Unit –07

Chemistry of Engineering Materials

Engineering materials are group of materials that are used in the construction of man made structures and ~~Compound~~ Components. The major classification of Engineering materials are—

1– Metals
2– Polymers
3– Ceramics
4– Composites

Polymers ⇒ "Polymers may be defined as a substances of high molecular mass formed by the Combination of a large no. of simple molecule."
The simple molecules which combine to give polymer are called Monomer.

Polymerisation ⇒ The process by which monomers are converted into polymer ~~is~~ called Polymerisation.

* Example ⇒ Polythene is a polymer formed by polymerisation of Ethane.

$$n\,CH_2=CH_2 \xrightarrow{\text{(Polymerisation)}} (-CH_2-CH_2-)_n$$

Ethene (monomer) → Polythene (Polymer)

Degree of Polymerisation ⇒ The number of repeating units (n) in the chain so formed is called degree of Polymerisation (DP).

DP is low ($n = 2-9$) is called Oligomers
DP is high ($n > 10$) is called high Polymer
DP is very high ($n = 5000 - 2,00,000$) high Molecular mass Range.

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Polymers & Macromolecules ⇒ All polymers are macromolecules but all macromolecules are not polymer. Because Very large numbers of repeating unit forms polymer while macromolecule may or may not contain repeating units.

Example Chlorophyll =

$C_{55}H_{72}O_5N_4Mg$

(*) [Classifications of Polymer]

(I) **Classification on the basis of type of monomer** ⇒

(A) Homopolymers (B) Copolymers

(A) **Homopolymers** ⇒ "A polymer formed from one type of monomer"

ex- Polythene, PVC, PAN, Nylon-6, Teflon etc.

$$n\ CH_2=CH_2 \longrightarrow (-CH_2-CH_2-)_n$$

(Ethene) (Polythene)

(B) **Copolymer** ⇒ A polymer formed from two or more different monomers) ex. Nylon-66.

$$n\ H_2N-(CH_2)_6-NH_2 + n\ HOOC-(CH_2)_4-COOH$$

(Hexamethylene diamine) (Adipic Acid)

(Different monomer)

Polymerisation

$$\left[-NH-(CH_2)_6-NH-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\right]_n$$

Nylon-66

(Polymer)

other Ex. Buna-S, Polyester, Alkyl resin, bakelite & malamine formaldehyde polymer etc.

(II) **Classification one the basis of Origin ⇒**

(A) **Natural Polymers ⇒** Polymers which are obtained from nature (animals & Plant) are called Natural Polymer. Ex. Starch, Cellulose, Protein, Rubber, Silk etc.

(B) **Synthetic Polymer ⇒** which are prepared in the laboratory are called Synthetic Polymer.

for Ex. Polythene, Polyvinyl Chloride (PVC), bakalite etc.

(III) **Classification on the basis of Synthesis ⇒**

(A) **Addition Polymer ⇒** It is the process in which the molecule of the same or different monomers simply add on one another leading to the formation of a macromolecule without elimination of simple molecule.

ex. Ethene and Polypropylene

(i) $n\ CH_2=CH_2 \xrightarrow{\text{Polymerisation}} (-CH_2-CH_2-)_n$

Ethene (Monomer) → Polythene (Polymer)

(ii) $n\ CH_3-CH-CH_2 \xrightarrow{\text{—"—}} \left(-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_2-\right)_n$

(Propylene) (Monomer) → (Polypropylene) (Polymer)

(B) **Condensation Polymers ⇒** It is the process in which large no. of monomer molecule combine together with the elimination of simple molecule like water, alcohol, ammonia etc. to form a macromolecule.

$n\ H_2N-(CH_2)_6-NH_2$ (Hexamithylene diamine)

$+$

$n\ HOOC-(CH_2)_4-COOH$ Adipic Acid

$\xrightarrow[525K]{\text{Polymerisation}}$

$\left(-NH-(CH_2)_6-NH-\overset{\displaystyle O}{\overset{\|}{C}}-(CH_2)_4-\overset{\displaystyle O}{\overset{\|}{C}}-\right)_n$

Nylon-66

$+\ n H_2O$

(III) Classification on the basis of Molecular Forces ⇒

1- Elastomers
2- Fibres
3- Thermoplastics
4- Thermosetting plastics

1- Elastomers ⇒ Polymers in which the intermolecular forces of attraction between the polymer chains are the weakest are called elastomers. as a result these polymer can be easily stretched.

2- Fibres ⇒ Polymer in which the intermolecular forces of attraction between the polymer chains are the strongest are called Fibres. These forces are due to H-bonding and dipole-dipole moment.

3- Thermoplastics ⇒ Polymers in which intermolecular forces of attraction are in between those of Elastomer and Fibre, there is no cross linking between the chain. They can be easily moulded on desired shape on heating. ex, PE, PVC, PS, PTFE etc.

4- Thermosetting Plastic ⇒ These are normally semi-fluid substances with low molecular mass. When heating they first become soft and further heating they undergo chemical change, acquire three dimensional cross linked structure with strong covalent bonds and set hard permanently.

ex- Buna S (SBR), Nylon-6, Nylon-66, Bakalite etc

** Thermoplastic **

Some Commen examples of thermoplastics are—

(i) **Polyethylene or Polythene (PE)** ⇒ It is a very popular polymerised product of ethene. These are as of following-

(a) Low density Polythen (LDP).

(b) High density Polythen (HDP)

(a) **LDP** ⇒ It is prepared by polymerisation of ethene at 350–570K under a pressure 1000–2000 atm in the presence of traces oxygen or peroxides.

$$n\,CH_2=CH_2 \xrightarrow[\text{(Traces of oxygen)}]{350-570K,\ 1000-2000\ atm} (-CH_2-CH_2-)_n$$

Ethene → Polythene

Polythene has high molecular mass about 2,00,000 & highly branched structure, these branches of polythene donot pack well hance called LDP (0.92 g/cm³).

Properties = LDP is chemically inert, highly tough & is a poor Conductor of electricity.

(b) **HDP** ⇒ It is prepared by the polymerisation of ethene at 330–350 K under pressure of 1 atm in th presence of triethylalleminium & titanium tetrachloride (Zieglar Natta Catalyst)

$$n\,CH_2=CH_2 \xrightarrow[\substack{(C_2H_5)_3Al \\ + \\ TiCl_4}]{330-350K,\ 1\ atm} (-CH_2-CH_2-)_n$$

(Ethene) → Polythene

The polymer made up from linear chain of monomer, molecules pack well hance so that polymer has higher density (0.97 g/cm³).

Properties ⇒ Chemically inert, Greater toughness, hardness & tensile.

Widly used in manufacturing of buckets, dustbins, bottles, pipes.

(ii) - PVC (Polyvinyl Chloride PVC) ⇒ It is prepared by polymerisation of vinyl chloride in the presence of peroxide.

$$n\,CH_2=\underset{Cl}{\underset{|}{CH}} \xrightarrow[(H_2O_2)]{\text{Peroxide}} \left[-CH_2-\underset{Cl}{\underset{|}{CH}}-\right]_n$$

(Vinyl Chloride) (Polyvinyl chloride)

It is hard rubber like materials, resistant to light, chemical and atmospheric oxygen. it is used for coating wires, and other electrical goods, Gramophone records, pipes.

(iii) - Polystyrene (PS) ⇒ It is a polymer of styrene.

$$n\,CH_2=\underset{C_6H_5}{\underset{|}{CH}} \longrightarrow \left[-CH_2-\underset{C_6H_5}{\underset{|}{CH}}-\right]_n$$

(Styrene) (Polystyrene)

It is colourless, transparent, good resistance of moisture, acids and alkalies. etc and used for making soft drink, baby feeding bottles and refrigerator lining. Its high dielectric constant makes it very usefull for Radio insulation.

(iv) - Polytetrafluoroethylene (PTFE) ⇒ prepared by polymerisation of tetrafluoroethane under pressure in the presence of benzoyl peroxide. (TEFLON)

$$n\,CF_2=CF_2 \xrightarrow{\text{Benzoyl Peroxide}} (-CF_2-CF_2-)_n$$

(Tetrafluoroethane) (Polytetrafluoroethane)
(Teflon)

It is very hard and tough and used for making non-stick utensils, gaskets, packing and seals.

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* Thermosetting Plastics *

Important plastics of this type are as follows —

(i) ⇒ **BUNA-S** or **Styrene butadiene Rubber (SBR)** ⇒ It is prepared by co-polymerisation of 1,3-butadiene and styrene in the presence of sodium.

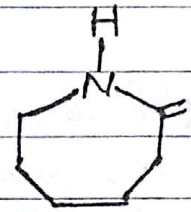
$$n\,CH_2=\underset{\underset{C_6H_5}{|}}{CH} + n\,CH_2=CH-CH=CH_2 \xrightarrow{Na,\ Heat} \left(-CH_2-\underset{\underset{C_6H_5}{|}}{CH}-CH_2-CH=CH-CH_2-\right)_n$$

(Styrene) (1,3-buladeine) (Buna-S)

Properties It is very tough and good substute for natural Rubber. and possess high load capacity and abrasion resistance.

USE It is used for making Auto tyres, floor tiles, shoe soles. Cable insulation. footwear components etc.

(ii) ⇒ **Nylon-6 (Perlon)** It is prepared by polymerisation of Caprolactum at 533-543K.



$$\xrightarrow[H_2O]{533\text{-}543K} \left[H_3\overset{+}{N}-(CH_2)_5-COO^-\right] \xrightarrow[\text{Polymerises}]{\Delta} \left[NH-(CH_2)_5-\overset{\overset{O}{\|}}{C}-\right]_n$$

(Caprolactum) ε-Aminocaproic Acid Nylon-6

It is called Nylon-6 since the monomer unit has 6 C-atom It is used for fabrics, ropes, tyre ~~cord~~ cords etc.

(iii) **Nylon-66 (Nylon-Six Six)** ⇒ It is prepared by the Condensation polymerisation of Hexamethylene diamine and adipic acid.

$$n\,H_2N-(CH_2)_6-NH_2 \text{ (Hexamethylene diamine)} + n(HOOC-(CH_2)_4-COOH) \text{ (Adipic Acid)} \xrightarrow[-nH_2O]{525K} \left[-NH-(CH_2)_6-NH-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\right]_n$$

Nylon-66

The fibre of Nylon 66 have very high tensile strength and resistance to abrasion. It is used for making bristles of tooth brush, socks and sweaters when blended with wool, sheets and climbing ropes.

(iv) - **Nylon 610** ⇒ (Nylon Six-ten) ⇒ It is prepared by Hexamethylene diamine and sebacic acid.

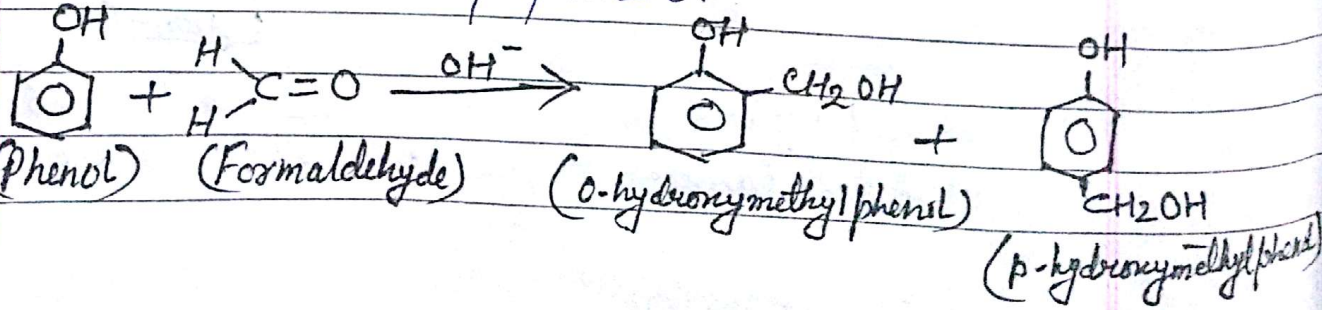
$$H_2N-(CH_2)_6-NH_2 + HOOC-(CH_2)_8-COOH \xrightarrow{\Delta,\ \text{Polymerisation}}$$

(Hexamethylene diamine) (Sebacic acid)

$$\left[HN-(CH_2)_6-\overset{H}{N}-\overset{O}{\overset{\|}{C}}-(CH_2)_8-\overset{O}{\overset{\|}{C}}-H\right]_n$$

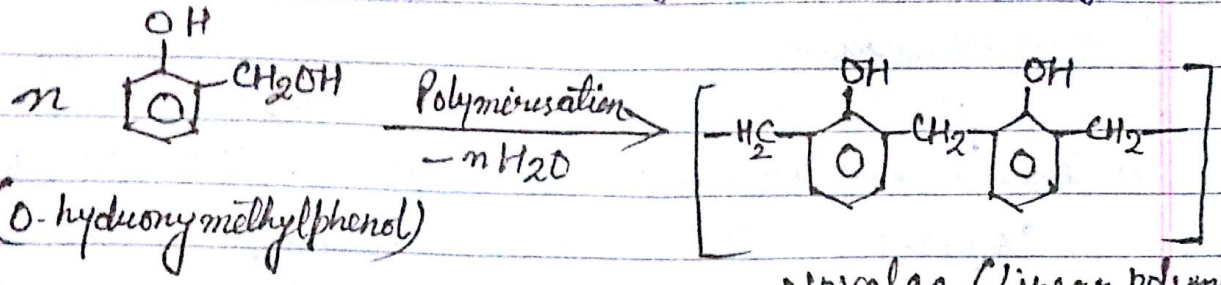
Nylon-610

(v) **Bakelite (Phenol formaldehyde Resin)** ⇒ It is a Condensation polymer and formed by the combination of phenol and formaldehyde in the presence of a base acting acting as Catalyst. A mixture of ortho and para hydroxybenzyl alcohol is initially formed.



(Phenol) (Formaldehyde) (O-hydroxymethyl phenol) (p-hydroxymethyl phenol)

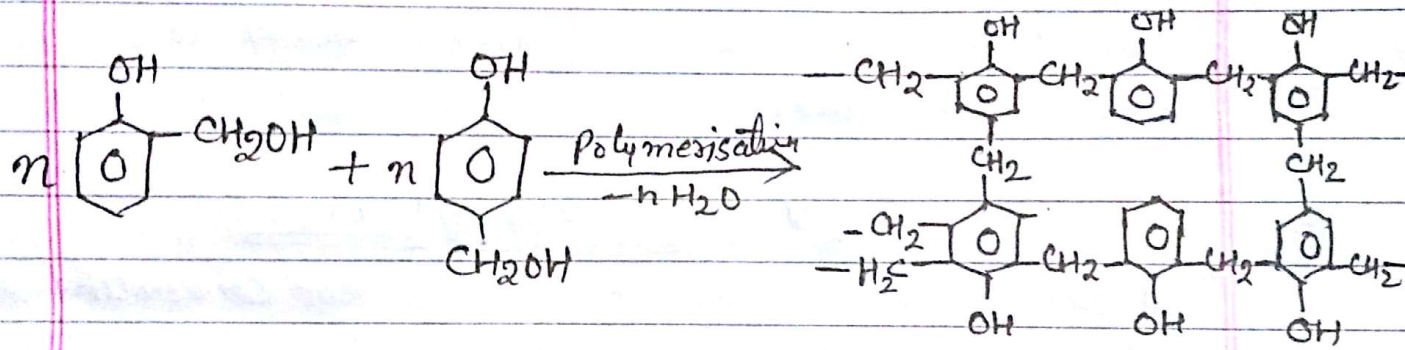
- The ~~Cond~~ Condensation of o-hydroxybenzyl ~~and~~ or p-hydroxybenzyl alcohol gives a linear polymer.



(o-hydroxymethylphenol)

Novolac (Linear polymer)

- The ortho and para substituted phenol can undergo polymerisation to produce a cross linked polymer known as bakelite.



(Bakelite)

[Cross linked polymer]

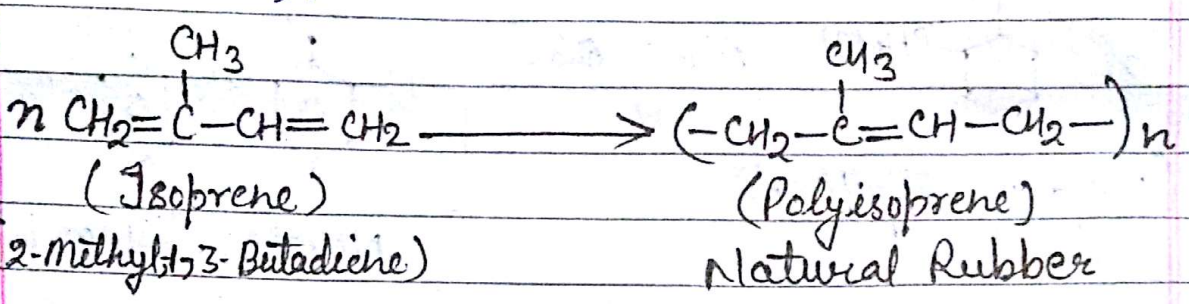
- Low degree of polymerisation gives soft bakelite and high degree of ~~bakelite gives~~ gives hard bakelite.

(a) Soft bakelite are used in varnishes, lacquers and for making glue fore making laminated wooden planks.

(b) Hard bakelite is used in th manufacture of fountain pens, combs, formika table tops and Electric goods.

"Natural Rubber"

Natural Rubber is a polymer of isoprene (2-methyl-1,3-buladiene).



(Isoprene)
(2-Methyl-1,3-Butadiene)

(Polyisoprene)
Natural Rubber

Natural Rubber is obtained from the saps of trees like guayule. When a small cut is made on the bark of trees, the sap called latex folows out. It is diluted with water and filtered. Then, acetic acid is added to coagulate natural rubber.

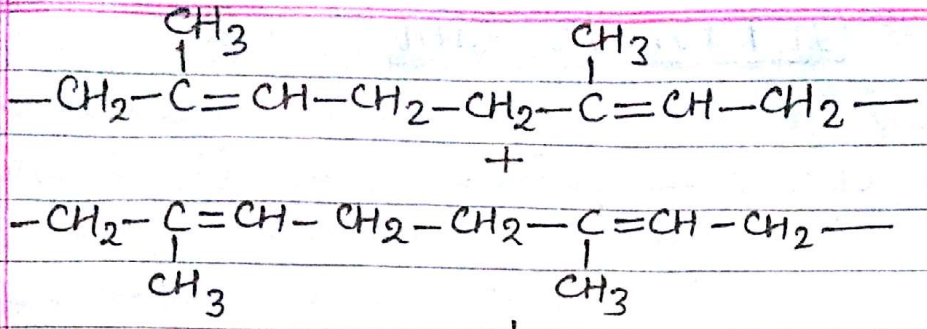
"Volcanisation of Rubber"

"Volcanisation is a chemical process for converting rubber into more durable materials via the addition of Sulphur."

It is carried out by heating raw rubber in the presence of sulphur at 110-140°C. Sulphur added combines chemically to double bond of different rubber springs. during vulcanisation, three dimensional cross linked structure are formed.

- Advantages ⇒ (1) It has low elastisity and absorption capacity.
(2) It has good resilience.
(3) It has high resistance to abrasion and to atmospheric oxygen.
(4) It has negligible tackiness.
(5) It has better resistance to chemicals.

R+n



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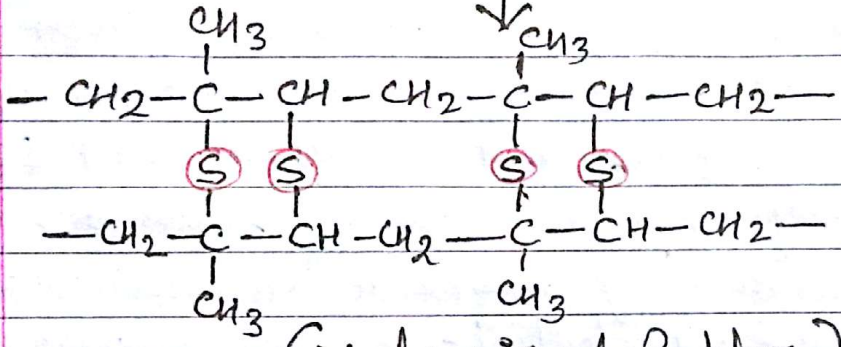
Heating with Sulphur
110–140°C

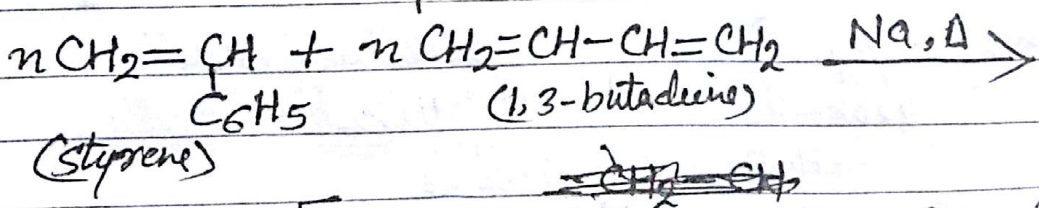


(Vulcanised Rubber)

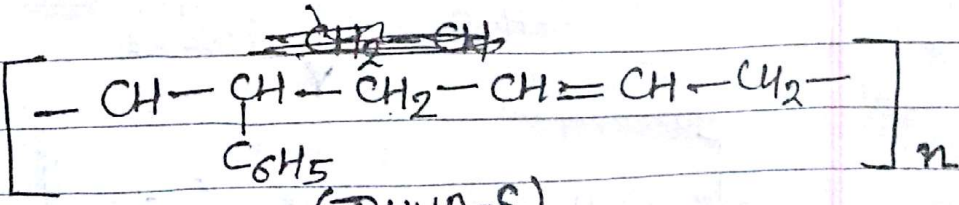
[Synthetic or Artificial Rubber]

Synthetic Rubber is any vulcanisable man-made rubber like polymer which can ~~made~~ be stretched to at least twice its length, but it returns to its original shape and dimensions on the removal of stretching force.

* **Buna-S (SBR)**:- It is prepared by co-polymerisation of 1,3-butadiene ~~rubber~~ styrene in the presence of Sodium



(Styrene) (1,3-butadiene)



(BUNA-S)

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"GUTTA PERCHA"

- It is a variety of natural rubber prepared by mature leaves of dichopsis Gutta. When the mature leaves are ground carefully. heated with water at about 70°C for half an hour and then poured into cold water, when Gutta Percha floats on water surface & is removed.
- It is trans-polyisoprene whearas natural Rubber is Cis-isomer. At room temp Gutta-percha is horny and tough, but it softens and tacky at about 100°C.
- It is widely used for preparing ropes of submarines and as an insulating material in electrical works. It is also used by dentists to make temporary filling.

Terylene ⇒ It is a polymer of ethylene glycol (ethane-1,2-diol) and terephthalic acid (Benzene-1,4-dicarboxylic Acid).

It is obtained by heating the mixture of ethylene glycol and terephthalic acid at 420K-460K in the presence of zinc acetate-antimony trioxide catalyst. It is known as terylene or Dacron.

⇒ $n[HOCH_2-CH_2OH] + n[HOOC-C_6H_4-COOH]$

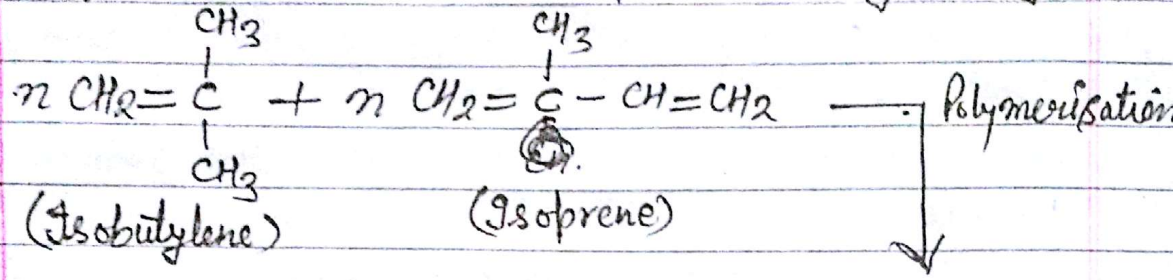
(Ethylene Glycol) (Terephthalic Acid)

$\xrightarrow[-H_2O]{420K-460K,\ Zn(OOCCH_3)_2 + Sb_2O_3}$

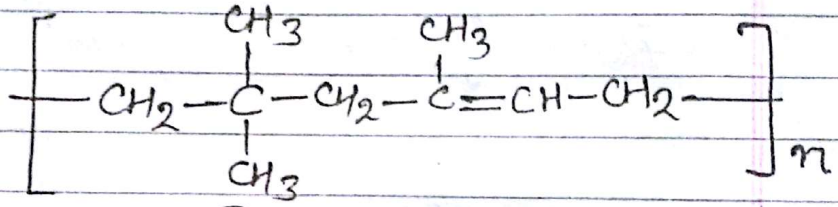
$$\left[-OCH_2CH_2-O-\overset{\overset{O}{\|}}{C}-C_6H_4-\overset{\overset{O}{\|}}{C}-\right]_n + nH_2O$$

(Terylene or Dacron)

(*) **Butyl Rubber** ⇒ It is a synthetic rubber and homocopolymer is prepared by polymerisation of about 98% isobutylene with about 2% isoprene. Chemical Name of it is Polyisobutylene.



(Isobutylene) (Isoprene)



(Butyl Rubber)

It has excellent beamcability and the long polyisobutylene segments of its polymer chain give it good flex properties.

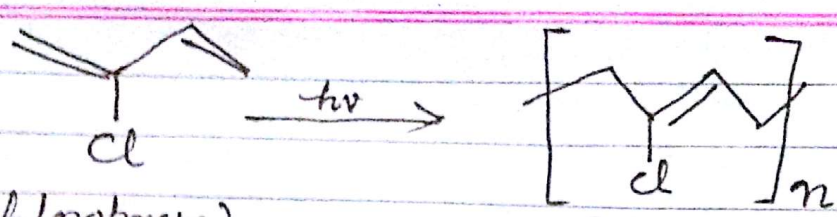
USES ⇒ It is used as —

1. Sealant for rubber work repair
2. additive in lubricating oils and motor fuels.
3. in binding agent in explosives.
4. used for the bladders in sporting balls e.g. rugby balls, football, basketballs, net balls etc.
5. used to mak inner lining of tyre.
6. most intresting use of ibutyl rubber is in making chewing gum, provides elasticity to it.

(*) **Neoprene** ⇒ Neoprene is a family of synthetic Rubbers that are provided by polymerisation of chloroprene. It exibits good chemical stability and maintains flexibility over a wide range of temperature.

Neoprene

⇒



(Chloroprene) Polychloroprene / Neoprene

or

$$CH_2=\underset{\underset{Cl}{|}}{C}-CH=CH_2 \xrightarrow{h\nu} \left[CH_2-\underset{\underset{Cl}{|}}{C}=CH-CH_2\right]$$

(Chloroprene) (Neoprene)

Neoprene is solid rubber or in the form of latex used in a wide variety of applications such as –

① Laptop sleeves ② Orthopadic braces (wrist, knee)
③ Electrical insulation ④ Automotive fan belts.
⑤ Liquid and sheet applied elastomeric membranes.

⊛ **BUNA-N** ⇒ It is a synthetic Rubber Copolymer of acrylonitrile and butadiene. It is also known as NBR, Buna-N and acrylonitrile butadiene Rubber.

$$n\,CH_2=CH-CH=CH_2 + n\,\underset{\underset{CN}{|}}{CH}=CH_2 \xrightarrow{\text{Polymerisation}} \left(CH_2-CH=CH-CH_2-CH_2-\underset{\underset{CN}{|}}{CH}\right)_n$$

(1,3-butadiene) (Acrylonitrile) (Buna-N)

Properties ⇒ It is resistant to oil, fuel, and chemical, high tensile strength but has poor resistance to ozone, sunlight and weathering.

Uses ⇒ ① It is used in Automotive & Aeronautical industry to make oil handling hoses, seals & grommets ② protective gloves in Nuclear industry.

③ It is useful material for disposable lab, cleaning and examination gloves. ④ Buna-N latex is used in the preparation of adhesives and as a pigment binder.

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7.2.5. Industrial and Daily Life Applications of Polymers

Natural and synthetic polymers are extensively used in many industries such as automobile, mechanical, chemical, textiles and construction etc.

1. Polypropene is used widely in industries like textiles, packaging, stationery, plastics, aircrafts, construction, rope, toys etc.
2. PVC *i.e.* poly vinyl chloride is used in the manufacture of sewage pipes. It is also used as an insulator in the electric cables.
3. PVC is also used in vinyl flooring.
4. Glyptal is used for making paints, coatings and lacquers.
5. Bakelite is used for making electrical switches, kitchen products, toys, jewellery, fire arms, insulators, computer disc etc.
6. Polystyrene is actively used in packaging industry. Bottles, toys, containers, trays, disposable glasses, plates, TV cabinets etc. It is also used as an insulator.
7. Polymers also find wide applications in aircrafts, aerospace and sports.
8. Polythene is used widely in manufacturing plastic bags and bottles.
9. Polymers are also used in medicines such as in formulation of proteins, antibiotics, gel caps or in coating of tablets.
10. Structure of polymers is used to determine the utilization of polymers in various medical fields such as surgery, ophthalmology, pharmacy, dermatology etc.

7.3. PLASTICS

Plastics are organic materials of high molecular weight, which can be moulded into any desired shape when subjected to heat and pressure in the presence of a catalyst.

Polythene, polypropylene and *polystyrene* etc. are common examples of plastics.

7.3.1. Additives for Plastics

The plastic industry has grown very rapidly. The raw materials used in this industry come from all parts of the nation mines supplying the basic needs for phenols, aldehydes, acids etc., the forests supplying the wood, farmers providing lactic acid from milk and bean meal from soya plants, the querries giving asbestos and vinyl resins, paper and textile mills providing paper and fibre for laminated plastics, cotton plantation growing cotton for cellulose and petroleum fields yielding hydrocarbons.

The various components are compounded together to produce the desired characteristics in the product. The main additives for plastics are as follows :

1. Binder : *It is the resin which is used as binder in the plastic.* Its function is to hold or bind the different components together. They are usually cellulose derivatives or some natural resins. Resin should have properties which makes it fusible and mouldable. Binder in the beginning has lesser number of cross-links but once these are part of adhered material, the number of cross-links increase to the extent that it cannot be moulded again.

2. Fillers : *Fillers are added to plastics to reduce their cost.* Fillers also improve hardness, tensile strength, finish and workability besides reducing shrinkage on setting and brittleness.

For example,

(*i*) Carborundum and mica are added to provide hardness.

(*ii*) Barium salts are added to make the plastic impervious to X-ray.

(*iii*) Asbestos is added to provide heat and corrosion resistance.

Most commonly used fillers are wood-flour, china clay, talc, saw-dust and paper pulp etc.

3. Plasticizers : *Plasticizers are materials which are added to resins to increase their plasticity and flexibility but at the same time decrease its strength.*

Most commonly used plasticizers are vegetable oils, camphor, esters and some phosphates (like tributyl phosphate).

4. Stabilizers : *Stabilizers are added to improve the thermal stability of the plastic during polymerisation.*

For example, vinyl chloride polymer shows a tendency to undergo decomposition and discoloration at moulding temperatures. So during moulding, heat stabilizers are used. Stabilizers commonly used are salts of lead (*e.g.* white lead, lead chromite, red lead etc.) and transparent moulding compounds like stearates of lead and cadmium.

5. Cross-linking agents : *Cross-linking is the formation of a chemical link between molecular chains to form a three-dimensional network of connected molecules.* Plastics cross-linking agents are Taic (triallyl isocyanurate) and china special rubber etc.

7.3.2. Types and Applications of Plastics

Plastics have been classified into thermoplastics and thermosetting plastics ;

Thermoplastics : The plastics in which the intermolecular forces of attraction are in between those of elastomers and fibres are called thermoplastics. They can be melted and moulded easily into desirable shape again and again. There is no cross-linked bonding among them. For example, polythene, PVC, PS etc.

(There properties and reactions have been discussed in previous section 7.2.4)

Thermosetting plastics : These are normally semi-fluid substances with low molecular masses. When heated, they first become soft and on further heating, they undergo chemical change and acquire three-dimensional cross-linked structure with strong covalent bonds and set hard permanently. Each molecule is held rigidly in place by others. They cannot move about when heated. Therefore, such plastics are hard and rigid and do not soften when heated again.

For example : Buna-S, Nylon-6 and Bakelite.

7.3.3. Examples of plastics and their applications

Various examples of plastics and their applications are mentioned in the following table :

Plastic type	General properties	Common household uses
 PETE Polyethylene Terepthalate	Good gas and moisture barrier properties High heat resistance Clear Hard Tough Microwave transparency Solvent resistant	Mineral water, fizzy drink and beer bottles Pre-prepared food trays and roasting bags Boil in the bag food pouches Soft drink and water bottles Fibre for clothing and carpets Strapping Some shampoo and mouthwash bottles
 HDPE High Density Polyethylene	Excellent moisture barrier properties Excellent chemical resistance Hard to semi-flexible and strong Soft waxy surface Permeable to gas HDPE films crinkle to the touch Pigmented bottles stress resistant	Detergent, bleach and fabric conditioner bottles Snack food boxes and cereal box liners Milk and non-carbonated drinks bottles Toys, buckets, rigid pipes, crates, plant pots Plastic wood, garden furniture Wheeled refuse bins, compost containers

Plastic type	General properties	Common household uses
 V Polyvinyl Chloride	Excellent transparency Hard, rigid (flexible when plasticised) Good chemical resistance Long term stability Good weathering ability Stable electrical properties Low gas permeability	Credit cards Carpet backing and other floor covering Window and door frames, guttering Pipes and fittings, wire and cable sheathing Synthetic leather products
 LDPE Low Density Polyethylene	Tough and flexible Waxy surface Soft-scratches easily Good transparency Low melting point Stable electrical properties Good moisture barrier properties	Films, fertiliser bags, refuse sacks Packaging films, bubble wrap Flexible bottles Irrigation pipes Thick shopping bags (clothes and produce) Wire and cable applications Some bottle tops
 PP Polypropylene	Excellent chemical resistance High melting point Hard, but flexible Waxy surface Translucent Strong	Most bottle tops Ketchup and syrup bottles Yoghurt and some margarine containers Potato crisp bags, biscuit wrappers Crates, plant pots, drinking straws Hinged lunch boxes, refrigerated containers Fabric/Carpet fibres, heavy duty bags/ tarpaulins
 PS Polystyrene	Clear to opaque Glassy surface Rigid or foamed Hard Brittle High clarity Affected by fats and solvents	Yoghurt containers, egg boxes Fast food trays Video cases Vending cups and disposable cutlery Seed trays Coat hangers Low cost brittle toys
 OTHER	There are other polymers that have a wide range of uses, particularly in engineering sectors.	Nylon (PA) Acrylonitrile butadiene styrene (ABS) Polycarbonate (PC) Layered or multi-material mixed polymers

7.3.4. Difference between Thermoplastics and Thermosetting plastics

Difference between thermoplastics and thermosetting plastics is as follows :

S.No.	Thermoplastics	Thermosetting plastics
1.	They are formed by addition polymerisation.	They are formed by condensation polymerisation.
2.	They consist of linear long chain polymers.	They consist of three-dimensional network structure.
3.	All the polymer chains are held together by weak Van der Waals forces.	All the polymer chains are linked by strong covalent bonds.
4.	They are weak, soft and less brittle.	They are strong, hard and more brittle.
5.	They soften on heating and harden on cooling.	They do not soften on heating.
6.	They can be remoulded.	They cannot be remoulded.
7.	They have low molecular weights.	They have high molecular weights.
8.	They are soluble in organic solvents.	They are insoluble in organic solvents.