

UNIT - II

POLYMERS

INTRODUCTION:

Matter is composed of many small units called molecules, which are in different sizes and shapes and associated with atoms. Polymers are giants or macro molecules which play a vital role in our daily life and provide the basic needs of our life (food, clothing and shelter)

The word polymer was derived from Greek word 'poly' = 'many' and 'mers' = 'parts /units'

Polymer: It is defined as a high molecular weight compound (macro molecule) made by linking together a large

number of small molecules called **monomers**.

Ex: PVC, Polyethylene, Starch, Poly styrene, Proteins, DNA etc

Monomer: The basic repeating units present in a polymer are called monomer.

Ex: Vinyl chloride is a monomer of PVC.

Ethylene is a monomer of poly ethylene.

Glucose is a monomer of starch.

Styrene is a monomer of polystyrene.

Amino acids are the monomers of proteins.

Nucleotides are the monomers of Nucleic acids.

Degree of polymerization: The number of repeating units (or) monomers present in the polymer is called as degree of polymerization. They may be hundreds (or) thousands (or) ten thousands.

$$\text{Degree of polymerization (D.P)} = \frac{\text{Mol.wt of polymer}}{\text{Mol.wt of monomer}}$$

$$\text{Molecular wt of polymer} = \text{D.P} \times \text{Mol.wt of monomer}$$

Classification of Polymers:

1. Based on degree of polymerization:

Polymers having high DP (having more number of monomers) are called **High polymers**.

Their molecular weight range is about 10,000 to 10,00,000 Daltons.

Polymers with low DP are called **Oligopolymers**. Their molecular weight ranges from 5,000 to 2,00,000 Daltons.

2. Based on occurrence:

Polymers may be either **Natural** (natural rubber, proteins, cellulose, starch etc) (or) **Synthetic** (PVC, PE, PS, Teflon, Nylon, Bakelite etc.....)

Basic Concepts:

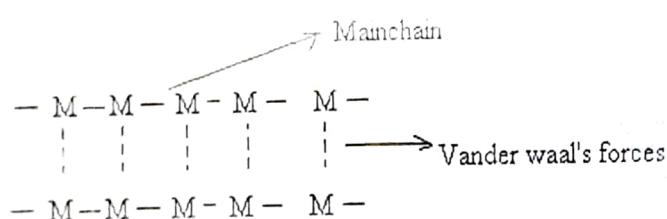
Functionality:

The number of bonding sites (or) reactive sites present in a monomer is called as functionality.

Each monomer should have minimum two bonding sides for polymerization.

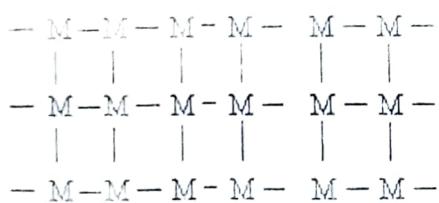
a) If the functionality of monomer is 2, the resulting polymer is linear (or) straight chained.

Ex: Ethylene, styrene, vinyl chloride.



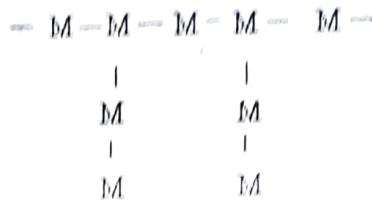
b) If the functionality of monomer is three (trifunctional), Cross linked three dimensional polymers are obtained.

E.g Bakelite.



c) If a mixture of bi functional and tri functional monomers is present, branched chain polymers are formed.

Ex: Buna - S - Rubber.



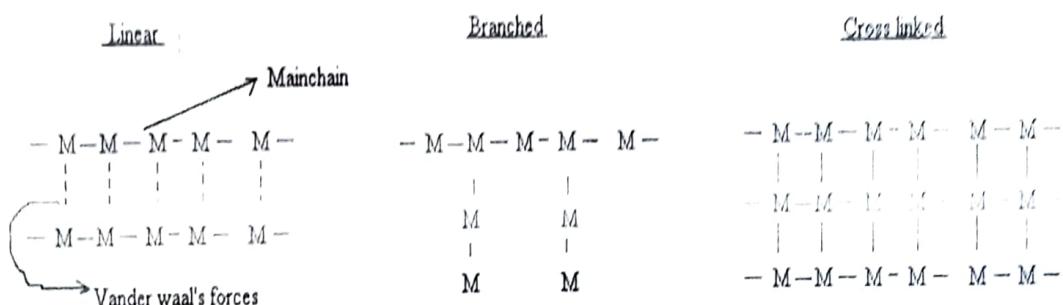
1) Nomenclature: polymers are given names based on two properties

- 1 Type of monomers present
- 2 Type of atoms present in back bone chain

(i) Type of monomers:

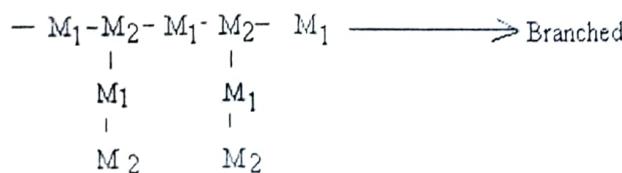
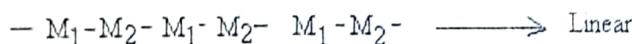
a) Homo polymer: If a polymer consists of identical monomers, then that polymers are called homo polymers. They may be linear, branched (or) Cross-linked.

Ex: PVC, Polythene, Teflon etc.....



b) Hetero or Co-polymers: If a polymer is composed of different types of monomers, then it is called Hetero

/ co - polymers. They may be generally linear (or) Branched.

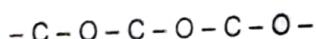


(ii) Type of atoms present in back bone chain:

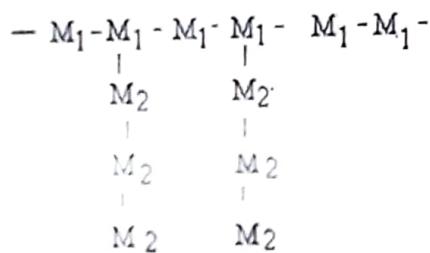
a) Homo chain polymer: If the main chain is made up of same species of atoms is called homo chain polymer.



b) Hetero chain polymer: If main chain is composed of different atoms is said to be Hetero chain polymer



c) Graft co-polymers: These polymers are branched structures in which the monomer units on the branches and back bone differ.

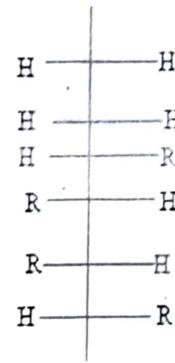


3) Tacticity: The orientation of functional groups in polymer is called as configuration. The difference in configuration of polymers because of the difference in arrangement of functional groups around main chain is called as Tacticity. Based on tacticity, polymers are of three types.

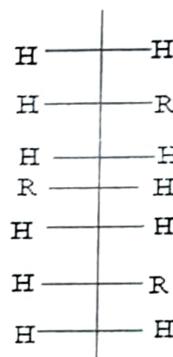
a) Isotactic: If all the functional groups are arranged on the **same side of the chain**, the polymer is called Isotactic polymer.



b) Atactic: If all the functional are arranged randomly around the main chain, the polymer is called Atactic polymer.



c) **Syndiotactic:** If all the functional groups are arranged alternately with respect to the main chain, the polymer is called syndiotactic polymer.



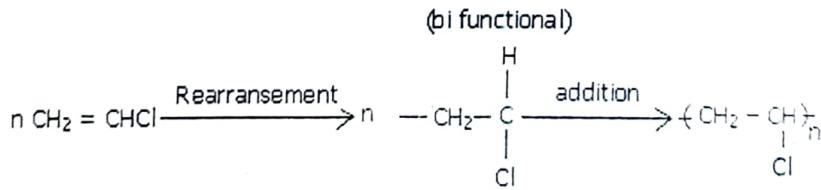
Polymerization:

1) Addition Polymerization:

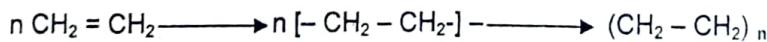
- This polymerization takes place between monomers that are bifunctional and contains double bonds in its structure.
- This can be defined as binding of several bifunctional monomers to form polymers without elimination of by products by addition reactions.
- This polymerization results in the formation of linear polymers.
- The produced polymer has same chemical composition as that of monomers.
- The molecular weight of polymer is an integral multiple of the monomer.

Examples:

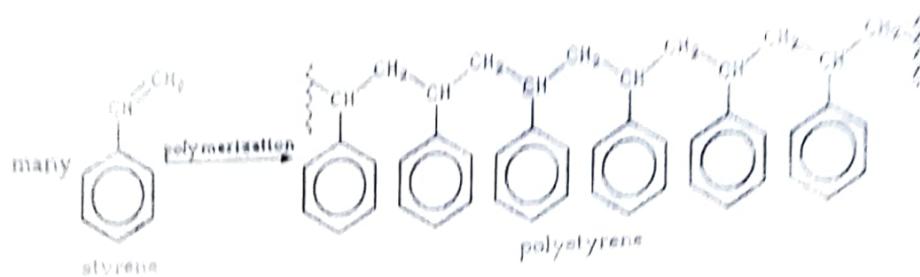
1. Formation of PVC:



2. Polymerization of ethylene:



3) Polymerization of Styrene:

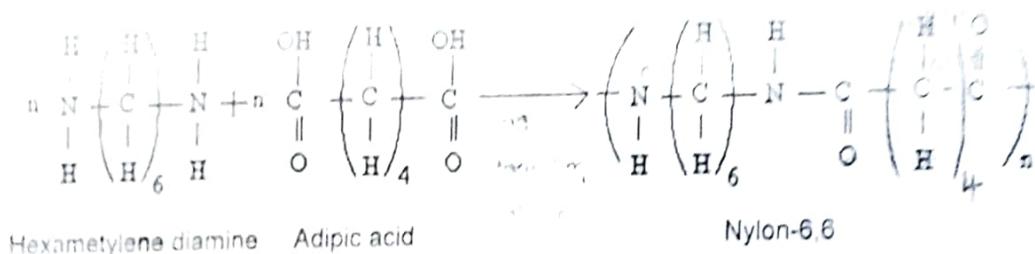


2) Condensation Polymerization:

- This is also called Step-wise polymerization
- This occurs between monomers that contain polar side groups.
- A reaction occurring between the same (or) different polar groups containing monomers and forms linear (or) cross-linked polymers is called condensation polymerization
- The molecular weight of polymer is not an integral multiple of the mol wt of monomer.
- The chemical composition of monomer and polymer are different
- It results in the formation of linear or cross linked polymers

Example:

1. Formation of Nylon-6,6: Formed by the condensation of Hexamethylenediamine with adipic acid (Tetra methylene dicarboxylic acid)



2. Formation of Polyester: Formed by the condensation between ethylene glycol and Terephthalic acid

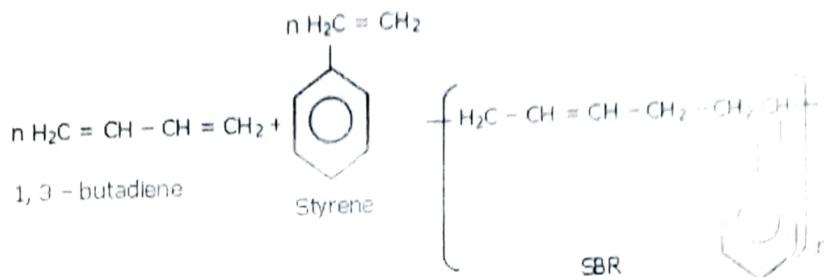


3) Co-polymerization:

- When two (or) more different types of monomers undergo simultaneous polymerization then it is called Co-Polymerization.
- The properties of co-polymer are different from those of individual monomers.
- The copolymers may be alternating, random, block and graft polymers.

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- The copolymers may be alternating, random, block and graft polymers

Ex: Styrene butadiene rubber (SBR)



Addition Polymerization	Condensation Polymerization
1. Reaction Proceeds in a fast manner under favorable conditions.	1. Reaction proceeds comparatively slow.
2. Proceeds by chain growth mechanism	2. Proceeds by a step growth mechanism
3. No-by Product is formed	3. By Products are formed
4. Monomers with Carbon-Carbon unsaturation ($\text{C}=\text{C}$ (or) $\text{C}\equiv\text{C}$) are involved.	4. Monomers with reactive functional groups are involved.
5. Number of monomers decreases throughout the course of the reaction	5. Concentration of Monomers decreases much faster in the early stages of the reaction.

MECHANISM OF ADDITION POLYMERIZATION

Addition Polymerizations are 3 types.

- ① Radicals (Free radicals)
- ② Carboniumions (Carbocation)
- ③ Carbanions.

(a) Free radical addition Polymerization

The mechanism involves the following three steps

(i) Initiation: This involves the dissociation of an initiator into two free radicals.

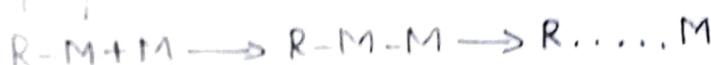


(Initiator) (Free radicals)

Then the free radicals so formed adds to the first monomer molecule (H)



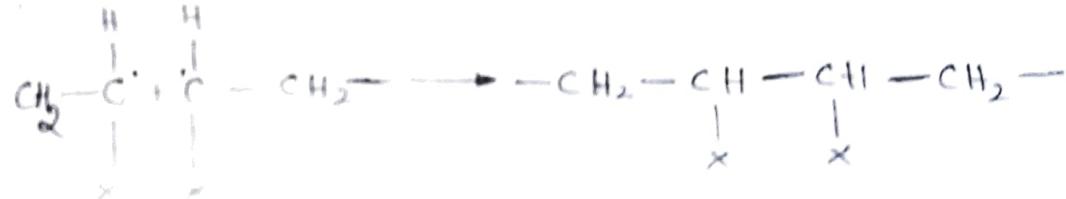
(ii) Propagation: This involves the growth polymer chain by successive addition of monomeric units resulting in the formation of polymeric chain with free radical centre.



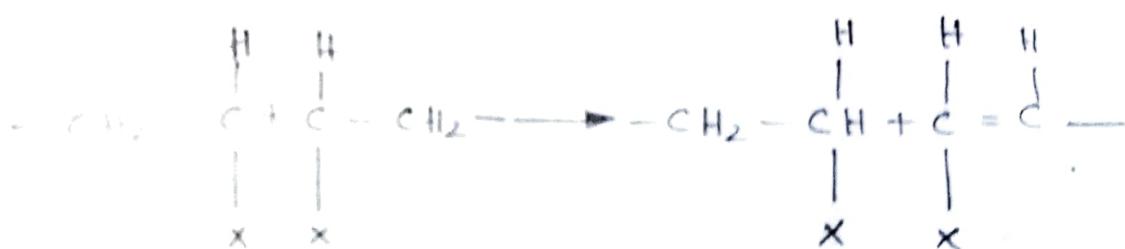
(iii) Termination: This can be taken place either of two.

(a) Coupling Termination: This involves collision between the active ends of two chains.

Eg:

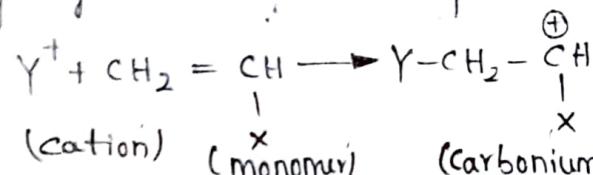


(b) Disproportionation Termination: This involves the transfer of a hydrogen atom of one radical centre to another radical centre, resulting in the formation of two polymer units one saturated and another unsaturated.

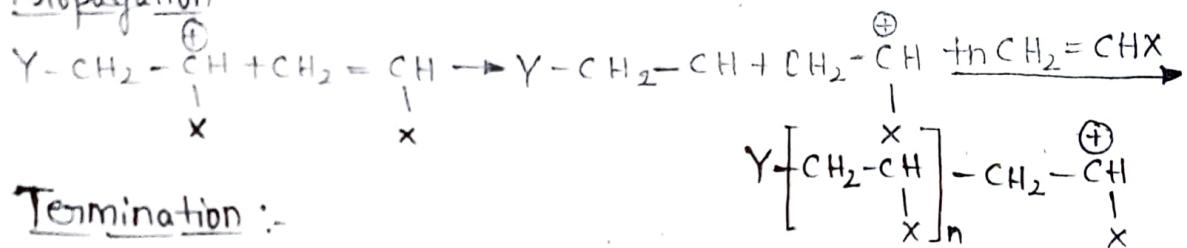


(b) Cationic addition Polymerization: This involves the following three steps.

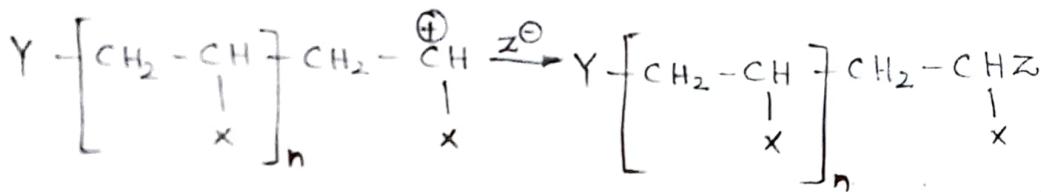
(i) Initiation: In this step formation of carbonium ion takes place usually by transfer of a proton.



(ii) Propagation

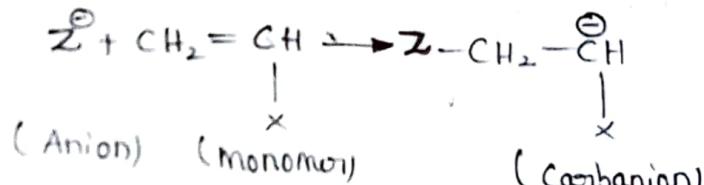


(iii) Termination:

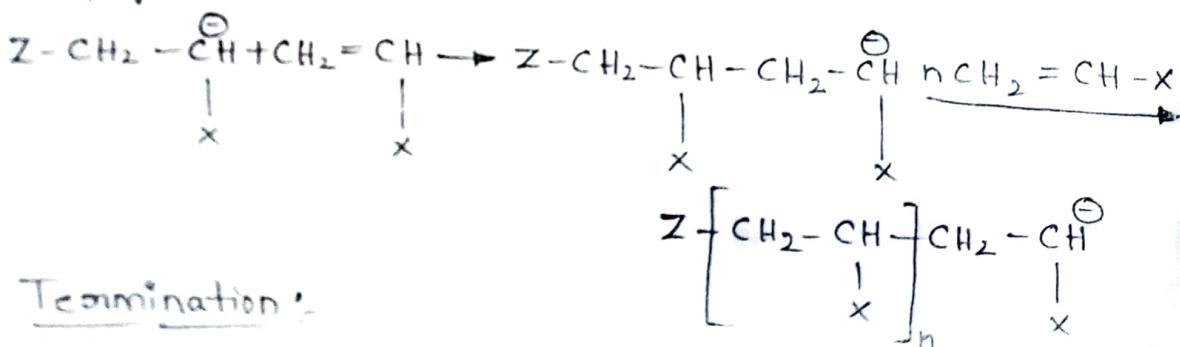


(c) Anionic addition Polymerization: This mechanism involves the following three steps

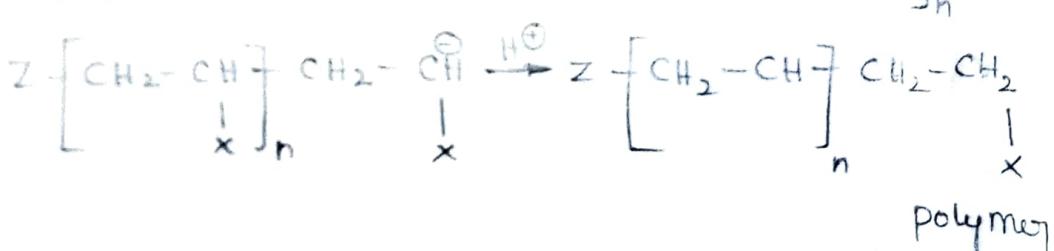
(i) Initiation: In this step formation of Carbanion takes place



(ii) Propagation:



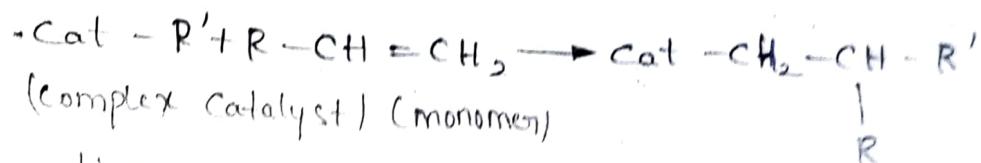
(iii) Termination:



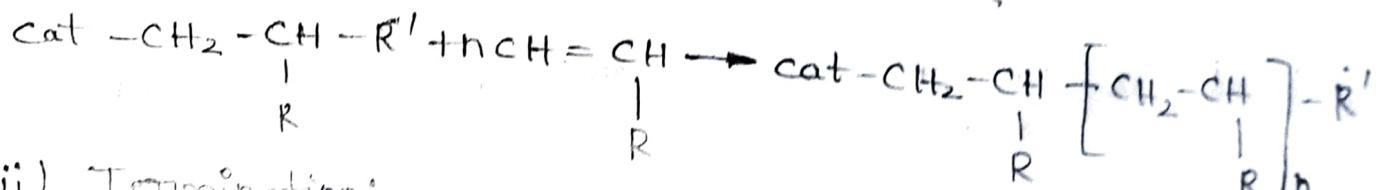
(d) Co-ordination or Ziegler-Natta Polymerization:

Ziegler and Natta discovered that in the presence of transition metal halide $TiCl_4$ with an organometallic compound, triethyl aluminium (Ziegler-Natta catalyst), stereo specific polymerization can be effected. Polymerization occurs due to insertion of alkene monomer molecules between the Ti-C bond. Mechanism of co-ordination polymerization involves the following steps.

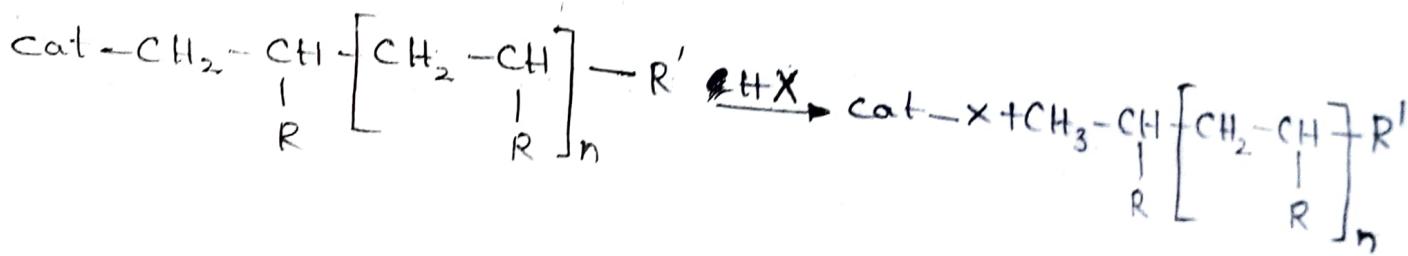
(i) Initiation:



(ii) Propagation:



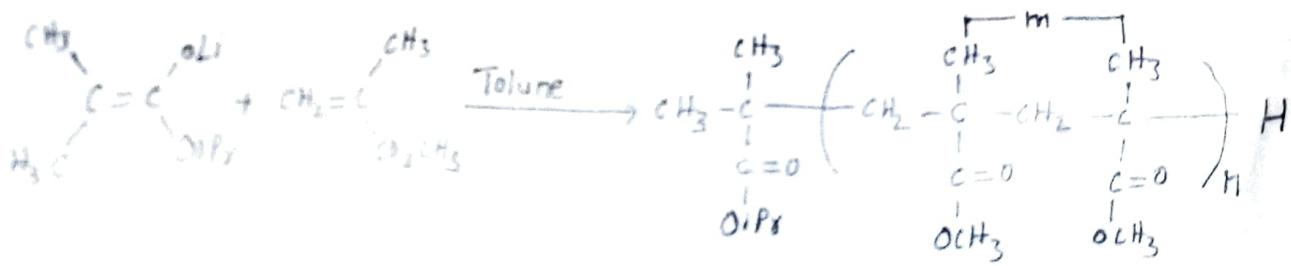
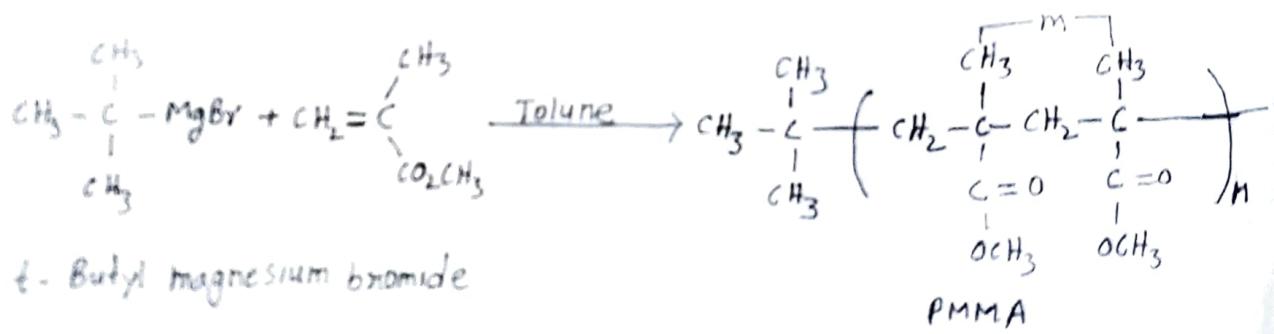
(iii) Termination:



Stereo-specific Polymerization

- Polymerisation in which a tactic polymer is formed. A tactic macromolecule is a regular macromolecule, in which essentially all the configurational repeating units are identical.
- A configurational repeating unit having defined configuration at all sites of stereoisomerism in the main chain is a stereorepeating unit.
- Stereoregular polymer is composed of stereoregular macromolecule that is a regular macromolecule essentially comprising only one species of stereorepeating unit.

In the 1980's highly *t*-specific anionic polymerization of methyl methacrylate (MMA, formula $\text{CH}_2=\text{C}(\text{CH}_3)\text{COOCH}_3$) initiated with *t*-butylmagnesium bromide (*t*- $\text{C}_4\text{H}_9\text{MgBr}/\text{MgBr}_2$) the polymerization proceeds in a living manner without side reactions and gives a highly isotactic polymer of PMMA.



PMMA
(poly(methyl methacrylate))

Properties:-

1. PMMA is strong and light weight
2. Superior properties including weatherability and scratch resistance.
3. It has a density of $1.150 - 1.99 \text{ g/cm}^3$ about less than half that of glass and similar other kinds of plastics.
4. It has good impact strength, higher than both glass and polystyrene, however, PMMA's impact strength is still significantly lower than polycarbonate and some modern polymers.
5. PMMA ignites at 4600°C and burns forming carbon dioxide, water, carbon monoxide and low molecular weight compounds including formaldehyde.

Applications:-

1. It is a transparent glass substitute
2. It is used as daylight redirection material.
3. Used in medical technologies and dental implants.
4. It is also used in artistic and aesthetic uses.
5. PMMA used as lenses which are commonly referred as "hand lenses".
6. PMMA used as shield to stop beta radiation emitted from radioisotopes.
7. PMMA was used in laserdisc optical media and in 3D optical data storage.
8. Small strips of PMMA are used as dosimeter devices during the Gamma irradiation process.

Plastics:

- An organic substance with high molecular weight, which can be moulded in to any desired form when subjected to heat (or) pressure in the presence of catalyst is called as plastic.
- The term plastic must be differentiated from resins.
- Resins are basic binding materials, which form a major part of the plastic and which actually undergo polymerization and condensation reactions during their preparations
- However, the term resin and plastic are considered as synonyms.

Advantages:

Now a days, plastics play a important role in daily life because of their certain unique properties

- Light in weight
- Transparent
- Low maintenance cost
- Chemically inert
- Corrosion resistance
- Insect resistance
- Easy transportability
- Easy workability
- Impermeable to water
- High resistance to abrasion

Disadvantages:

- Low heat resistance, so combustible
- High softness
- Poor ductility
- Major pollutant not degraded by soil

Uses:

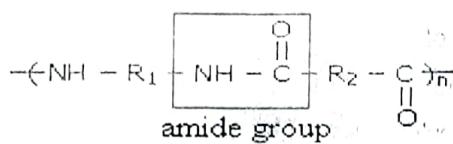
- For Making many house hold articles
- For making furniture
- For making electric goods

Types of Plastics: Plastics are classified in to two types

- Thermo plastics
- Thermo setting plastics.

THERMOPLASTICS	THERMO SETTING PLASTICS
<ul style="list-style-type: none"> They are formed by addition reactions. (some times formed by condensation r/n) They become softened on heating & hardened on cooling They are soft, weak and less – brittle. Adjacent polymer chains are held together by weak Vanderwaal's forces  <ul style="list-style-type: none"> They have either linear (or) branched structures The chemical nature is not altered during heating & cooling. They can be remoulded, reshaped & reused so they can be reclaimed from waste. Low molecular weight thermoplastics are soluble in suitable organic solvents <p>Ex: PE, PVS, PS, Nylon Teflon etc...</p>	<ul style="list-style-type: none"> Formed by condensation reactions. They become soft on initial heating and hard on cooling. On reheating they become more hard. They are hard, strong and more – brittle. Adjacent polymer chains are held together by strong covalent bonds.  <ul style="list-style-type: none"> Due to strong bonds, they exhibit cross-linked 3D-structure. Chemical changes takes place during moulding process. They cannot be remoulded and reused so they cannot be reclaimed from the waste. Due to strong bonds and cross links, they are not soluble in almost all organic solvents. <p>Ex: Bakelite, amino resins, poly ester resins, poly urethanes epoxy resins etc.....</p>

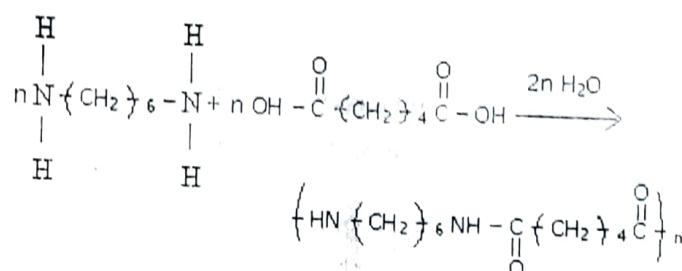
1. Nylon: (Poly Amide Resin)



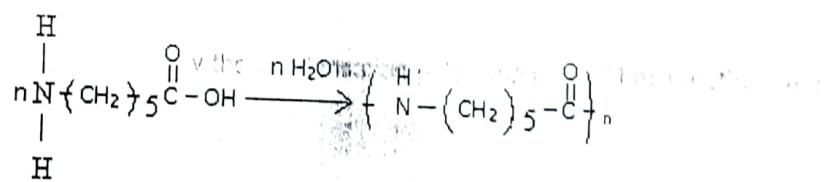
Nylon is a poly amide resin consists of amide group produced by condensation polymerization of diamine with di-acid. The Nylon has been named on the basis of the number of carbon atoms in the monomer chain.

Ex: Nylon 6:6, Nylon 6:10, Nylon 6, Nylon 11 etc..... where the first number indicates that the number of carbon atoms in diamine and the second number indicates that number of carbon atoms in diacid

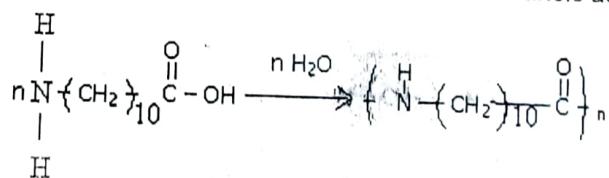
a) Nylon 6:6: Nylon 6:6 is produced by the condensation polymerization of hexa methylene di-amine with adipic acid.



b) Nylon 6: It is produced by the self condensation of α -amino caproic acid (α – amino hexanoic acid).



c) Nylon 11: It is made by self – condensation of ω – amino uni decanoic acid.



Properties:

- It show plastic and fibre property
- Insoluble in common solvent and soluble in pharmitic acid and phenol
- Posses high strength and high melting point ($160 - 264^\circ\text{C}$)
- They absorb little moisture
- Possess resistance to environmental conditions and chemicals.
- They are good electrical insulators.

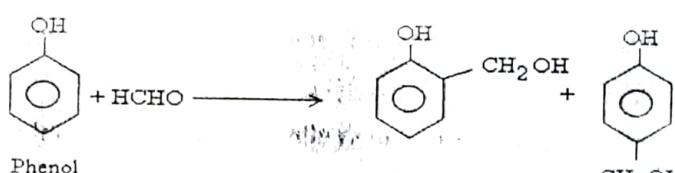
Applications:

- Nylon 6:6 is used as fiber for making socks, dresses, lady's hoses, carpets, under garments etc..... (i.e., Used in textile industry)
- Nylon 6 and Nylon 11 are mainly used for moulding purposes of gears and bearings etc.....
- They are also used for making filaments, films, Tire cords, bristles for tooth brushes etc.....

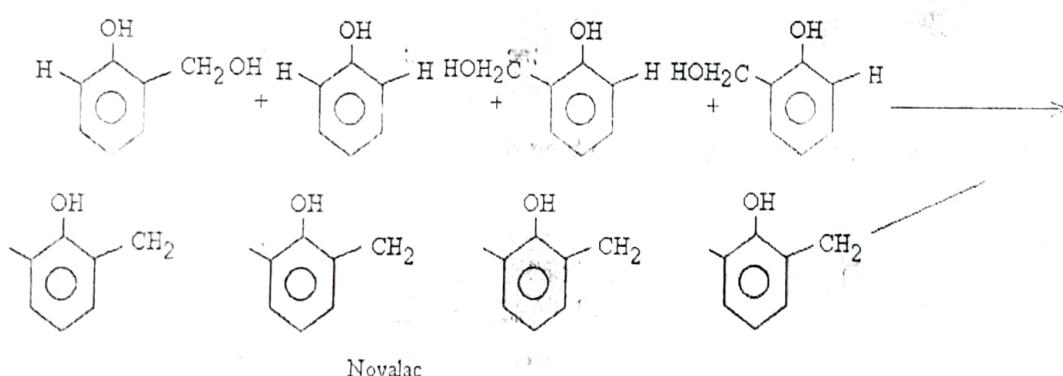
BAKELITE: (Phenol formaldehyde resin / phenolic resin / phenoplasts)

- Bakelite is an important thermosetting resin named after the scientist Bakeland, who synthesized this resin in the year 1909.
- It is prepared by the step polymerization of phenol with formaldehyde in presence of an acid (or) Alkali as a catalyst.
- This polymerization takes place in three steps:

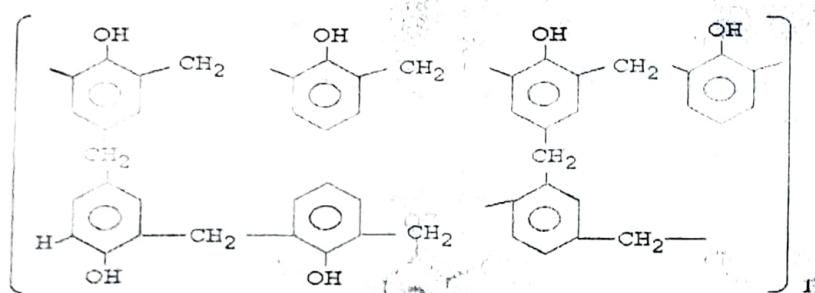
Step I: Phenol can condense with formaldehyde to produce O – hydroxy methyl phenol and P – hydroxy methyl phenol



Step II: condensation takes place between O – hydroxy methyl phenol and phenol to give linear polymer, called Novalac



Step III: During molding, Hexa methylene tetraamine ($(\text{CH}_2)_6 \text{N}_4$) is added, it produces formaldehyde and ammonia. Formaldehyde converts the soluble and fusible Novalac into a hard infusible and insoluble solid of cross – linked structure called Bakelite, whereas NH_3 neutralizes the acid.



Properties:

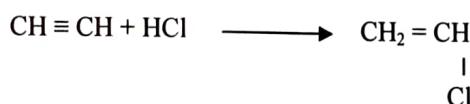
- * Bakelites are rigid, hard, scratch resistant, infusible, water resistant, solid substance.
- * Resistant to acids, salts and most organic solvents but attacked by alkali due to the presence of hydroxyl groups.
- * Good electrical insulator

Applications:

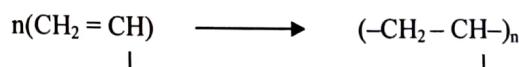
- * For making electric insulator parts like switches, plugs, holders, switch boards, heater etc.....
- * For making moulded article like telephone parts, cabinets for radio and T.V.
- * Used in paints and varnishes
- * as adhesives for grinding and wheels.
- * In the product of ion exchange resin
- * For making bearings used in propeller shops, for paper industry and Rolling mills.

4. Poly Vinyl Chloride (PVC):

Preparation: Vinyl chloride is used as monomer for the manufacture of polyvinyl chloride. Vinyl chloride is prepared by reacting acetylene with hydrogen chloride at 100-150°C in the presence of metal salt catalyst.



PVC is prepared by heating a water- emulsion of vinyl chloride in presence of Benzoyl Peroxide in a autoclave under pressure.



Properties:

- PVC is colorless and odorless Powder.
- It is non-inflammable and chemically inert.
- It is soluble in chlorinated hydrocarbons like ethyl chloride, etc. and ketones.
- It has high resistance to light, inorganic acids, alkalis, and atmospheric oxygen.

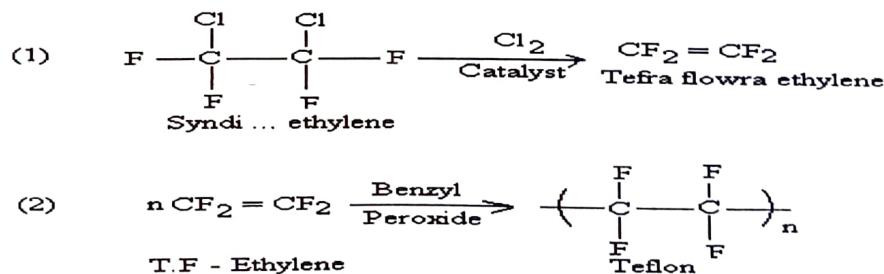
Uses:

- Plasticized PVC is used for making table cloths, rain coats, coatings for electric wire and cables, toilet articles, radio, T.V components, pipes, coupling valves, etc.
- Un-plasticized PVC or rigid PVC is used for making refrigerator components, cycle and motor cycle mudguards, tubes, pipes, etc.

5. Teflon: (Fluon / Poly Tetra Flouro Ethylene): $(-\text{CF}_2 - \text{CF}_2-)_n$

Teflon is obtained by the polymerization of water emulsion of Tetra fluoro ethylene in the presence of benzoyl peroxide as catalyst. The monomer Tetra fluoro ethylene is obtained by de-chlorination of syn-dichloro tetra fluoro ethane in presence of catalyst.

Preparation:



Properties:

- It is a thermo plastic resin.
- Having high melting point – 330°C
- High density – 2.1 to 2.3 gm / CC
- Highly resin – 93 to 98%
- High chemical resistance
- Good electrical and mechanical properties
- Not soluble in any solvent

Applications:

- For insulation of motors, generators, capacitors, transformers etc.....
 - Used in making stop cocks for burettes, non-lubricating bearings, gaskets, pump parts etc.....
- Used for coating on articles like bakery trays, frying pans etc.....

Carbon fibres

- carbon fibres (alternatively cf, graphite fiber or graphite fibre) are fibers about 5-10 micrometres in diameter and composed mostly of carbon atoms. Carbon fibres are usually combined with other materials to form a composite.
- when carbon-reinforced fibre impregnated with a plastic & s and dried it forms carbon-fibre-reinforced polymer.
- Carbon fibres are also composited with other materials, such as graphite, to form reinforced carbon-carbon composites, which have a very high heat resistant.
- Carbon fibres have been described as -the fibers containing at least 90% carbon obtained by the controlled pyrolysis of appropriate fibres.

Preparation:-

- Majority of carbon fibres are synthesized from the polyacryl-nitrile (PAN) method. Alternatively, a small amount (about 10 percent) are manufactured from rayon or the petroleum pitch process.
- The synthesis of carbon-fibres involves two kinds of process like chemical and mechanical in nature.

Spinning:-

- Acrylonitrile ($\text{CH}_2=\text{CH}-\text{C}\equiv\text{N}$) plastic powder is mixed with another plastic, like methyl acrylate or methyl methacrylate (MMA), and is reacted with a catalyst in a conventional suspension/solution polymerization process to form a polyacrylonitrile plastic.
- The plastic is mixed with certain chemicals and pumped through tiny jets into a chemical bath or quench chamber in which the plastic coagulates and solidifies into fibres.
- The spinning step is important because the internal atomic structure of the fibres is formed during this process.
- The formed fibres are then cleaned and stretched to the suitable fiber diameters.

Stability:-

- Before the fibers are carbonized, they need to be chemically altered to convert their linear atomic structure to a more thermally stable branched structure.
- This is achieved by heating the fibers in air to about 200-300°C for 30-120 minutes. As a result, the fibers interact with oxygen molecules from the air, and rearrange their atomic bonding skeleton.

Carbonizing:-

- Once the fibers are stabilized, they are heated to a temperature of about 1,000- 3,000°C for several minutes in a furnace filled with a gas mixture that does not contain oxygen, which prevents the fibres from burning in the very high temperatures.
- The gas pressure inside the furnace is maintained at higher than the outside atmospheric pressure and the points where the fibres enter and exit in the furnace are sealed to avoid oxygen to enter.
- As the fibers are heated, they begin to lose their non-carbon atoms, plus a few carbon atoms, in the furnace are sealed to avoid in the form of various gases such as water vapour, ammonia, carbon monoxide, carbon dioxide, hydrogen, nitrogen, and others.
- As the non-carbon atoms are expelled the remaining carbon atoms from tightly bonded carbon crystals that are aligned more or less parallel to the long axis of the fibre.

Treating the surface:-

- After the carbonizing, the fibers have a surface that does not react with the epoxies and other materials that are used in the preparation of composite materials.

- To give the fibers better bonding properties, their surface is slightly oxidized.
- The addition of oxygen atoms to the surface of fibre provides better chemical bonding properties and also etches and roughens the surface for better mechanical bonding properties.
- Oxidation is carried out by submerging the fibers in different gases like air, carbon dioxide (CO_2), ozone, or in various liquids such as sodium hypochlorite or nitric acid.

Sizing :-

- After the surface treatment, the fibers are coated to protect them from damage during winding or weaving and process is called sizing.
- Coating materials are opted which is compatible with the adhesive employed to form composite materials.

Properties of carbon fibers :

1. It has low density, high specific strength and stiffness.
2. Carbon fibres have excellent chemical stability (except in highly oxidizing environments).
3. They have excellent fatigue, low coefficient of thermal expansion and creep behaviour.
4. The highest grade carbon fiber with the best modulus properties are used in demanding applications like aerospace.

RUBBER (ELASTOMERS):

- The polymers which possess the property of elasticity are called as rubber.
- Rubbers are high polymers, which have elastic properties in excess of 300%.
- The molecular weight of raw rubber is about 1,00,000 to 1,50,000 Daltons.
- Most of the Indian production comes from Kerala state.

Natural rubber: It is a high polymer of polyisoprene, which are arranged in Cis – Configuration (functional groups are arranged on the same side).



Natural rubber is mainly produced from the milk of the rubber tree "Hevea brasiliensis".

Small quantities of natural rubber is also produced from the milk of a shrub known as "guayule".

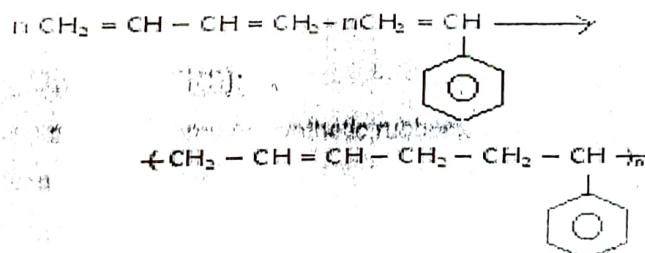
SYNTHETIC RUBBER: (ELASTOMERS):

The following rubbers are considered as synthetic rubbers.

1. Buna – S - Rubber
2. Buna – N – Rubber
3. Polyurethane rubber
4. Silicone rubber

1. Buna – S / Styrene / GR – S rubber:

Preparation: It is prepared by copolymerization of 1, 3 – butadiene and styrene.



Properties:

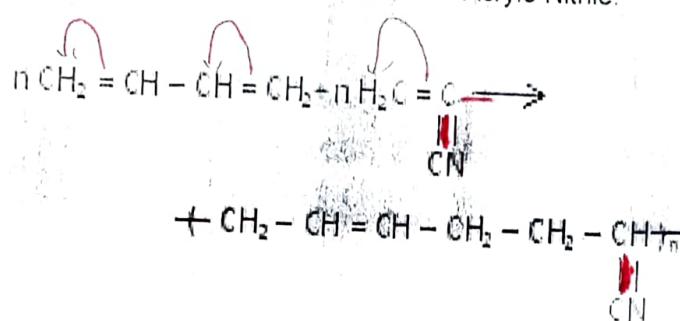
- a) It has high abrasion resistance and high load bearing capacity
- b) Easily oxidized in presence of ozone
- c) It swells in oils and organic solvents
- d) Its Vulcanization process is similar to natural rubber.

Applications / Uses:

1. It is mainly used for manufacture of tyres.
2. It is also used for floor tiles, shoe soles, gaskets, wire and cable insulations, Tank linings etc.....

2. Buna - N / Nitrile rubber / GR - A rubber:

It is formed by copolymerization of 1, 3 butadiene and Acrylo Nitrile.



Properties:

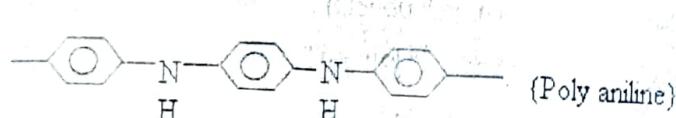
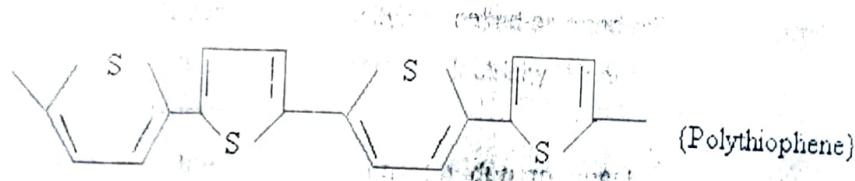
- It can be vulcanized in same way as natural rubber.
- It has good oil resistance, heat resistance and abrasion resistance
- It is attacked by alkalis, due to presence of cyano groups.

Uses: making air craft components, conveyor belts, tank linings, gaskets, hoses, printing rollers, automobile parts etc.

CONDUCTING POLYMERS:

- The polymers which conduct electricity are called as conducting polymers.
- Usually polymers are poor conductors of electricity. Hence, act as good electrical insulators due to non-availability of electrons.
- The conduction of the polymers may be due to unsaturation or by the addition of chemical ingredients such as copper, silver, etc.....(Conducting elements / metals).

Ex: Poly acetylene, poly aniline, polythiophene etc.....



CLASSIFICATION:

Conducting polymers are classified in to two

1. Intrinsically conducting polymers
2. Extrinsically conducting polymers

1. Intrinsically conducting polymers: The conjugation of double bond present in the structure is responsible for conductance. Intrinsic again be classified in to two types.

- (i) π -electrons conducting polymers
- (ii) Doped conducting polymers

(i) π -electrons conducting polymers: Conductance is due to π -electrons present on the polymer back bone chain

Ex: Poly acetylene

(ii) Doped conducting polymers: Conductance is due to positive (or) Negative charges present in the polymer back bone

Ex: Poly Napthalene

2. Extrinsically conducting polymers: Added ingredients are responsible for conductance. It is of two types

1. Conducting element filled polymer
2. Blended Conducting polymer

(i) Conducting element filled polymer:

Polymer holds (or) binds the conducting element such as metal oxide, metallic fibres and carbon black

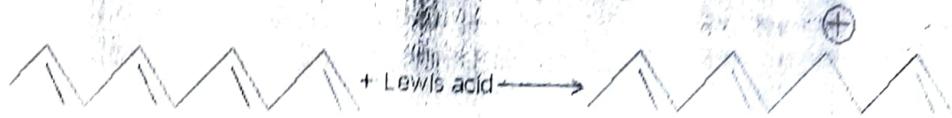
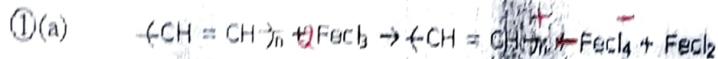
(ii) Blended Conducting polymer

These are made by blending (mixing) a conventional polymer with a conducting polymer.

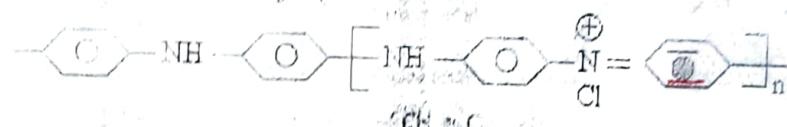
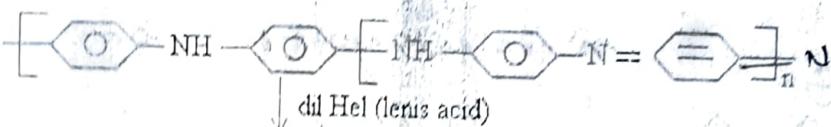
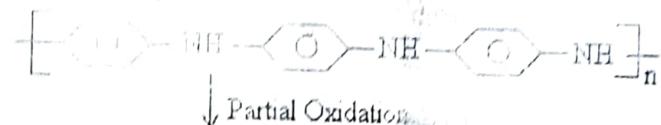
Preparation of Doped conducting polymers:

- The conducting polymers having π -electrons in their back bone can easily be oxidized (or) reduced because they possess low ionization potential and high electron affinity
- Hence their conductance can be increased by introducing a positive or negative charge on polymer back bone by oxidation (or) reduction
- This synthetic process is called as Doping
- Doping are of two types
 1. P - doping
 2. n - doping

1. P - doping: It is done by oxidation of conducting polymers like polyacetylene with Lewis acid (electron pair acceptor) or Iodine or Bromine vapors. By oxidation, a positive charge is created on polymer back bone.

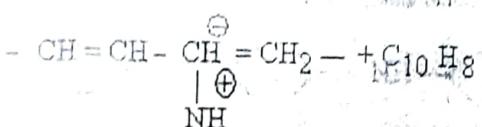
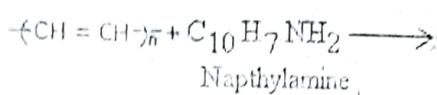
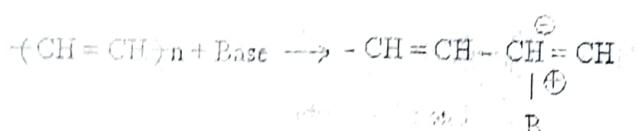


② Poly aniline



conducting polymer

2. n - doping: It is carried out by reduction process by the addition of Lewis base (electron pair donor) thereby negative sites are created on polymer back bone which are responsible for conductance. Commonly used n-dopants are Lithium, Na, Ca, Tetra butyl ammonium etc.



Applications:

- Used in solar cells
- In photo voltaic devices
- In non-linear optical materials
- In Tele communication systems.

- As electrode material for commercial rechargeable batteries
- In antistatic (not for charge) coatings for clothing
- As film membranes for gas separations
- In wiring, in Aircrafts and air space components
- In fuel cells as the electro catalytic material.

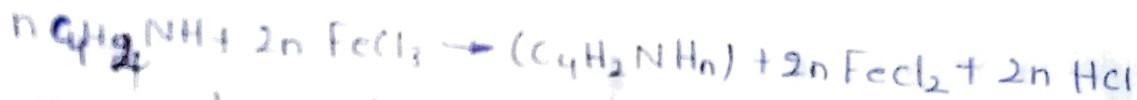
Poly Pyrroles : (PPy)



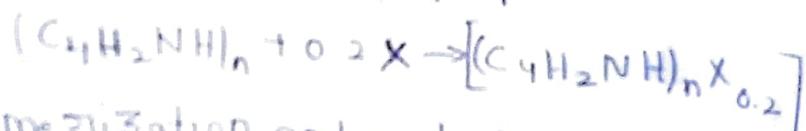
This is a type of organic polymer formed by the polymerization of pyrrole. It is a solid with the chemical formula of $\text{H}_2\text{C}(\text{CH}_2\text{NH})_n$. On oxidation poly Pyrrole converts to a conducting polymer.

Pyrrole can be polymerized electrochemically and form polypyrrrole.

Synthesis of polyPyrrrole
Poly Pyrrole is Prepared by oxidation of Pyrrole in presence of ferric chloride.



Conductive forms of polypyrrrole (PPy) are synthesised by oxidation ("p. doping") of the polymer



The polymerization and p-doping can be also be carried out electrochemically.

Properties:

- They are amorphous, showing only weak diffraction.
- PolyPyrrrole is designated as "quasi-one-dimensional" because one dimensional since there is some crosslinking and chain hopping.

3) PPy is an insulator, but its oxidized derivatives are good electrical conductors. The conductivity of the material depends on the conditions and reagents used in oxidation.

Application :-

1. Polypyrroles and its derivatives relative Conductive polymers have two main application in electronic devices and for Chemical Sensors.
2. Polypyrrole has been found to be as a catalyst Support for fuel Cells.
3. Polypyrrole has been Considered as a material for artificial muscles.
4. Polypyrrole was used in the microwave synthesis of multiwalled Carbon nanotubes, a fast method to produce Carbon Nano Tubes(CNT's)