

## Unit-III

### Polymeric Materials.

#### Syllabus:

Definition - Classification of Polymers with examples - Types of Polymerization - addition (free radical addition) & condensation Polymerization with examples - Nylon 6,6, Terylene.

Plastics: Definition & Characteristics - Thermoplastic & thermosetting Plastics, Preparation, Properties & engineering applications of PVC & Bakelite, Teflon, fibre reinforced plastics (FRP).

Rubbers: Natural rubbers & its vulcanization

Elastomers: Characteristics - Preparation - Properties & applications of Buna-S, Butyl & Thiokol rubber.

conducting Polymers: Characteristics & Classification with examples - mechanism of Conduction in trans-Polyacetylene & Applications of conducting Polymers.

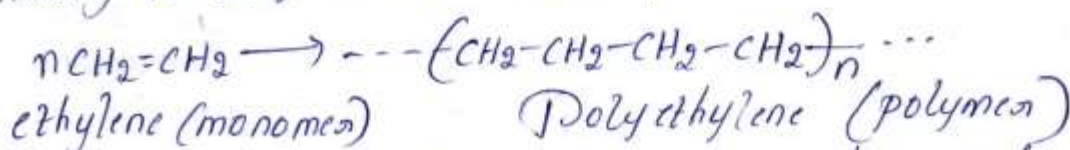
Biodegradable Polymers: Concept & advantages - Polylactic acid & Polyvinyl alcohol & their applications.

#### 1. Polymers:

The word Polymer is derived from Greek words "poly" means "many" & "mer" means "unit" or "part".

→ Polymers are macromolecules (giant molecules of high molecular weight) formed by the repeated linkage of large number of small molecules called monomers.

eg: Polyethylene is a Polymer formed by the repeated linking of large number of ethylene molecule.

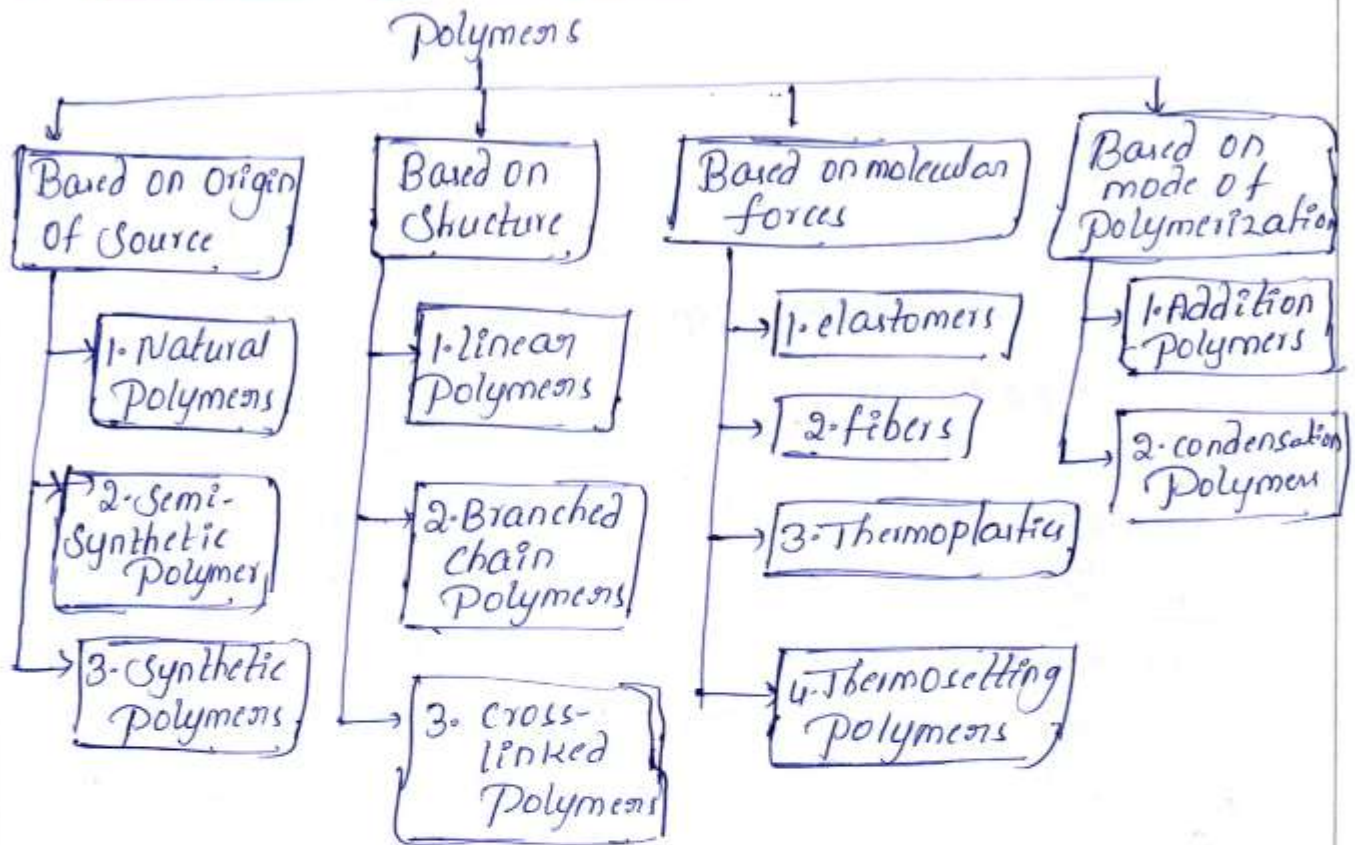


→ Polymers are widely used in automobiles, defence, electrical goods & computer components etc.



Monomer: Monomer is a micro molecule (small molecule) which combines with each other to form a Polymer.

## \* Classification of Polymers:



### 1. Based on Origin of Source.

#### a) Natural Polymers

They occur naturally & are found in plants & animals.

eg: cellulose, proteins, Starch, rubber.

#### b) Semisynthetic Polymers

They are derived from naturally occurring Polymers & undergo further chemical modification

eg: cellulose, nitrate & Cellulose acetate.

#### 3. Synthetic Polymers

These are man-made Polymers. Plastic is the most common & widely used Synthetic polymer. It is used in industries & various daily products eg: nylon 6, 6, Polyether's etc.



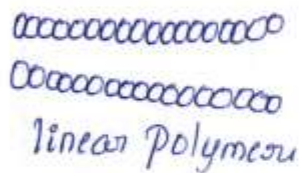
## 2. classification of Polymers based on Structure:

### linear polymers

The structure of polymer containing long & straight chain falls into this category.

eg: PVC → Polyvinyl chloride

→ PVC → used for making pipes & electrical cables.



### branched-chain polymers

When linear chains of a polymer form branches, then such polymers are categorized as branched chain polymers.

eg: low density Polythene

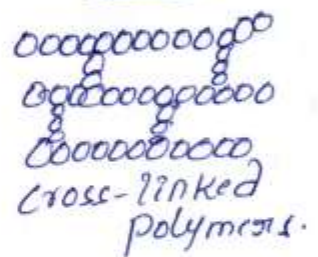


### Cross-linked polymers

They are composed of bifunctional & trifunctional monomers.

→ They have a stronger covalent bond in comparison to other linear polymers.

eg: Bakelite & melamine



## 3. classification based on molecular forces

### Elastomers

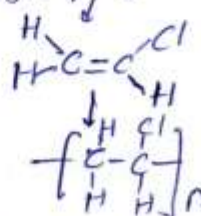
These are rubber-like solids weak interaction forces are present.  
eg: natural rubbers, Styrene-butadiene block copolymers etc.

### Fibres

These are strong, tough high tensile strength & strong forces of interaction are present.  
eg: nylon 6,6

### Thermoplastics

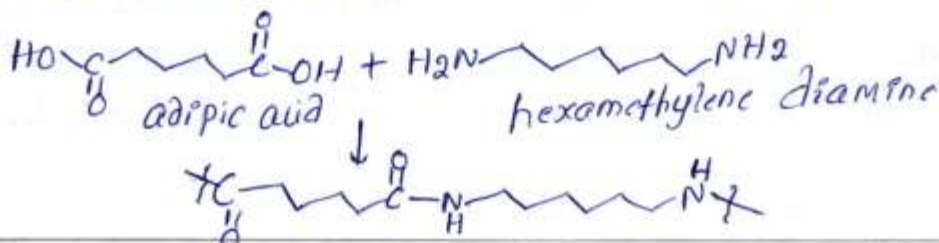
These have intermediate forces of attraction.  
eg: PVC



### Thermosetting polymers

These polymers greatly improve the material's mechanical properties.  
→ It provides enhanced chemical & heat resistance.  
eg: Phenolic, Silicones

Nylon 6,6 → adipic acid + hexamethylene diamine





## 4. classification based on mode of polymerization

### addition Polymerization

(or)

Chain growth Polymerization

The formation of addition Polymer occurs by the repeated addition of monomer molecules which possess triple or double bond

eg: Polypropene  $(C_3H_6)_n$  from Propene  $(C_3H_6)$

### condensation Polymerization

(or)

Step-wise Polymerization

The formation of condensation Polymers occurs by the repeated condensation reaction b/w two different tri-functional or bi-functional monomeric units.

→ In this type of reaction, small molecules such as alcohol, water, HCl are eliminate

ex: Nylon 6,6, nylon 6.

## \* Polymerisation:

Polymerisation is a process in which large number of small molecules (called monomers) combine to give a big molecule (called a polymer) with or without elimination of small molecules like water.

### Degree of Polymerisation:

The number of repeating units ( $n$ ) in a polymer chain is known as degree of polymerisation. It is represented by the following relationship:

$$\text{Degree of Polymerisation (DP)} = \frac{\text{molecular weight of the polymeric network}}{\text{molecular weight of the repeating unit}}$$

eg:  $5 CH_2=CH_2 \rightarrow -CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$   
It has five repeating units are present in the polymer chain. So, the degree of polymerisation is 5.

### Oligomers:

Polymers with low degree of polymerization are known as Oligomers.

→ Their molecular weight ranges from 500-5000

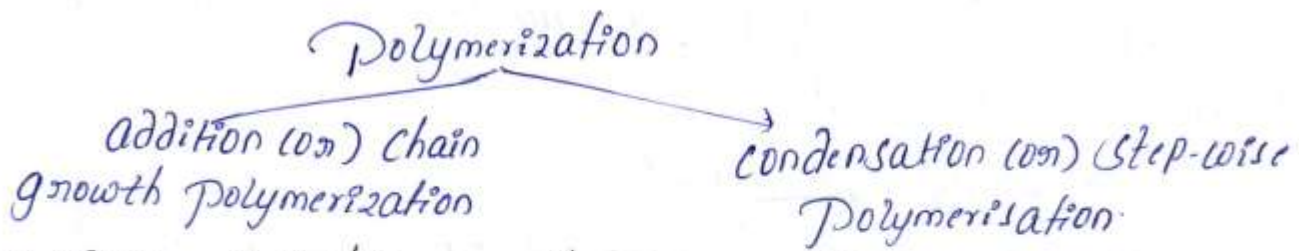
### High Polymers:

Polymers with high degree of polymerization are known as high Polymers.

→ Their molecular weight ranges from 10,000-2,00,000.



## \* Types of Polymerization

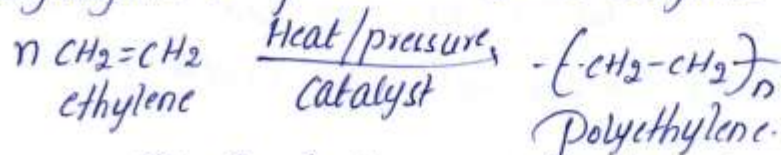


### a) Addition (or) chain growth Polymerisation:

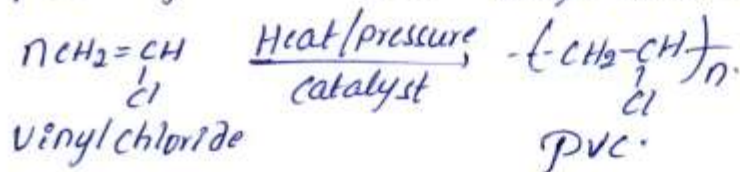
It is a reaction that yields a polymer, which is an exact multiple of the original monomeric molecule. The original monomeric molecule, usually, contains one (or) more double bonds.

→ In this addition Polymerization there is no elimination of any molecule.

ex: 1. Polyethylene is produced from ethylene



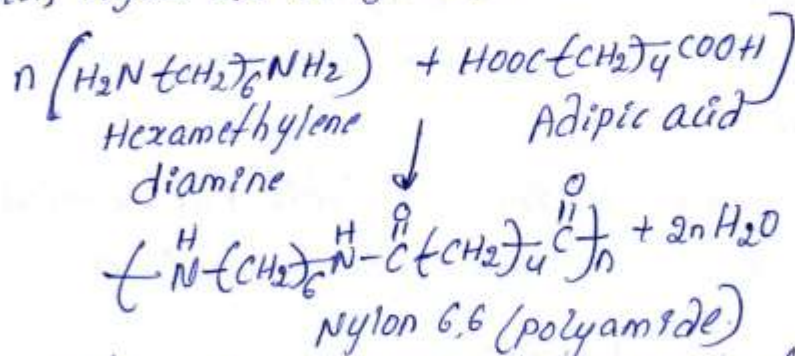
2. PVC is produced from vinyl chloride.



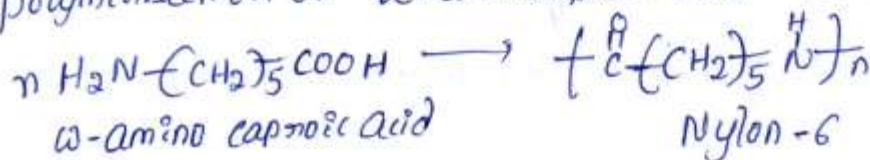
### b) Condensation (or) step-growth Polymerization:

It is a reaction b/w simple polar groups containing monomers with the formation of polymer & elimination of small molecules like  $\text{H}_2\text{O}$ ,  $\text{HCl}$  etc.

ex: 1. Hexamethylene diamine & adipic acid condense to form a polymer, Nylon 6,6 (polyamide).



2. Polymerisation of  $\omega$ -aminocaproic acid to form Nylon-6.





In some cases condensation Polymerisation takes place without the elimination of small molecules like  $H_2O$ ,  $HCl$  etc. but by just the opening of cyclic compounds.

### \* Mechanism of addition Polymerisation:

#### a) free radical mechanism (or) free radical Polymerisation:

free radical Polymerisation occurs in three major steps:

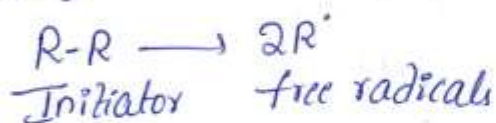
1. Initiation    2. Propagation    3. Termination

##### 1. Initiation:

Initiation involves two reactions

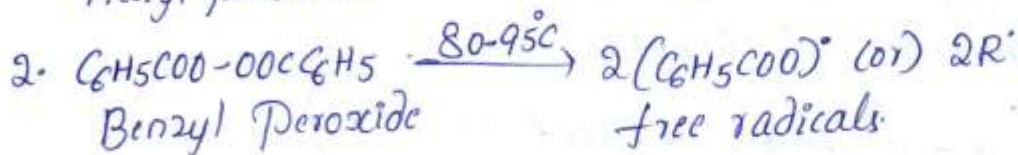
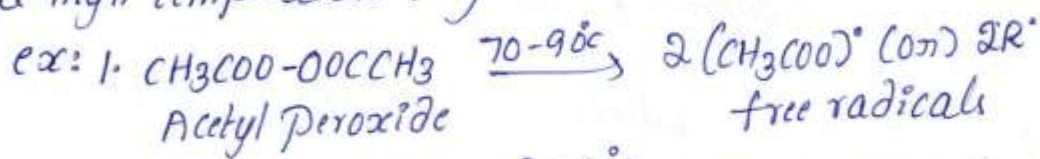
##### a) first reaction:

first reaction involves production of free radicals by homolytic dissociation of an initiator (or catalyst) to yield a pair of free radicals ( $R^\cdot$ ).



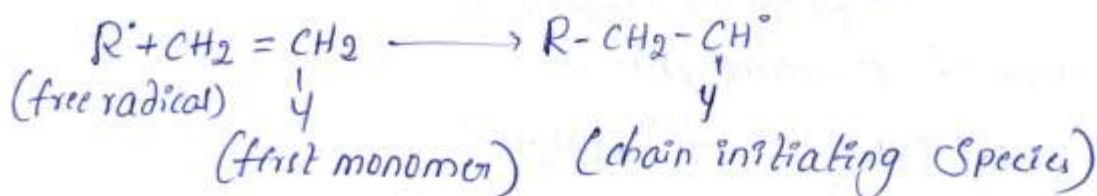
##### Initiators:

Initiators are compounds which produce free radicals by the homolytic dissociation. If the homolytic dissociation is carried out at high temperature they are called thermal initiators.



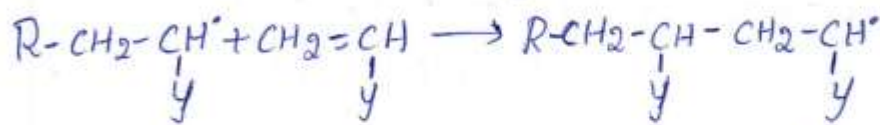
##### b) Second reaction:

Second reaction involves addition of this free radical to the first monomer to produce chain initiating species.



## 2. Propagation

It involves the growth of chain initiating species by the successive addition of large number of monomers



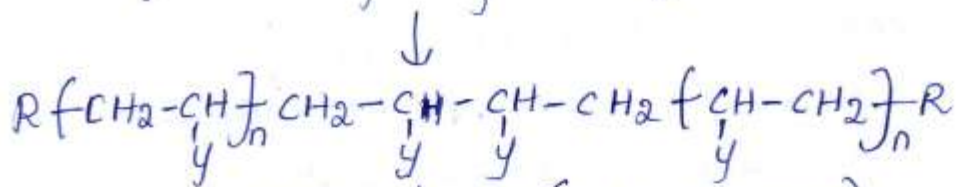
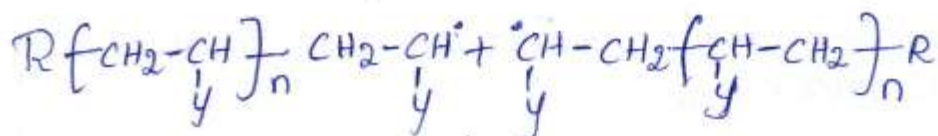
Growing chain.

## 3. Termination:

Termination of the growing chain of the polymer occurs either by coupling reaction or disproportionation.

### a) coupling (or) combination:

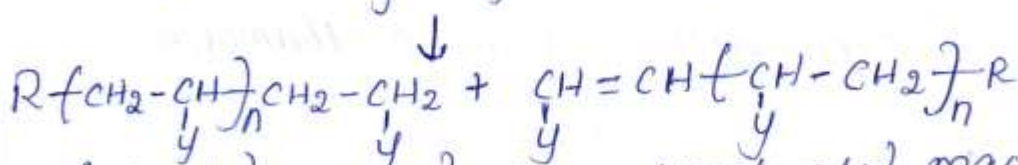
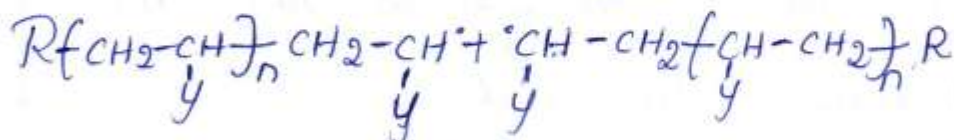
It involves coupling of free radical of one chain end to another free radical to form macromolecule (dead polymer).



Macromolecule (Dead Polymer)

### b) disproportionation:

It involves transfer of a hydrogen atom of one radical centre to another radical centre forming two macromolecules, one saturated & another unsaturated.



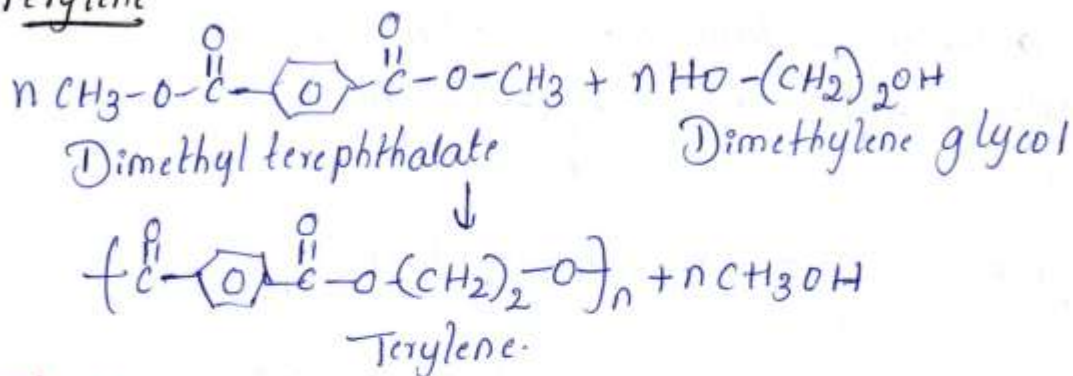
Saturated macromolecule      unsaturated macromolecule  
(Dead Polymers)

→ The product of addition polymerisation is known as Dead Polymers



## \* Condensation Polymerisation

### Terylene



## \* Plastics:

Def: Plastics are high molecular weight Organic materials, that can be moulded into any desired shape by the application of heat & Pressure in the presence of a catalyst.

### Characteristics of Plastics:

- Plastics are characterised by light weight, good thermal, & electrical insulation, Corrosion resistance.
- plastics are chemical inertness, adhesiveness.
- Plastics are easy workability, low-fabrication cost
- High abrasion resistance, dimensional stability.
- Strength toughness & impermeability to water

### Plastics

#### Thermoplastics

#### Thermosetting Plastics

Resin :- Resin is a binding material, Present in Plastics, which undergoes Polymerization reaction during moulding.

Resins → 1. Thermoplastic resins

2. Thermosetting resins or Thermosets

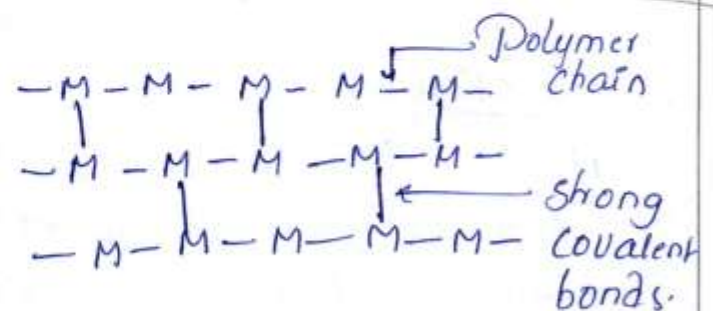
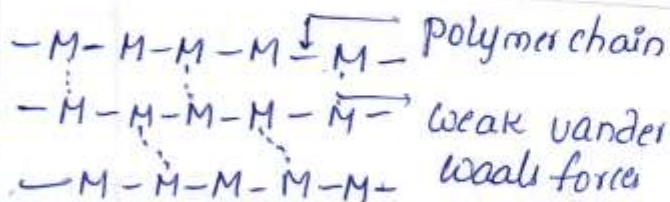


# Differences between Thermoplastic & Thermosetting resins

## Thermoplastic resins

## Thermosetting resins

- |   |  |
|---|--|
| 1. They are formed by addition Polymerisation                           | 1. They are formed by condensation Polymerisation.             |
| 2. They consists of linear long chain Polymers                          | 2. They consists of three dimensional network Structure.       |
| 3. All the Polymer chains are held together by weak Vander Waals forces | 3. All the Polymer chains are linked by strong covalent bonds. |
| 4. They are weak, soft and less brittle.                                | 4. They are strong, hard and more brittle.                     |
| 5. They soften on heating and harden on cooling                         | 5. They do not soften on heating                               |
| 6. They can be remoulded.   | 6. They cannot be remoulded.                                   |
| 7. They have low molecular weights                                      | 7. They have high molecular weights                            |
| 8. They are Soluble in organic Solvents.                                | 8. They are insoluble in organic Solvents.                     |
| 9. The resin is Synonymous with Plastics                                | 9. Resin is not Synonymous with plastics.                      |
| 10. ex: Polyethylene, PVC etc.  | 10. ex: Bakelite, urea formaldehyde resin etc.                 |





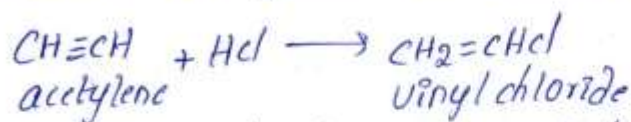
## \* Preparation, Properties, engineering applications of plastics

### 1. PVC (poly vinyl chloride)

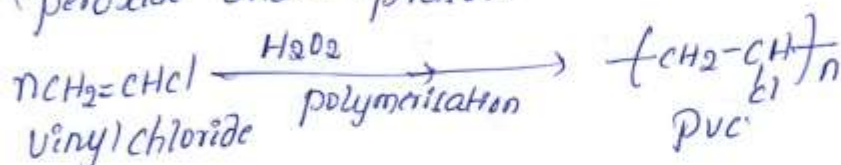
#### Preparation:

Preparation of PVC involves the following two steps.

Step:1 Vinyl chloride is prepared by treating acetylene with HCl at 60-80°C in the presence of metal chloride as catalyst.



Step:2 Polyvinyl chloride is obtained by heating water emulsion of vinyl chloride in presence of benzoyl peroxide (or) hydrogen peroxide under pressure.



#### Properties:

- i) PVC is colourless, odourless & chemically inert powder.
- ii) It is insoluble in inorganic (solid) acids & alkalis, but soluble in hot chlorinated hydrocarbons such as ethyl chloride.
- iii) It undergoes degradation in presence of heat (or) light.

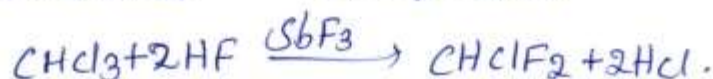
#### Applications:

- i) It is used in the production of pipes, cable insulation, table covers, rain coats etc.
- ii) It is also used for making sheets, which are employed for tank-linings, light fittings, refrigerator components etc.

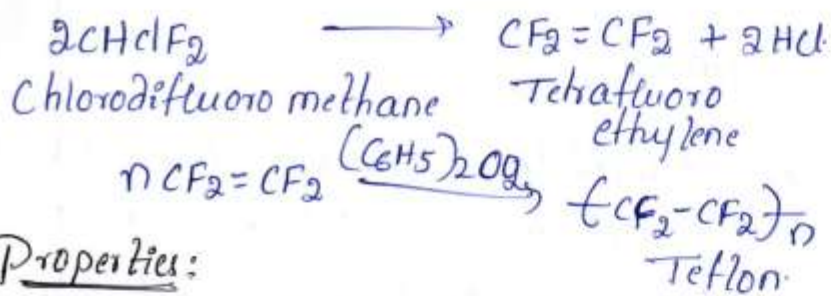
### 2. Teflon (or) fluoron (or) Poly tetra fluoroethylene (PTFE)

#### Preparation:

Teflon is obtained by polymerization of water-emulsion of tetrafluoroethylene in presence of benzoyl peroxide under pressure.







### Properties:

- Teflon is extremely tough, flexible material possessing high softening point (about  $350^\circ\text{C}$ )
- It possesses extremely good electrical & mechanical properties
- It is chemically resistant towards all chemicals (except hot alkali metal & hot fluorine).
- It has an excellent thermal stability.

### Applications

- It is used as a very good electrical insulating material in motors, cables, transformers, electrical fittings.
- It is also used for making gaskets, packings, pump parts, tank linings etc.
- It is also used for making non-lubricating bearings, chemical carrying pipes etc.
- It is used in making non-sticking stop cocks for burettes.

### 3- Bakelite (or) Phenolic resin:

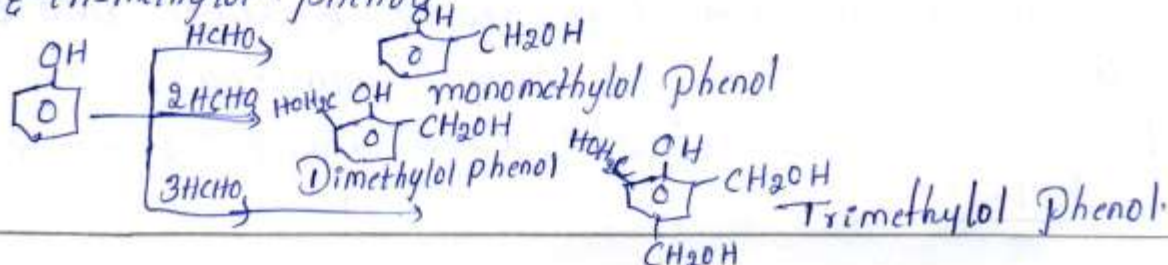
It is obtained by the condensation polymerisation of Phenol & formaldehyde in the presence of acid or alkali catalyst.

### Preparation:

The reaction involves the following 3 steps

#### Step-1: Methylation:

The first step is the reaction b/w Phenol & formaldehyde, forms mono, di & tri-methylol Phenol.

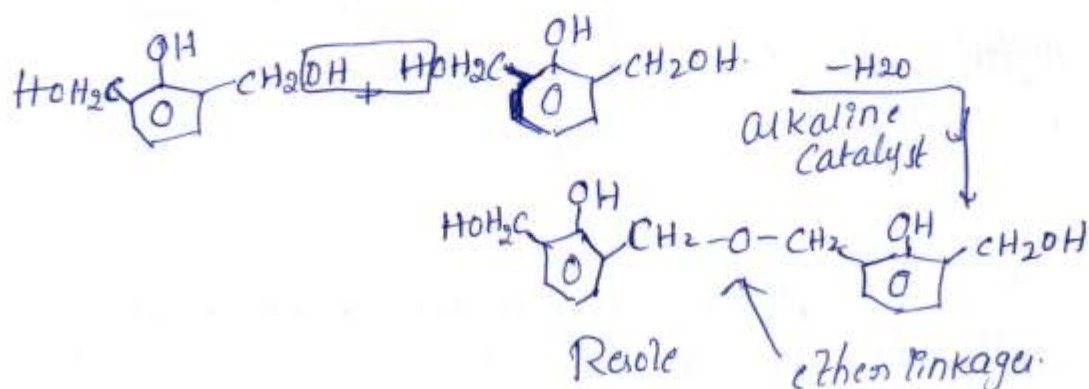
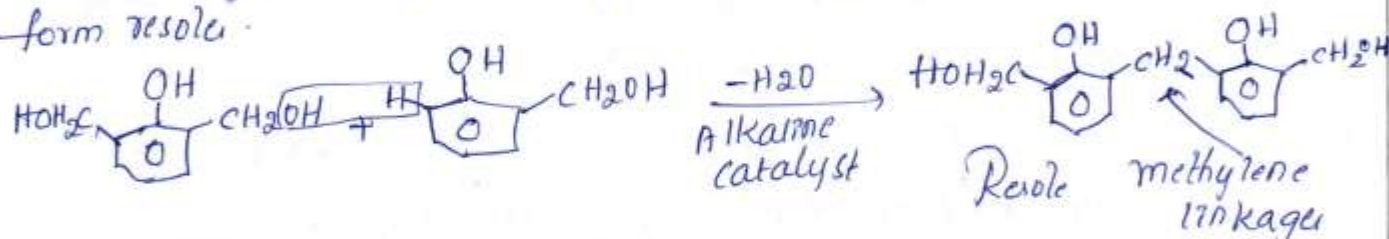




## Step-II

### i) formation of A-stage resin (Resole)

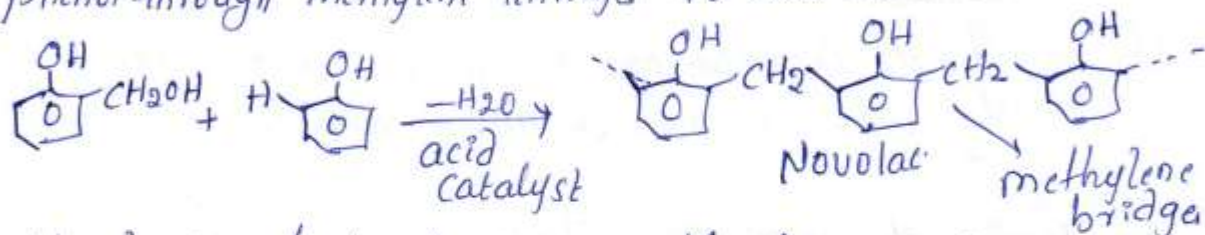
When methylol Phenols are heated with the excess of formaldehyde in presence of alkaline catalyst. The methylol Phenols condense either through methylene linkages or through ether linkages to form resole.



Resole is a low molecular weight linear Polymer. It is completely Soluble in alkaline Solution.

### ii) formation of B-stage resin (Novolac or Resitol):

When methylol phenols are heated with excess of Phenol in presence of acid catalyst, the methylol Phenols condense with Phenol through methylene linkages to form novolac.

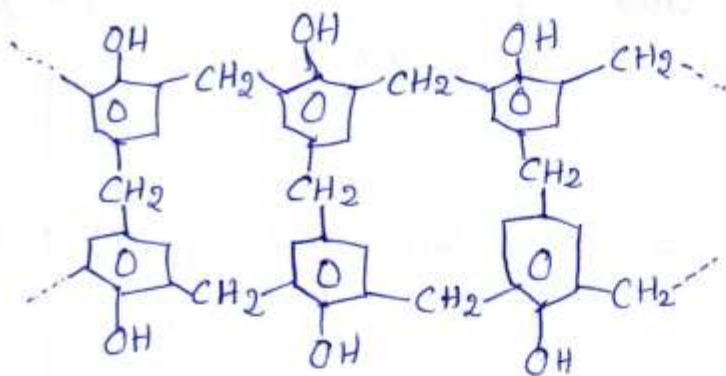


Novolac is a high molecular weight linear Polymer. It is insoluble in alkaline Solutions.

## Step-III: Production of C-stage resin

Further heating of A-stage resin or B-stage resin or both in the presence of a curing agent (hexamethylene tetramine) produces hard, rigid, infusible, cross linked Polymer called- Bakelite





Bakelite.

Properties:

- i) Bakelite is resistant to acids, salts & most Organic Solvents, but it is attacked by alkalis because of the Presence of -OH groups.
- ii) It possesses excellent electrical insulating Property.

Applications

- i) Bakelite is used as an adhesive in Plywood lamination & in grinding wheels etc.
- ii) It is also widely used in paints, varnishes.
- iii) It is used for making electrical insulator parts like Plugs, Switches, heater handles etc.

4) Fibre reinforced Plastics (FRP)

The fibre reinforced Plastics composite constitute more than 90% (by weight) of the total composites used in various industries.

→ The advantages of using Polymer in Structural composite is the ease of fabrication of complex Structural shapes. It can be easily manufactured.

Preparation:

→ fibre reinforced Plastics are Produced by suitably bonding a fibre material with a resin matrix & curing them under pressure and heat.

→ The main reinforcing agents used in FRP Composites are glass, Graphite, alumina, Carbon, boron etc.

→ The reinforcement material can be in different forms such as Short fibres, continuous filaments or woven fabrics.



→ The resin matrix commonly used in FRP are polyester, epoxy, Phenolic, Silicone & Polyamide Polymer resins.

### Properties:

1. It possess Superior Properties like higher yield strength, fracture strength & fatigue life.
  2. Since fibre prevents slip & crack propagation, the mechanical properties of FRP gets increased.
  3. It possess high corrosion resistance & heat resistance property.
- The Properties of FRP mainly depends on nature of the resin matrix.

S.No	Resin	Reason
1.	Polyester resin	To Provide very good strength & mechanical Properties
2	Epoxy resin	To impart good mechanical Properties.
3.	Silicone resins	To impart excellent thermal & electrical Properties
4.	Phenolic resins	To with stand high temperatures.
5	Thermoplastics (polyamide, PET etc)	Because of its repeatability & reparability.

### Applications:

S.No	Name of F.R.P	Properties	Applications
1.	Glass-FRP	i) Lower densities, dielectric constants ii) higher tensile strength & impact resistance iii) excellent corrosion resistance, chemical resistance, non-flammability	Automobile Parts, storage tanks, Plastic pipe, floorings, transportation industries etc.
2	Boron-FRP	i) excellent stiffness & compressive strength ii) manufacturing of B-FRP is difficult	Horizontal & vertical tail in aeroplane, stiffening spars, ribs etc.



3	Carbon-FRP	i) lighter density ii) excellent resistance to corrosion iii) Retention of desired properties even at elevated temperatures	Structural components of aircraft & helicopters, recreational equipment, sports materials, Antenna disc, solar panel etc.
4	Aramid-FRP	They are metal-like ductile & respond non-catastrophically to compressive stresses (because, capable of absorbing energy)	Structural component in aircraft, helicopter parts.
5	Alumina-FRP	Good abrasion resistance, creep resistance and dimensional stability	Components of engine parts in automobile industry, and components of turbine engine.

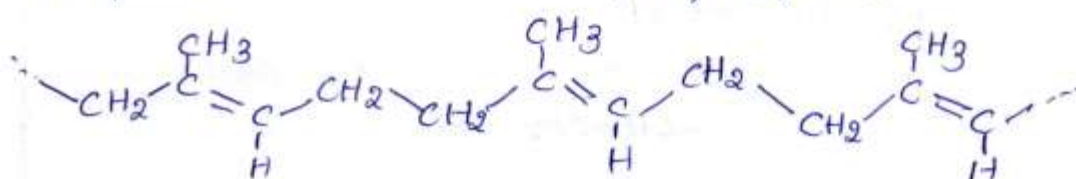
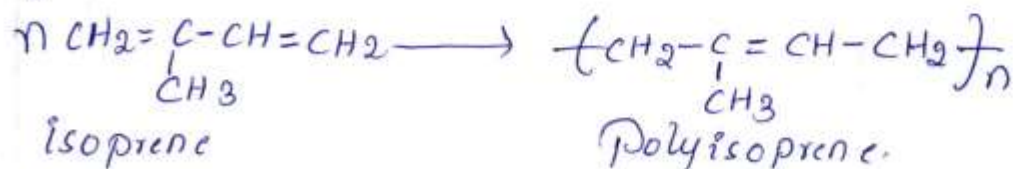
### \* Rubbers (or) Elastomers:

Def: Rubbers (or) elastomers are non-crystalline high polymers (linear polymers), having elastic & other rubber like properties.

#### 1. Natural rubbers:

Natural rubber is obtained from the tree as a latex, which is a dispersion of isoprene.

→ During the treatment of latex, these isoprene molecules undergo polymerisation to form long coiled chain of Polyisoprene.



cis form of Polyisoprene.



## \* Vulcanization of Rubber:

How to improve the Properties of rubber?

The Properties of rubber can be improved by compounding it with some chemicals like rubber, hydrogen Sulphide, benzoyl chloride etc. But most important addition is Sulphur.

Objective of Vulcanization:

Uncross-linked rubber products, such as natural rubber obtained from latex, are soft & have poor tensile strength & abrasion resistance.

→ To obtain a cross-linked structure of rubber, the process of vulcanization is made.

Process of Vulcanization:

The process of vulcanization consists of heating the raw rubber with Sulphur to about 100-140°C.

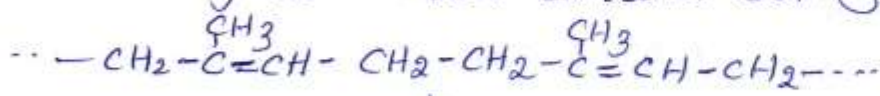
→ The added Sulphur combines chemically at the double bonds of different long chain rubber springs.

→ Thus the vulcanization prevents intermolecular movement of rubber springs.

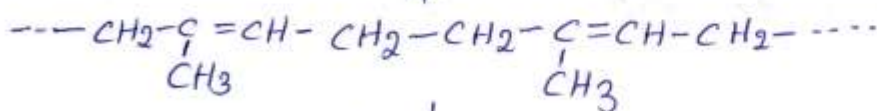
→ The extent of stiffness of vulcanized rubber depends on the amount of Sulphur added.

ex: i) Tyre rubber contains 3 to 5% Sulphur

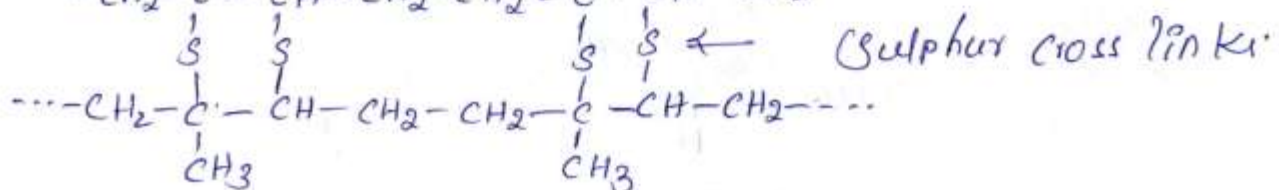
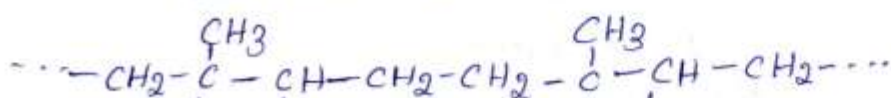
ii) Battery case rubber contains 30% Sulphur.



+



Vulcanization  $\downarrow$  + S  
100-140°C





## Advantages (or) Properties of Vulcanized rubber

### Comparison b/w raw & Vulcanized rubber.

S.No	Raw rubber	Vulcanized rubber.
1.	Tensile strength is low ( $200 \text{ kg/cm}^2$ )	Tensile strength is high ( $2000 \text{ kg/cm}^2$ )
2.	Water absorbing tendency is high	low water absorbing tendency
3.	Oxidation resistance low	Oxidation resistance is high.
4.	little durability	High durability
5.	low resistance to wear & tear	High resistance to wear & tear.
6.	It has <sup>high</sup> elongation (1200%)	It has moderate elongation (800%)
7.	The useful temperature range is $10-60^\circ\text{C}$ .	The useful temperature range is $40-100^\circ\text{C}$ .
8.	low resist <sup>n</sup> It is attacked by organic solvents	It is resistant to organic solvents

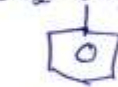
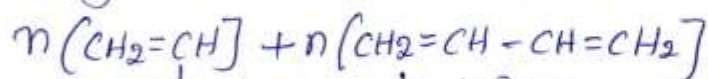
## \* Characteristics - Preparation - Properties & applications of elastomers

### 1. Buna-S: (or) SBR (Styrene-butadiene rubber).

SBR is the polymer of about 75% butadiene & 25% Styrene.

#### Preparation:

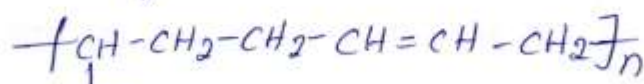
SBR is obtained by copolymerizing an aqueous emulsion of the mixture containing 75% butadiene, 25% Styrene & an emulsifying agent (Cumene hydroperoxide)



Styrene

butadiene

↓ Copolymerization



Styrene-butadiene rubber.



### Properties:

1. SBR is resistant to abrasion & possess high load bearing capacity.
2. It undergoes Oxidation readily, when traces of Ozone is present in the atmosphere.
3. It requires less Sulfur for vulcanization when compared to natural rubber.
4. Tensile strength & flexibility of SBR are inferior to those of natural rubber.

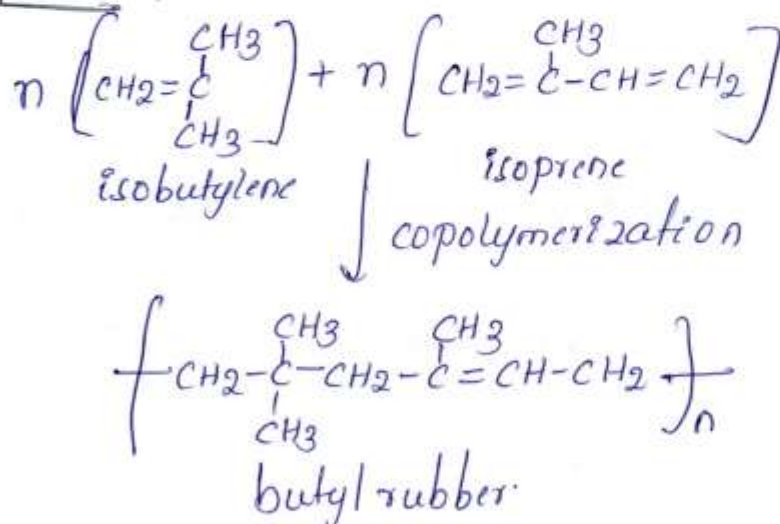
### Uses:

1. SBR is used for making light duty tyres, belts, hoses & gaskets.
2. It is also used in footwear industry.
3. It is also used as an adhesive & in electrical insulation.

### 2- Butyl rubber (GR-I rubber):

Butyl rubber is the copolymer of isobutylene & a small amount of isoprene.

### Preparation:



→ It is obtained by copolymerizing isobutylene with 1.5 to 4.5% isoprene in methyl chloride.

→ A catalyst solution, made by dissolving anhydrous  $\text{AlCl}_3$  in methyl chloride, is added to the reaction mixture.

### Properties:

1. Butyl rubber is amorphous under normal conditions.
2. Unstabilized polyisobutylene are degraded by light or heat to sticky low molecular weight products.



3. It has low permeability to gases
4. It is soluble in hydrocarbon solvent
5. It possesses good electrical insulating property & resistance to heat & abrasion.

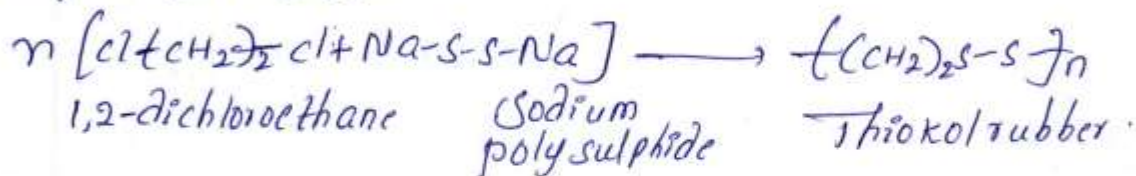
#### Uses:

1. Butyl rubber is used for making tubes, hoses, conveyor belts etc.
2. It is also used for wire & cable insulation.

### 3. Thiokol (or) Polysulphide rubber (or) GR-P rubber:

#### Preparation:

It is prepared by the reaction b/w Polysulphide ( $\text{Na}_2\text{S}_2$ ) & ethylene dichloride.



#### Properties:

1. It possesses extremely good resistance to mineral oils, fuels etc.
2. It is also impermeable to gases.
3. It does not form hard rubber bcz it cannot be vulcanized.
4. It possesses poor strength & abrasion resistance.

#### Uses:

1. It is used for making gaskets, seals & hard rubber products to be exposed to oil & pressure.
2. Thiokol rubber mixed with oxygen releasing chemicals is used as a solid fuel in rocket engines.
3. It is used for making hoses & linings of vessels used in the manufacture of chemicals.

### \* Conducting Polymers

Those polymers which conduct electricity are called conducting polymers.

→ The conduction in the polymers is mainly due to the following reasons.



1. Presence of unsaturated conjugated double bonds in the Polymer.
2. Addition or removal of electrons (doping) into the Polymer.

### \* Classification of conducting Polymers:

#### Conducting Polymers

##### Intrinsic conducting Polymers

(The conjugation of double bonds present in the structure is responsible for conductance)

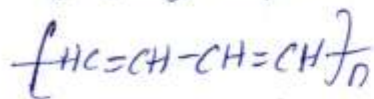
##### Extrinsic conducting Polymers

(The ingredients added externally are responsible for conductance)

##### Intrinsic Polymer with conjugation:

(Conductance is due to the  $\pi$  electrons present in the backbone of the Polymer chain)

eg: Polyacetylene



& Polyaniline



##### Doped conducting polymer

(Conducting is due to a +ve or -ve charge created on Polymer backbone).

eg: Emeraldine Salt.

##### Conductivity element

filled polymers, Polymer holds a conducting element.

eg: carbon black in Polymers.

##### Blended conducting polymers

Blending the conducting & non conducting Polymers.

eg: 40% Polypyrrole.

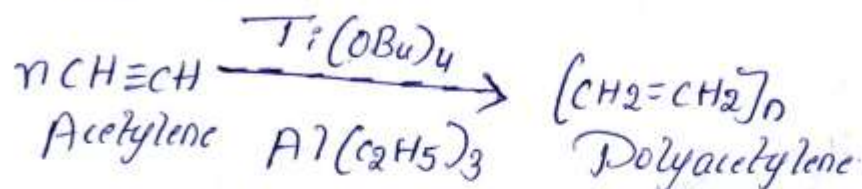


## \* Important Conducting Polymers:

### 1. Polyacetylene:

#### Preparation:

Polyacetylene is Prepared by the addition Polymerisation of Acetylene. Acetylene gas is Passed Over the Ziegler-Natta catalyst to get Polyacetylene.



Polyacetylene is infusible, insoluble & becomes brittle on exposure to air.

#### Mechanism Of conduction (or) Synthesis of conducting Polyacetylene

The conductivity of cis-polyacetylene is less when compare to trans Polyacetylene.

→ The conductivity of Polyacetylene can be improved by either P-doping or n-doping.

1. P-doping: Oxidation with Lewis acids (or) halogens.

→ In doping an intrinsically conducting polymers or the polymer having conjugated  $\text{C}=\text{C}$  bonds are treated with Lewis acid (or) halogens, which oxidises the polymers & creates positively charged sites on polymer backbone.

→ Due to the positive charge on the polymer backbone they are acting as good conductors of electricity like metal.

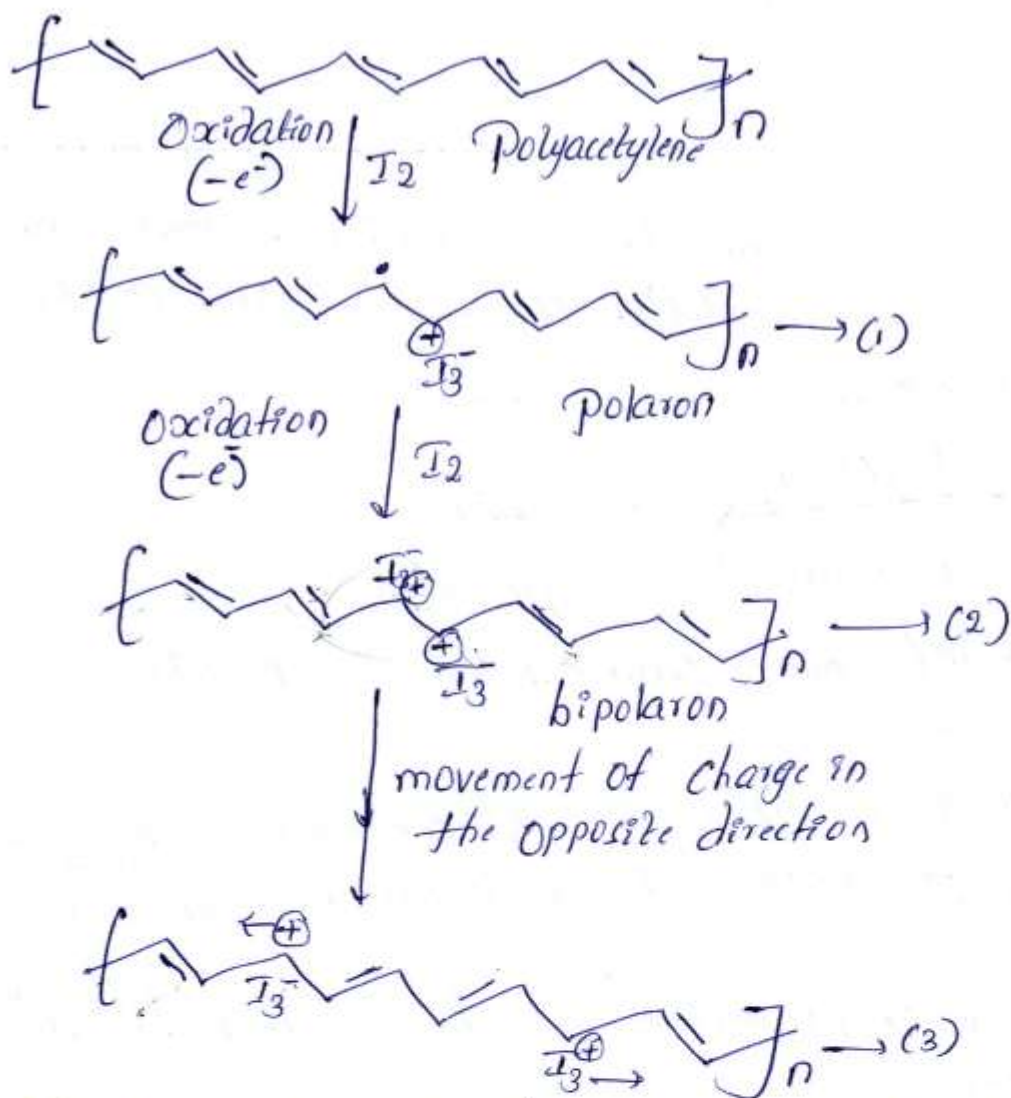
eg:  $\text{I}_2$ ,  $\text{Br}_2$ ,  $\text{AsCl}_3$ ,  $\text{AsF}_5$ ,  $\text{FeCl}_3$ .

It involves the following two steps.

#### Step-1:

I. Step involves the Oxidation of a Polyacetylene with Iodine vapour (Lewis acid).





During Oxidation (as shown in reaction 1) the iodine molecule removes an electron from polyacetylene chain & becomes  $I_3^-$ .  
 → Now the Polyacetylene chain carrying the +ve charge called Polaron.

### Step-II:

The Second Oxidation of Polaron (as shown in reaction 2) produces two +ve charges on the chain called bipolaron.  
 → These +ve charges are mobile because of delocalisation & responsible for electrical conductance (as shown in reaction 3).

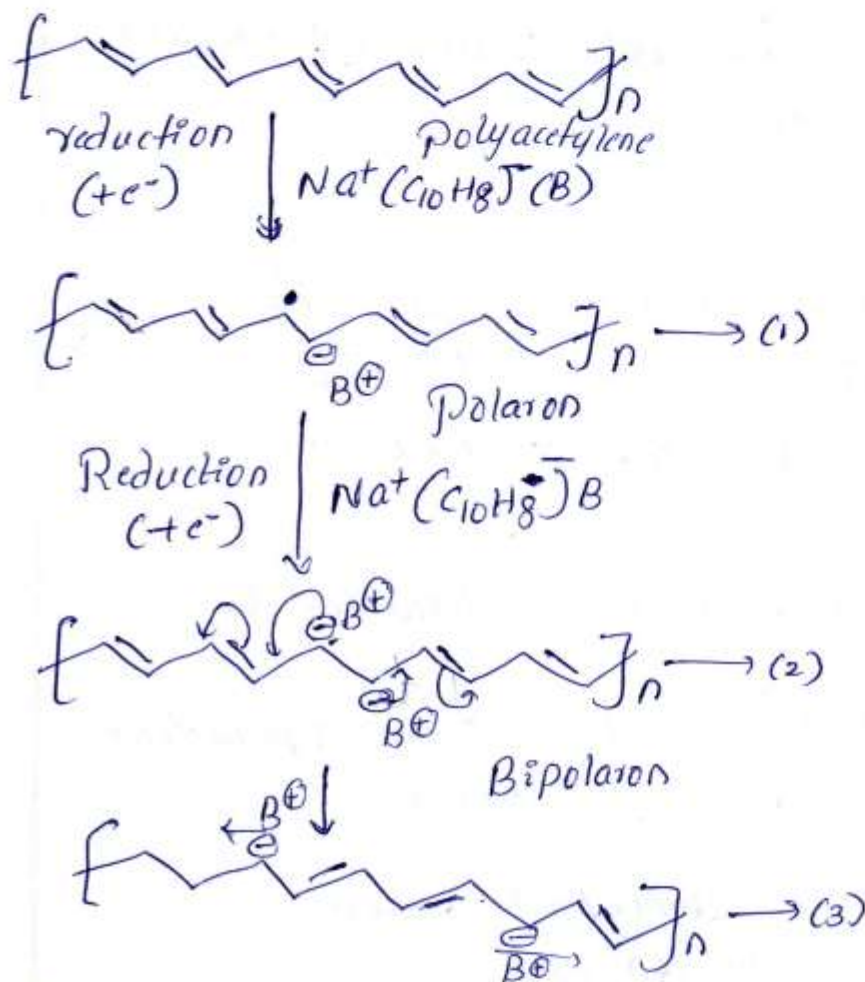
2. n-doping: Reduction with Lewis acids (or) alkali metals;

→ In n-doping an intrinsically conducting Polymers (or) the Polymers having conjugated  $C=C$  bonds are treated with Lewis bases or alkali metals, which reduces the Polymers & creates negatively charged sites on Polymer back bone.



→ Due to the negative charge on the Polymer back bone, they are acting as good conductor of electricity like metal eg: Na, K etc.

n-doping involves two steps.



Step-1:

It involves reduction of polyacetylene with sodium naphthalide  $\text{Na}^+(\text{C}_{10}\text{H}_8)^-$ . During the reduction (as shown in reaction 1) sodium naphthalide donates an electron to polyacetylene chain. Now the polyacetylene carrying the (-)ve charge. This is called polaron.

Step-2:

It involves second reduction of polaron (as shown in reaction 2) to produce two (-)ve charges on the chain called bipolaron.  
→ This (-)ve charge is mobile because of delocalisation & responsible for electrical conductance (as shown in reaction 3).



### Applications of Polyacetylene:

1. Polyacetylene can be used to Prepare an electro chemical cell. Hence, it can be used to Prepare light weight rechargeable Organic Storage batteries.
2. It can be used for low-cost Solution-Processing for film-forming Polymers.

### \* General applications of conducting Polymers:

1. conducting Polymers are used in Solar cells.
2. It is used in telecommunication Systems.
3. It is also used as a very good electrode material for rechargeable batteries.
4. conducting Polymers are used in antistatic coatings for clothing.
5. It is used as a membrane film for gas separations.
6. conducting Polymers are used as electrocatalytic materials in fuel cells.
7. It is used for making analytical Sensors.
8. It is used for making ion exchangers.

### \* Bio-degradable Polymers:

Definition: Bio-degradable Polymers are polymers which undergo degradation by the naturally occurring microorganisms like algae, fungi & bacteria.

- biodegradable Polymers are easily compostable.
- composting is the process of controlling the biological decomposition of biodegradable materials into human like material called compost.
- It also transforms them into biologically decomposable materials.



## \* Advantages of bio-degradable Polymers:

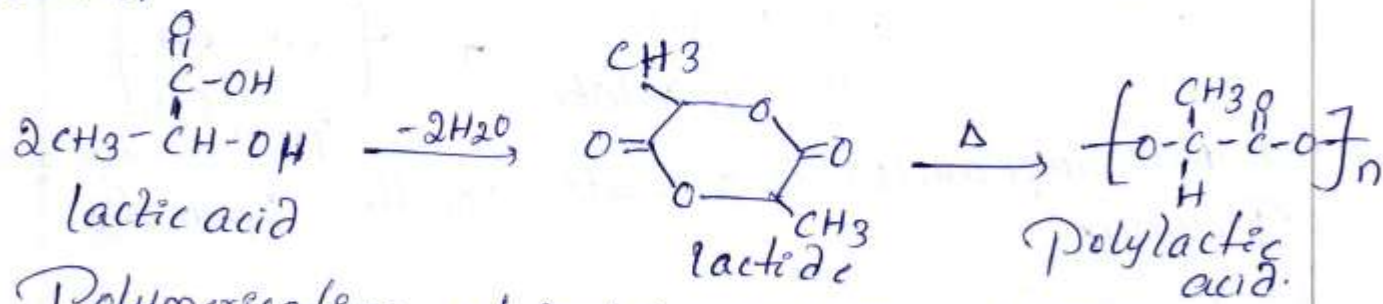
1. Biodegradable Plastics are easy to recycle.
2. They consume less energy during their manufacture
3. Reduction of the amount of waste produced
4. lower Petroleum Consumption
5. compostability
6. Reduction of carbon dioxide levels.
7. Reduction of emission of Greenhouse gas levels.

### 1. Polylactic acid:

Polylactic acid is a bio-degradable aliphatic thermoplastic polymer. It is derived from renewable sources such as starch, sugarcane etc.

#### Preparation:

It is prepared by the catalytic dimerisation of lactic acid resulting in the formation of lactide (Polym)<sup>2</sup> monomer.



Polymerisation of lactide monomer, in presence of Stannous Octate, to give Polylactic acid.

#### Properties:

1. PLA Posses good bio-compatibility, Processability, high strength.
2. D-isomer of PLA is crystalline & L-isomer is amorphous.
3. Bio-degradation of D-isomer is slower than L-isomer.

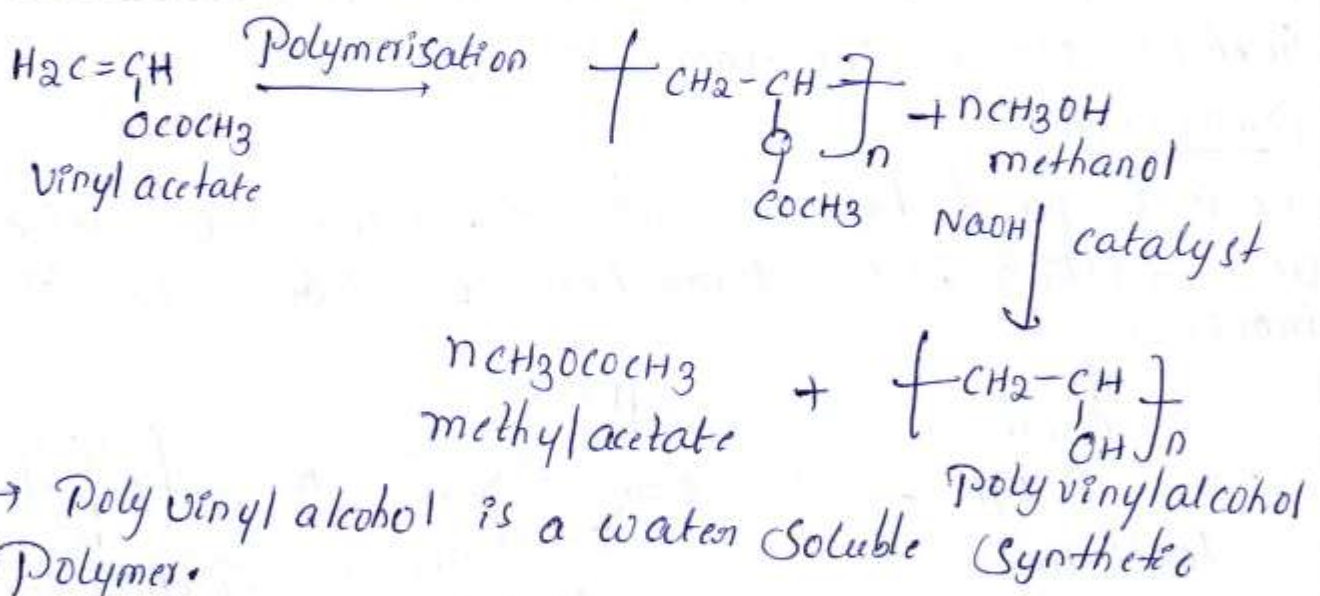


## Application:

1. PLA is used for making medical implants like screws, pins, anchors etc.
2. It is used in a number of biomedical applications like drug delivery (Service) devices & dialysis media.
3. It is used in the Preparation of bioplastics for Packing food & disposable tableware.
4. It is also used for making compostable Packing materials, food Packing etc.

## 2. Polyvinyl alcohol

### Preparation:



### Properties:

1. PVA is a Partially Crystalline upon formation & it has Chemical resistance, water Solubility & biodegradability.
2. The Similarity in Physical Properties make it compatible with human (body) tissues.

### Applications:

- \* PVA is used in many industries such as Textile, Paper, & food Packing industry becz of its high chemical & thermal stability & low manufacturing cost.
- \* It has high strength & high optical transparency in water.