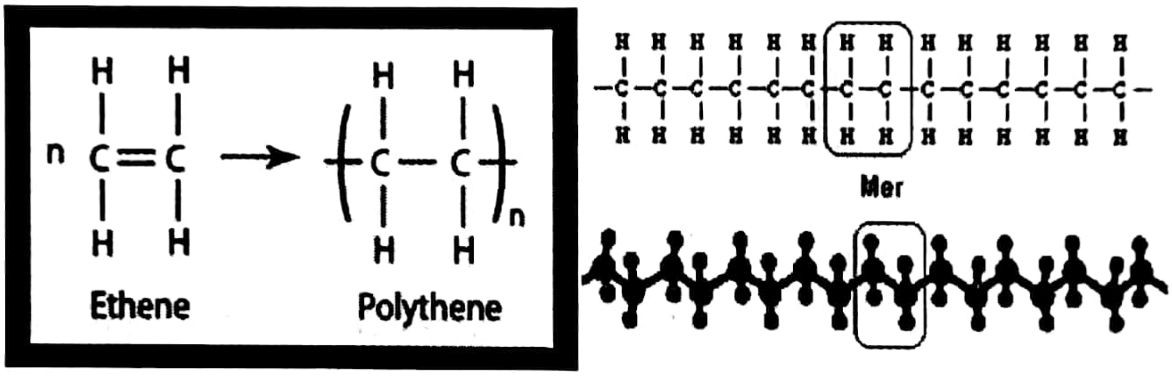
UNIT-I
POLYMER TECHNOLOGY

INTRODUCTION:

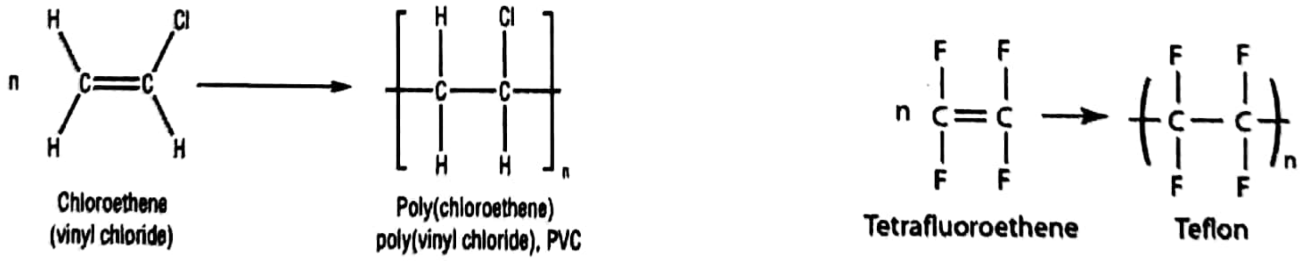
Polymers (Greek – poly – many, mers – units or parts)

- Polymers are macromolecules (giant molecules of high molecular masses) built up by the linking together of a large number of small molecules (called monomers). by the **polymerization** process
- Eg 1. Polyethylene is a polymer formed by linking together of a large number of ethylene (C_2H_4).



Ethylene (monomer) Polyethylene (Polymer)

- Thus small molecules which combine with each other to form polymer molecules are termed monomers and the 'repeat unit' in a polymer is called <u>mer.</u>
- Eg 2.



Vinylchloride poly vinyl chloride (polymer)

Degree of Polymerization (Dp)

- The number of repeated units in the polymer chain is known as degree of polymerization.

$$\textbf{Degree of polymerization} = \frac{\text{Total molecular weight of polymer}}{\text{Molecular weight of monomer unit}}$$

Classification of Polymers

- Polymers may be classified in to various monomers.
- On the Basis of origin – polymers are of two types

1. Natural Polymers 2. Synthetic Polymers

1. Natural Polymers – They are polymers that occur in nature.
   - Eg: Starch (Polymer of 2 D Glucose) Cellulose (Polymer of β D Glucose) Proteins (Polymer of 2 Amino acids) Natural Rubber (Polymer of Isoprene)
2. Synthetic Polymers –Polymer is prepared artificially in the laboratory.
   - Eg: Polyethene (PE), Poly vinyl chloride (PVC), Nylon, Terylene, Bakelite, Synthetic Rubber.

Q 1) What are the different types of polymerization? Explain with examples?

Types of Polymerization: Polymerization is mainly of two types

1. Addition Polymerization or Chain growth Polymerization
2. Condensation Polymerization or Step growth Polymerization

Addition Polymerization

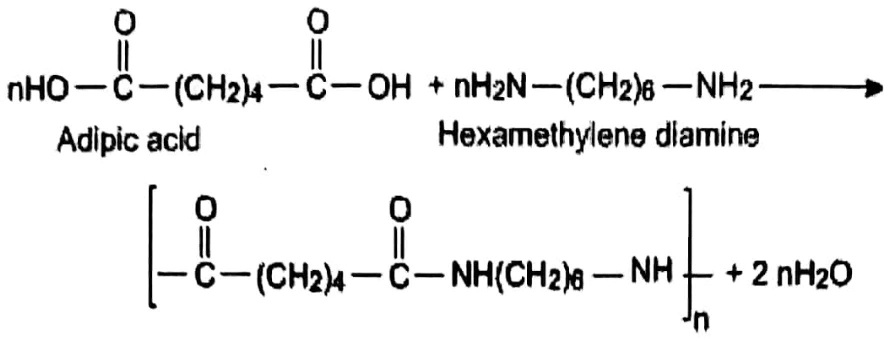
- Addition Polymerization is the addition of unsaturated monomers to form a polymer without elimination of any by products by rapid chain reaction. The polymerization in which product is an exact multiple of monomers is called addition polymerization.
- The molecular weight of the polymer is sum of molecular weight of all monomers.
- The Addition Polymerization must be initiated by the application of heat or light and presence of a catalyst.

  Eg: Polyethene, PVC, Teflon etc.

Condensation or Step growth Polymerization

- The polymerization reaction, in which the monomer having at least one or more polar functional groups (such as COOH, OH, NH_2etc) are involved.
- It involves step by step mechanism with the elimination of some by product like H_2O, HCl, NH_3 etc.

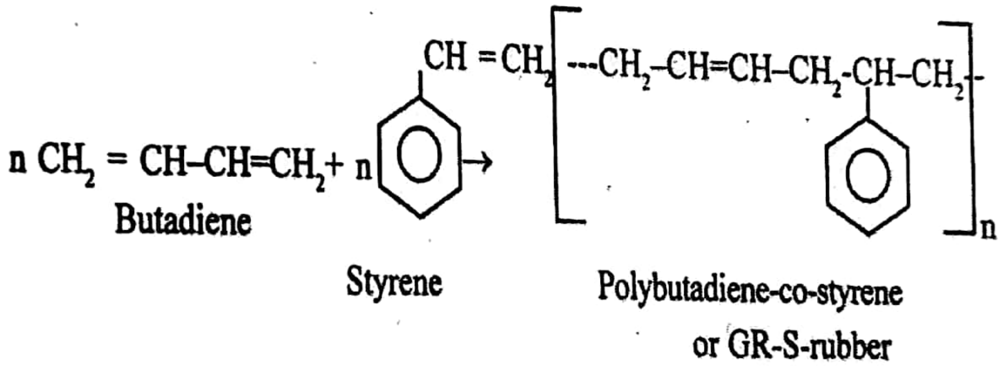
  Eg: Nylon[6,6] , Bakelite etc.



Co – polymerization

- It is the type of addition polymerization in which, monomers with different multiple bonds combine together to give rise to large Molecular weight polymer.

Eg: BUNA – S (Poly Butadiene Co-Styrene)

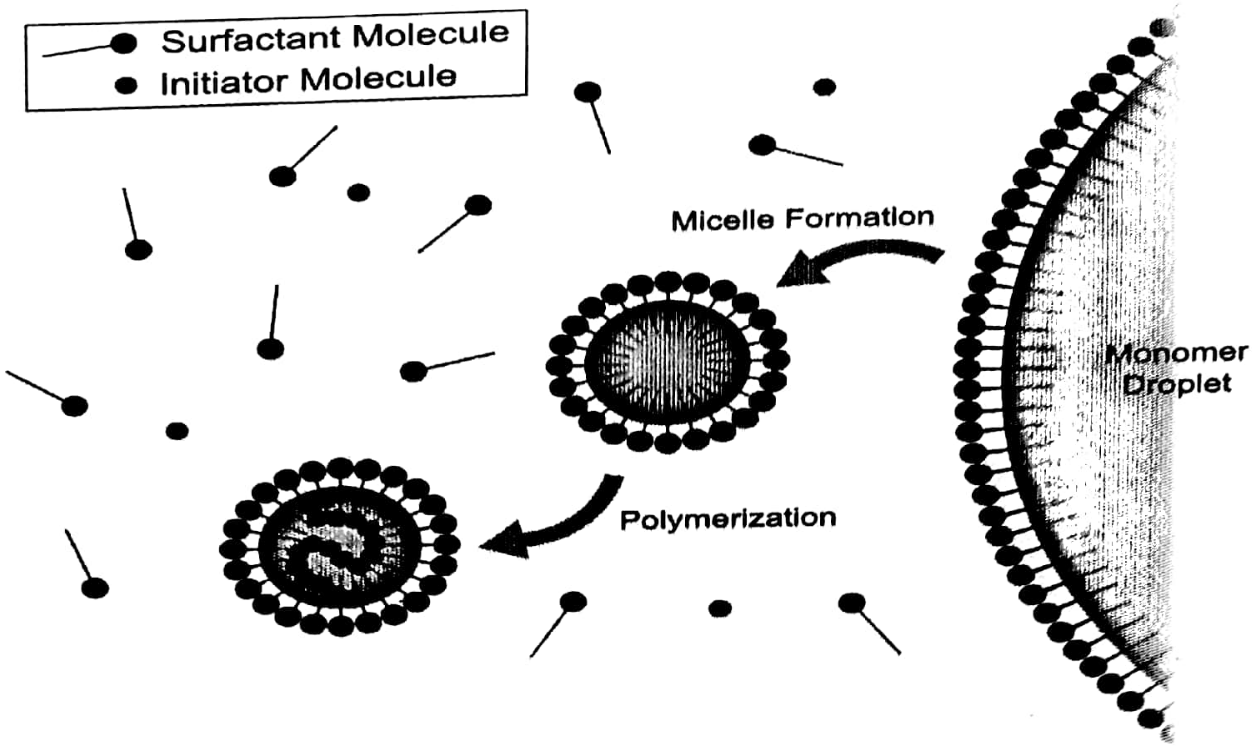


Q 2) Explain in detail the methods of polymerization (Polymerization Techniques)?

1. Emulsion Polymerization
2. Suspension Polymerization

Emulsion Polymerization

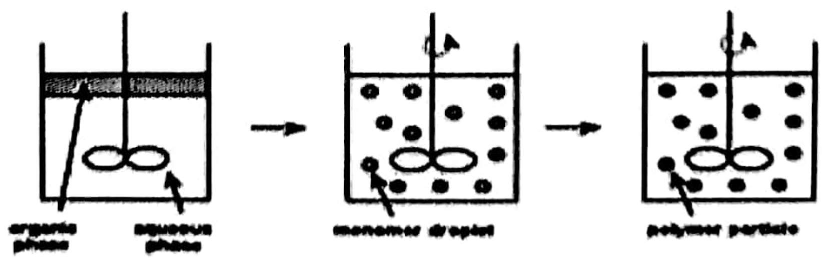
- In this method the monomer is dispersed as fine droplets in large amount of water, and then it is emulsified (stabilized) by using soap or detergent.
- The initiators used are hydrogen peroxide and persulphates. These radicals diffuse into micelles and react with monomer molecules.
- As the Polymerization proceeds, more and more monomers migrate into micelles to continue reaction.
- The polymer in the emulsion will be separated by adding a solvent, followed by washing, drying.
- Emulsion Polymerization is used in industry for manufacturing water based (latex) paints or Adhesives and also used for preparing tacky polymers such as PVC, Vinyl Acetate, Chloroprene etc.



Suspension Polymerization

- In this method the monomer is dispersed mechanically in solvents like water.
- The resistant monomer droplets are polymerized using a monomer soluble initiator.
- The suspension is stabilized by the addition of small amount of stabilizers like Poly Vinyl Alcohol (or) Methyl Cellulose.
- When the reaction is completed polymer is obtained in the form of granular beads; so it is called Bead or Pearl Polymerization.
- It is washed to remove the stabilizer and dried.
- **This method is used to prepare polymers like polystyrene, PMMA (poly methyl methacrylate), divinyl benzene beads (used in Ion Exchanger)**

SUSPENSION POLYMERIZATION



Q 3) Explain the physical and mechanical properties of polymers?

Physical properties of polymers:

Degree of Polymerization and Molecular Weight: The degree of polymerization (DP)-$_n$ in a polymer molecule is defined as the number of repeating units in the polymer chain. For example,

$$-(-CH-CH-)-_n$$

The molecular weight of a polymer molecule is the product of the degree of polymerization and the molecular weight of the repeating unit. The polymer molecules are not identical but are a mixture of many species with different degrees of polymerization, that is, with different molecular weights. Therefore, in the case of polymers we talk about the average values of molecular weights.

Crystallinity: A polymer is not practically 100%crystalline like a non-polymer as polymer consists of long chains. Crystallinity is observed if it contains regions of three-dimensional ordering. Synthetic polymers may consist of 60% crystalline and 40% amorphous regions. For example HDPE (high density polyethylene) has a crystallinity of about 80%.

Solubility and swelling property of a polymer: A polymer is not freely soluble in a solvent .When a polymer is dissolved in a solvent, it absorbs the solvent and swells by absorbing the solvent. the swollen polymer slowly disintegrates in the solution to form a viscous polymer solution which is heterogeneous.

Effect of heat on a polymer: At room temperature all polymers are solids existing in rubbery or visco elastic state. As the temperature increases the polymer melts and this is called softening point (T_f) where the polymer exists in visco fluid state. As the temperature further increases to boiling (T_b) the polymer decomposes to monomers which are in vapour phase. When the temperature is lowered below zero degree and a temperature comes where the polymer becomes hard, brittle and glassy and behaves as glass. This temperature is called glass transition temperature (T_g).The glass transition temperature of rubber is (-73°C).

Mechanical properties:

Tensile strength: The tensile strength of a material quantifies how much elongating stress the material will endure before failure. This is very important in applications that rely upon a polymer's physical strength or durability. In general, tensile strength increases with polymer chain length and crosslinking of polymer chains.

Elasticity: It is defined as the property by virtue of which a rubber can regain its original shape after deformation, when the deforming stress is removed. Elastomers contain high degree of elasticity.

Plasticity: It is the property of plastics by virtue of which they undergo permanent deformation when a stress is applied.

Q 4) What is a Plastic? Explain the different types of plastics and distinguish between them?

Plastics are high molecular weight organic polymers which show the property of plasticity and can be moulded into desired shape by the application of heat and pressure in presence of catalyst.

- **Advantages of plastics over other materials**

  1) They show good thermal and electrical insulation.
  2) High corrosion resistance.
  3) They are light in weight and high in strength to weight ratio.
  4) Show easy workability and decorative glossy surface.
  5) Low maintenance cost.
  6) Some plastics exhibit high abrasion and chemical resistance.

Types of plastics: On the basis of their physical characteristics, plastics are usually divided into two types.

(1) Thermoplastics (2) Thermosetting

1. **Thermoplastics:** Thermoplastics are linear or branched chain polymers, can be softened on heating and hardened on cooling reversibly.
   - These are formed by addition polymerization. Weak intermolecular forces are present between the polymer chains.
   - These can be remolded, reshaped and reused. Thermoplastics can be recycled. Eg: **Polyethene, PVC, Polystyrene, and Teflon etc.**

2. **Thermosetting plastics:**
   - Thermosetting plastics are three dimensional, cross-linked polymers, which once set during molding but cannot be remoulded or reshaped. Plastics cannot be recycled.

     Eg: Bakelite, Urea formaldehyde resins.

Distinguish between Thermo plastics and Thermosetting Plastics

S.No	Thermoplastics	Thermosetting Plastics
1	Thermo plastics resins are softened on heating and hardened on cooling.	Thermosetting plastics are three dimensional, cross-linked polymers, which once set during molding but cannot be remoulded or reshaped.
2	They are formed by addition polymerization.	They are formed by condensation polymerization
3	They have either linear (or) branched chain structure.	They have three dimensional cross-linked structures.
4	They can be remoulded reshaped and reused.	They can't be remoulded and reused.
5	They are tough materials.	They are brittle materials.
6	They can be reclaimed from waste i.e., they can be recycled.	They cannot be reclaimed from waste, they can't be recycled.
7	Low softening points Eg: polyethene, PVC, Teflon.	High softening points. Eg: Phenol formaldehyde resin, Urea formaldehyde resin

Q 5) What is meant by Compounding of plastics or what are the different moulding ingredients added to the plastics?

Compounding of plastics:

Definition: The process of addition of moulding ingredients to improve the properties of polymer and make them convenient for moulding is known as compounding of plastics.

The main types or compounding ingredients are

1. **Resins:** Resin is the binder, which holds the different constituents added to the plastic together. They are two kinds of binder namely thermoplastic resins and thermosetting resins.
2. **Plasticizers**: These are added to plastics to increase the plasticity and flexibility. Further they improve flowing of plastics and reduce the brittleness of the plastics.

   Eg: **Tri phenyl phosphate, tri cresyl phosphate , esters of steric or oleic acids etc.**
3. **Fillers or Extenders:** Fillers are generally added to plastics to increase hardness and crack resistance. Fillers improve thermal stability, strength, non-combustibility, water resistance, electrical insulation properties and external appearance. They also reduce the cost of the plastics.

   Particulate fillers Example-saw dust, talc, asbestos, Mica, Carbon black, Graphite, Barium sulphate etc.

   Fibrous fillers examples –Scraps of clothes like polyester, cotton, nylon and silk.

4. **Lubricants:** Lubricants make the moulding of plastic easier and to impart a flawless, glassy finish to the products.

Eg- **waxes, oils, stearates, camphor, oleates and soaps.**

5. **Catalysts or Accelerators:** These are added to give fusible plastic to convert into cross-linked, infusible plastic during moulding operation.

Eg: **H_2O_2, dibenzoyl peroxide, metallic oxides such as ZnO, ammonia etc.**

6. **Stabilizer:** These are added to plastics to improve the thermal stability during moulding.

For example: vinyl chloride has the tendency to undergo decomposition. So during their moulding heat stabilizers are used.

Eg: **i) Opaque stabilizer like salts of lead (white lead, lead chromate, litharge, red lead).**

Transparent stabilizers like lead, cadmium and barium stearate.

7. **Anti-oxidants:** These are added to plastics during moulding to prevent oxidation and gives long life to the plastic material.

Eg: **diphenyl amines, dialkyl thiopropionate etc.**

8. **Colouring materials:** These materials provide attractive colors. These may be organic stuff and opaque inorganic salts.

Eg: **Lead chromate (yellow), ferro cyanide (blue), Purssian blue dye(blue),Titanium dioxide(white), Carbon black (black)etc.**

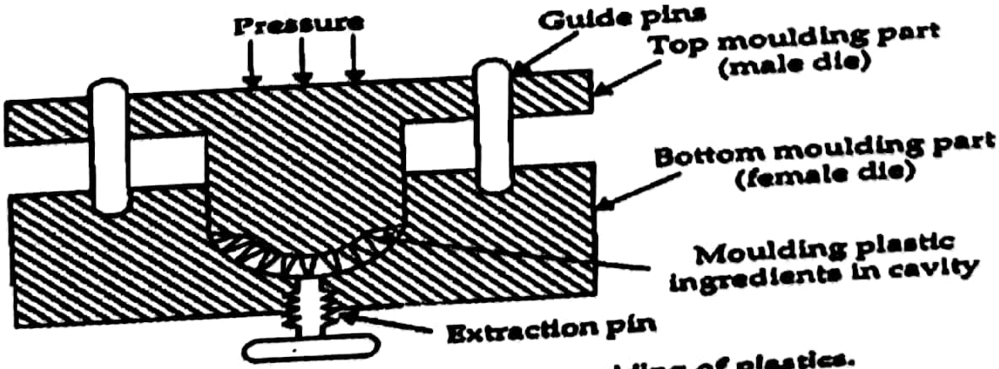
Q 6) Explain Moulding of the plastics (Fabrication of the plastics)?

- Many methods of fabricating the plastics into desired shape of articles are:

  1) Compression moulding 2) Injection moulding 3) Extrusion moulding

  4) Blow film moulding

1) Compression Moulding:



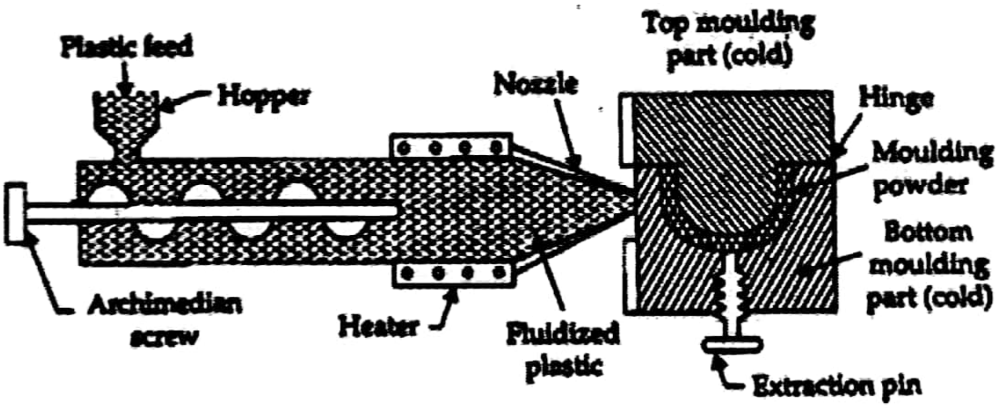
Compression moulding of plastics.

- This method raw material is placed in closed mould
- High temperature and high pressure applied to complete the curing process
- This technique is applied for themoplastics and thermosetting plastics.
- Thermoplastics curing is done by heating while thermosetting plastics curing is done by cooling.

Advantages:

- Low cost mould.
- Used for making handles, gears & cylinders.
- It is a Fast Process.

2) Injection Moulding:

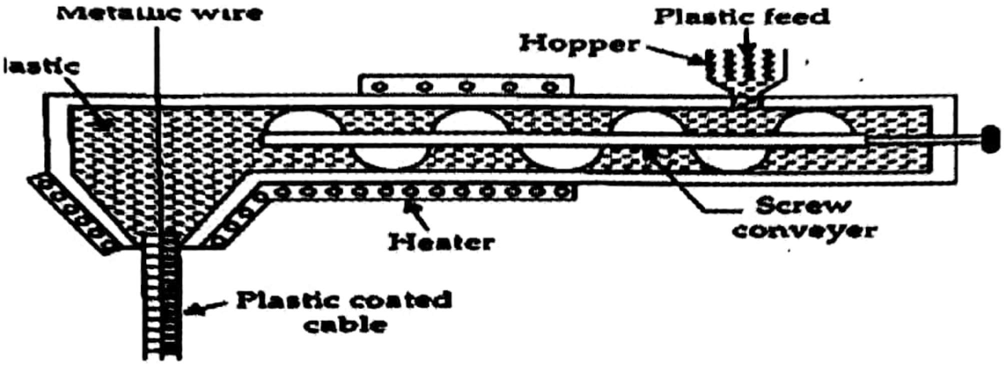


Injection moulding of plastics.

- This method used for thermosetting plastics because high speed production.
- The moulded plastic powder is heated in cylinder and injected by screw arrangement.
- The mould is kept cold so that hot plastic become solid (curing)

Uses: Injection moulding is used for moulding of containers, bottle caps etc.

3) Extrusion moulding:

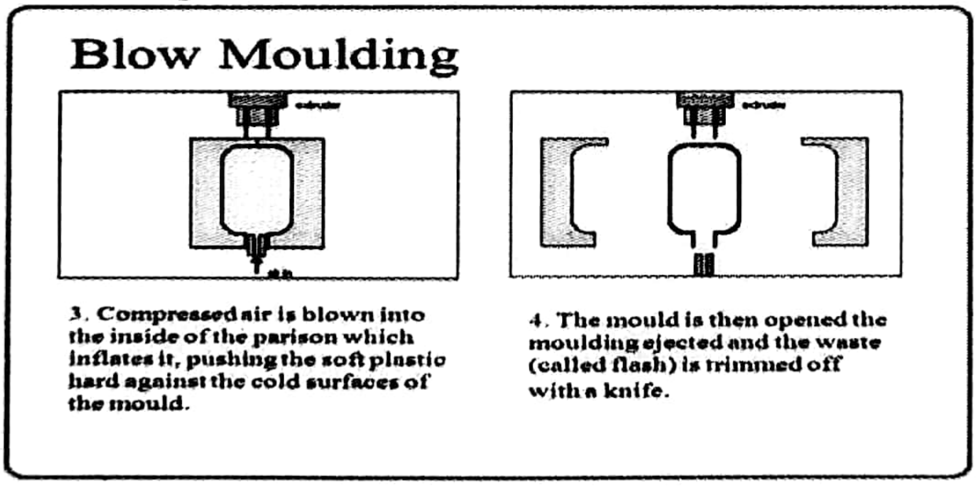


Extrusion moulding.

- It is applicable to thermoplastics
- The material is forced by screw conveyor into a heated chamber. Softened material is pushed into dye and cooled out by spraying with water.

Uses -It is used for making continues shapes like rods, tubes, cables, sheets etc.

4) Blown moulding:

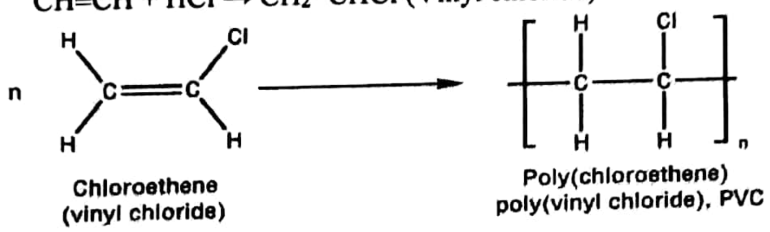


- The process of blow moulding is used for the production of hollow glass and plastic objects in large quantities.
- The blow molding process begins with melting down the plastic and forming it into a parison.
- The parison is a tube-like piece of plastic with a hole in one end through which compressed air can pass.
- The plastic gets inflated across the walls of the mould and takes a shape of the mould.
- Finally the hollow plastic is collected by opening the mould.

Q 7) Give the preparation, properties, applications and uses of
1. PVC 2. Polycarbonate and 3. Bakelite?

1. PVC (poly vinyl chloride): Vinyl chloride is prepared by treating acetylene (CH≡CH) with HCl at 60-80^{0}C under 1.5 atm

$$CH\equiv CH + HCl \rightarrow CH_2{=}CHCl \text{ (Vinyl chloride)}$$



PVC is obtained by heating a water Emulsion of vinyl chloride in presence of benzoyl peroxide and H_2O_2 as catalyst in an autoclave under pressure.

Properties:

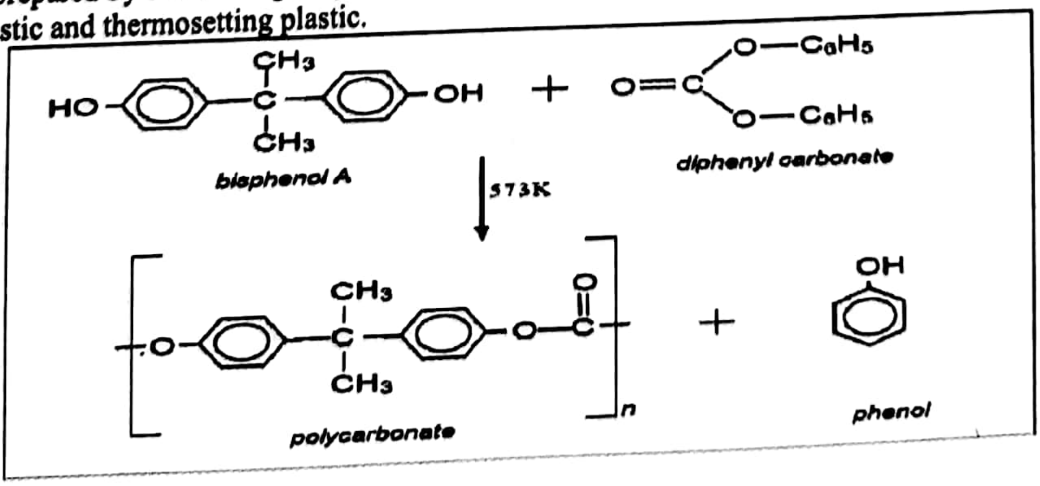
- PVC is insoluble in alcohol, water and the hydrocarbons but soluble in chlorinated hydrocarbons and Ketones.
- It is colourless, odourless, non-inflammable and chemically inert.
- Resistant to light and atmospheric oxygen.

Uses:

Plasticized PVC - It is used for making pipes and injection moulded articles like tool handles. PVC pipes are used for carrying corrosive chemicals in petro chemical factories. Used for making Radio, TV cabinets and automatic cameras.
Unplasticized PVC –Used for making safety Helmets, refrigerator doors, cycle and motor cycle mud guards.

2. Poly Carbonates:

They are prepared by condensing Bisphenol-A with Phosgene or with diphenyl Carbonate. It can act as both thermoplastic and thermosetting plastic.



Polycarbonate Properties:

- Its glass transition temperature 147°C.
- It is transparent and have good impact and tensile strength over a wide range of temperature.
- It is a tough polymer.
- It has electrical insulation property.
- However, they are soluble in organic solvents and alkalies.

Uses:

- It is used for making moulded domestic ware and insulation for electronic and electrical industries like dielectrics in capacitors and hardware components..
- For making safety shields like helmets, telephone parts, bullet proof glasses.
- For making CD's and DVD's.
- Used for making sunglasses, and eye glasses.

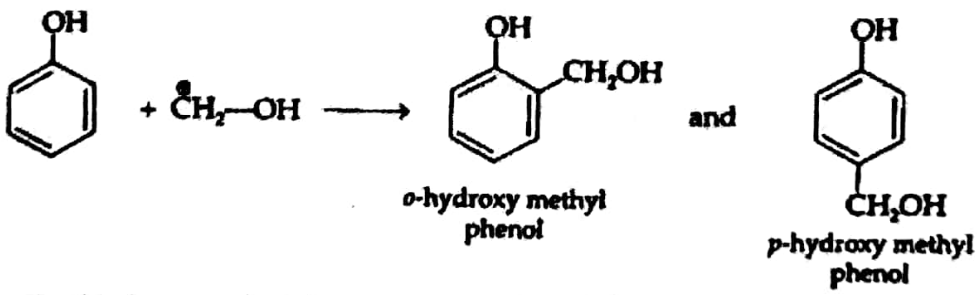
3. Bakelite (phenol –formaldehyde resin)

Preparation:

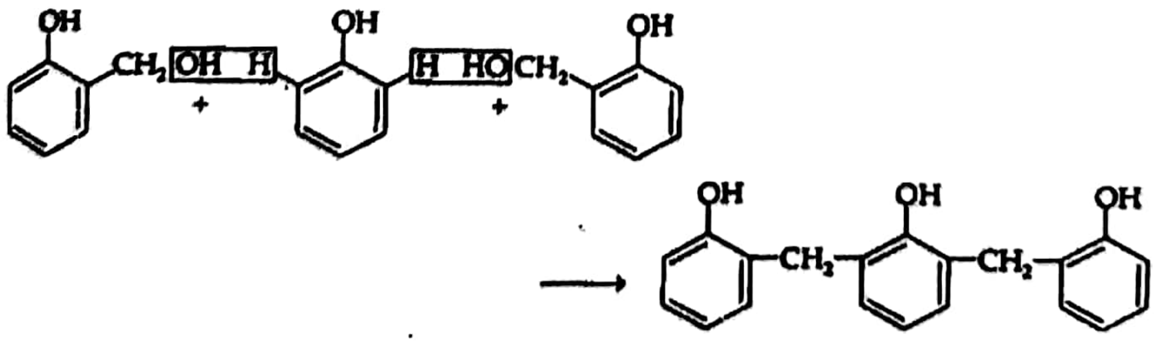
Bakelite is prepared by condensing phenol with formaldehyde in presence of acidic/alkaline catalyst.

Step I. Phenol reacts with formaldehyde produce o-Hydroxy methyl phenol and p-Hydroxy methyl phenol.

$$CH_2{=}O + H^{\oplus} \longrightarrow \overset{\oplus}{C}H_2{-}OH$$



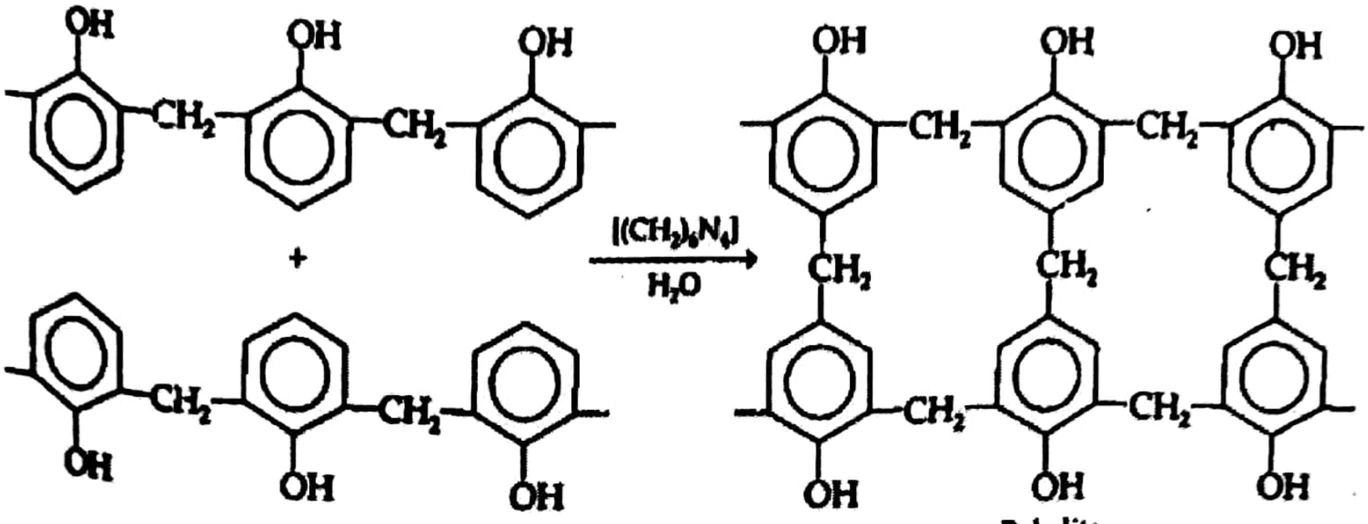
Step II. o-Hydroxy methyl phenol and phenol, which reacts to form linear polymer Novalac resin.



Novalac

Step III. During moulding, catalyst hexamethylene tetraamine [$(CH_2)_6N_4$] is added. Addition of this catalyst provides excess of formaldehyde, which converts the soluble and fusible Novalac resin into hard, infusible and insoluble solid of cross-linked polymer Bakelite.

$$[(CH_2)_6N_4] + H_2O \longrightarrow 6CH_2O + 4NH_3$$



Bakelite

Properties:

- Phenol resins are hard, rigid and strong materials
- They have excellent heat and moisture resistance.
- They have good chemical resistance
- They have good abrasion resistance
- They have electrical insulation characteristics
- They are usually dark coloured.

Applications:

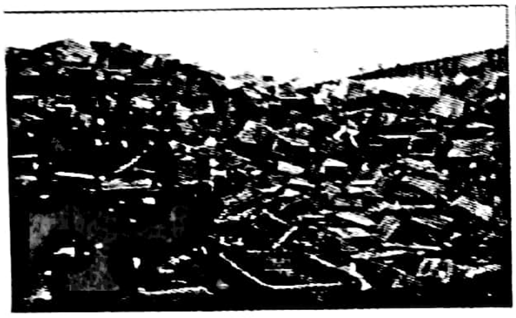
- It is used for making electric insulator parts like switches, plugs, switch boards etc.
- For making moulded articles like telephone parts cabinet of radio and television.
- As an anion exchanger in water purification by ion exchange method in boilers.
- As an adhesive (binder) for grinding wheel etc.,
- In paints and varnishes.
- For making bearings used in propeller shafts, paper industry and rolling mills.

Q 8) Mention some examples of plastic materials used in electronic gadgets. How the e-plastic waste is recycled?

A) There is a huge percentage of PVC in electronic devices including televisions, DVD players, Rechargeable Hair Removal, laptops, desktop computers, mobile phones, iPods, iPads, cameras, fans, ovens, Socket, printers vacuum cleaners, washing machines, microwave ovens, kettles and radio, a fax machine and a telephone.

Bakelite is used for making switches, plugs, cabinets for TV and Radio.

"As many as 3,000 personal computers; 8,500 mobile handsets; 5,500 TV sets and are dismantled in the Delhi everyday for reuse of their component parts and materials"



- **E-Waste**

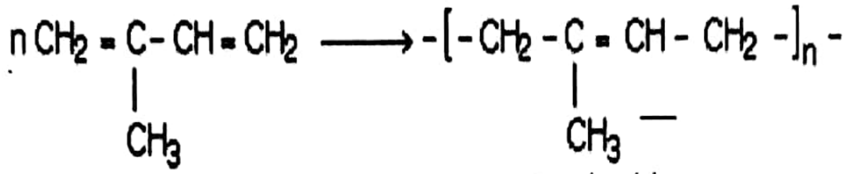
The rapid obsolescence of gadgets combined with high demand for new technology has created mountains of E-Waste. E- waste is the fastest growing waste stream in the society today. Of fastest growing toxic waste are laptops, mobile phones, stereos and printers.

The recycling of e-waste involves extraction of precious metals present inside safely and efficiently. These methods include:

1. Sending the electronic devices to processing plants where they can be safely dismantled. Plastic material is removed and the internal components are separated by further processing.
2. The materials are then pulverized into granular materials and metal components are extracted with magnets. The non-magnetic metals remain in the material itself.
3. The plastic components are blown by blasting with air and the light plastic materials are collected separately.
4. The final process of extraction can be done by using acid baths where different metals dissolve at varying degrees depending on the strength of the acid. From the metallic solutions metals can be precipitated out and the acid can be reused.

Rubbers (elastomers)

- Natural Rubber is a high molecular weight hydrocarbon polymer represented by the formula $(C_5H_8)_n$ having elasticity property. It is obtained from a milky white emulsion called latex by tapping the bark of the tree "Hevea brasiliensis". It is a polymer of isoprene units.



isoprene [2- methyl butadiene] → natural rubber [poly isoprene]

Q (9) What are the drawbacks of natural rubber. How they can be overcome by Vulcanization process.

Disadvantages of Natural Rubber:

- It is having plastic nature.
- Rubber suffers at the high temperature becomes soft and at low temperature becomes brittle.
- It is destroyed by oxidation.
- It absorbs lot of water there by become swollen.
- It tensile strength is $200 kg/cm^2$.
- It possesses tackiness.
- It undergoes permanent deformation when stretching to great extent.
- It also reacts with acids and bases.

Vulcanization of Natural Rubber

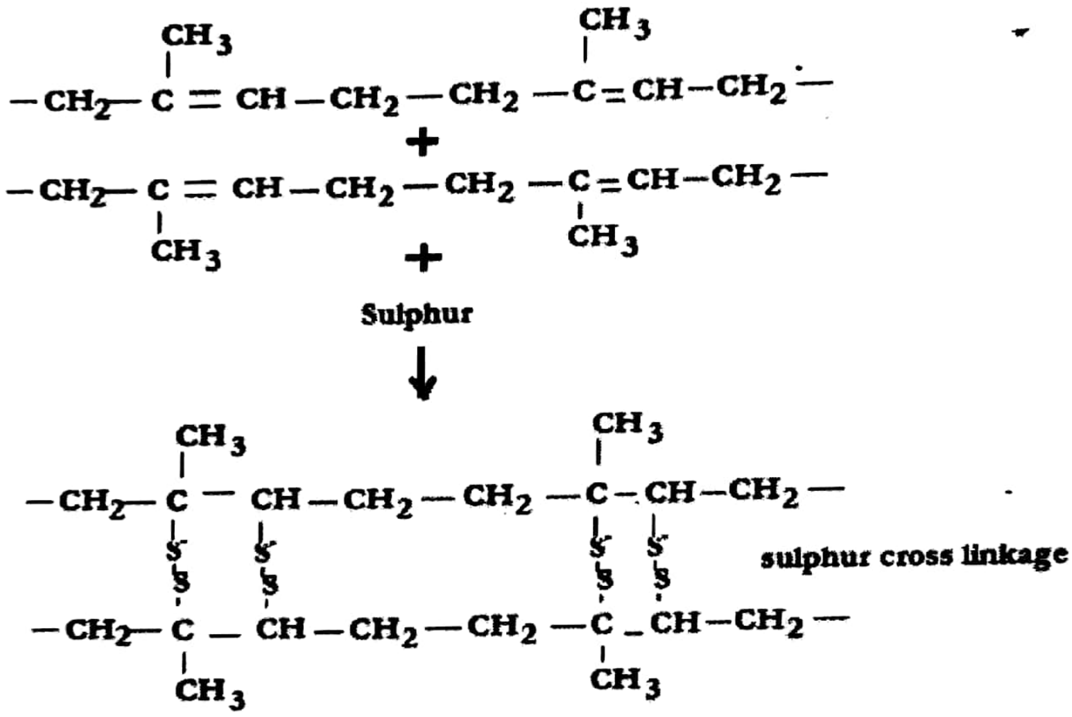
- **Vulcanization process** was discovered by Charles Good year in1839.
- In vulcanization process plastic state of raw rubber transformed into elastic state.
- During this process the following important changes takes place.

NATURAL RUBBER	VULCANISED RUBBER
1. Low tensile strength(200kg/cm2)	1. High tensile strength(2000kg/cm2)
2. Plastic state	2. Elastic state
3. High retentivity	3. Low retentivity
4. Thermoplasticity	4. Non-Thermoplasticity
5. Tackiness	5. Non Tackiness
6. Unvulcanized	6. Vulcanized

Vulcanization process also increases the resistance of natural rubber to oxidation.

Vulcanization Process:

- When a mixture of 100 parts of raw rubber with 5-8 parts of sulphur is heated at 140 °C for 3-4 hours.
- To reduce curing time some suitable accelerators are added.
- If we add 32% of sulphur to the raw rubber, high tensile strength hard rubber is obtained which is known as ebonite rubber, it is used in automobile tyres.



Advantages of vulcanization:-

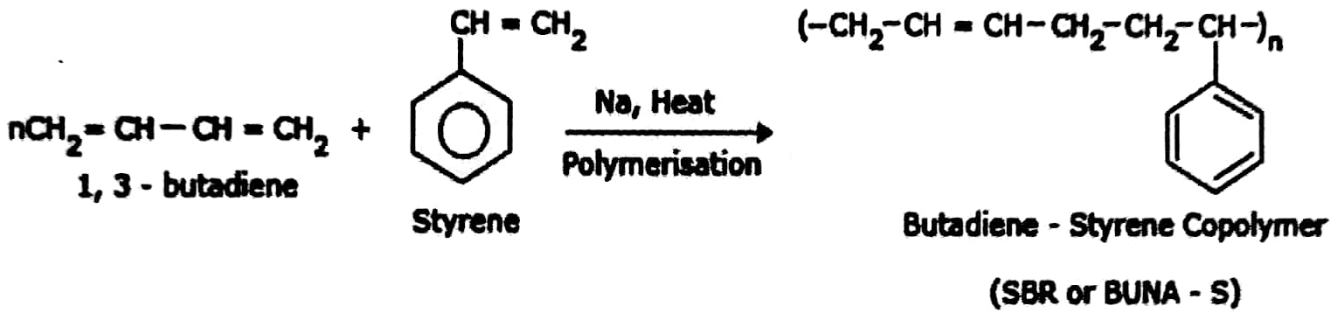
- The tensile strength increases.
- Vulcanized rubber has excellent resilience.
- It is resistance to organic solvents like CCl_4, Benzene & petrol etc.
- It has only slight tackiness.
- It has low elasticity.
- It has better resistance to moisture, oxidation & abrasion.

Q 10) Give the preparation, properties and applications of Synthetic rubbers:

1. BUNA – S 2.Thiokol 3.Poly Urethanes.

BUNA – S (Styrene rubber)

- Buna-S rubber is probably the most important type of synthetic rubber, which is produced by Copolymerization of butadiene (about 75% by weight) and styrene (25% by weight).



Properties:-

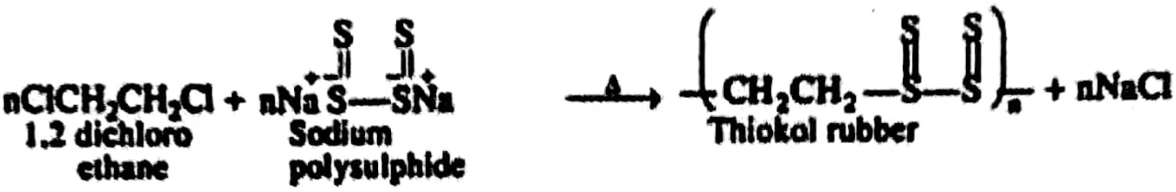
- It is a strong & tough polymer.
- The rubber can be vulcanized similar to natural rubber using either sulphur or sulphuryl chloride (S_2Cl_2).
- It is a good electrical insulator.
- It possess excellent abrasion resistance
- It is resistance to chemicals but swell in oils and attacked by even traces of ozone present in the atmosphere
- It possess high load bearing capacity and resilience.

Applications:-

- Major application of styrene rubber is in manufacture of tyres.
- It is used in foot wear industry for making shoe soles and footwear components.
- It is also used for making wires and cable, insulators.
  It is also used for the production of floor coverings, tank linings in chemical industries.

Thiokol rubber (or) poly sulphide rubber (or) GR-P:-

- Thiokol is prepared by the condensation polymerization of sodium poly sulphide (Na_2S_x) and ethylene dichloride ($Cl\ CH_2 - CH_2Cl$).
- In these elastomers, sulphur forms a part of the polymer chain.



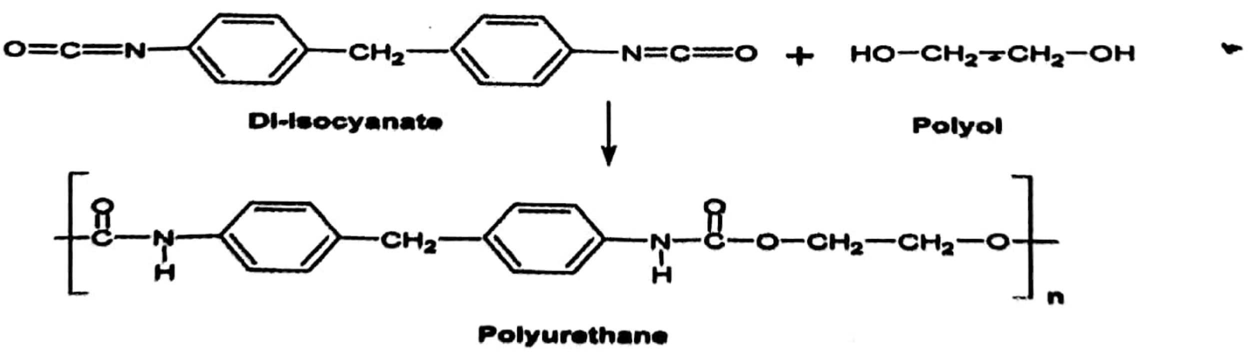
Properties:-

- These rubbers possess strength and impermeability to gases.
- This rubber cannot be vulcanized because its structure is not similar to natural rubber and it cannot form hard rubber.
- It possesses extremely good resistance to mineral oils, fuels, oxygen, solvents ozone & sunlight.

Applications:-

- It is mainly used as solid propellant fuel for rockets.
- It is also used for making gaskets, hoses, cable linings, tank linings etc.
- It is also used for printing rolls, Containers for transporting solvents etc.

Poly Urethane (or) ISO cyanate rubber- It is produced by reacting poly alcohols with di-isocyanates



PROPERTIES:

- It possesses excellent resistance to oxidation.
- It shows good resistance to many organic solvents but are attacked by acids and alkalies
- These are light, tough and resistant to heat, abrasion, chemicals and weathering.

Uses: For surface coatings, manufacture of foams and spandex fibers.

Q 11) What are FRPs Composite materials. Give their properties and applications.

Constituents of Composites: Two essential constituents of composites or FRPs are

1. Matrix 2. Fiber

- **Matrix:** The matrix phase is a polymer (or) plastic. Generally thermosetting plastics are used as matrix. The polymers used in composites are epoxy, polyamide, vinyl esters etc.
- **Fiber:** Fibers are used to strengthen thermoplastic compounds.
- There are three types of fibres – Carbon, Glass and Aramid fiber.

Fiber Reinforced Plastics (FRP's): Fiber reinforced plastics are produced by reinforcing a plastic matrix with high strength fiber materials such as glass, carbon and aramid fiber. The process of adding fibers to the plastic is called reinforcement and the plastic obtained due to reinforcement is called reinforced plastic.

FRP's are the following three types

1. Glass fiber reinforced plastics (GFRP's)
2. Carbon fiber reinforced plastics (CFRP's)
3. Aramid fiber reinforced plastics (AFRP's)

Glass fiber reinforced plastics: Glass fiber is made up of sand, limestone, folic acid and other minor ingredients. The mixture is heated till it melts at about 1260^0C. The molten glass is then allowed to flow through fine holes in a platinum plate. These fibers are used in composites.

Carbon fiber reinforced plastics: Carbon fibers can be combined with a wide variety of plastic resins to yield composite materials. Many thermosetting resins and thermoplastic resins are suitable for combination with carbon fibers.

Aramid fiber reinforced plastics: Aromatic polyamines are known as Aramids. Aramids are a family of nylons including Kevlar and Nomex. Kevlar is the best "Bullet proof plastic"

Applications:

- Fiber reinforced plastics find extensive use in space crafts, aeroplanes, boat hulls, acid storage tanks, motor cars and building materials.
- Melamine FRP is used for insulation & making baskets.

Advantages of FRP:

Low efficiency of thermal expansion. High dimensional stability. Low cost of production. Good tensile strength. Low dielectric constant. Non inflammable, corrosion resistance and chemical resistance.

Q 12)What are Conducting Polymers? Give their types and applications.

Most polymeric materials are poor conductor of electricity, because of the non – availability of large number of free electrons in the conduction process.

"The polymeric materials, which possess electrical conductivities on par with metallic conductors, are called conducting polymers"

Different types of conducting polymers are discussed below:

(1) Intrinsically conducting polymer (ICP) (or) Conjugated – Electrons conducting polymer

(2) Extrinsically conducting polymer

(1) Intrinsically conducting polymer (ICP) or Conjugated – Electrons conducting polymer

The polymers which conduct electricity are called conducting polymers. The conduction of the polymers is may be due to the presence of double bonds in the structure (Intrinsic Conducting Polymers) or due to the presence of externally added ingredients in them (Extrinsic Conducting Polymers).

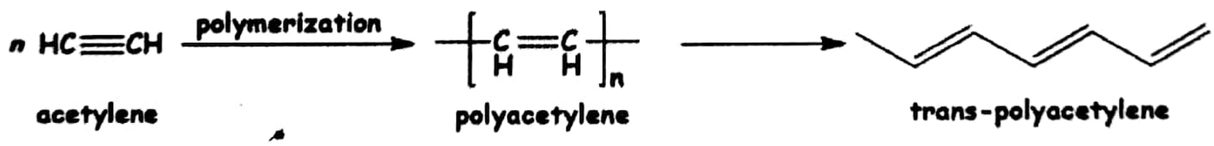
Intrinsic conducting polymers are classified into two types.

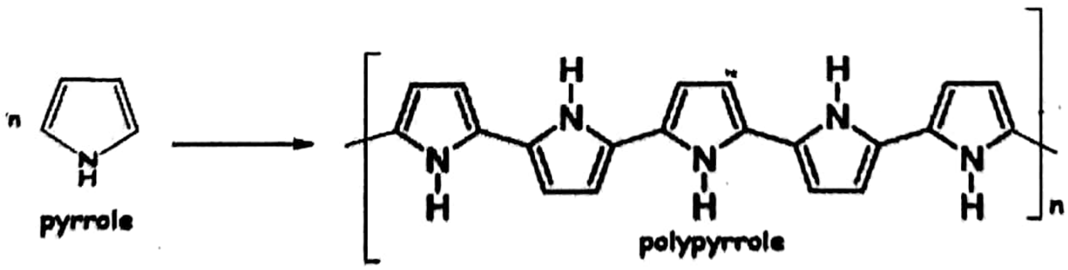
(a) Conducting polymers having conjugation:

These polymers have conjugated double bonds in the backbone and possess their conductivity due to pi-electrons.

The orbitals of conjugated electrons overlap the entire backbone of the polymer and result in the formation of valence bands and conduction bands, which were separated by a significant Fermi energy gap. The electrical conductivity will takes place only after thermal or activation of the electrons, which give them sufficient energy to jump the gap and reach into conduction band.

Ex:-Polymerization of acetylene over Zeigler Natta catalysts will give polyacetylene, which is predominantly in cis-form. On rising the temperature of the film gives more stable trans-form.





(b) Doped conducting polymers:

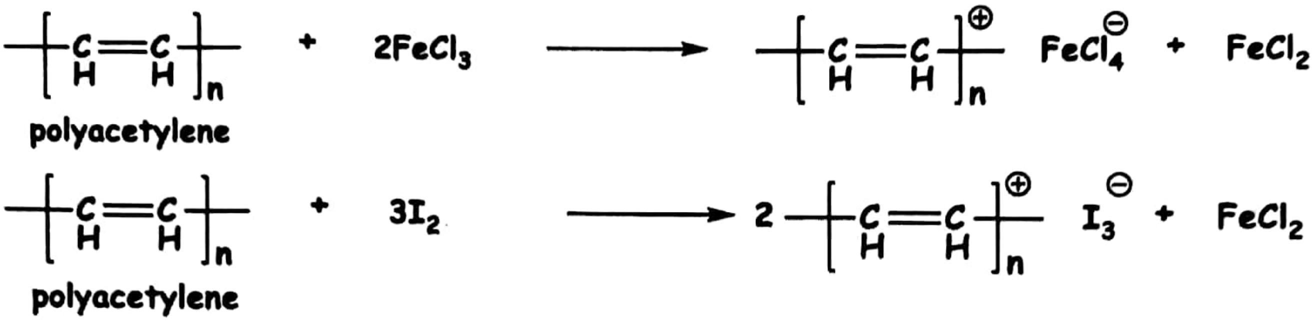
The conducting polymers having pi-electrons in their backbone can be easily oxidized or reduced because of their low ionization potential and high electron affinities. Hence their conductance can be increased by the introduction of a +ve charge or –ve charge on backbone by oxidation or reduction.

If the conductivity increased by the oxidation process by adding some alkali metal ion or electron acceptor, then it is said to be "p-doping". If the conductivity is increased by reduction process by adding an electron donor is called "n-doping".

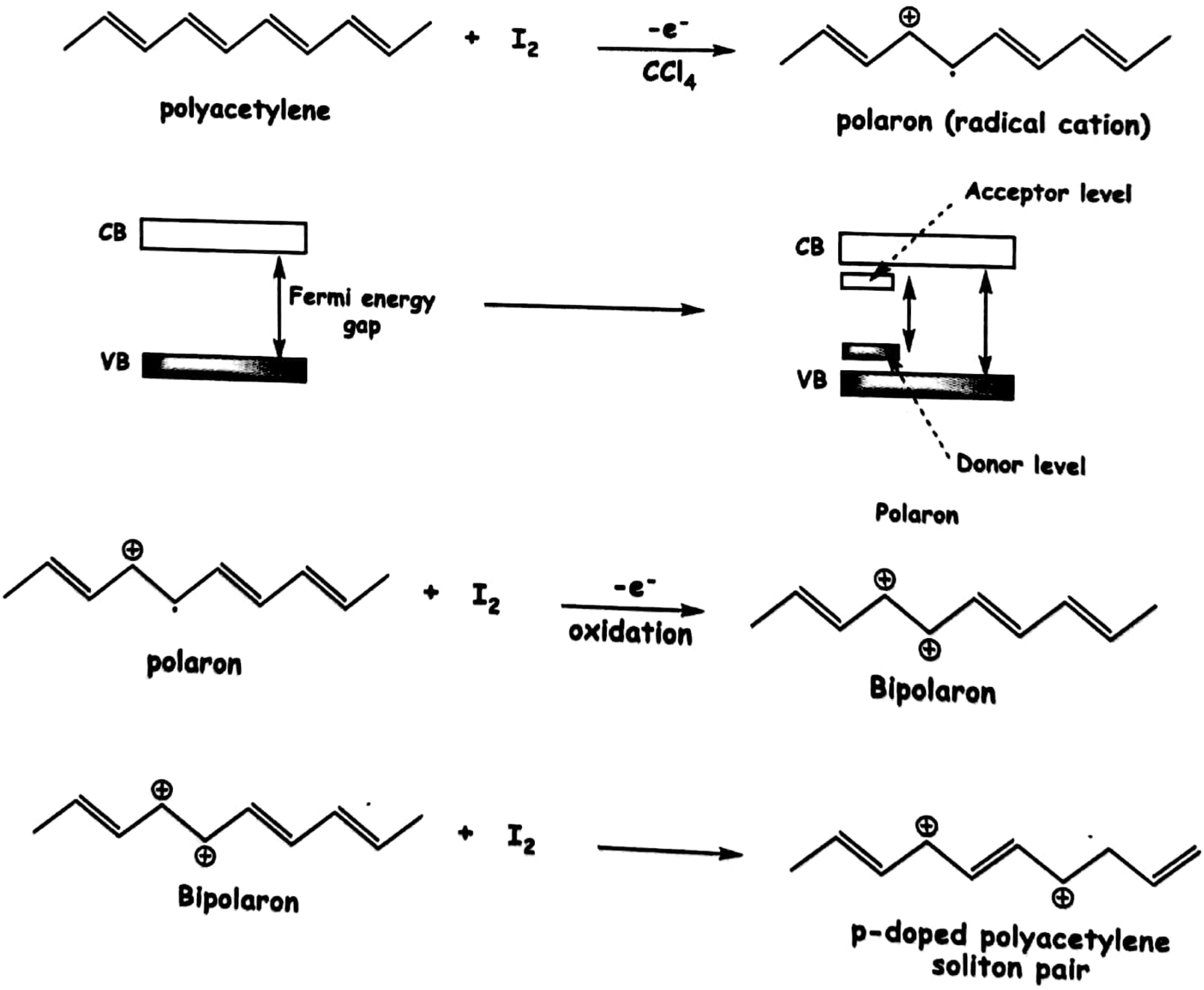
➢ **Oxidation process (p-doping):**

In this process, -electrons are removed from conjugated double bonds and positive hole or radical cation is created. The radical cation is called 'polaron' which stabilizes itself by polarizing the medium. The polarons are mobile and this delocalization is responsible for the conduction of current in the polymers. The p-doping is generally brought by adding Lewis acids (such as FeC13), iodine, bromine arsenic pentafluoride (AsF5) etc.

Ex: polyacetylene

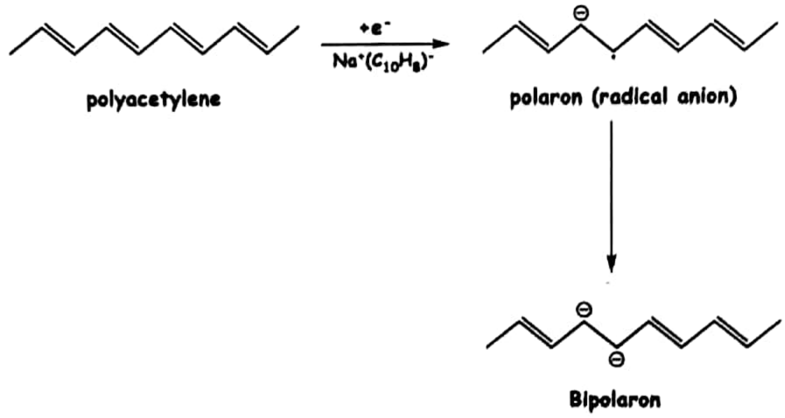


Doping of polyacetylene:



➢ **Reduction process (n-doping):**

In this type of doping some electrons are introduced into the polymer by reducing agent like sodium naphthalide[Na+(C10H8)-]or by adding Lewis base (electron donor). Formation of polaron, bipolaron takes place in two steps, followed by recombination of radicals, which yields two charge carriers on the polyacetylene chain, which are responsible for the conduction as shown below.



The n-doping in less common, because on earth, atmosphere is oxygen rich, which creates an oxidizing environment. An electron rich 'n-doped' polymer will react immediately with oxygen and converts into the neutral state by re-oxidizing.

(2) Extrinsically conducting polymers:

Extrinsically conducting polymers are those polymers whose conductivity is due to the presence of "externally" added ingredient in them. These are of the following two types.

(a)**Conductive element filled polymer:** It is a resin or polymer filled with conducting elements such as carbon black, metallic fibres, metal acids, etc. In this, the polymer acts as the binder to hold the conducting elements together in the solid entity.

(b) **Blended conducting polymer:** It is the product obtained by blending a conventional polymer with a conducting polymer either by physical or chemically change.

Applications:

Conducting polymers are finding increased use because they are light weight, easy to process and have good mechanical properties. Some of the important applications of conducting polymers are:

(A) In rechargeable light weight batteries based on perchlorate doped polyacetylene – lithium system. These are about 10 times, lighter than conventional lead storage batteries. Such batteries are sufficiently flexible to fit a variety of designed configuration.

(B) In optically display devices based on polythiophene. When the structure is electrically based, the optical density of the film changes, i.e., colour changes. Such electrochromic systems produce coloured displays with faster switching time and better viewing than conventional liquid crystal display devices. (LCD)

(C) In wiring in aircrafts and aerospace components

(D) In telecommunication systems

(E) In antistatic coatings for clothing.

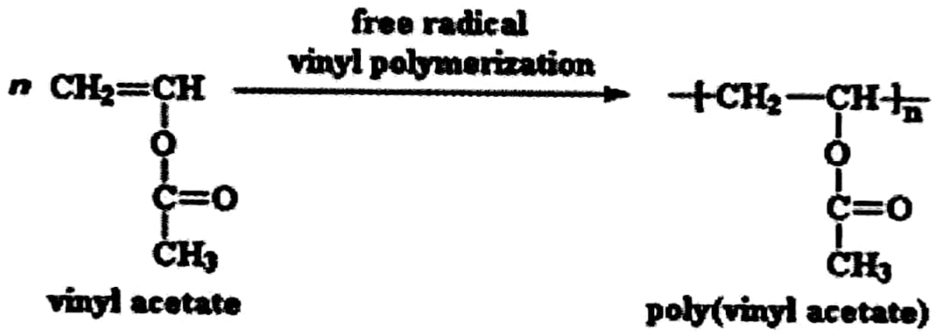
Bio degradable polymers

- These are a specific type of polymer that breaks down after its intended purpose to result in natural byproducts such as gases (CO_2, N_2), water, biomass, and inorganic salts.
- These polymers are found both naturally and synthetically made, and largely consist of ester, amide, and ether functional groups.
- Their properties and breakdown mechanism are determined by their exact structure. These polymers are often synthesized by condensation reactions, ring opening polymerization, and metal catalysts.

EX: POLY VINYL ACETATE

PVA is water soluble biodegradable polymer produced from starch. It can be hydrolyzed to glucose by microorganisms and then metabolized to CO_2 and H_2O.

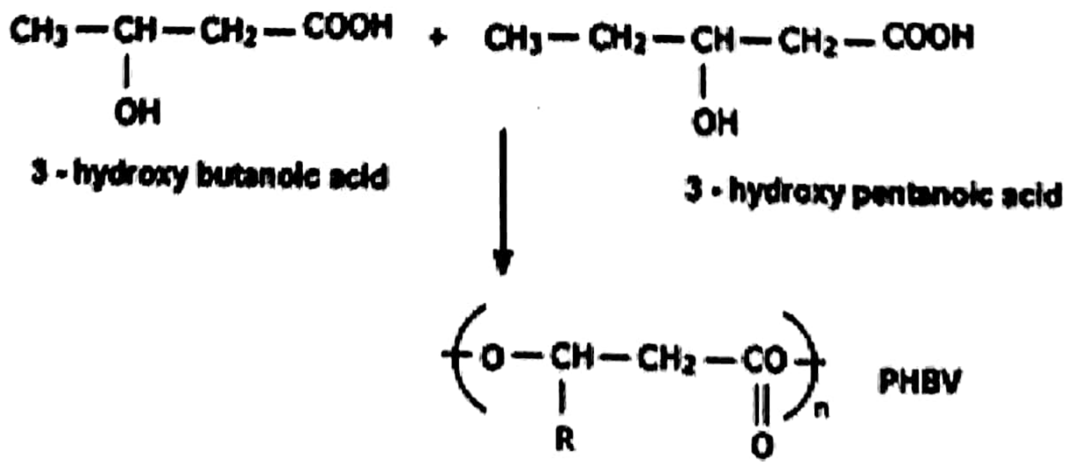
Biodegradable PVA is synthesized by heating vinyl acetate in presence of acetyl chloride as catalyst.



- PVA is used in food industry as a packing materials and food storage.
- It is used for bonding papers and mailing compost bags
- It is used for making records, chewing gums.

- Synthetic biodegradable polymer is **poly-β-hydroxy butyrate co- β -hydroxy valerate Ex: PHBV**

  Preparation: It is a co-polymer of 3-Hydroxy butanoic acid and 3-ydroxy pentanoic acid.



BIOPOLYMERS

Biopolymers are polymers produced by living organisms

- Biopolymers contain monomer units that are covalently bonded to form larger structures.
- There are three main classes of biopolymers based on the differing monomeric units used and the structure of the biopolymer formed:

1. **polynucleotides:** which are long polymers composed of 13 or more nucleotide monomers:
2. **polypeptides:** which are short polymers of amino acids: and
3. **Polysaccharides:** which are often linear bonded polymeric carbohydrate structures.

- Many of the polysaccharides earlier studies are also biopolymers since they have repeating units cellulose most abundant biopolymer

BIOMEDICAL POLYMERS

- Biomedical polymers are essentially a biomaterial, that is used and adapted for a medical application
- Biomedical polymer can have a beginning functional, such as being used for a heart valve and more interactive purpose such as hydroxyl apatite coated in implant and such implants are lunching upwards of twenty year.
- Many prostheses and implants made from polymers have been in use for the last three decades and there is a continuous search for more biocompatible and stronger polymer prosthetic materials.

Properties of Biomedical Polymers:

- Flexibility, good biocompatibility.
- Available in a wide variety of compositions which can be easily manufactured into products with resistance to biochemical attack.
- Light weight, adequate physical and mechanical properties and the desired shape.