrogen chloride, etc. take place.
- The examples are Terylene (Dacron), nylon 6, 6, nylon 6, etc.
- For example, nylon 6, 6 is formed by the condensation of hexamethylene diamine with adipic acid.



D. Molecular Forces



A large number of polymers can be used in different fields because of their mechanical properties like tensile strength, elasticity, toughness etc.

These mechanical properties are governed by intermolecular forces, e.g., van der Waals forces and hydrogen bonds, present in the polymer. These forces also bind the polymer chains.

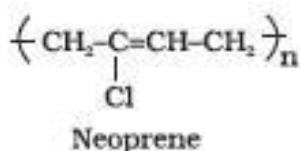
The polymers are classified into the following four sub groups on the basis of magnitude of intermolecular forces present in them.

a) Elastomers: -

These are rubber – like solids with elastic properties.

The polymer chains are held together by the weakest intermolecular forces. These weak binding forces permit the polymer to be stretched.

A few 'crosslinks' are introduced in between the chains, which help the polymer to retract to its original position after the force is released as in vulcanised rubber. The examples are Buna-S, Buna-N, neoprene, etc.

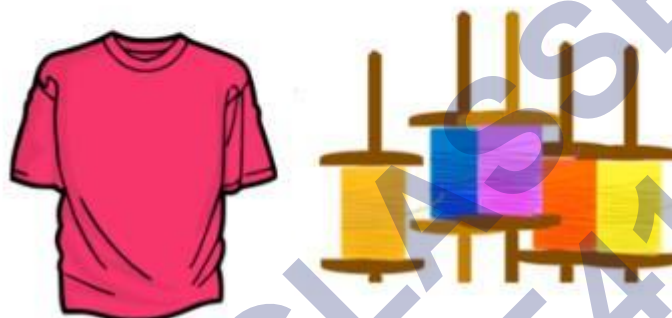
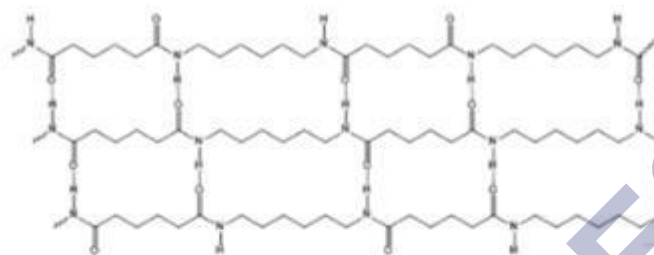
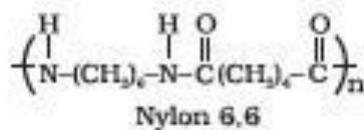


b) Fibres:-

Fibres are the thread forming solids which possess high tensile strength and high modulus.

These characteristics can be attributed to the strong intermolecular forces like hydrogen bonding.

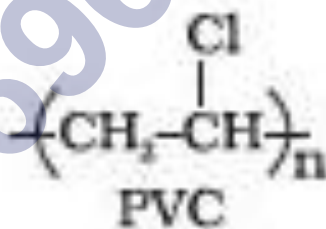
These strong forces also lead to close packing of chains and thus impart crystalline nature. The examples are polyamides (nylon 6, 6), polyesters (terylene), etc.

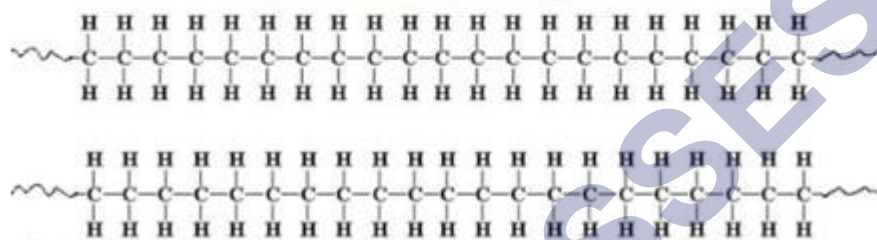


c) Thermoplastic Polymers:-

These are the linear or slightly branched long chain molecules capable of repeatedly softening on heating and hardening on cooling.

These polymers possess intermolecular forces of attraction intermediate between elastomers and fibres.

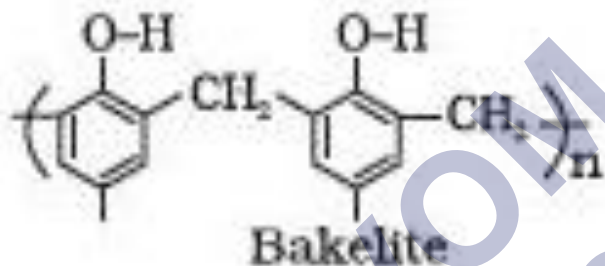




d) Thermosetting Polymers:-

These polymers are cross linked or heavily branched molecules, which on heating undergo extensive cross linking in moulds and again become infusible.

These cannot be reused. Some common examples are Bakelite, urea-formaldehyde resins, etc.



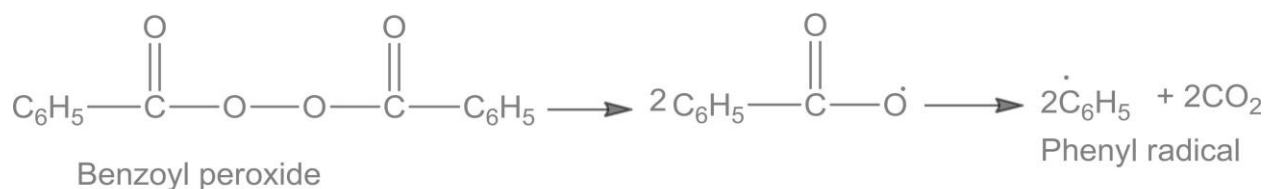
Types of Polymerisation Reactions

➤ Addition or chain growth polymerisation

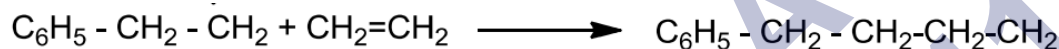
- In addition polymerisation, the molecules of the same monomer or different monomers add together on a large scale to form a polymer.
- The most common mechanism for addition polymerisation reactions is free radical mechanism.
- The steps involved are as follows:

Step 1:

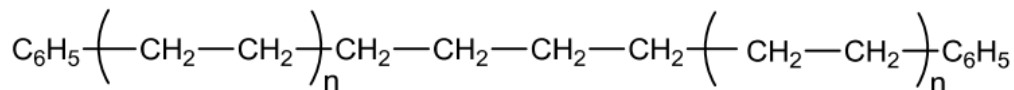
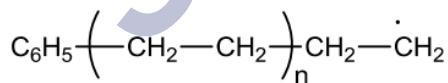
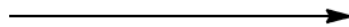
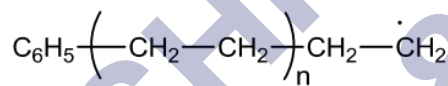
Chain initiating step: Organic peroxides undergo homolytic fission to form free radicals which act as an initiator. The initiator adds to the C—C double bond of an alkene molecule to form a new free radical.

**Step 2:**

Chain propagating step: Free radicals formed by homolytic cleavage add to a double bond of monomer to form a larger free radical. Radicals formed add to another alkene molecule to form a larger free radical. This process continues until the radical is destroyed. These steps are called propagation steps.

**Step 3:**

Chain terminating step: For termination of the long chain, free radicals combine in different ways to form polythene. One mode of termination of chain is shown below.



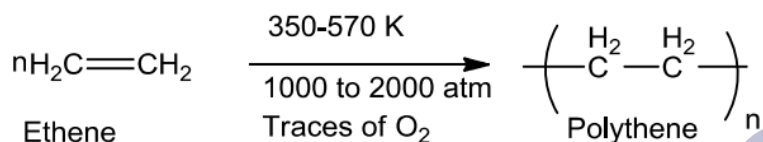
Addition polymerisation is called chain growth polymerisation because it occurs through stages leading to increase in chain length, and each stage produces reactive intermediates for use in the next stage of the growth of the chain.

➤ **Preparation of some important addition polymers**

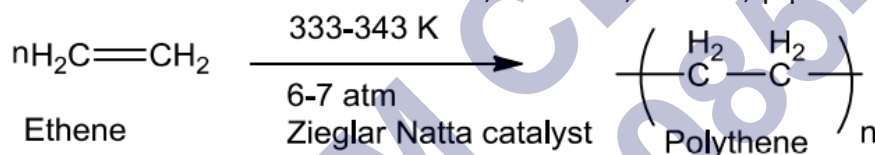
(a)

Low density polythene

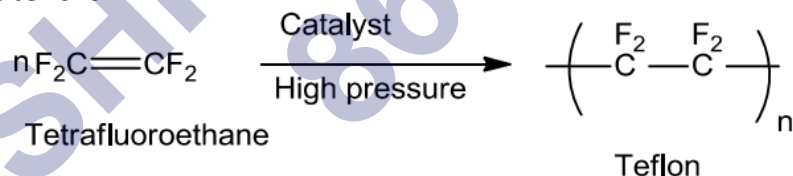
- It is obtained by the polymerisation of ethene under high pressure of 1000-2000 atmospheres at a temperature of 350 K to 570 K in the presence of traces of dioxygen or a peroxide initiator(catalyst).
- It is a poor conductor of electricity and hence it is used as an insulator in electrical wires and manufacture of squeeze bottle, toys and flexible pipe.

**High density polythene**

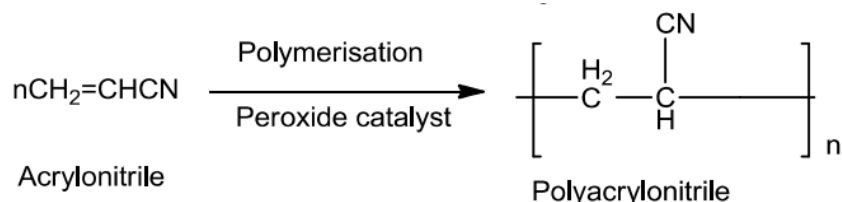
- It is formed when addition polymerisation of ethene takes place in a hydrocarbon solvent in the presence of a catalyst such as triethylaluminium and titanium tetrachloride at a temperature of 333 K to 343 K and under a pressure of 6-7 atmospheres.
- It is used to manufacture buckets, dustbins, bottles, pipes etc.

**(b) Polytetrafluoroethene (Teflon)**

- It is synthesized by heating tetrafluoroethene with a free radical or persulphate at high pressures.
- It is used in making oil seals and gaskets and also used for non-stick surface-coated utensils.

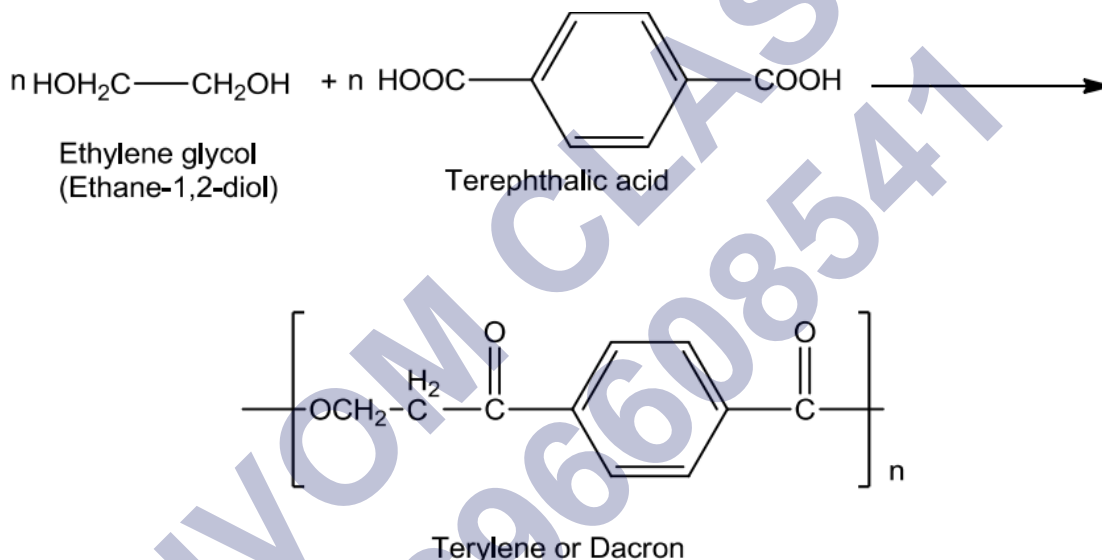
**(c) Polyacrilonytrile**

- It is prepared by the addition polymerisation of acrylonitrile in presence of a peroxide catalyst.
- It is used as a substitute for wool in making commercial fibres as orlon or acrilan.



➤ Condensation or step growth polymerisation

- In this type of polymerisation, there is a repetitive condensation reaction between two bi-functional monomers with the loss of some simple molecules like water leading to the formation of high molecular mass condensation polymers.
- The product of each step is again a bi-functional species and the sequence of condensation goes on.
- Since each step produces a distinct functionalised species and is independent of each step, this process is called as step growth polymerisation.
- Interaction of ethylene glycol and terephthalic acid leading to the formation of terylene is an example of this type of condensation.



➤ Some Important Condensation Polymerisation

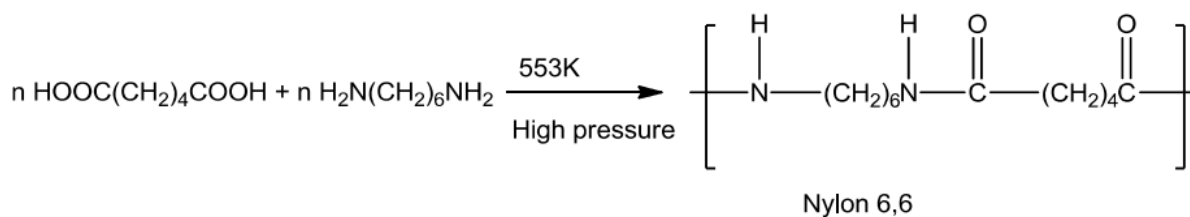
1. Polyamides

Nylons are polymers possessing amide linkages and are important examples of synthetic fibres. They are prepared by condensation polymerisation of diamines with dicarboxylic acids and also of amino acids and their lactams.

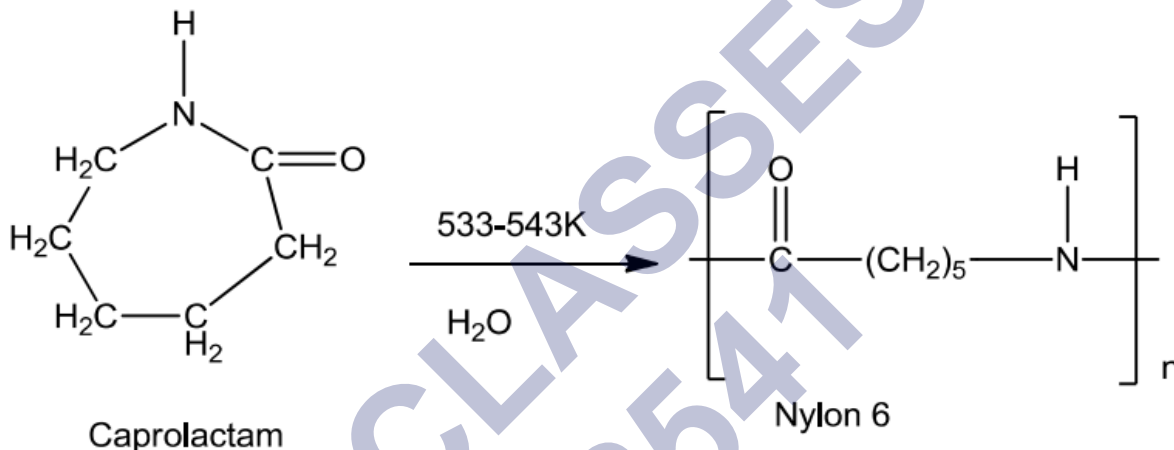
Preparation of Nylons

(i) Nylon 6,6

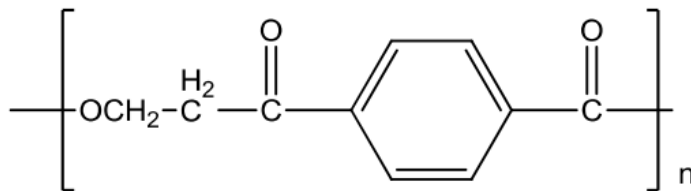
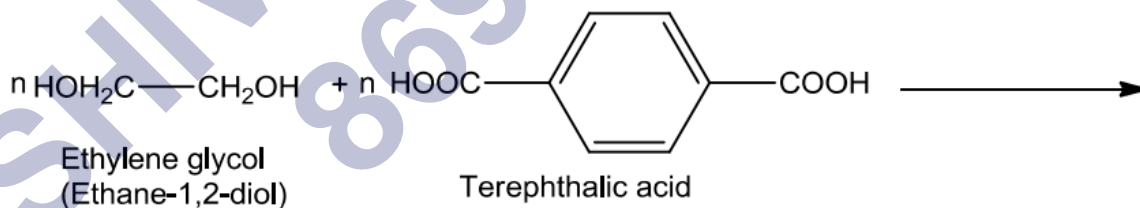
- It is prepared by the condensation polymerisation of hexamethylenediamine with adipic acid under high pressure and at high temperature.
- It is used in making sheets, bristles for brushes and in textile industry.

**(ii) Nylon 6**

- It is obtained by heating caprolactam with water at a high temperature.
- It is used for the manufacture of tyre cords, fabrics and ropes.

**2. Polyesters**

- It is manufactured by heating a mixture of ethylene glycol and terephthalic acid at 420 to 460K in the presence of zinc acetate-antimony trioxide catalyst.
- Dacron or terylene is an example of polyester which is crease resistant and is used in blending with cotton and wool fibres and also as glass reinforcing materials in safety helmets etc.



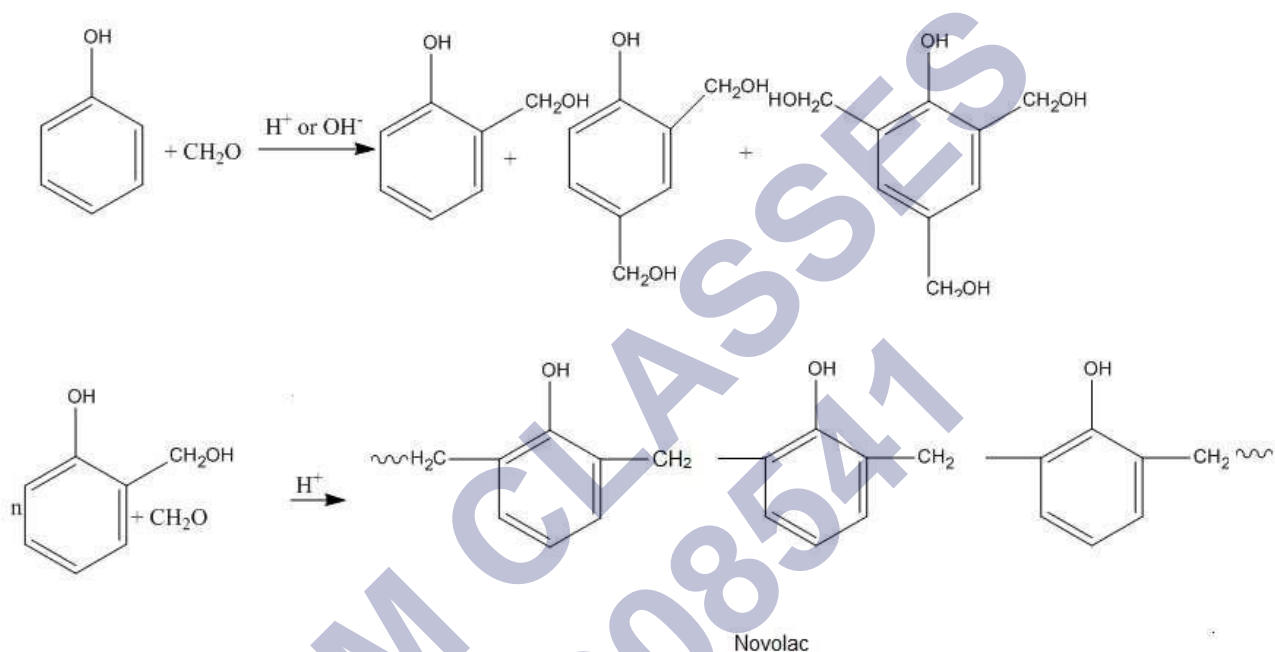
Terylene or Dacron

3. Phenol-formaldehyde polymer (Bakelite and related polymers)

- It is obtained by the condensation reaction of phenol with formaldehyde in the

presence of either an acid or a base catalyst.

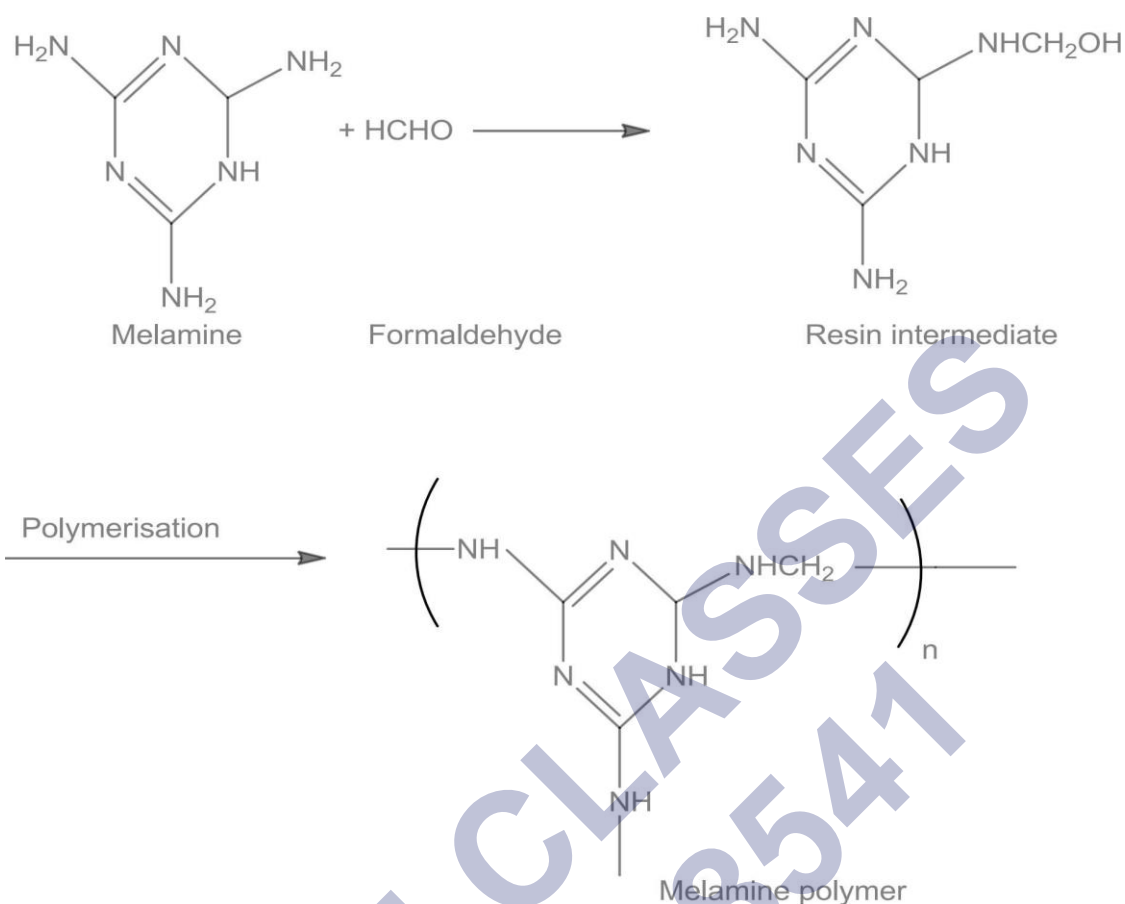
- The reaction proceeds with the initial formation of o-and/or p-hydroxymethylphenol derivatives which further react with phenol to form compounds having rings joined to each other through $-\text{CH}_2$ groups.
- The initial product could be a linear product — Novolac used in paints.



- Novolac on heating with formaldehyde undergoes cross linking to form infusible solid mass called Bakelite.
- It is used for making combs, phonograph records, electrical switches and handles of various utensils.

4. Melamine-formaldehyde polymer

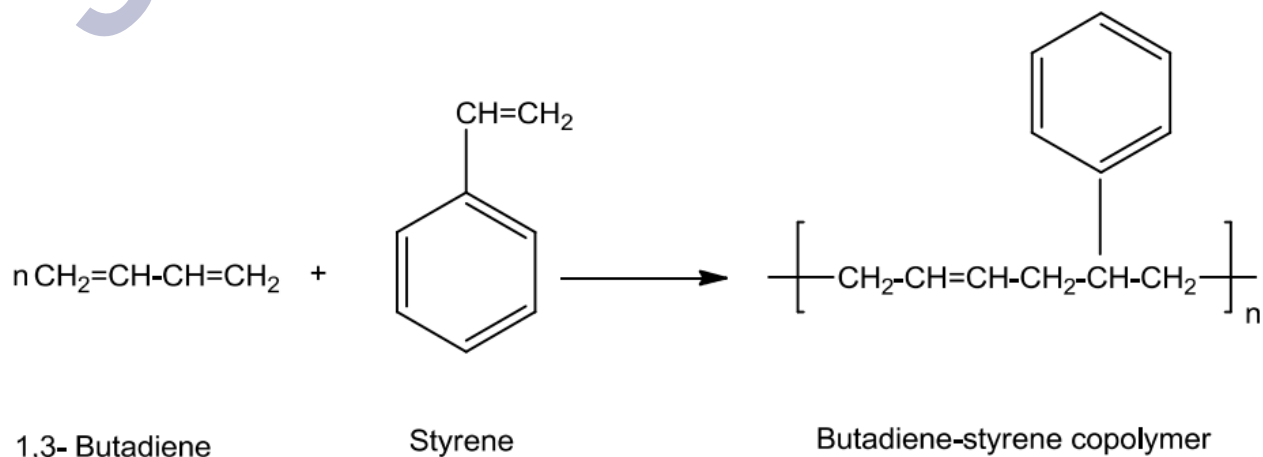
It is formed by the condensation polymerisation of melamine and formaldehyde.



It is used in the manufacture of unbreakable crockery.

➤ Copolymerisation

- It is a polymerisation reaction in which a mixture of more than one monomeric species is allowed to polymerise and form a polymer.
- The copolymer can be prepared by both chain growth polymerisation and step growth polymerisation.
- It contains multiple units of each monomer used in the same polymeric chain.
- A mixture of 1, 3-butadiene and styrene can form a polymer.



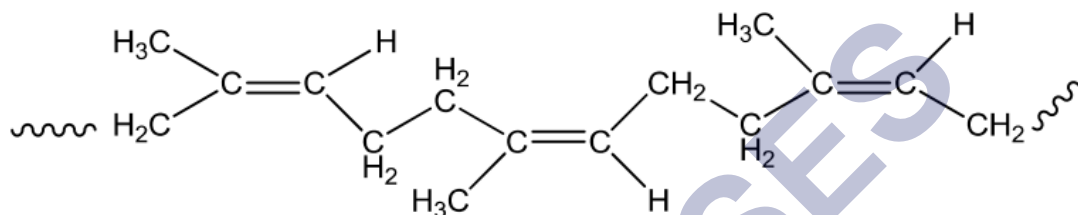
- Copolymers have properties quite different from homopolymers.

- Butadiene-styrene copolymer is quite tough and is a good substitute for natural rubber.
- It is used for the manufacture of auto tyres, floor tiles, footwear components, cable insulation etc.

➤ Rubber

1. Natural Rubber

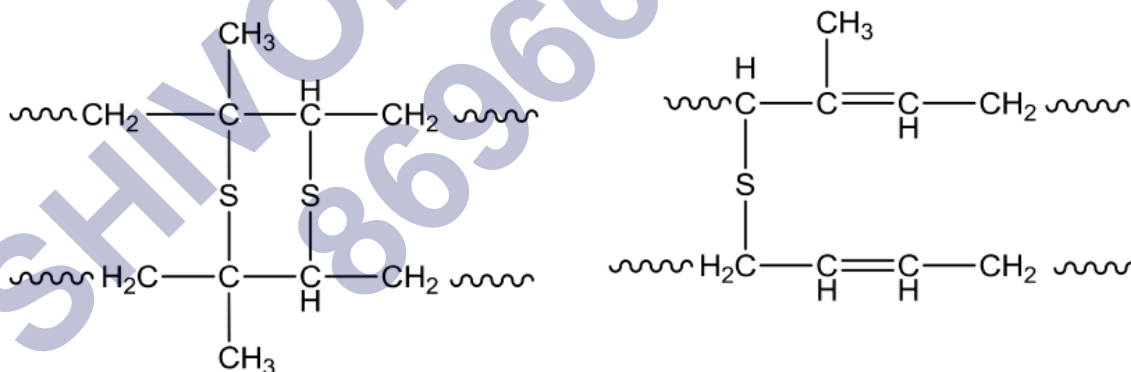
- It is prepared from rubber latex which is a colloidal dispersion of rubber in water.



- It can be considered as a linear polymer of isoprene (2-methyl-1, 3-butadiene) and is also called as cis-1, 4-polyisoprene.

Vulcanization of Rubber

- This process is used to improve the physical properties of rubber.
- In this process, mixture of raw rubber is heated with sulphur and appropriate additive at a temperature range between 373 K to 415 K.
- On vulcanisation, sulphur forms cross links at the reactive sites of double bonds and thus the rubber gets stiffened.
- Only 5 % of sulphur is used as a cross linking agent in the manufacture of tyre rubber.



Sulphur cross links in vulcanised rubber

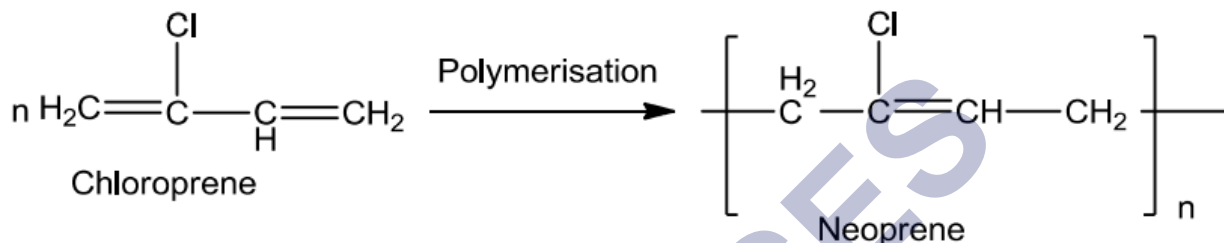
2. Synthetic Rubbers

- It is a vulcanisable rubber like polymer.
- It is stretchable to twice its length and returns to its original shape and size as soon as the external force is released.
- Thus synthetic rubbers are either homopolymers of 1, 3-butadiene derivatives or copolymers of 1,3-butadiene or its derivative with another unsaturated monomer.

Preparation of Synthetic Rubbers

1. Neoprene

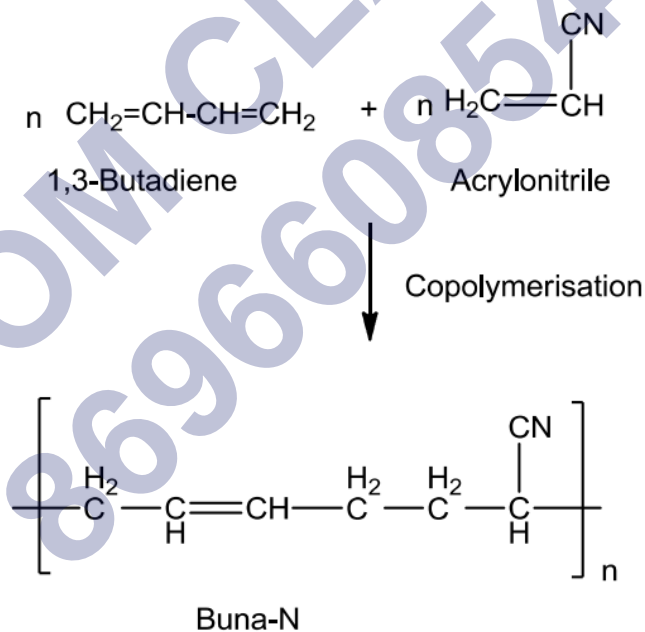
- Neoprene or polychloroprene is prepared by the free radical polymerisation of chloroprene.



- It is used for manufacturing conveyor belts, gaskets and hoses.

2. Buna - N

- It is prepared by the copolymerisation of 1, 3-butadiene and acrylonitrile in the presence of a peroxide catalyst.



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

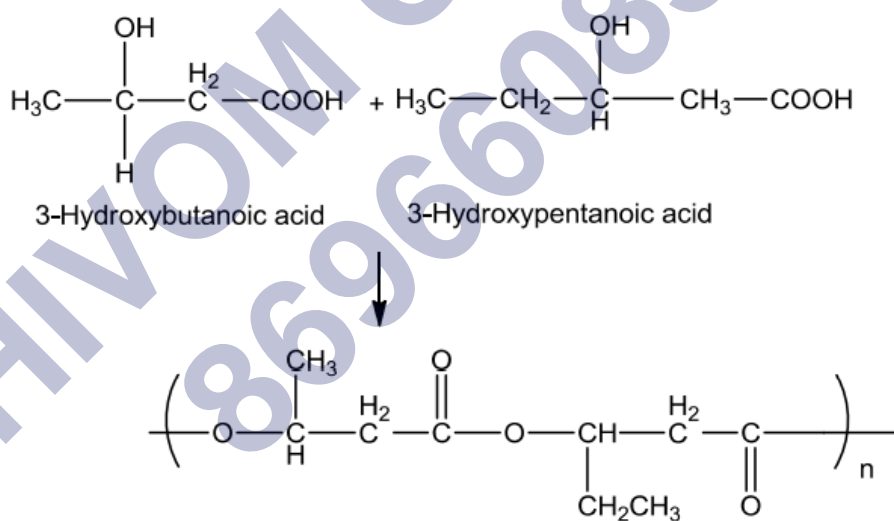
Molecular Mass of Polymers

- The polymer sample contains chains of varying lengths and hence its molecular mass is always expressed as an average.

- The molecular mass of polymers can be determined by chemical and physical methods.

Biodegradable Polymers

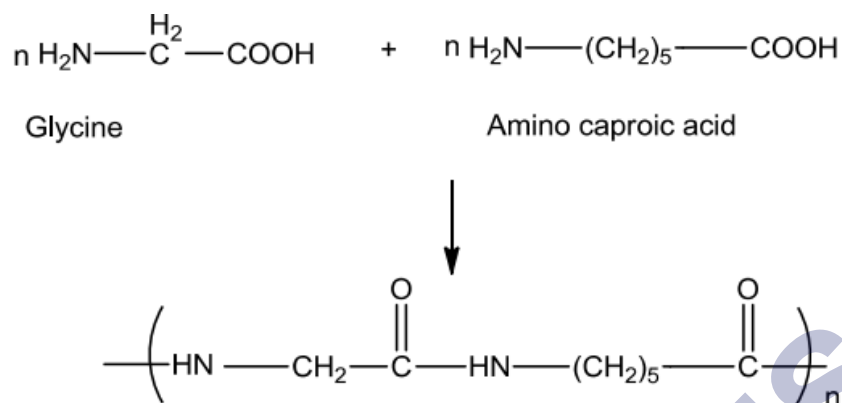
- Polymers which are degraded by microorganisms within a suitable period so that biodegradable polymers and their degraded products do not cause any serious effects on the environment.
- Certain new biodegradable synthetic polymers have been designed and developed.
- These polymers contain functional groups similar to the functional groups present in biopolymers.
- Aliphatic polyesters are one of the important classes of biodegradable polymers.
- Examples of biodegradable polymers:
 - Poly- β -hydroxybutyrate-co- β -hydroxyvalerate (PHBV): It is obtained by the copolymerisation of 3-hydroxybutanoic acid and 3-hydroxypentanoic acid.



PHBV

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

- Nylon 2—nylon 6: It is an alternating polyamide copolymer of glycine ($\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$) and aminocaproic acid ($\text{H}_2\text{N}(\text{CH}_2)_5\text{COOH}$).



Preparation of Important Addition Reaction

Polyamides:-

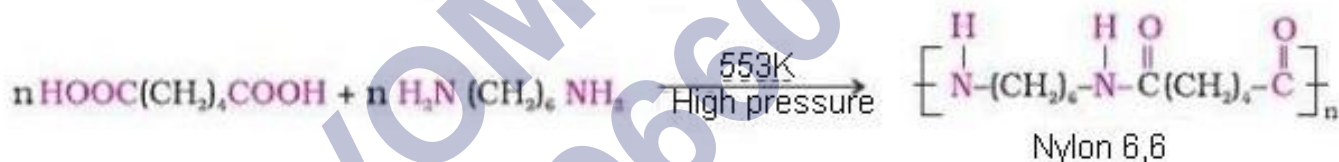
These polymers possessing amide linkages are important examples of synthetic fibres and are termed as nylons. The general method of preparation consists of the condensation polymerisation of diamines with dicarboxylic acids and also of amino acids and their lactams.

Preparation of Nylons

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It is prepared by the condensation polymerisation of hexamethylenediamine with adipic acid under high pressure and at high temperature.

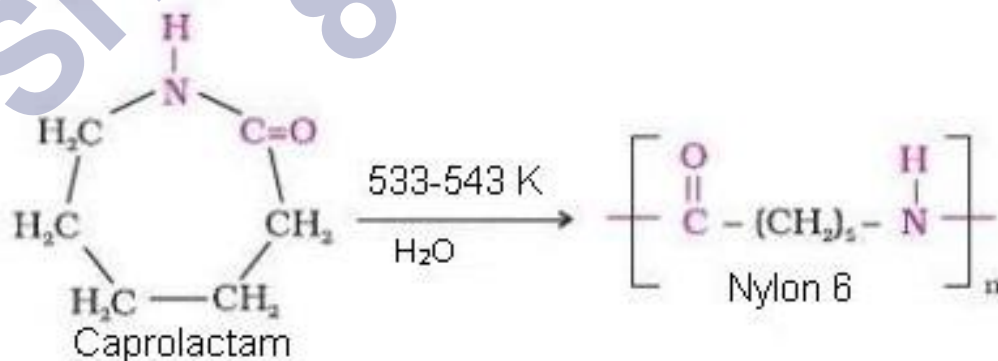
Nylon 6, 6 is used in making sheets, bristles for brushes and in textile industry.



Nylon 6:-

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Nylon 6 is used for the manufacture of tyre cords, fabrics and ropes.



Polyesters: - These are the poly condensation products of dicarboxylic acids and diols.

Dacron or Terylene is the best known example of polyesters. It is manufactured by heating a mixture of ethylene glycol and terephthalic acid at 420 to 460 K in the presence of Zinc acetate antimony trioxide catalyst.

Dacron fibre (Terylene) is crease resistant and is used in blending with cotton and wool

fibres and also as glass reinforcing materials in safety helmets, etc.

Phenol – formaldehyde polymer (Bakelite and related polymers):-

Phenol - formaldehyde polymers are the oldest synthetic polymers.

These are obtained by the condensation reaction of phenol with formaldehyde in the presence of either an acid or a base catalyst.

The reaction starts with the initial formation of o-and/or p-hydroxymethylphenol derivatives, which further react with phenol to form compounds having rings joined to each other through $-\text{CH}_2$

The initial product could be a linear product – Novolac used in paints.

Novolac on heating with formaldehyde undergoes cross linking to form infusible solid mass called Bakelite. It is used for making combs, phonograph records, electrical switches and handles of various utensils.

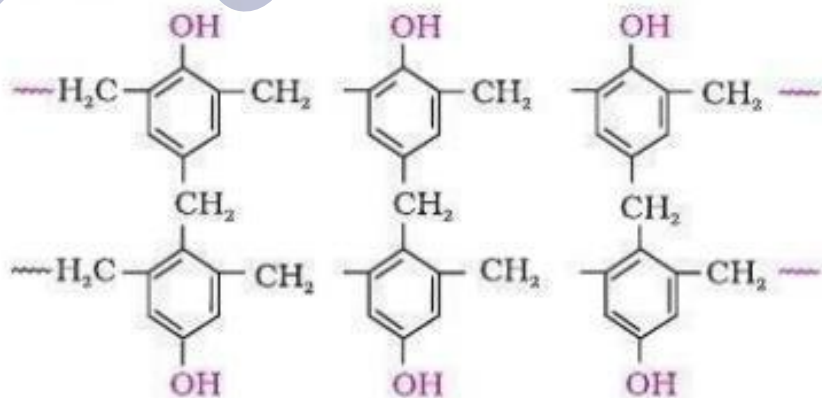
Melamine- formaldehyde Polymer:-

Melamine formaldehyde polymer is formed by the condensation polymerisation of melamine and formaldehyde.

It is used in the manufacture of unbreakable crockery.



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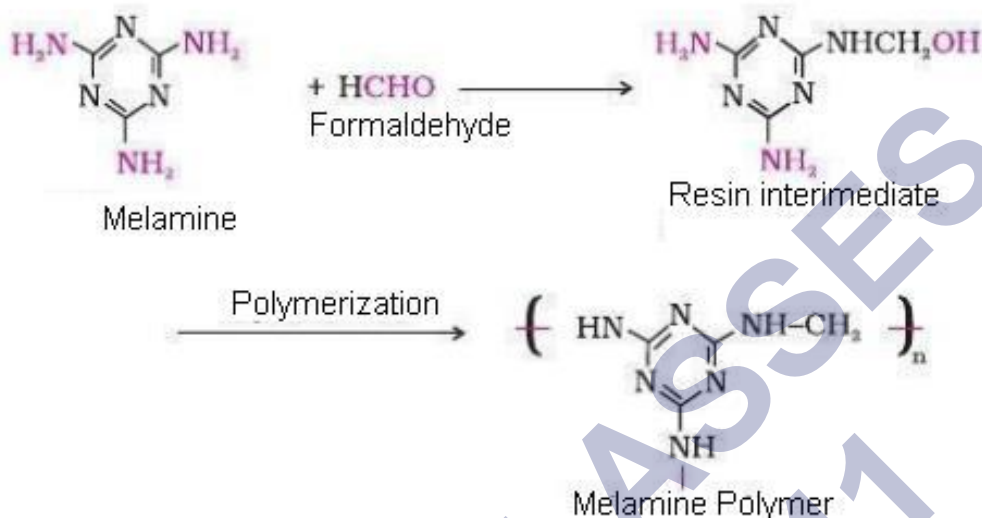


Bakelite

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o Polymerization

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The copolymer can be made not only by chain growth polymerisation but by step growth polymerisation also.

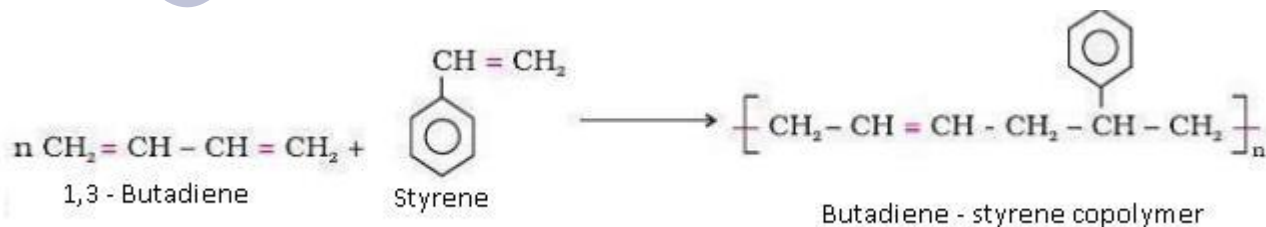
It contains multiple units of each monomer used in the same polymeric chain.

For example:-a mixture of 1, 3 – butadiene and styrene can form a copolymer.

Copolymers have properties quite different from homopolymers.

For example: - butadiene - styrene copolymer is quite tough and is a good substitute for natural rubber.

It is used for the manufacture of auto tyres, floor tiles, footwear components, cable insulation, etc.



Rubber

Rubber is a natural polymer and possesses elastic properties.

It is also termed as elastomer and has a variety of uses.

It is manufactured from rubber latex which is a colloidal dispersion of rubber in water. This latex is obtained from the bark of rubber tree and is found in India, Sri Lanka, Indonesia,

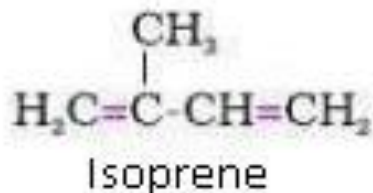
Malaysia and South America.

Natural Rubber

Natural rubber may be considered as a linear polymer of isoprene (2-methyl-1, 3-butadiene) and is also called as cis - 1, 4 -polyisoprene.

The cis-polyisoprene molecule consists of various chains held together by weak van der Waals interactions and has a coiled structure.

Thus, it can be stretched like a spring and exhibits elastic properties.



Vulcanization of Rubber:-

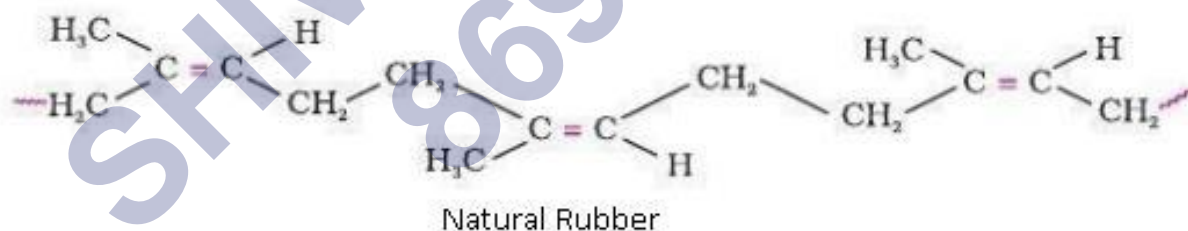
Natural rubber becomes soft at high temperature (>335 K) and brittle at low temperatures (<283 K) and shows high water absorption capacity.

It is soluble in non-polar solvents and is non-resistant to attack by oxidising agents. To improve upon these physical properties, a process of vulcanisation is carried out. This process consists of heating a mixture of raw rubber with sulphur and an appropriate additive at a temperature range 373 K to 415K.

On vulcanisation, sulphur forms cross links at the reactive sites of double bonds and thus the rubber gets stiffened.

In the manufacture of tyre rubber, 5% of sulphur is used as a crosslinking agent.

The probable structures of vulcanised rubber molecules are depicted below:



Synthetic Rubber

Synthetic rubber is any vulcanisable rubber like polymer, which is capable of getting stretched to twice its length.

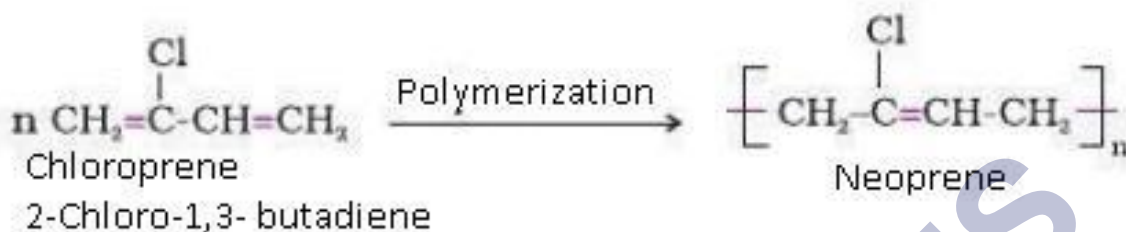
However, it returns to its original shape and size as soon as the external stretching force is released.

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

Preparation of Synthetic Rubbers

Neoprene:-

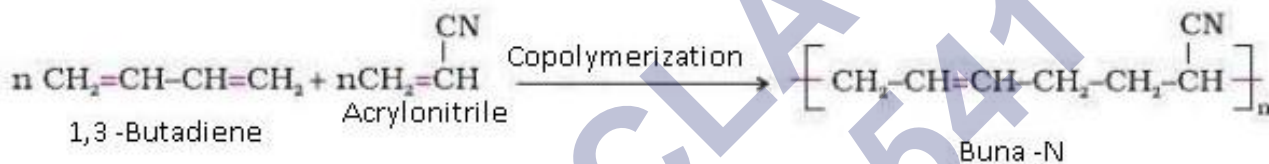
Neoprene or poly chloroprene is formed by the free radical polymerisation of chloroprene. It has superior resistance to vegetable and mineral oils. It is used for manufacturing conveyor belts, gaskets and hoses.



Buna -N:-

Buna -N is obtained by the copolymerisation of 1,3-butadiene and acrylonitrile in the presence of a peroxide catalyst.

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



Based on mode of polymerization:

(i) **Addition polymers:** Repeated addition of monomers containing double or triple bonds. (Polythene from ethene)

Homopolymer : Single monomeric species (Polythene)

Copolymer : Two different monomers (Buna-S, Buna-N)

(ii) **Condensation polymers:** Repeated condensation between two different bi-functional or tri-functional monomeric units. (Terylene, Nylon 6)

Based on structure of polymers high density:

(i) Linear polymers : Long and straight. (Polythene, PVC) \cong

(ii) Branched chain polymers : Linear chains with branches (low density polythene) \approx

(iii) Cross linked or network polymers: Strong covalent bond between various linear polymer chains. (Bakelite, Melamine) ---

Based on source:

(i) Natural polymers: Found in plants and animals. (Proteins, rubber)

(ii) Semi-synthetic polymers: (Cellulose derivatives)

(iii) Synthetic polymers: Man-made. (Polythene, Buna-S)

Based on Molecular Forces:

(i) Elastomers : Rubber-like solids with elastic properties (Buna-S, Buna-N)

(ii) Fibres : Thread forming solids. (Nylon 6,6, Terylene)

(iii) Thermoplastic polymers : Linear or slightly branched long chain molecules capable of repeatedly softening on heating and hardening on cooling. (polythene, polystyrene)

(iv) Thermosetting polymers : Cross linked or heavily branched molecules which on heating undergo extensive cross linking in moulds and become infusible. (Bakelite)

Classification

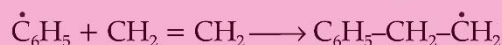
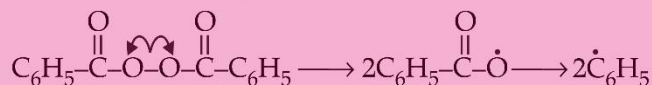
Polymers

Types of polymerization Reaction

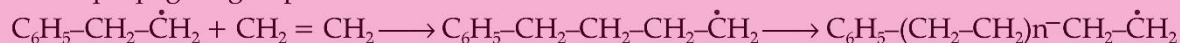
(i) Addition/Chain Growth : Molecules of the same/different monomers add together on a large scale.

Free radical mechanism:

(a) Chain initiation step:



(b) Chain propagating step:



(c) Chain terminating step:



(ii) Condensation/Step Growth: Repetitive condensation reaction between two bi-functional monomers. (Formation of terylene)

Class : 12th Chemistry
Chapter-15 : Polymers Polymers (Part_2)

Rubber: Types

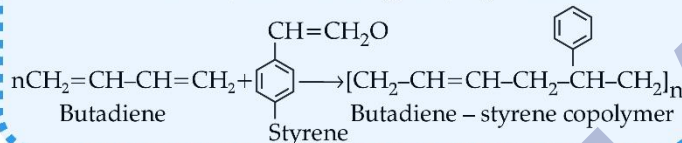
- (i) Natural rubber : natural and manufactured from rubber latex. It is a linear polymer of isoprene.
(ii) Synthetic rubber : Any vulcanisable rubber. These are homopolymers of 1,3 butadiene derivatives.



Molecular mass of polymers

- Expressed as an average.
- Determined by chemical and physical methods.

Copolymerization: A mixture of more than one monomeric species undergoes polymerization



Biodegradable polymers

Contain functional groups similar to biopolymers (PHBV, Nylon 2- nylon 6)

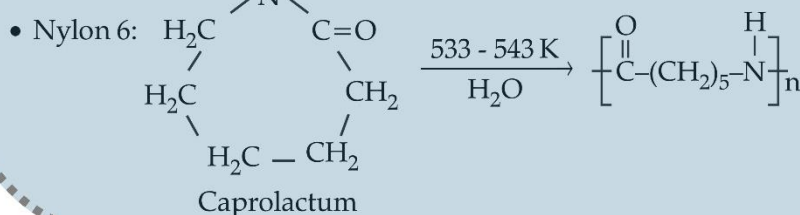
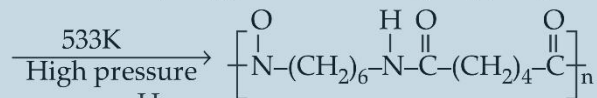
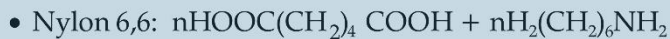
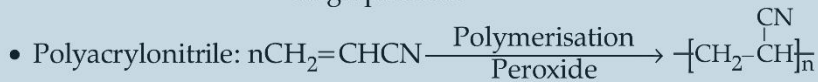
Very large molecule having high molecular mass

Polymers

Preparation

• Polythene

Low density : Polymerization of ethene under 1000–2000 atm at 350–570 K + catalyst
Higher density : addition polymerization of ethene in a hydrocarbon solvent at 333–343 K and 6–7 atm + catalyst



Important Questions

Multiple Choice questions-

1. Monomer of $[-(\text{CH}_3)_2\text{CCH}_2-]$

- (a) 2-Methyl propene
- (b) Styrene
- (c) Propylene
- (d) ethene.

2. Bakelite is

- (a) addition polymer
- (b) elastomer
- (c) thermoplastic
- (d) thermosetting.

3. Buna-Sis

- (a) natural polymer
- (b) synthetic polymer
- (c) sulphur polymer
- (d) none of these.

4. The S in Buna-S refers to

- (a) sodium
- (b) sulphur
- (c) styrene
- (d) just a trade name.

5. The repeating units of PTFE is

- (a) $\text{Cl}_2\text{CH}-\text{CH}_3$
- (b) $\text{F}_2\text{C}=\text{CF}_2$
- (c) $\text{F}_3\text{C}-\text{CF}_3$
- (d) $\text{FCIC}=\text{CF}_2$.

6. The inter-particle forces between linear chains in Nylon-66 are

- (a) H-bonds
- (b) covalent bonds
- (c) ionic bonds
- (d) unpredictable.

7. Nylon-66 is a polyamide of

- (a) vinyl chloride and formaldehyde
- (b) adipic acid and methyl amine
- (c) adipic acid and hexamethylene diamine
- (d) formaldehyde and malamine.

8. Which of the following is not a condensation polymer?

- (a) Glyptal
- (b) Nylon-66
- (c) Dacron
- (d) PTFE

9. Which of the following is a condensation polymer?

- (a) Polystyrene
- (b) Neoprene
- (c) PAN
- (d) Poly (ethylene glycol phthalate)

10. The monomer of PVC is

- (a) ethylene x
- (b) tetrafluoroethylene
- (c) Chloroethene
- (d) none of these.

Very Short Questions-

1. Give an example of elastomers. (Delhi, All India 2009)
2. What does the part '6, 6' mean in the name nylon-6, 6? (Delhi, All India 2009)
3. What is the primary structural feature necessary for a molecule to make it useful in a condensation polymerization reaction? (All India 2009)
4. 4. What does the designation '6, 6' mean in the name nylon-6, 6? (All India 2010)
5. 5. What is meant by 'copolymerisation'? (All India 2010)
6. What are biodegradable polymers? (Delhi 2010)
7. In nylon 6, 6, what does the designation '6, 6' mean? (Delhi 2010)
8. Define the term, 'homopolymerisation' giving an example. (Delhi 2010)
- 9.

Is $\left(\text{CH}_2 - \underset{\text{Cl}}{\text{CH}} \right)_n$ a homopolymer or a copolymer?

10. Give one example of a condensation polymer. (All India 2013)

Short Questions-

1. Draw the structures of the monomers of the following polymers : (Delhi 2009)
 - (i) Teflon
 - (ii) Polyethene
2. What is the repeating unit in the condensation polymer obtained by combining

- $\text{HO}_2\text{CCH}_2\text{CH}_2\text{CO}_2\text{H}$ (succinic acid) and $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ (ethylene diamine)? (Delhi 2009)
- Differentiate between molecular structures and behaviours of thermoplastic and thermosetting polymers. Give one example of each type. (All India 2009)
 - Differentiate between condensation and addition polymerisations. Give one example each of the resulting polymers. (All India 2009)
 - Draw the molecular structures of the monomers of
 - PVC
 - Teflon (All India 2010)
 - Draw the structures of the monomers of the following polymers : (All India 2010)
 - Bakelite
 - Nylon-6
 - Mention two important uses of each of the following :
 - Bakelite
 - Nylon 6 (Delhi 2011)
 - Name the sub-groups into which polymers are classified on the basis of magnitude of intermolecular forces. (Delhi 2011)
 - Draw the structure of the monomer for each of the following polymers : (Delhi 2012)
 - Nylon-6
 - Polypropene
 - Define thermoplastic and thermosetting polymers. Give one example of each. (All India 2012)

Long Questions-

- Explain the mechanism of polymerisation of ethene.
- Differentiate between LDP and HDP.
- What are Bakelite and Melamine? Give their structures.
- Give monomers and preparation of Nylon – 6, 6 and Dacron.
- How are polymers classified on the basis of structure?
- Distinguish between the terms homopolymer and copolymer and give an example of each.
- How can you differentiate between addition and condensation polymerisation?
- Explain the term copolymerisation and give two examples.

Assertion and Reason Questions:

1. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

- a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
- b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
- c) Assertion is correct statement but reason is wrong statement.
- d) Assertion is wrong statement but reason is correct statement.

Assertion: In vulcanisation of rubber, sulphur cross links are introduced.

Reason: Vulcanisation is a free radical initiated chain reaction.

2. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

- a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
- b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
- c) Assertion is correct statement but reason is wrong statement.
- d) Assertion is wrong statement but reason is correct statement.

Assertion: Teflon has high thermal stability and chemical inertness.

Reason: Teflon is a thermoplastic.

MCQ Answers-

- 1. (c) Propylene
- 2. (d) thermosetting.
- 3. (b) synthetic polymer
- 4. (c) styrene
- 5. (b) $F_2C = CF_2$
- 6. (a) H-bonds
- 7. (c) adipic acid and hexamethylene diamine
- 8. (d) PTFE
- 9. (d) Poly (ethylene glycol phthalate)
- 10. (c) Chloroethene

Very Short Answers-

1. Buna-S, Buna-N.
2. Nylon '6,6' implies that it is a condensation polymer of two types of monomer molecules each containing six carbon atoms i.e. adipic acid ($\text{HOOC}(\text{CH}_2)_4\text{COOH}$) and hexamethylenediamine ($\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$)
3. The presence of two bifunctional monomer molecules undergo condensation with the loss of simple molecule of water, alcohol to form dimer.
4. Since both adipic acid and hexamethylenediamine contain six carbon atoms each.
5. When two or more different monomers are allowed to polymerize together, the product formed is called a copolymer and the process is called copolymerisation.
6. Biodegradable polymers : All those biopolymers which disintegrate by themselves in biological systems during certain period of time by enzymatic hydrolysis are called biodegradable polymers.

Example : Poly-p-Hydroxybutyrate-Co-p-Hydro-xyvalerate (PHBV)

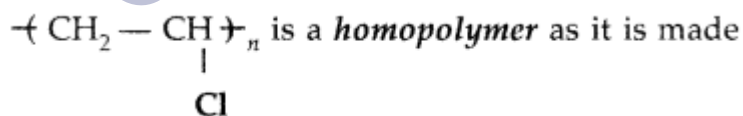
Uses : These are used

- in packaging
- in orthopaedic devices
- in controlled drug release
- in bacterial degradation

7. Since both adipic acid and hexamethylenediamine contain six carbon atoms each.
8. The polymer formed by the polymerization of a single/same monomeric species is known as homopolymerization.

Example : Polythene/PVC/Polypropene.

9. Answer:



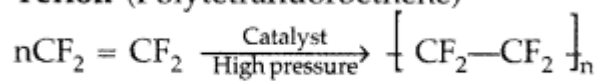
up of some monomer units

10. Example : Nylon 6,6

Short Answers-

1. Answer:

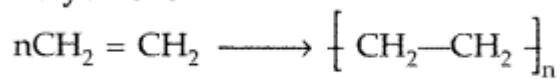
Teflon (Polytetrafluoroethene)



Tetrafluoroethene

Teflon

Polyethene

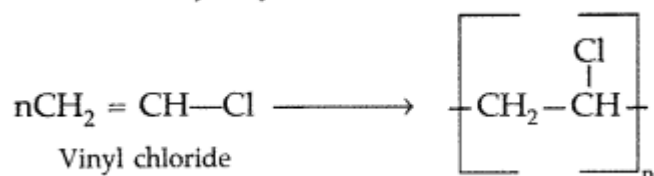


Ethene

Polyethene

2. Answer:

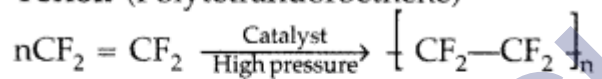
(i) **PVC** (Polyvinyl chloride)



Vinyl chloride

Polyvinyl chloride (PVC)

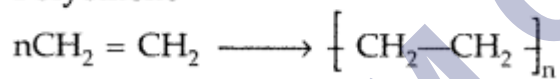
Teflon (Polytetrafluoroethene)



Tetrafluoroethene

Teflon

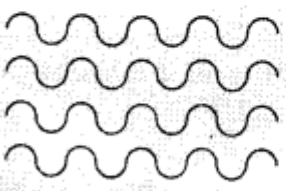

Polyethene



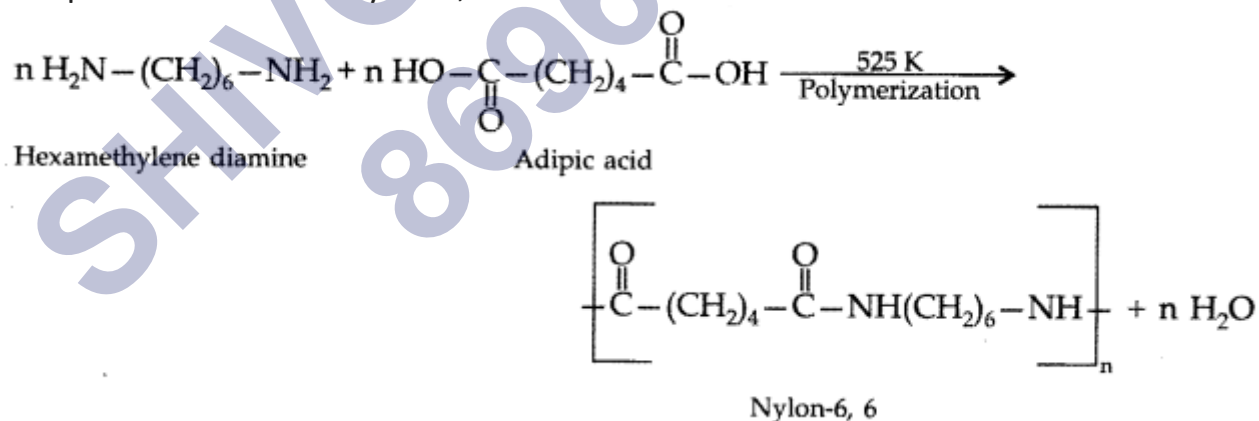
Ethene

Polyethene

3. Answer:

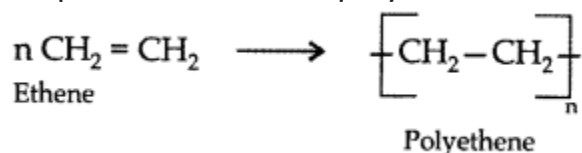
<i>Thermoplastic polymers</i>	<i>Thermosetting polymers</i>
(i) These polymers have intermolecular forces of attraction between those of elastomers and fibres.	(i) These are semifluid substances with low molecular masses which when heated in a mould, undergo change in chemical composition to give a hard, infusible and insoluble mass.
(ii) These are linear or slightly branched chain polymers which are hard at room temperature and become soft and viscous on heating and again rigid on cooling. 	(ii) These have extensive cross-linking between different polymers chain to give a three dimensional network solid on heating. 
(iii) These can be melted again and again without any change.	(iii) These can be heated only once when these are permanently set into a solid which cannot be remelted and reworked.
<i>Example</i> : PVC, polyethene	<i>Example</i> : Bakelite, melamine

4. Answer: Condensation polymerisation : In this, two or more bifunctional molecules undergo a series of independent condensation reactions with the elimination of simple molecules like H₂O, alcohol, NH₃, CO₂, HCl etc. to form a macromolecule.
Example : Formation of nylon 6, 6



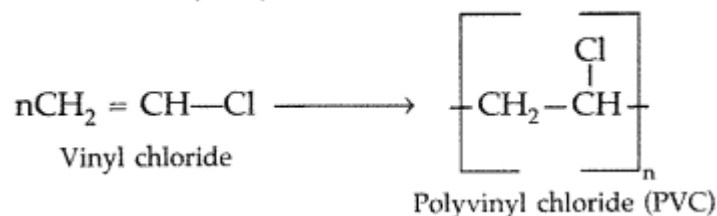
Addition polymerisation : In this, the molecules of the same or different monomers simply add on one another to form macromolecule. These molecules occur among molecules containing double and triple bonds.

Example : Formation of polyethene



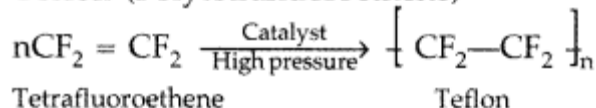
5. Answer:

(i) **PVC** (Polyvinyl chloride)



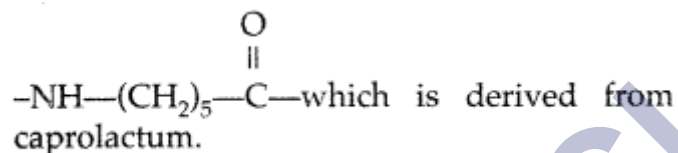
(ii)

Teflon (Polytetrafluoroethene)



6. Answer: (i) Bakelite : Phenol and formaldehyde → Condensation polymer.

(ii) Nylon-6 : The monomeric repeating unit of Nylon-6 is



7. Answer:

(i) Bakelite :

(a) It is used in making handles of utensils.

(b) Also used in production of billiard balls, dominoes and pieces for games like chess.

(ii) Nylon 6 :

(a) Nylon is used in making stockings.

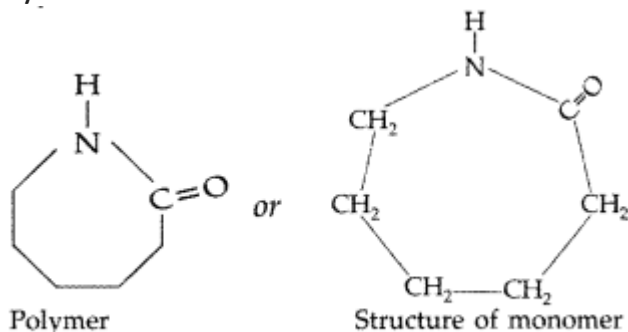
(b) It is also used for making parachutes.

8. Answer:

1. Elastomers
2. Fibres
3. Thermoplastic polymers
4. Thermosetting polymers.

9. Answer:

(i) Nylon-6 :

(ii) **Polypropene** : $\text{-(CH}_3\text{-CH=CH}_2\text{)-}$
Propene

10. Answer: Thermoplastic polymers : Linear polymers in which the intermolecular forces of attraction are in between those of elastomers and fibres and can be melted again and again on heating followed by moulding to give desired shape.

Example : Polyethene, Polyvinyl chloride (PVC) etc.

Thermosetting polymers : These are semifluid substances with low molecular masses which when heated in a mould, undergo change in chemical composition to give a hard, infusible and insoluble mass. These cannot be re-melted.

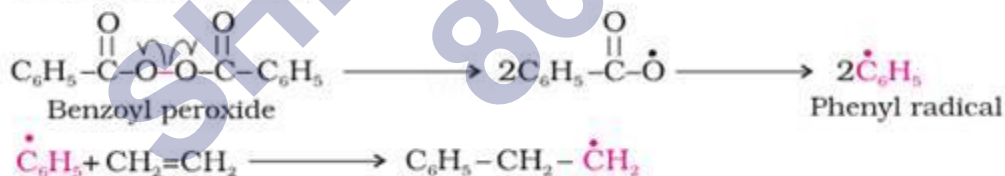
Example : Bakelite, Melamine etc.

Long Answers-

1. Ans. Polymerisation of ethene takes place by free radical mechanism. It follows a three step mechanism:-

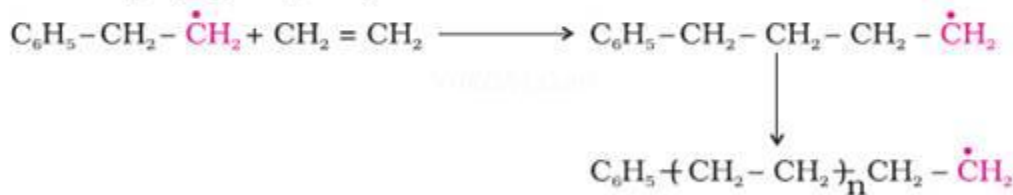
Step I: chain initiating step formation of phenyl free radical.

Chain initiation steps

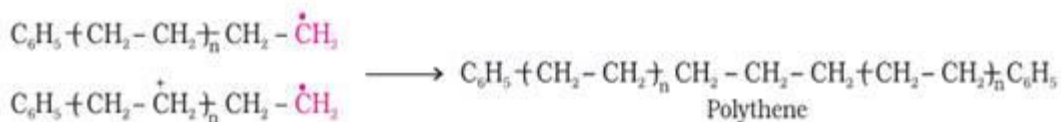


Step II:

Chain propagating step



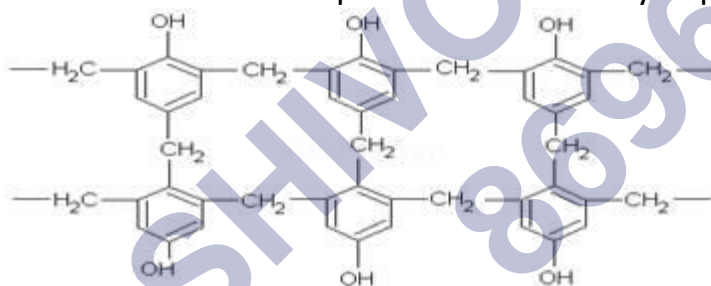
Step III: Chain termination step



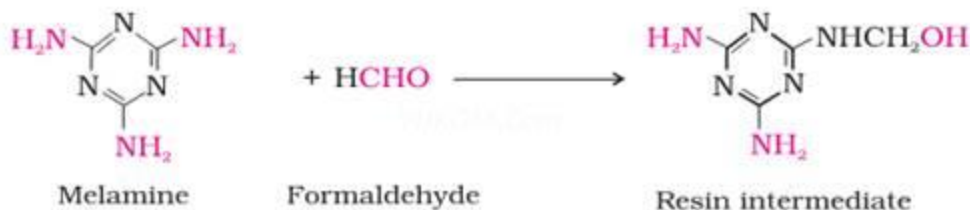
2. Ans.

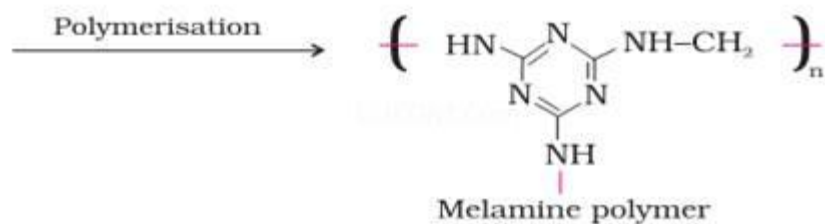
(LDP) Low Density Polythene	(HDP) High Density Polythene
<ol style="list-style-type: none"> 1. It is obtained by polymerisation of ethane under pressure of 1000 to 2000 atm. & temperature of 350K to 570K. 2. It is prepared in the presence of dioxygen or a peroxide initiator. 3. It has highly branched structure. 4. It is chemically inert, tough and flexible. 5. It is a poor conductor of electricity. 6. It is used in toys, flexible pipes etc. 	<ol style="list-style-type: none"> 1. It is formed when polymerisation takes place in a hydrocarbon solvent in presence of a catalyst e.g. Ziegler-natta catalyst at 333K-343K and 6-7atm pressure. 2. It requires Ziegler – Natta catalyst. 3. It has a linear structure. 4. It is more tougher and harder. 5. It is used for making buckets, dustbins, pipes etc.

3. Ans. Bakelite – It is phenol – formaldehyde polymer.



Melamine – It is melamine – formaldehyde polymer

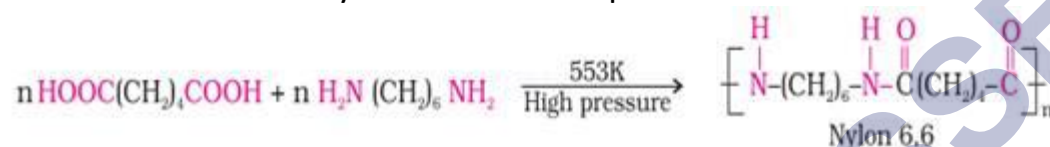




4. Ans. Preparation

(i) Nylon – 6, 6

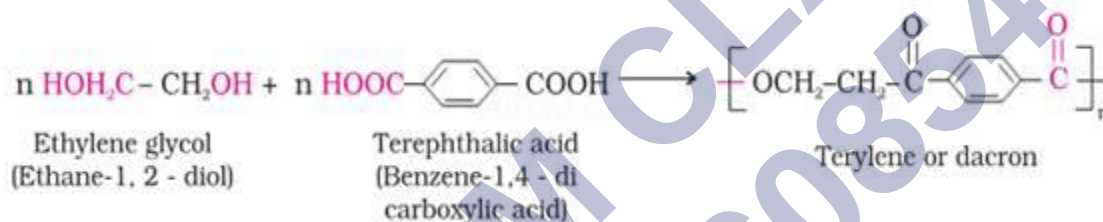
Monomers: Hexamethylene diamine Adipic acid.



(ii) Dacron

Monomers: Ethylene Glycol

Terephthalic acid



5. Ans. Polymers are classified on the basis of structure as follows:

1. Linear polymers:

These polymers are formed of long straight chains. They can be depicted as:

For e.g., high density polythene (HDP), polyvinyl chloride, etc.



2. Branched chain polymers:

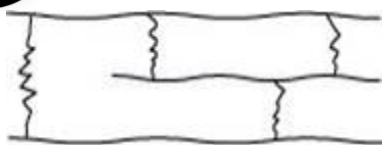
These polymers are basically linear chain polymers with some branches. These polymers are represented as:

For e.g., low density polythene (LDP), amylopectin, etc.



3. Cross-linked or Network polymers:

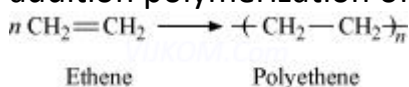
These polymers have many cross-linking bonds that give rise to a network-like structure. These polymers contain bi-functional and tri-functional monomers and strong covalent bonds between various linear polymer chains. Examples of such polymers include bakelite and melmac.



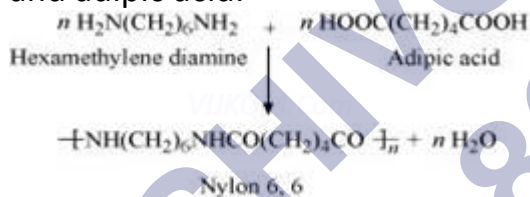
6. Ans.

Homopolymer	Copolymer
The polymers that are formed by the polymerization of a single monomer are known as homopolymers. In other words, the repeating units of homopolymers are derived only from one monomer. For example, polythene is a homopolymer of ethene.	The polymers whose repeating units are derived from two types of monomers are known as copolymers. For example, Buna – S is a copolymer of 1, 3-butadiene and styrene.

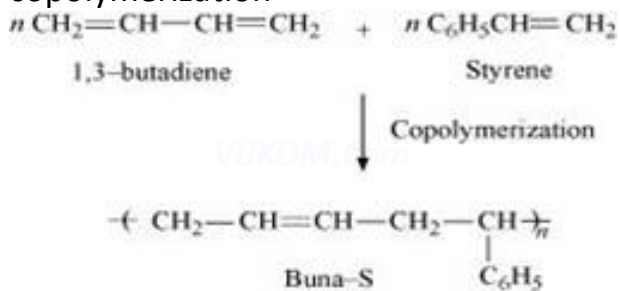
7. Ans. Addition polymerization is the process of repeated addition of monomers, possessing double or triple bonds to form polymers. For example, polythene is formed by addition polymerization of ethene.



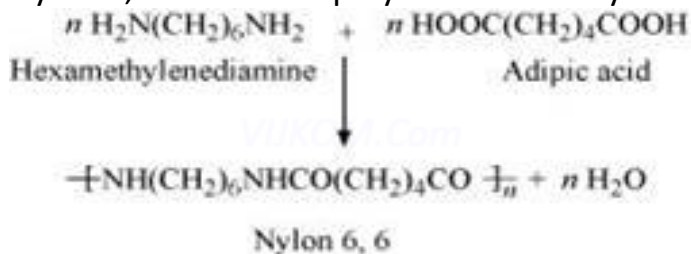
Condensation polymerization is the process of formation of polymers by repeated condensation reactions between two different bi-functional or tri-functional monomers. A small molecule such as water or hydrochloric acid is eliminated in each condensation. For example, nylon 6, 6 is formed by condensation polymerization of hexamethylenediamine and adipic acid.



8. Ans. The process of forming polymers from two or more different monomeric units is called copolymerization. Multiple units of each monomer are present in a copolymer. The process of forming polymer Buna-S from 1, 3-butadiene and styrene is an example of copolymerization



Nylon 6, 6 is also a copolymer formed by hexamethylenediamine and adipic acid.



Assertion and Reason Answers:

1. (c) Assertion is correct statement but reason is wrong statement

Explanation:

Bakelite can be heated only once.

2. (b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

Explanation:

Due to the presence of strong C–F bonds, teflon has high thermal stability and chemical inertness.