

Polymer

Polymer

↓ many units/parts

• polymers are large molecule with

high molecular mass.

(macromolecule) ($10^3 - 10^6$)

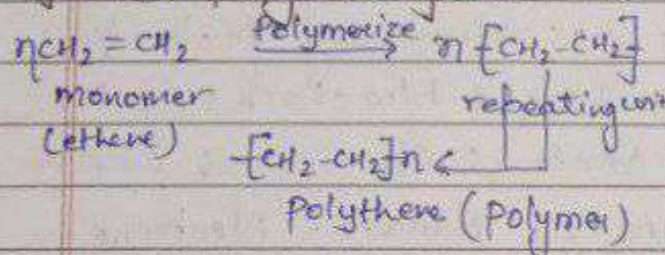
• Formed by joining by repeating structural (monomers)

are large scale.

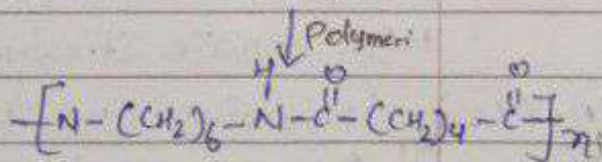
• monomers are joined by covalent bond.

• formation of polymer from monomer is called polymerization

eg - ① polyethene from ethene



eg ② Hexamethylenediamine + adipic acid → nylon 6,6.



① Natural polymer: - found in plant & animals.

eg:- protein, cellulose, starch, rubber.

② Semi-synthetic: - Derivative of natural polymer. (cellulose derivative)

eg:- cellulose acetate (Rayon), cellulose nitrate.

③ Synthetic: - man-made polymer

eg:- plastic (polyethene)

Nylon-6,6 (synthetic fibre)

Synthetic Rubber (Buna-S)

② Based on structure of polymer

① Linear polymer: - long & straight chain.



eg:- High density polyethene

PVC (Polyvinyl chloride)

② Branched chain: - linear chain having some branches.



eg:- Low density polyethene

Classification of polymer: - 5 types: -

① Based on source

① Natural polymer.

② Semi-synthetic.

③ Synthetic polymer.

③ Cross-linked: - formed from bifunctional & trifunctional monomer & contain strong covalent b/w polymer chain.

eg:- Bakelite, melamine

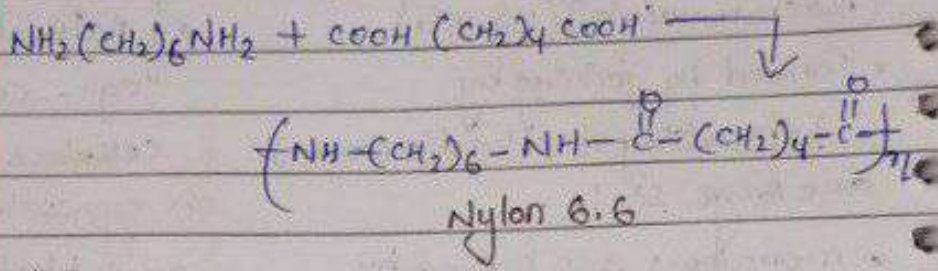
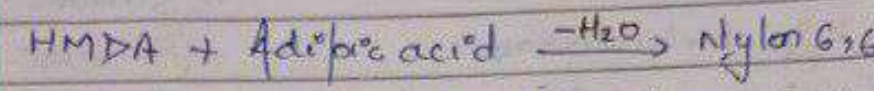


⑤ Based on mode of polymerization:-

• Small molecule like H₂O, alcohol, HCl are eliminated.

① Addition polymer:-
Repeated addition of monomer containing double or triple bond
eg:- polyethene from ethene
polypropene from propene

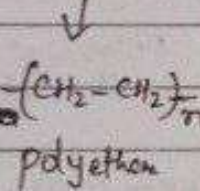
eg:- terylene (dacron), nylon 66, nylon 6



④ Based on Molecular forces:-

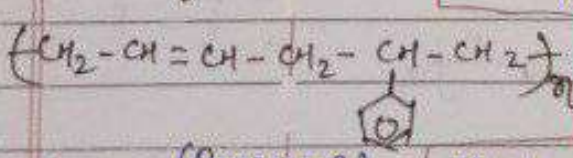
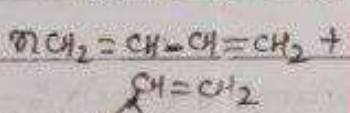
Homo polymer
Polymerization of single monomer

eg:- Polyethene

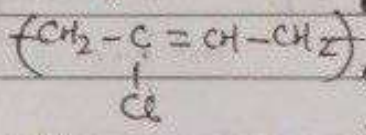


Co-polymer
Polymerization of two different monomer

eg:- 1,3 Butadiene + styrene
 \downarrow
 Buna S



① elastomer:- Rubber like solid with elastic property. polymer chains are held by weak intermolecular force due to which it has stretching property.
 • few cross linked b/w chain help the polymer to retract its original position.
 eg:- Buna-S, Buna-N, Neoprene.



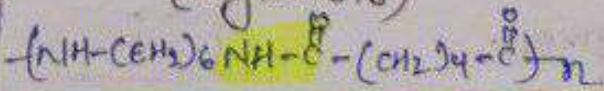
② Fibres:- Thread forming solid high tensile strength, high modulus. due to strong intermolecular forces like hydrogen bonding.

⑥ Condensation Polymer:-
formed by repeated condensation reaction b/w two different bi-functional or tri-functional monomer.

• crystalline \Rightarrow closed packing \Rightarrow due to strong force.

eg:- polyamide, polyester (terylene)

\downarrow
 (Nylon 6,6)

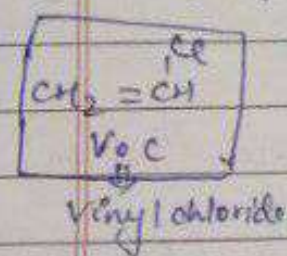


(c) Thermoplastic :-

linear / slightly branched long chains capable of softening on heating and hardening on cooling.

• Intermolecular force is intermediate b/w elastomer & fibre.

eg:- polyethylene
polystyrene
polyvinyl (PVC)
etc

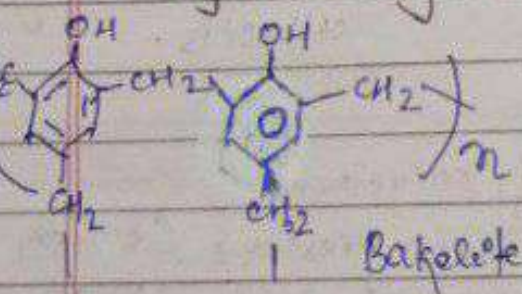


(d) Thermo setting :-

polymers are cross-linked or heavily branched.

• on heating it undergoes extensive cross linking.

eg:- Bakelite,
Urea formaldehyde resin



Intermolecular force :-

fibre > Thermo setting > Thermo plastic > elastomer

(e) Based on growth polymerisation :-

Addition & condensation polymer now-a-days are also referred as chain growth & step growth polymer.

Types of polymerisation

(1) Addition or chain growth polymerisation

- Polyethylene
- polytetrafluoroethene (Teflon)
- polyacrylonitrile (PAN)

(2) condensation or step growth :-

- polyamide $\begin{cases} \text{nylon 6,6} \\ \text{nylon 6} \end{cases}$
- Polyester
- phenol formaldehyde polymer
- Melamine formaldehyde polymer.

(1) Addition / chain growth

• molecule of same monomer or different monomer add together to form polymer.

• monomers are alkenes, alkydienes, its derivative.

• polymerization takes place via free-radical / ionic mechanism

↓
not common.

LDP

HDP

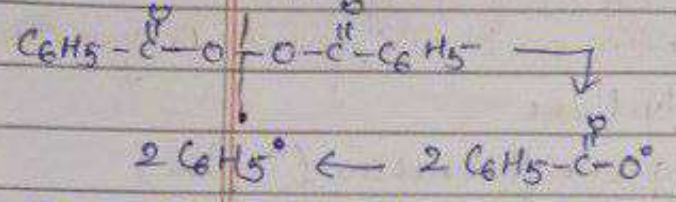
free radical mechanism:

- free radical generating initiator (catalyst) is used
- eg:- Benzoyl peroxide, acetyl peroxide, Tetra- butyl - peroxide.
- eg:- polymerization of ethene to poly ethene (free radical mechanism)

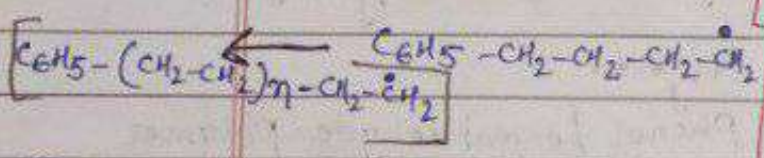
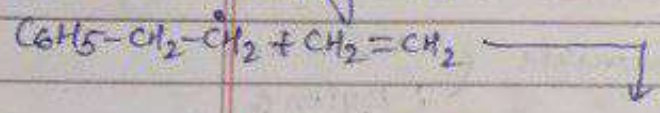
- free radical mechanism.
- High branching
- chemically inert
- Tough, flexible, poor conductor of electricity
- manufacture of squeeze bottles, toys, flexible pipes, insulation of electric wire.

- linear molecule but high density due to close packing
- chemical inert
- (more tough & hard)
- manufacture of bucket, hard bottles, pipes

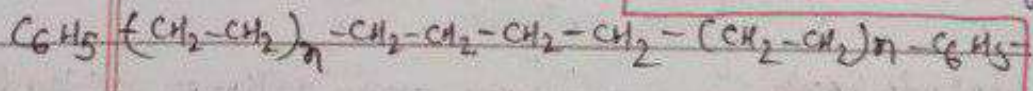
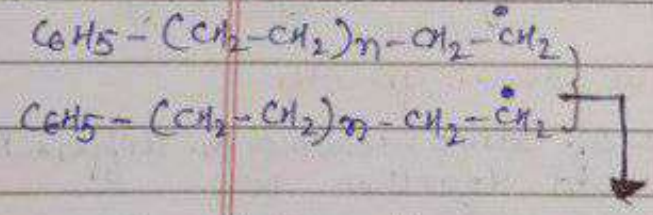
① chain initiation:



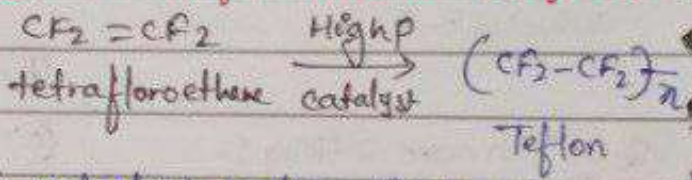
③ chain propagation



③ chain termination



② Tetrafluoroethene (Teflon)



- catalyst: free radical generator per sulphate.
- chemically inert.
- manufacture of oil seals, gaskets, non-sticky utensils.

Important Addition polymer:

① polyethene

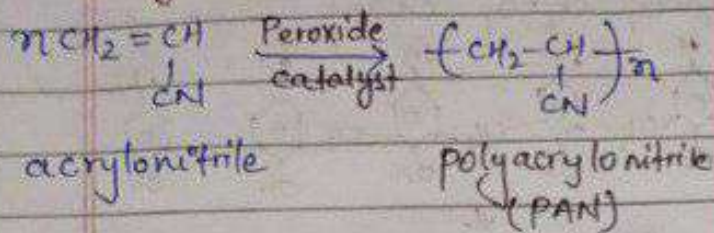
Low density polyethene

- (250-300K)
- High Temp
- High Pressure (1000-2000atm)
- Traces of dioxygen (O₂) or peroxide as initiator (catalyst) is used.

High density polyethene

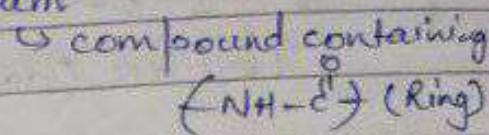
- (333-300K)
- Low Temp
- Low Pressure (1-10atm)
- Hydrocarbon solvent with Ziegler Natta catalyst $[Al(C_2H_5)_3 + TiCl_4]$

④ Polyacrylonitrile (PAN)

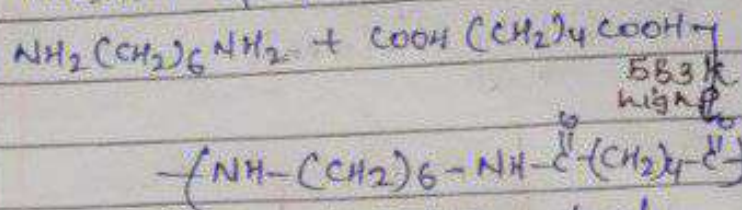


- PAN is good substitute for wool in making commercial fibre (Orlon, acrilon).

• Prepared by condensation polymerization of diamines with dicarboxylic acid. also of amino acid & their lactam

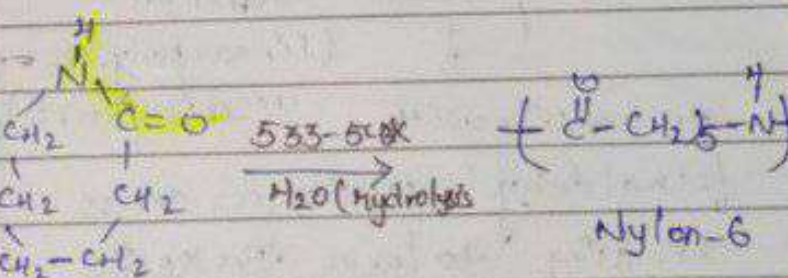


Nylon 616 :- condensation polymer
HMDA + Adipic acid.



- manufacturer of brushes of of brush, sheet.

Nylon 6 :- caprolactum hydrolysis



Tyre cords → manufacture.

Polyester :-

Polyamide → diamine + dicarboxylic acid.

polyester → diol + dicarboxylic acid
eg:- dacron (Terylene)

ethylene + Terephthalic acid (420-460 K)
glycol.

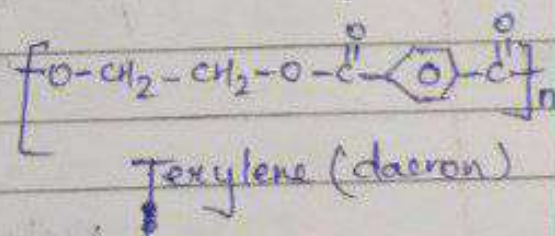
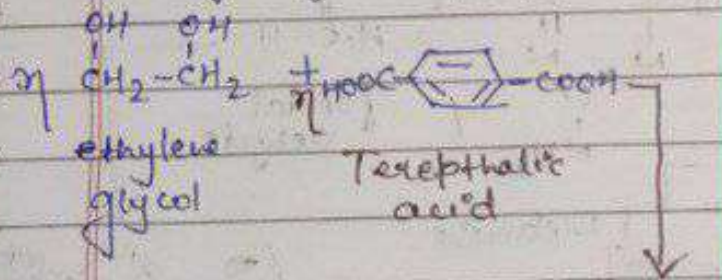
catalyst → Zn-acetate → Zn(CH₃)₂
Antimonyoxide → Sb₂O₃

Condensation or step growth

Polymerization :-

- Repeated condensation b/w two bifunctional monomers. H₂O, alcohol, HCl are eliminated

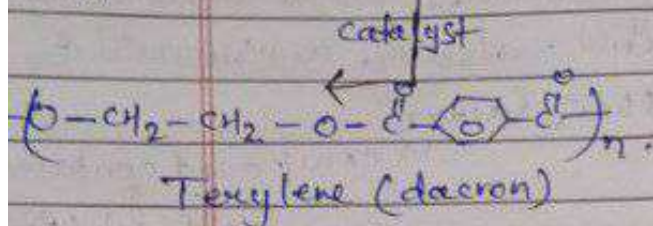
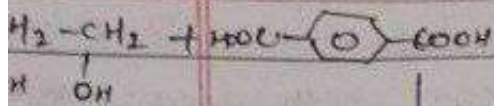
eg:- Terylene (dacron) → ethylene glycol + terephthalic acid.



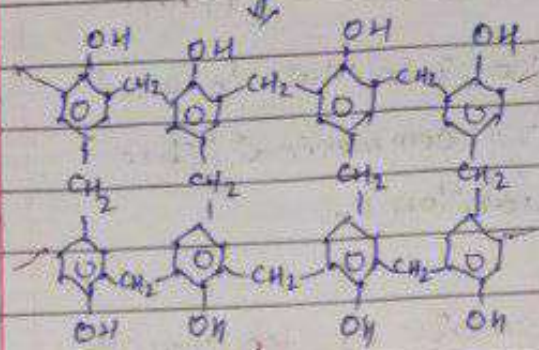
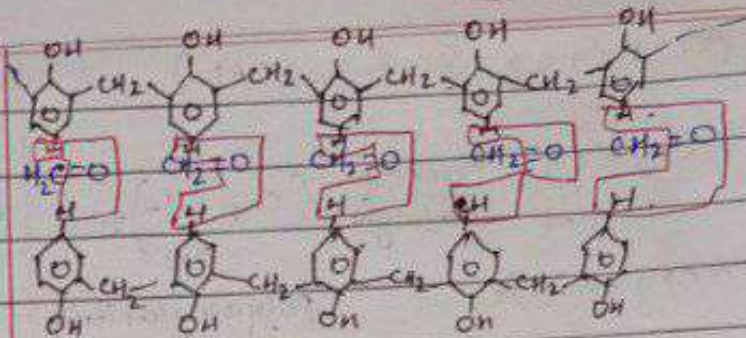
Imp - condensation polymer

① Polyamide :- polymer containing amide linkage

eg:- Nylon.



- blending with cotton & wool
- glass reinforcing material in safety helmets.



(Bakelite)

- comb, → phonograph records
- electric switch → handle of utensils.

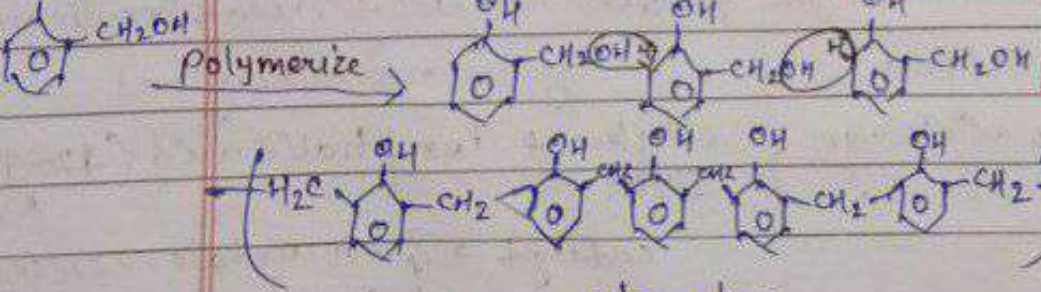
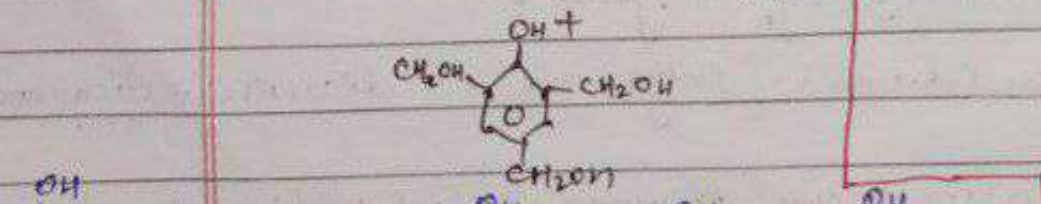
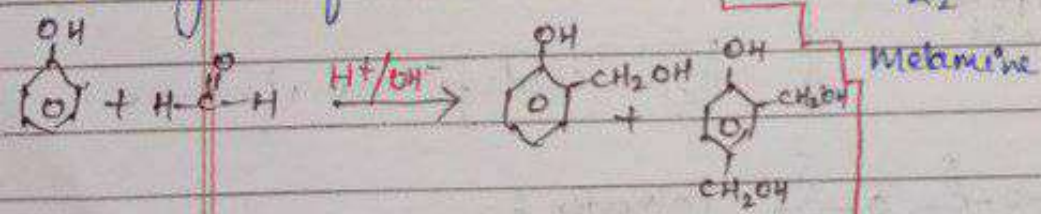
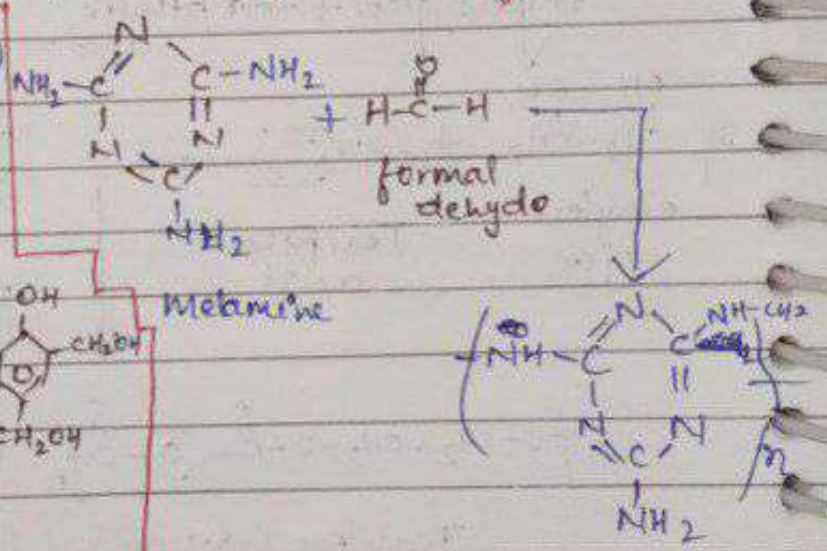
Phenol-formaldehyde :-

oldest synthetic polymer.
 • condensation rxn Phenol & formaldehyde either in acid or base catalyst.

Initial product → Novolac
 (linear polymer used in paints)

on heating with formaldehyde undergoes cross linking to form Bakelite

Melamine formaldehyde :-

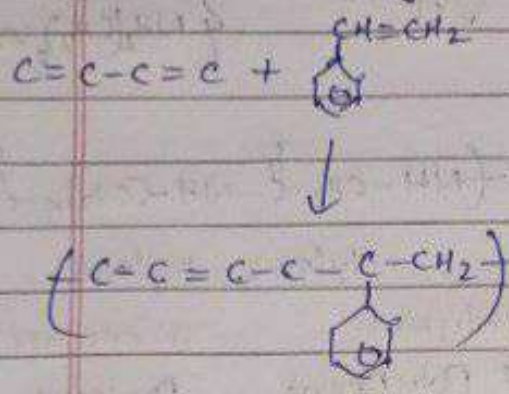


Novolac

- unbreakable crockery.

co-polymerization :-
 more than one monomers
 polymerize to form
 co-polymer.

1,3 butadiene + styrene



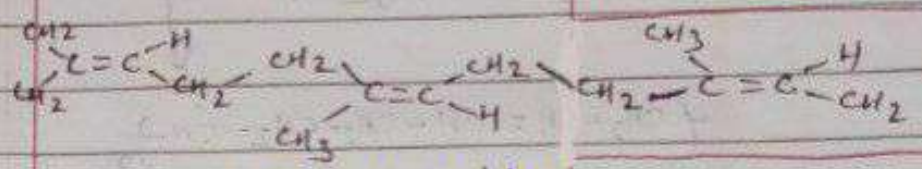
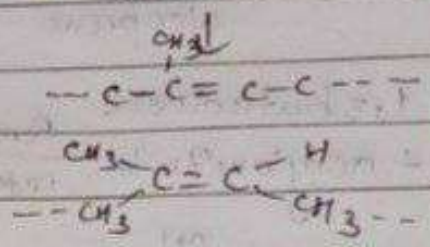
• Butadiene styrene

Rubber :-

- elastic property also k/a elastomers.
- polymer chains are held by weak intermolecular forces
 ↓
 due to which it can be stretched.
- few crosslinked b/w polymer chain help the polymer to retract its original position.
- manufactured from rubber latex (obtained from rubber tree)
 ↓
 colloidal soln of rubber in water

• Natural rubber is a linear polymer of isoprene

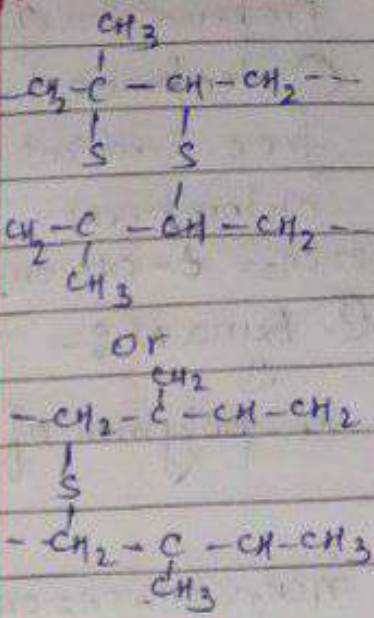
(2-methyl-1,3butadiene)



Natural rubber

is 1,4-polyisoprene

→ weak van der Waal force & have coiled structure



Synthetic Rubber :-

any vulcanized rubber which can stretched to twice its length (Returns back to original form)

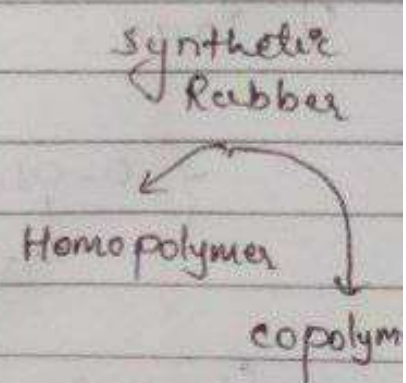
Vulcanization of Rubber :-

T > 335K → soft (Rubber)
 T > 283K → brittle (??)

To improve physical property → vulcanization is used

Heating raw rubber with 'S' (sulphur)

Sulphur forms cross-linked & rubber gets stiffer.



Preparation of Synthetic Rubber

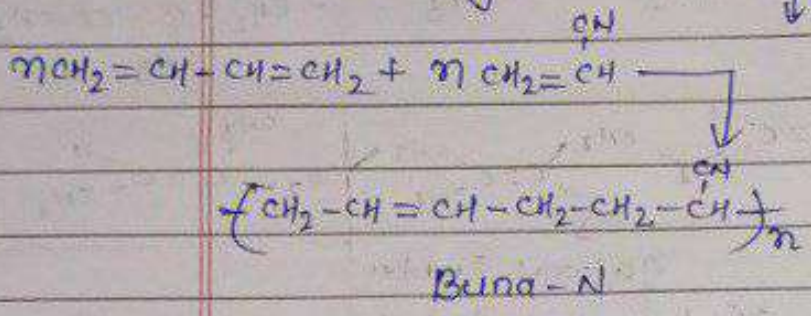
① Neoprene :-

free radical polymer of chloroprene.



② Buna N :-

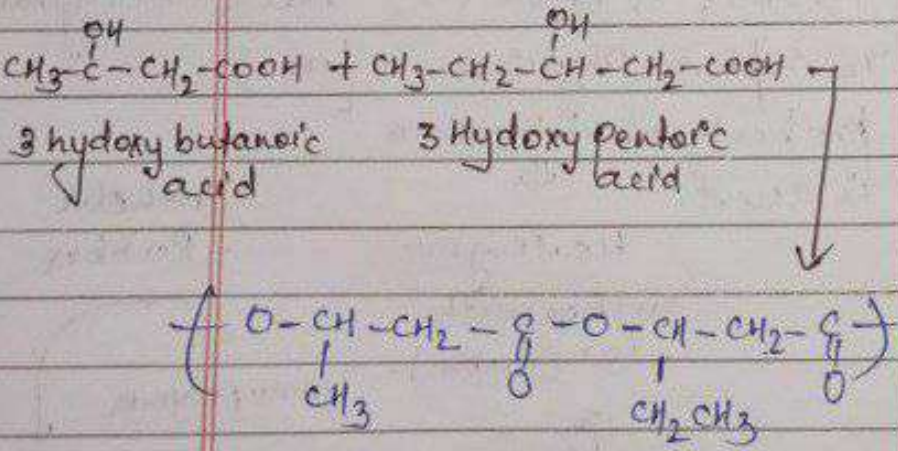
co-polymer of 1,3 butadiene + acrylonitrile Peroxide catalyst



Bio-degradable polymer :-

PHBV, Nylon 2 Nylon 6

(Poly β-hydroxybutyrate-co-β-hydroxybutirat)
→ co-polymer of 3-hydroxybutanoic acid & 3-hydroxypentanoic acid

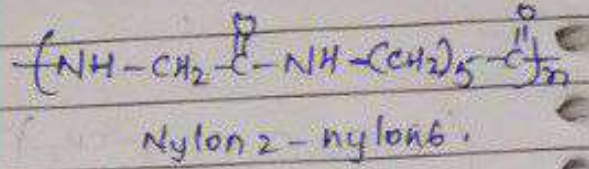
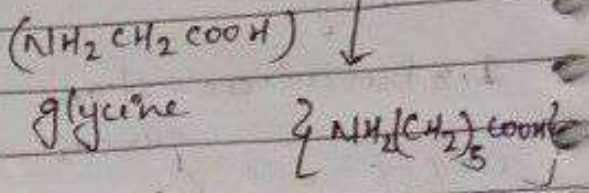


PHBV

→ (Bacterial degradation)

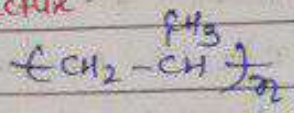
Nylon 2 - nylon 6 :-

co-polymer of glycine & aminocaproic acid



Polymer	Monomer
# Polyprene	propene (C=C)

Structure

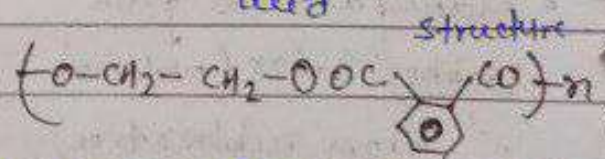


Polymer	Monomer	Structure
Polystyrene	styrene	$\left[\text{CH}_2 - \overset{\text{C}_6\text{H}_5}{\text{C}} \right]_n$

PVC	vinyl chloride	$\left[\text{CH}_2 - \overset{\text{Cl}}{\text{C}} \right]_n$
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Urea formaldehyde resin	① Urea	$\left[\text{NH} - \text{CO} - \text{NH} - \text{CH}_2 \right]_n$
	② formaldehyde	

glyptal	① ethylene glycol
	② phthalic acid



Bakelite ① Phenol

