Unit 3. Advanced Materials

Polymers

- **Introduction:-**
  1) A high molecular weighed compound formed linking by large number of small molecules (monomer) is known as Polymers. (Poly=Many).
  2) The small molecules linked together to form polymer are known as monomer.
  3) The total number of single monomer units linked together to form a polymer is called as degree of polymerization.
  4) Example of polymers:-
     Polyethene, polystyrene, urea formaldehyde, polyvinyl chloride (PVC), nylon-6 etc.
- **Polymerization:-**
  1) The process of formation of polymers is called as polymerization.
  2) There are two methods of polymerization addition polymerization and condensation polymerization.
     a) Addition/ Chain polymerization
     b) Condensation / Step Polymerization

a) Addition or Chain Polymerization:-

i) The word chain indicates the elongation of carbon skeleton to form a polymer.

ii) Generally such polymer contains C=C link in monomer. The double bond breaks and as a result two single bonds on either side of each carbon are formed to elongate carbon chain.

iii) Addition polymerization reaction rate is very high. It involves three steps as, Initiation, Propagation & Branching and Termination.

iv) Initiation requires normally initiators or catalyst like, free radicals, ions or coordination compounds. Commonly used initiators are H_2O, H^+ etc.

v) In second step propagation or elongation of chain takes place.

vi) The polymerization reaction stops (termination step) only if it is interrupted with chain transfer otherwise reactions continuous till monomers are available.

vii) The addition polymerization may be between same monomers or between different monomers species which react to form a third monomer which in turn form a polymer.

viii) If two same monomers joined to form a polymer, the method is known as chain polymerization while if two monomers combined to form a product which in turn acts as a monomer the method is known as copolymerization.

ix) Example:-

$$\underset{\text{Ethene (Monomer)}}{n CH_2 = CH_2} \rightarrow \underset{\text{Molecular Rearrangement}}{- CH_2 - CH_2 -} \rightarrow \underset{\text{Polyethene (Polymer)}}{(- CH_2 - CH_2 -)_n}$$

b) Condensation or Step Polymerization:-

i) The monomers having certain functional groups such as –OH, -COOH, -NH_2 etc. show the tendency to undergo polymerization by the elimination of one molecule of simple by-product such H_2O, HCl etc.
ii) Unlike addition polymerization, polymer losses simple molecules at every combination.
iii) Condensation polymerization is undergone by the monomers which posses functional groups.
iv) This type of polymerization occurs stepwise hence the rate of polymerization is comparatively low.
v) Example:- Nylon-6,6

- **Plastics:-**

1) These high polymers are substances with high molecular weights. The name plastic refers to its meaning that these are the polymers which mould themselves into articles by heat & pressure.
2) As these are synthetic or artificial prepared it is also called as 'synthetic resins'.

- **Types of Plastics**

On the basis of setting manner in final stage of manufacture the plastic materials or plastic articles are classified into two classes

A. Thermoplastic or Thermosoftening plastics
B. Thermosetting plastic

A. Thermoplastic or Thermosoftening plastics:-

1) These show reversible change on heating i.e. they soften on heating but regain their original properties on cooling.
2) They gain or lose hardness with rise or fall in temperature.
3) Their chemical nature does not get affected even on repeated heating & cooling i.e. the changes is more physical in nature.
4) If these resins are softened, they retain their softness at that temperature.
5) The method usually used to manufacture polymers is addition polymerization.
6) These resins can be reclaimed from waste.
7) They are soft, weak & less brittle as compared to Thermosoftening plastics.
8) They are soluble in specific organic solvents.
9) Examples- Cellulose Nitrate, polyvinyl resins, styrene or polystyrene resins etc.

B. Thermosetting plastic:-

1) These polymers on heating change shape irreversibly into hard & rigid materials.

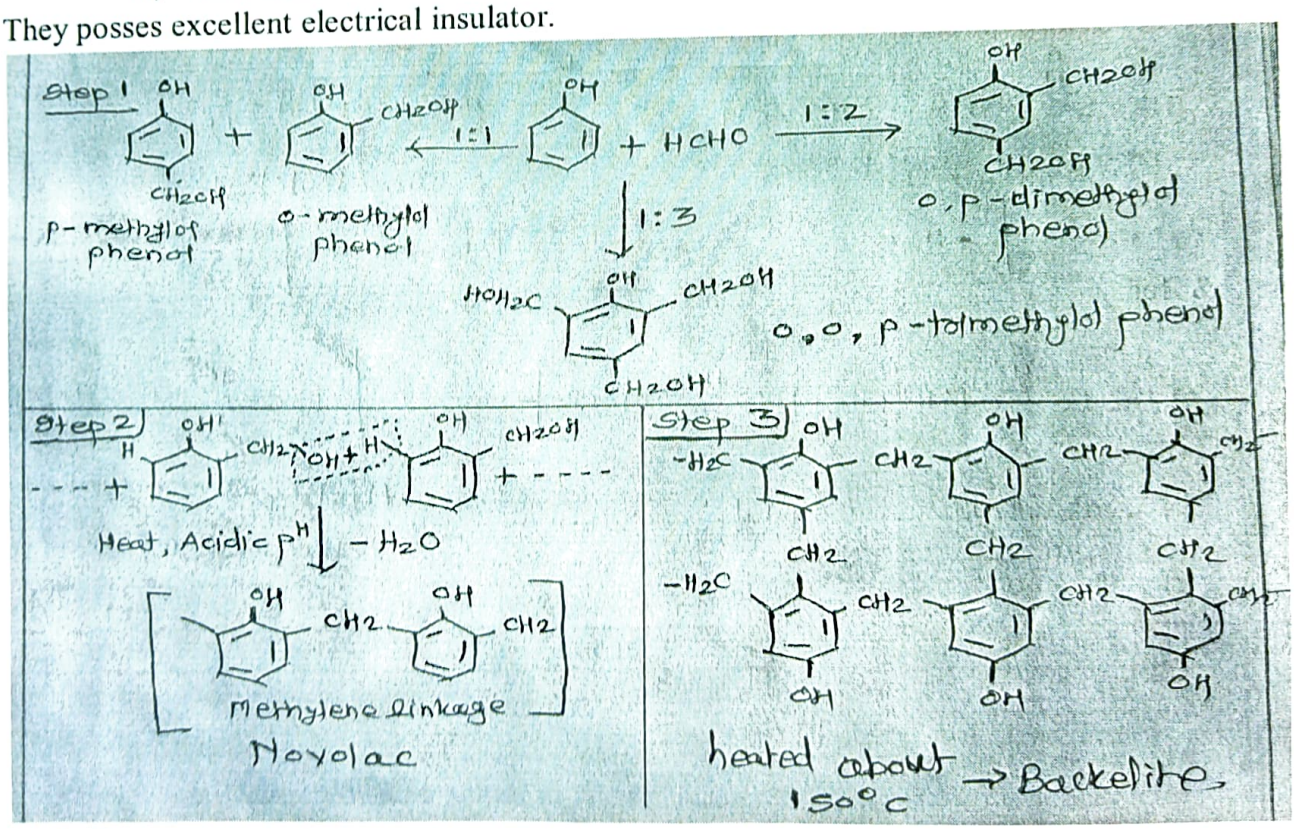
2) When this melt set into mould to form an article is an almost a permanent set.
3) On reheating article does not soften again.
4) These cannot be reclaimed from waste due to their irreversibility.
5) They are hard, strong and brittle than thermoplastics.
6) The method by which these are formed is called condensation polymerization.
7) These are also known as thermohardening plastics or permanent setting resins.
8) They are insoluble in almost all organic solvents.
9) Examples:- Phenol formaldehyde, Silicon plastics, etc

- **Industrially Important Plastics**

1) Phenol Formaldehyde:-

1) The monomers used for preparation of phenol formaldehyde are phenol & formaldehyde.
2) They undergo condensation polymerization to give rise to three dimensional structures.
3) Properties:-
   i) It is rigid, hard, infusible solid, insoluble solid.
   ii) Water resistant, Scratch Resistant.

iii) They posses excellent electrical insulator.

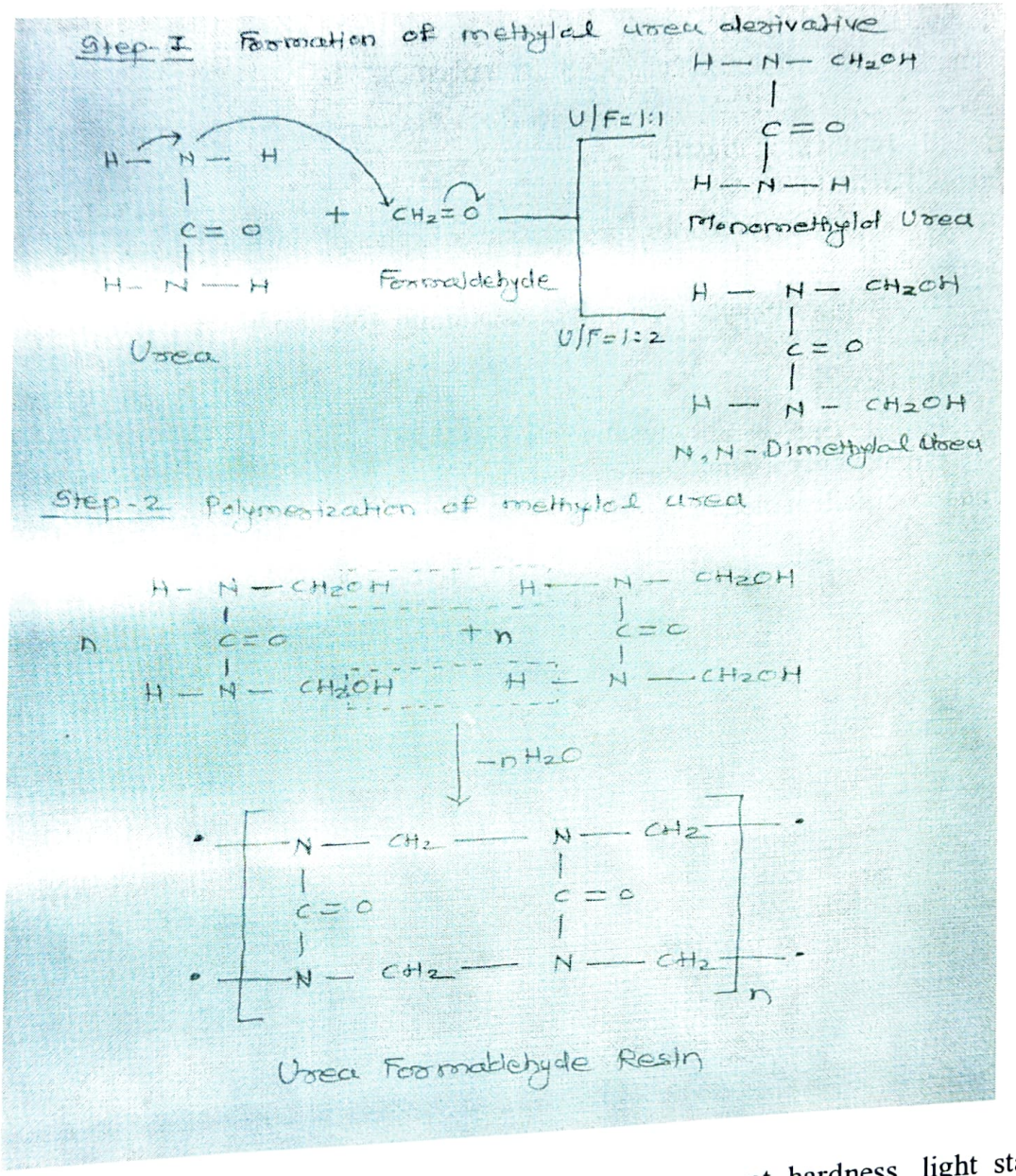


4) Uses:-
   i) It is used for making electric insulator part like switch, plugs, switch board etc.
   ii) In paint & varnish.
   iii) Hydrogen exchanger resin in water softening.

iv) For impregnating fabrics, wood and paper.

2) Urea Formaldehyde

1) Urea formaldehyde resin is prepared by the condensation reaction between urea & formaldehyde in neutral or alkaline conditions.



2) Properties:- Good insulator, chemical resistive, possess great hardness, light stability, good tensile strength, Resistant to water, Resistant to flame/heat.

3) Uses:-
   i) It is used to make molded articles like jugs, bottle caps, plates, drinking glasses, dishes etc.
   ii) Manufacture of cation exchange resins.

b) Doped Conducting Polymers (DCP)
c) Extrinsically Conducting Polymers (ECP)
d) Coordination Conducting Polymers (CCP) / Inorganic polymers

a) Intrinsically Conducting Polymers (ICP):-

i) These posses conjugated Π electrons backbone.
ii) When an electric filled is applied such polymers, electrons get excited and hence move through polymeric material.
iii) In this valence bond and conduction bonds are developed which get distributed over surface of polymer.
iv) Example- polyacetylenes, polyquinoline.

b) Doped Conducting Polymers (DCP):-

i) These are prepared by exposure of the polymer to a charged transfer agent either in gas phase or in liquid phase (i.e. solution).
ii) DCP can be made more conductive by creating positive or negative charge on its backbone by oxidation or reduction.

c) Extrinsically Conducting polymers (ECP):-

i) These are conducting polymer they passes conductivity due to externally added in gradient in them.
ii) There are two types of ECP's

- **Conductive Element Filled Polymer:-**

  In this resin or polymer is filled up with conducting element e.g. carbon black, metal oxide. The polymer holds the metallic element thus acting as binder. Cost is low, strong, can be easily molded, they are light weight.

- **Blended Conducting Polymer:-**

  These are blend of normal polymer with conducting polymer. The blending is either only physical change or in certain cases chemical change. They have good mechanical properties.

d) Coordination Conducting Polymers (CCP) / Inorganic Polymers:-

i) These are inorganic in nature.
ii) They have very low degree of polymerization.
iii) They are corrosion resistant.

4) **Applications**:-

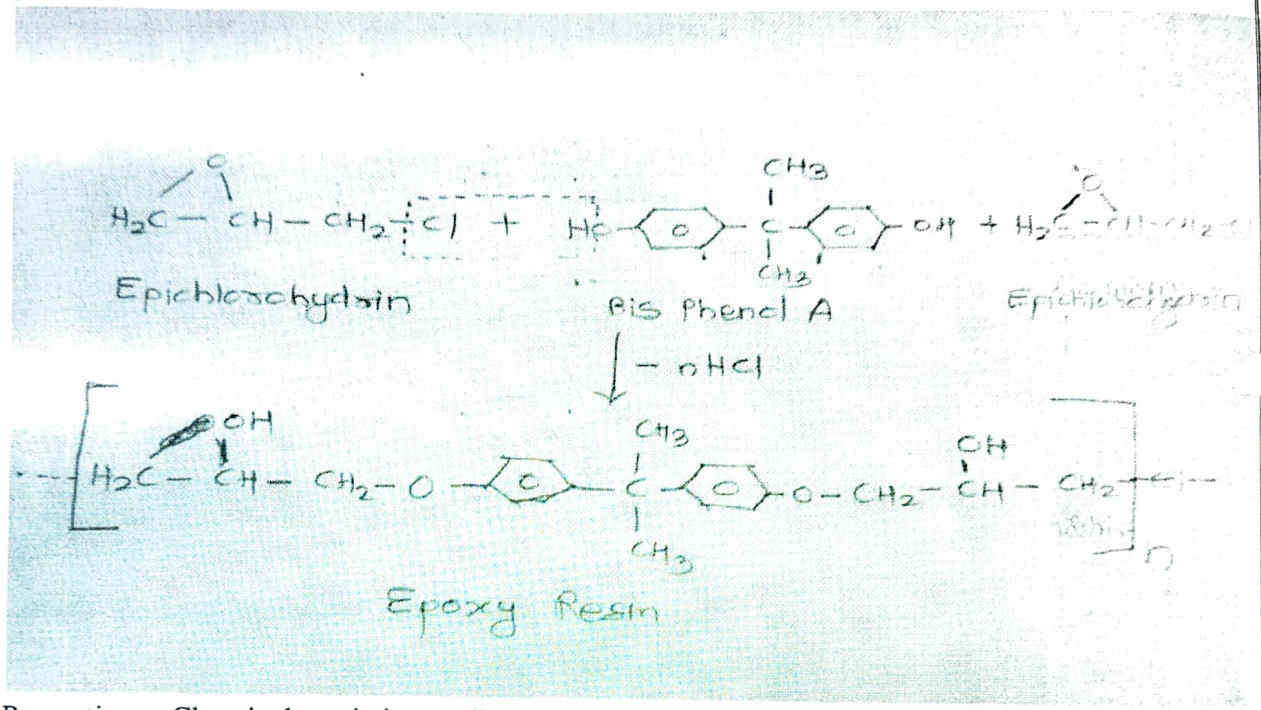
i) In light emitting diodes and optically display devices.
ii) In telecommunication systems.
iii) In electromagnetic screening material.
iv) Solar cells, photovoltaic devices, transistors, diodes, molecular wires and switches etc.
v) In antistatic materials and as electrode materials in rechargeable batteries.

- **Biodegradable Polymers (Biopolymers)**

iii) It is used as an electric insulation.
iv) Used in bonding grinding wheels, bonding plywood.

3) Epoxy Resin

1) Epoxy resin is prepared by the condensation reaction between epicholrohydrin&bis-pheno-A.



2) Properties:- Chemical resistive, adhesion quality, Resistant to water, Resistant to flame/heat, dimension stability, electric insulator

3) Uses:-
   i) Adhesives for glass and metals etc.
   ii) Cotton rayen fabrics (crease resistance)
   iii) Outstanding toughness and flexibility
   iv) In floorings, table tops etc.

- **Conducting Polymers:-**

1) These are specialty polymers. A most of polymers acts as insulator because of unavailability of large number of free electrons in the condensation.
2) Polymers with high crystalline nature develop conductivity easily. e. g. polyacetylene or polyparaphemylene.
3) There are following types of conductivity polymers.
   a) Intrinsically Conducting Polymers (ICP)

generation of extraordinary materials with the combination of metals, ceramics and polymers with superior mechanical properties such as toughness, stiffness and high temperature strength.

- **Constituents**

1) Composite materials are formed by two phase's **matrix** which is continuous and surrounds the other phase called the **dispersed phase(Reinforcement)**.
2) The properties of composites depends upon properties of constituent phases, their relative amounts and the geometry of the dispersed phase namely shape and size of the particles, their distribution and orientation.
3) **Matrix phase:-**
   a) Matrix phase performs several functions such as, it binds the fibers together, it acts as medium by which an externally applied stress transmitted & distributed to the fibers, protects fibers from damage, it separates individual fibers.
   b) Properties of matrix material are the matrix material should be ductile, it's elastic modulus should be less than fiber, adhesive bonding forces between the fiber and matrix must be high i.e. a bonding strength in between these two.
   c) Since some ductility is essential, only metals and polymers are used as the matrix materials. Metals like Al, Cu while polymers like commercial thermoplastic and thermosetting polymers can be used as matrix.
4) **Dispersed Phase (Reinforcement):-**
   a) Second constituent of composites is dispersed phase or reinforcement provides high strength, rigidity and enhances the matrix properties.
   b) Various reinforcements used are fibers, filled, whiskers, flakes, particulates.

- **Types of Composites:-**

There are three main types of composites as

A) Fiber Reinforced Composites
B) Particular Composites
C) Layered Composites

- **Advantages:-**
  1) Composite materials are of higher strength.
  2) They are having lower specific gravity than other materials.
  3) They withstand even at high temperature.
  4) Fabrication is easy and cheap.
  5) Composite materials having lower electrical conductivity.
  6) These are having high strength, great toughness, and thermal resistance.
  7) Resistant t corrosion, oxidation.

- **Composition, Properties & Uses of FRP & GRP**

1) These polymers are biodegradable polymers. They degrade on their own in environment.
2) Biodegradable polymers 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.
3) These polymers are found both naturally and syntheticallymade, and largely consist of ester, amideand etherfunctional groups. Their properties and breakdown mechanism are determined by their exact structure.
4) The materials used in production of these polymers may be either renewable i.e. based agricultural plant or animal or synthetic.
5) These are classified as starch, sugar, cellulose, synthetic materials.
6) Two main strategies are followed when polymer is synthesized,
   i) To form a polymer of monomer by process of chemical polymerization.
   ii) Another one is take naturally occurring polymer and chemically modify it to give it desired properties.
7) Examples- Polypeptides, polysaccharides, polynucleotide's etc.
8) Any protein or nucleic acid produced by a living organism also is a biopolymer. Also biopolymers are a class of polymers produced by living organism.
9) **Applications:-**
   - It is used in packaging food trays, thin films for wrapping.
   - Biopolymers are renewable, sustainable hence used in many industries.

➢ Composite Materials

- **Introduction:-**

1) In growing world of technologies we require the materials with extraordinary combinations of properties that cannot be provided by the conventional metal alloys, ceramics and polymeric materials.
2) A composite is an artificially prepared multiphase material in which the chemically dissimilar phases are separated by a distinct surface.
3) A composite is multiphase material that exhibits a significant proportion of the properties of both the constituent materials. Efforts has been put to produce new

I. Fiber Reinforced Plastics (FRP):-

1) Composition:-

Fiber reinforced plastics mainly contain textile glass fibers these fibers are different from other forms of glass fibers used for insulating applications. Textile glass fibers consists of varying proportion of oxides such Al_2O_3, SiO_2, CuO & MgO in powder form.

2) Properties:-

a) Low weight lighter than equivalent volume of steel or aluminium.
b) High Mechanical Strength- FRP show high mechanical strength due to carbon fiber & Kevlar fiber & also it shows good stiffness property.
c) High impact strength.
d) Formability:- FRP moulded to almost any desired shape.
e) It shows high chemical resistance.
f) It shows high corrosive resistance, thermal resistance property.
g) Once FRP installed it requires minimum maintenance.
h) FRP accept durable custom colours.
i) FRP posses long life.

3) Uses:-

It is useful in the construction of tanks, hoods, covers, pipes, ducts & other structures in paper, chemical water treatment & petroleum industries.

II. Glass Reinforced Plastics (GRP):-

1) Composition:-

It is made of a plastic matrix reinforced by fine fibers of glass as a dispersed phase. The plastic matrix phase may be epoxy resin, polyester, thermoplastic or thermosetting plastics.

2) Properties:-

a) It has low specific density.
b) It has high tensile strength & stiffness.
c) GRP shows high corrosive & chemical resistance property.
d) Stiffness of GRP can be increased to desired requirement by laying multiple layers of fiber on top of one after another.
e) It is strong in tension and compression.
f) GRP is light weight &strong material.

3) Uses:-

a) GRP have abroad spectrum application in construction, electrical industry, transportation, consumer good, sports activities etc.
b) It is used to make boats, water tanks, roofing, cladding & external door skins.

Q.1 Write short note on thermosetting plastics. **5M**

Q.2 Compare thermoplastics with thermosetting plastics. **5M**

Or

Distinguish between thermoplastics with thermosetting plastics.

Or

Distinguish between thermoplastics with thermosetting plastics with respectto structure, solubility, biodegradability and examples. **4M**

Q.3 Explain preparation, properties & applications of phenol formaldehyde plastic. **5M**

Q.4 Write preparation, properties & applications of urea-formaldehyde resin. **5M**

Q.5 Explain various types of conducting polymers with example. **5M**

Or

Write notes on conducting polymers. **4M/5M**

Q. 6 Enlist applications of conducting polymers. **4M**

Q.7 Write short note on biodegradable polymers. **4M**

Or

Discuss the classification of biopolymers with suitable examples. **4M**

Q.8 Write composition and different applications of FRP. **5M**

Q.9 What is FRP? Mention different properties and commercial uses of FRP. **4M**

Q.10 Explain properties and different applications of GRP. **5M**

Q. 11 Write preparation, properties & applications of epoxy resin. **5M**