MODULE 4 – POLYMERS AND COMPOSITES

Syllabus:

Polymer: Introduction, methods of polymerization, molecular weight of polymers, numerical problems. Synthesis, properties, and engineering applications of polyethylene (PE) and Chloro-poly-vinyl-chloride (CPVC).

Fibers: Synthesis, properties and applications of nylon fibers.

Polymer composites: Introduction, properties, and applications of fiber reinforced polymers composites (FRPC), Geopolymer concrete: Introduction, synthesis, constituents, properties, and applications.

Adhesives: Introduction, properties, and applications of epoxy resin.

Biodegradable polymers: Synthesis of polylactic acid (PLA)and their applications.

Self-learning: Biopolymer: Introduction, structural properties, and applications of cellulose and lignin

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Polymers

Polymers are defined as high molecular weight compounds formed by repeated small units of monomers.

Polymerization is defined as the process of linking up monomers to form polymer with or without the elimination of byproducts.

Types of Polymerizations.

1. **Addition Polymerization**: (chain-growth polymerization)
   The process in which polymer is obtained from simple addition reaction of monomers without eliminating any simple molecule is called addition polymerization.
   Example: polyethylene is obtained by the addition reaction of ethylene monomers.
   n ($H_2C{=}CH_2$) → --(---H_2C- CH_2--- $)_n$-
   ethylene polyethylene

   Based on the kind of intermediate formed, there are three methods of addition polymerization namely:
   a) Free radical addition polymerization: in this type of polymerization, reaction is initiated by using an initiator. Organic or inorganic peroxides like dibenzoyl peroxide, hydrogen peroxide, potassium persulphates are commonly used as initiators. These initiators undergo photochemical dissociation or thermal decomposition easily when exposed to light radiation or to heating. Free radicals thus generated will initiate polymerization.
   b) Cationic addition polymerization.
   c) Anionic addition polymerization.

2. **Condensation Polymerization:** the process in which a polymer is obtained by condensation reaction of monomers with the elimination of small molecules like H_2O, NH_3, CH_3OH is called condensation polymerization.

Example: Nylon 6,6 is obtained by condensation polymerization of hexamethylenediamine and adipic acid.

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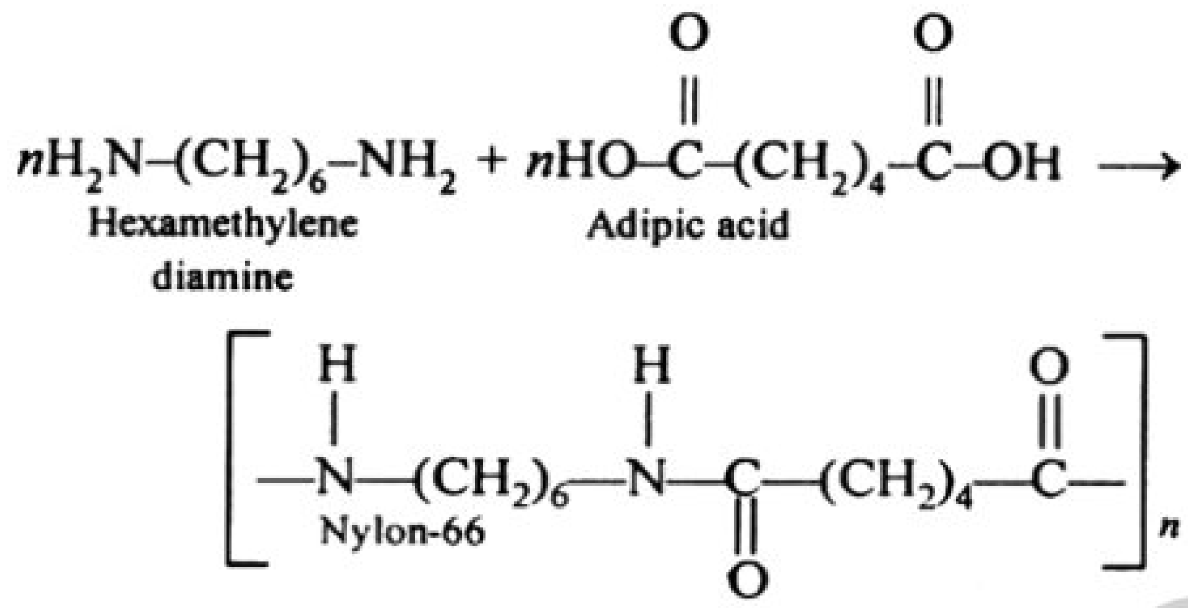


Expression of molecular masses of polymer:

There are two ways to express molecular masses.

1. Number- average molecular mass ($\overline{M}_n$)
2. Mass - average molecular mass or weight average molecular mass ($\overline{M}_w$)

Number average molecular mass is the mass obtained when total mass of all the molecules of a sample is divided by the total number of molecules.

$$\overline{M}_n = \frac{N_1M_1 + N_2M_2 + N_3M_3 + \cdots}{N_1 + N_2 + N_3 + \cdots}$$

number average molecular weight ($\overline{M}_n$)

$$\overline{M}_n = \frac{\Sigma N_i \overline{M}}{\Sigma N_i}$$

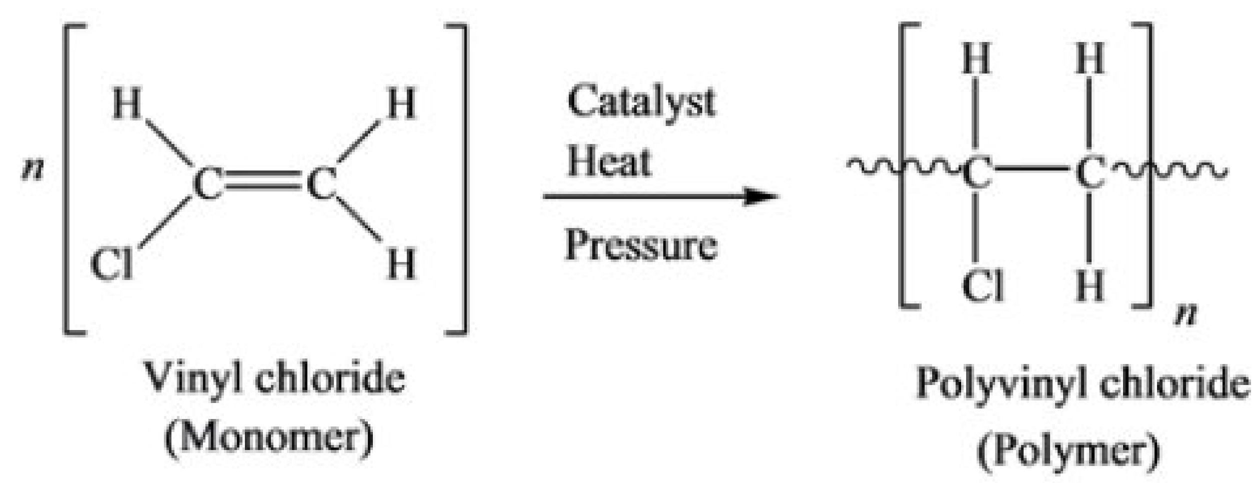
Mass- average molecular mass is defined as mass obtained when sum of the products of total mass of group of molecules and their respective molecular mass is divided by total mass of all the molecules.

$$\overline{M}_w = \frac{N_1M_1^2 + N_2M_2^2 + N_3M_3^2 + \cdots}{N_1M_1 + N_2M_2 + N_3M_3 + \cdots}$$

$$M_w = \frac{\sum M_i^2 N_i}{\sum M_i N_i}$$

PVC (polyvinyl chloride)

PVC is obtained by emulsion polymerization of vinyl chloride at 40° C - 60° C in the presence of potassium persulphate ($K_2S_2O_8$) as initiator.



Properties:

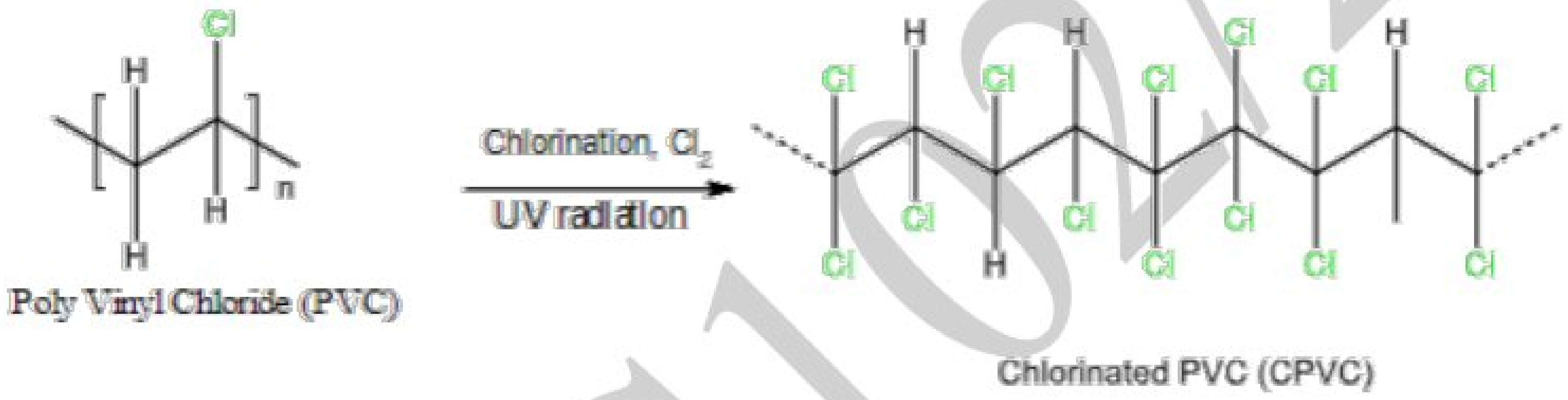
1. PVC is a hard and rigid polymer.
2. It has high impact resistance and chemical resistance.
3. It is a very good electrical insulator.
4. It can be molded to any shape with the addition of plasticizer.

Applications:

1. Used in PVC pipes.
2. Used as covering for cable and wires.
3. Used as thin film and sheets for floor coverings.
4. Used in window frames and bathroom doors.

Chloro Poly Vinyl Chloride (CPVC)

CPVC is obtained by further chlorination of PVC under UV radiation. Chlorine Free radicals produced by UV radiation. Which initiates the reaction and proceeds. Commercial CPVC is chlorinated to get 63% to 69% chlorine content.



Properties:

1. They have high mechanical strength, ductility and flexibility.
2. They have corrosion resistance to water and other chemicals.
3. They have good electrical insulating properties.

Applications:

1. Used to store industrial chemicals and solvents.
2. Used in water piping systems for hot and cold-water delivery.
3. Used as electrical insulator.

Polyethylene:

Preparation: polyethylene is obtained by addition polymerization reaction of ethylene monomers.

Reaction:

$$n(\underset{\text{Ethylene}}{H_2C{=}CH_2}) \longrightarrow \underset{\text{Poly ethylene}}{-\!\!\!(\, H_2C{-}CH_2 \,)\!\!\!-_n}$$

Polymerization can be carried out by free radical polymerization using dimethoxy peroxide as an initiator.

Low Density Polyethylene (LDPE): Polymer obtained by addition polymerization using dimethoxy peroxide having more branches with less close packing and it is called low density polyethylene (LDPE)

High Density Poly Ethyle (HDPE): when polymerization is carried out by Zeigler -Natta catalyst using $TiCl_4$ and $AlCl_3$, polyethylene with less number of branches with more close packing is called high density poly ethylene.

Properties:

1. LDPE has high degree of branching with low crystallinity
2. LDPE exhibits good flexibility, transparency , good moisture barrier properties.
3. HDPE has very low degree of branching with high crystallinity
4. HDPE exhibits excellent chemical resistance , high tensile strength, excellent moisture barrier

Applications:

1. LDPE is used as carry covers, squeezable bottles, garbage bags and laminates
2. HDPE are used in injection moldings, hollow plastic products and pipes.

Polypropylene:

Preparation: It is prepared from propene monomer by Zeigler – Natta catalyst i.e $TiCl_4$ and $AlCl_3$

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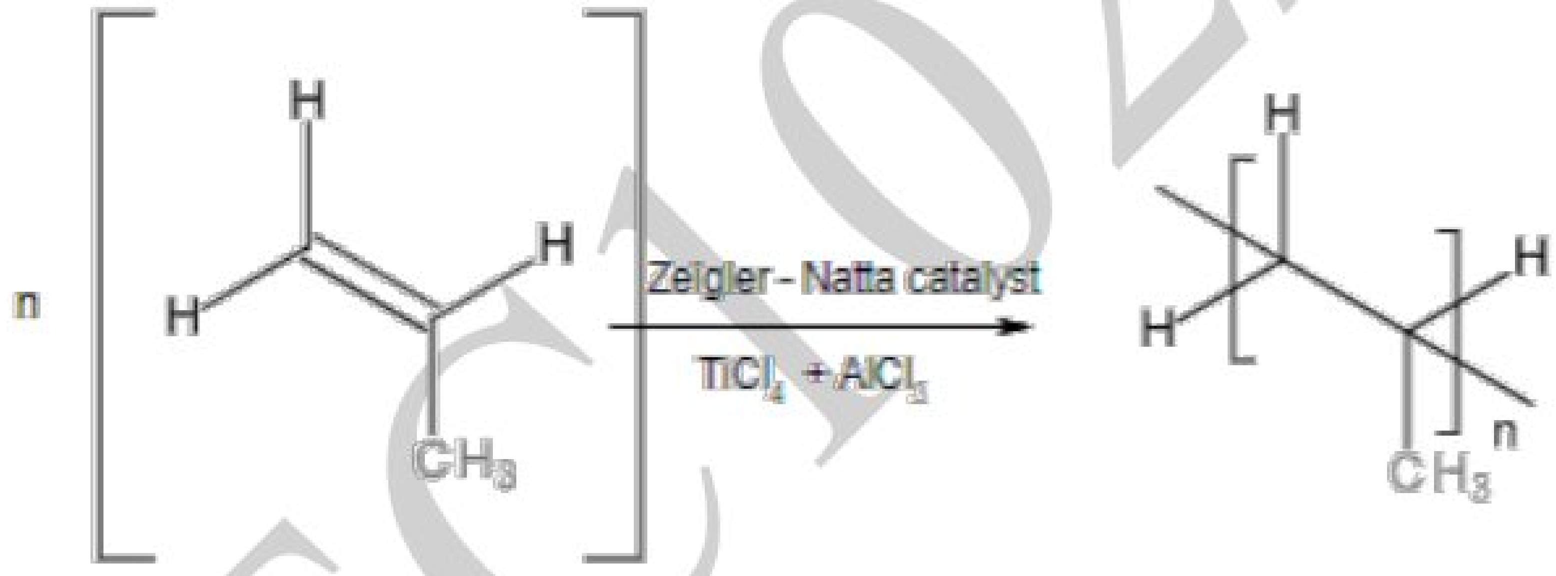

Properties:

1. Polypropylene is tough , rigid, light weight synthetic fiber.
2. It has better mechanical properties and thermal stability than polyethene
3. It has good chemical resistance.
4. It has good fatigue resistance.

Applications:

1. It is used in packaging, cast films
2. Due to high thermal stability it is used in laboratory and medical products.
3. Used in piping system
4. Used in water storage containers.
5. Used as materials for ropes.

NYLON:

Preparation:

Nylon 6,6 is obtained by condensation polymerization of hexamethylene diamine and adipic acid under high pressure and temperature (553K).

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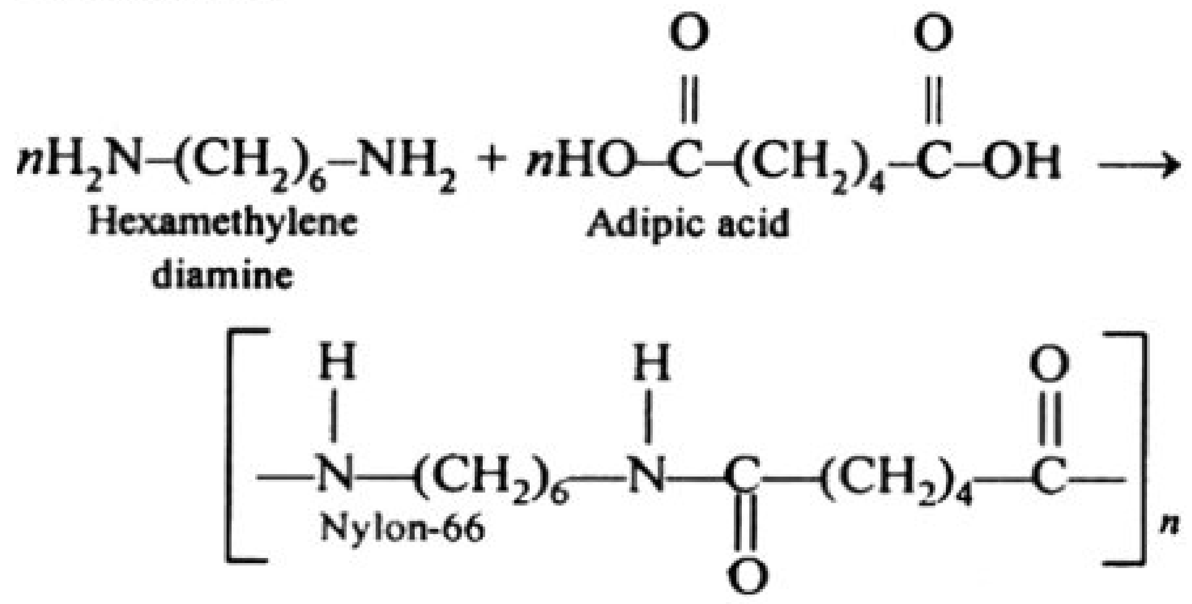

Properties:

1. It is a high mechanical strength and high rigidity synthetic fiber.
2. It exhibit high thermal stability.
3. It has high chemical resistance.
4. It has high resistance for abrasion.

Application:

1. Used in the textile industry.
2. Used in tires.
3. Used in conveyor belt, carpets etc
4. Used in making sleeping bags, tents, ropes, bristles for brushes etc.

Polymer Composite Materials:

A composite is a multiple material made by the combination of two or more materials having specific characteristics properties. The constituents of composite materials do not dissolve or merge completely into each other but act together. And retain their individual identities.

Composite materials are made up of only two phases, namely matrix which is a continuous phase and surrounds the other phase called dispersed phase.

Fiber reinforced composites:

1. These are the composite obtained by the combination of matrix and fiber.
2. Matrix is usually a thermosetting plastic like polyester, polyurethane, phenolic and epoxy resins.
3. Commonly used fibers are Kevlar, polyester, polyamide, CNT, graphenes and metal nano particles.
4. The fiber is embedded in between two matrix layers.

Properties:

- They exhibit high strength, stiffness, high abrasion.
- Thry show impact resistance and corrosion resistance.
- They have low weight, low density.

Applications:

These are useful in aerospace and automobile industries.

Geopolymer Concrete:

These are formed by the reactions of alumino silicate and alkaline solutions. Binding phase of geopolymer is because of an alkali aluminosilicates gel, in which Si and Al are linked in a 3D TETRAHEDRAL gel network.

Preparation of Geo Polymer:

Constituents:

1. Fly ash: which is obtained by burning coal from power stations which serve as a source of alumino silicate.
2. Coarse and fine aggregates like Portland cement.
3. Alkaline solution made from sodium silicate and sodium hydroxide solution.
4. Naphthalene sulphonates which acts as super plasticizer.

Preparation:

1. Fly ash and aggregates are mixed in a pan mixer for about 3 minutes.(dry materials)
2. Alkaline liquid and super plasticizer are mixed well with some more water .(liquid component)
3. Liquid component are added to dry materials and mixed well for about 4minutes.
4. Silica and alumina oxides reacts with alkaline liquid to form geopolymer paste. That binds loose coarse aggregates , fine aggregates and other un reacted materials together to form geopolymer concrete.

Properties

1) They have high strength
2) Low shrinkage power
3) Sulphate and corrosion resistance

Applications:

1. Used in construction materials as it emits less carbon dioxide.
2. Used as fire protection coating in cruse ships.
3. Used as resin in carbon-fiber composites.

Adhesive: these are the materials used to bind two or more materials like wood, glass, metals etc. .as result of which new material is obtained for usage.

Example: epoxy resin

Preparation of Epoxy Resin:

Epoxy resin is obtained by the reaction of Bisphenol-A and epichlorohydrin in the presence of NaOH as catalyst.

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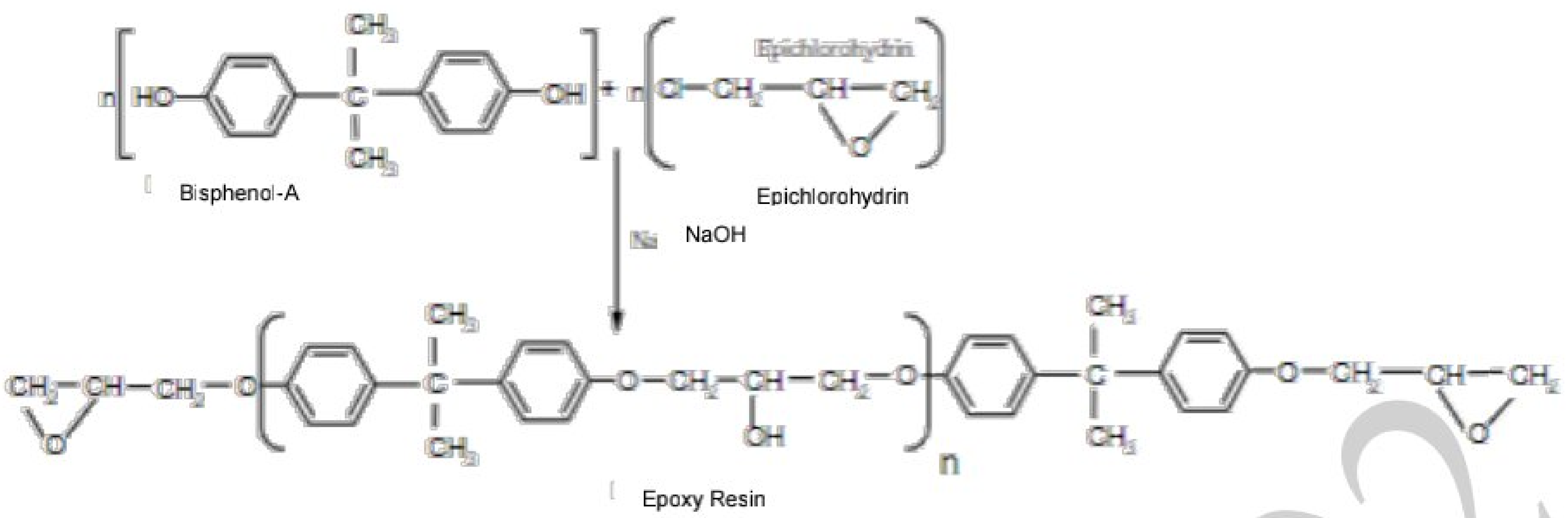

Properties:

a) It has resistance to water, alkali, acids, and various solvents.
b) Cured resins have more toughness, adhesion, and heat resistance.
c) Good electrical insulating properties.
d) Good abrasion and wearing resistance.

Applications:

a) Used to bind metals, glass, wood, ceramics, concrete, leather materials.
b) In industrial floorings.
c) Production of aircraft and automobiles.
d) Used as laminating materials for electrical equipment.

Biodegradable Polymers:

These are the polymers which can undergo degradation (decomposition) by the microbial activities (like bacteria, fungi and algae etc)

Example: poly lactic acid (PLA)

Synthesis of Poly Lacic Acid:

- It is obtained by the polymerization of lactic acid monomers.
- Lactic acid is concentrated and subjected to condensation reaction resulting in poly lactic acid oligomers.
- This oligomer under elevated temperature undergoes cyclization in the presence of catalyst to give Lactide.
- Lactide undergoes ring open polymerization to yield high molecular weight PLA.

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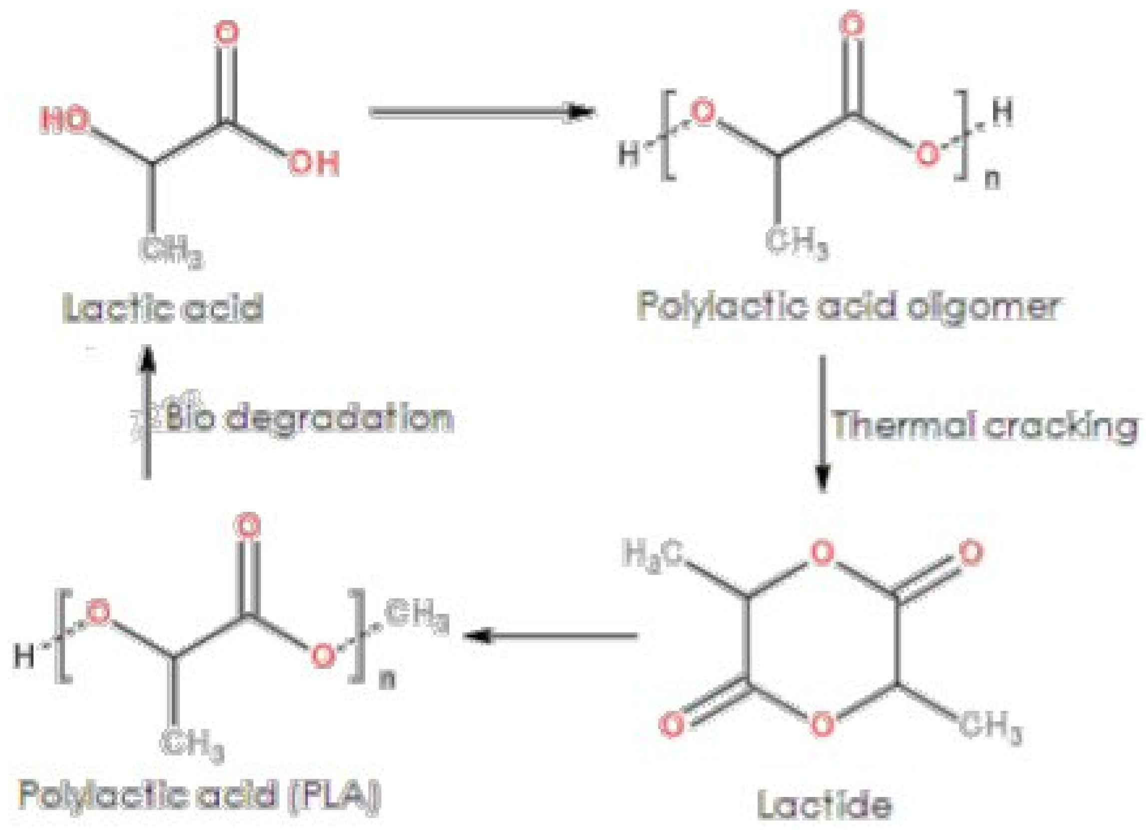

Properties:

1) It has resistance to fat, food oil, solvents, humidity etc.
2) It is bright and transparent but brittle in nature.
3) Molecular weight ranges from a few thousands to millions.
4) Can be easily converted into fil fiber.

Applications:

- ✓ Used as dissolvable sutures as materials for drug delivery, bone fracture internal fixation.
- ✓ As plant growth promoters.
- ✓ Used in textiles, diapers, candy wrap, thermoformed cups, and containers etc.

Question Bank

1) Write a note on number average molecular mass and weight average molecular mass and numerical problems.
2) Give the synthesis, properties and applications of polyethylene and PVC.
3) Give the synthesis, properties, and applications of choloropolyvinyl chloride (CPVC)
4) Give the synthesis, properties, and applications of polypropylene.
5) Give the synthesis, properties, and applications of nylon fiber(nylon-6,6)
6) What are polymer composites? Write a note on properties and application of fiber reinforced polymer composites. (FRPC)
7) What are geopolymer concrete? Give the synthesis, properties, and applications of geo polymer concrete.
8) What are adhesive? Give the synthesis, properties and applications of epoxy resins.
9) What are biodegradable polymer? Give the synthesis, properties and applications of poly lactic acid (PLA)