Unit 5

Polymers
Introduction & Classification

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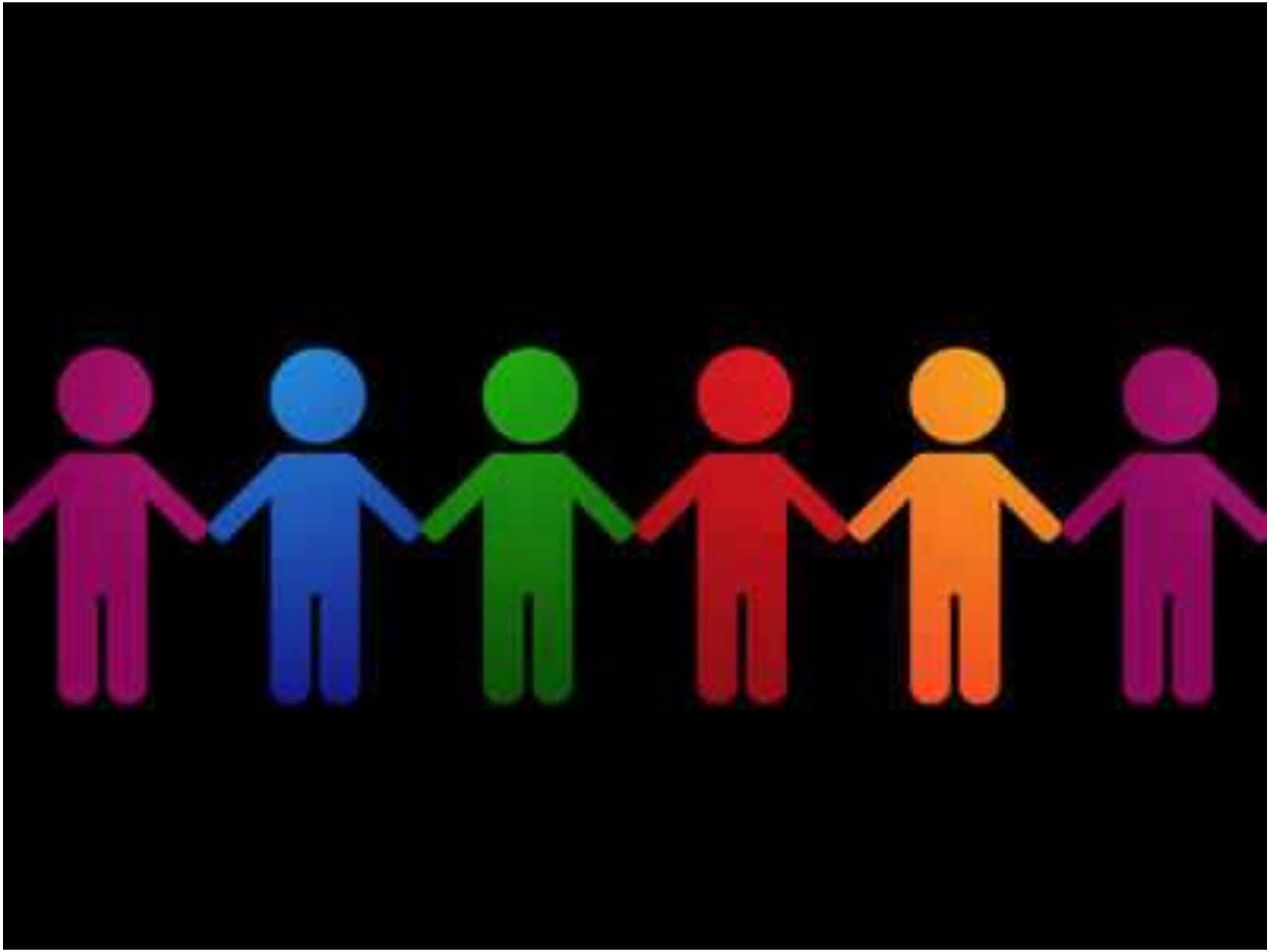
Polymers

The word 'Polymer' is derived from the Greek words,
Polys means many and Meros means parts or units. So, Many Units

Polymer is a large molecule, formed by repeated linking of small molecules called 'monomers'.
They have high molecular weight in the range of 10^3 to 10^7.

$nCH_2—CH_2$	→	$(—CH_2—CH_2—)_n$
Ethene		Polyethene

Monomer:	A monomer is the single unit or the molecule which is repeated in the polymer chain.	
Monomer	A	one unit
Dimer	A—A	Two units
Trimer	A—A—A	Three units
Tetramer	A—A—A—A	Four units
Polymer	$(A—A—A—A—A)_n$	Many units
	-A-A-A-A-A-A-A-A-	Polymeric Chain (Polymeric Backbone)
Oligomer:	A molecule of intermediate relative molecular mass,	



Requirement for a molecule to act as a Monomer

The essential requirement for a molecule to act as a monomer is the presence of at least **Two Active Sites.**

The number of reactive functional groups or multiple bonds is active sites which are called as **Functionality.**

Functionality = 2, a **linear polymer** is formed

Functionality ≥ 3, leads to **branching point**, so, form **cross-linked polymers**

$CH_2=CH_2$	**Ethene**	**Functionality =2**
$CH\equiv CH$	**Acetylene**	**Functionality = 4**
$CH_2(OH)–CH_2(OH)$	**Ethylene glycol**	**Functionality = 2**
CH_2OH | $CHOH$ | CH_2OH	**Glycerol**	**Functionality = 3**

CLASSIFICATION OF POLYMERS

1. Origin	Natural, synthetic and semi synthetic
2. Polymeric Structure	Linear, Branched, Cross-linked, Globular
3. Chemical Structure	Organic & Inorganic
4. Types of monomers	Homopolymers and Copolymers
5. Mode of Polymerization	Addition & Condensation
6. Physical State	Amorphous & Crystalline
7. Thermal Behaviour	Thermoplastic & Thermosetting plastics
8. Conductance	Conducting & Non-conducting Polymers
9. Degradation	Biodegradable & Non-biodegradable

1. Origin Natural, synthetic and semi synthetic

Natural polymers

The polymers, which occur in nature are called natural polymer also known as biopolymers.

Examples :

- Natural Silk,
- Cellulose,
- Starch,
- Proteins,
- Nucleic Acid,
- Natural Rubber Etc

Synthetic polymer

The polymer which has been synthesized in the laboratory is known as synthetic polymer. These are also known as manmade polymers.

Examples :

Polyethylene (PE),

Polystyrene (PS),

Polyvinyl Chloride (PVC),

Nylon,

Polyester,

Bakelite,

Polypropylene (PP) etc.. And Many More

Semi synthetic polymer

They are the chemically modified natural polymers such as

Vulcanized rubber

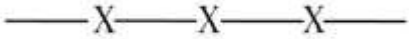
Cellulose Nitrate

Cellulose Acetate etc.

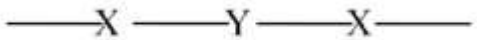
2. On the basis of Polymeric Structure

On the basis of structure, polymers are of three types.

a. Linear polymer:- If the monomer units are joined in a linear fashion, polymer is said to be linear polymer.



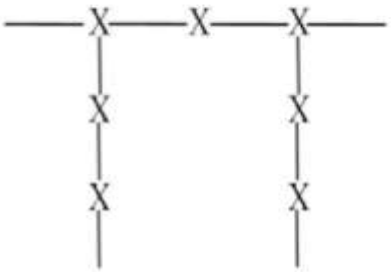
Linear Homopolymer

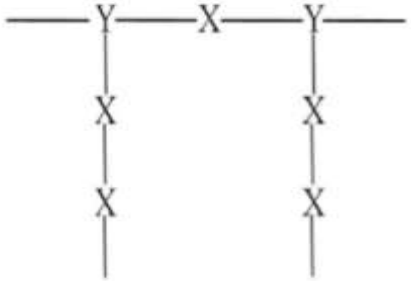


Linear Copolymer

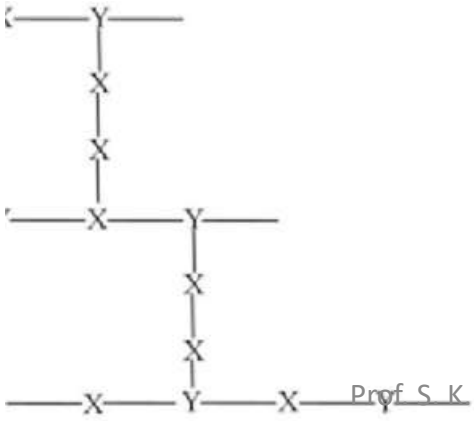
b. Branched polymer:-

When monomer units are joined in branched manner, it is called branched polymer.





c. Cross-linked Polymer



3. On the basis of Chemical Structure

a. Organic Polymers

The polymers are generally organic compound. They have C-C linkage in their polymeric back bone chain.

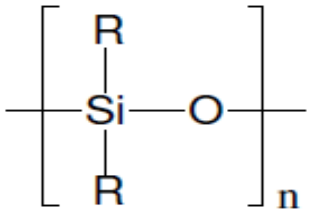
~C-C-C-C-C-C-C-C~

Examples: PVC, PE, PP, PS, PVA, Rubber etc.

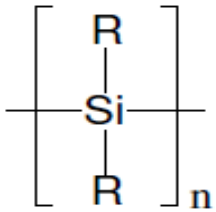
b. Inorganic Polymers

Those polymers that have atoms other than C-atom in their polymeric back bone chain.

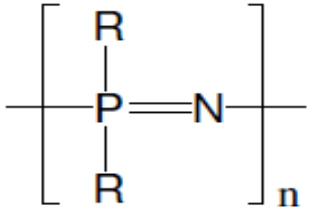
~Si-Si-Si-Si-Si-Si-Si~



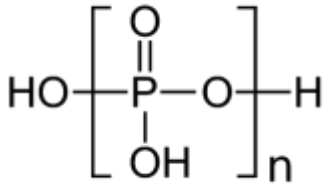
Polysiloxanes (Silicone)



Polysilanes

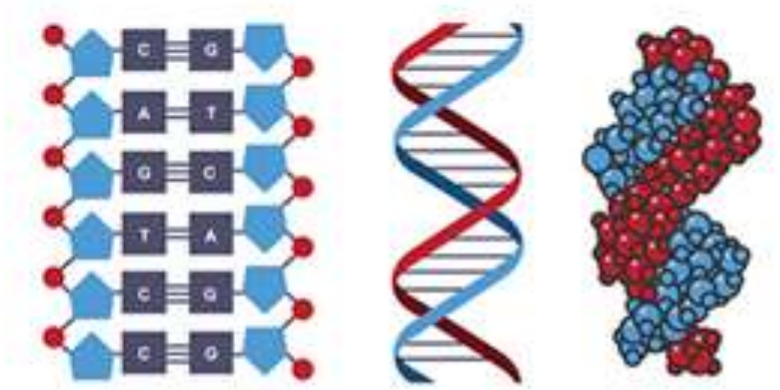


Polyphosphazenes,



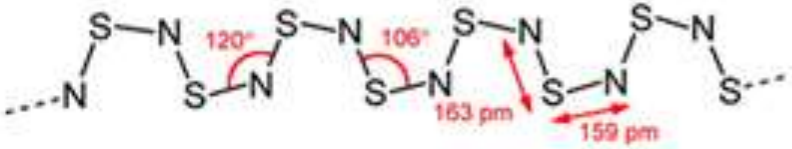
Polyphosphoric acid

DIFFERENT TYPES OF POLYMERS



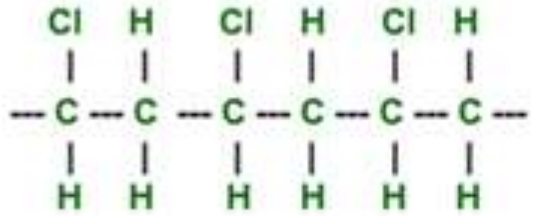
NATURAL POLYMERS

SYNTHETIC POLYMERS



INORGANIC POLYMERS

Polythiazyl (Polymeric Sulfur Nitride)



ORGANIC POLYMERS

Polyvinylchloride (PVC)

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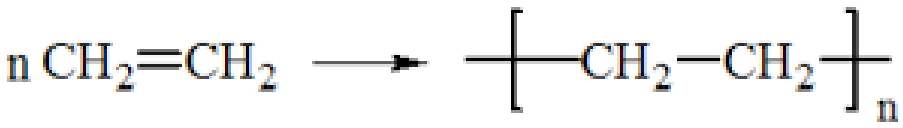
Homopolymer & Co-polymer

4. Types of monomers Homopolymers and Copolymers

a. Homopolymer:

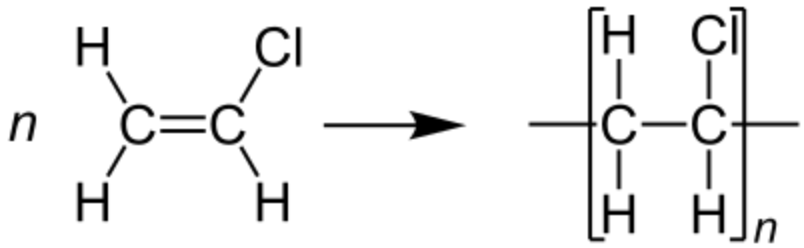
Only one type of monomers are present --A-A-A-A-A-A-A-

Polymer of Ethene is Polythene



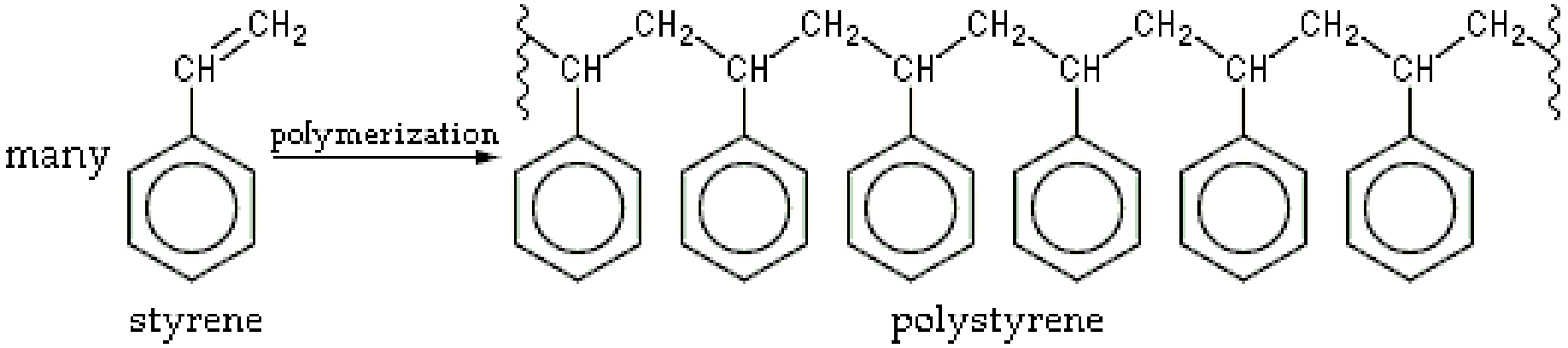
Ethene **Polythene**

Polymer of Vinyl Chloride is Polyvinyl Chloride

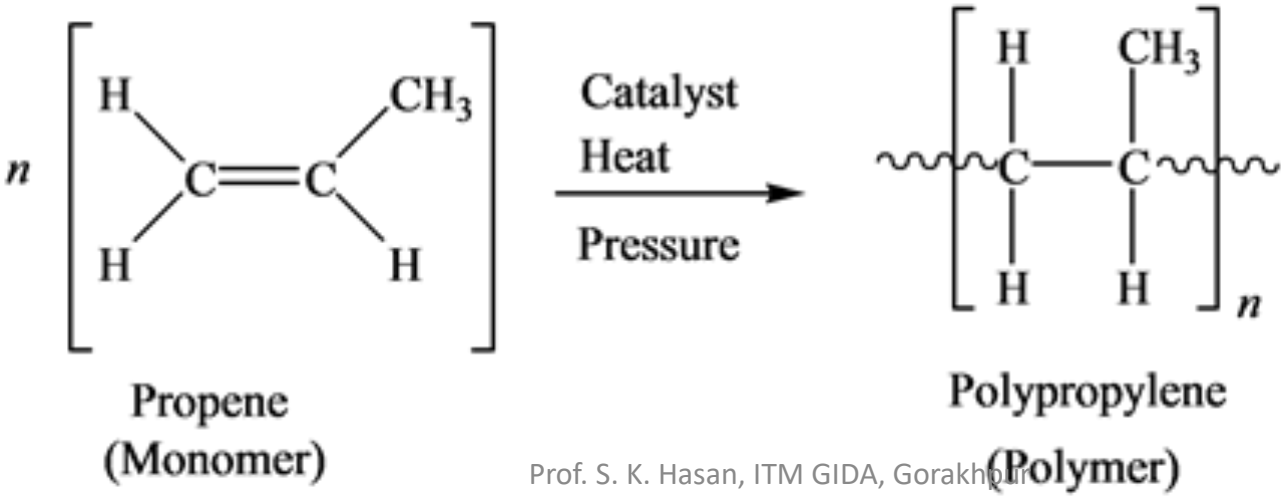


Vinyl Chloride **Polyvinyl Chloride (PVC)**

Polymer of Styrene is Polystyrene



Polymer of Propylene is Polypropylene



b. Copolymers : If more than one types of monomers are present

If A & B monomers are present together, the various types of co-polymers are:

- **Random type**

  Monomers A & B are arranged randomly in chain

  ---A–B-A-A-B-B-A-B-B-A-A-A ----

- **Alternating type**

Monomers A & B are arranged at alternate positions in chain

----A–B-A-B-A-B-A-B-A-B-A-B----

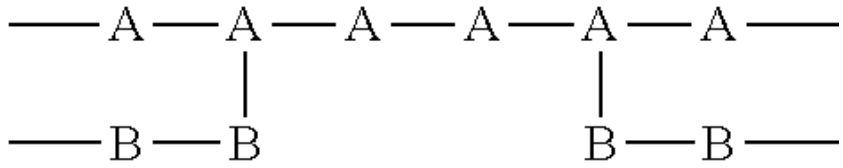
- **Block Polymerization**

polymer resulting from straight polymerization coupled together in blocks.

---A-A-A—B-B-B—A-A-A—B-B-B----

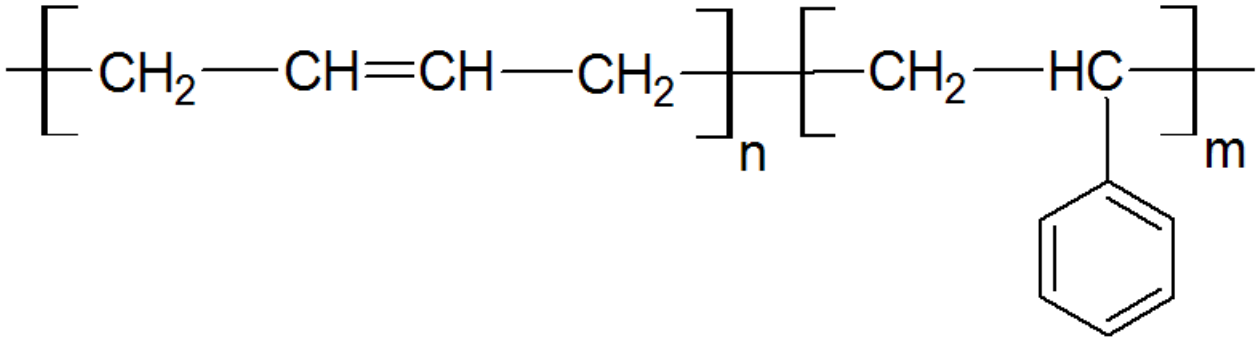
- **Graft Polymerization**

In this type of polymers, one type of monomers make back bone chain and other monomers are arranged in branches,



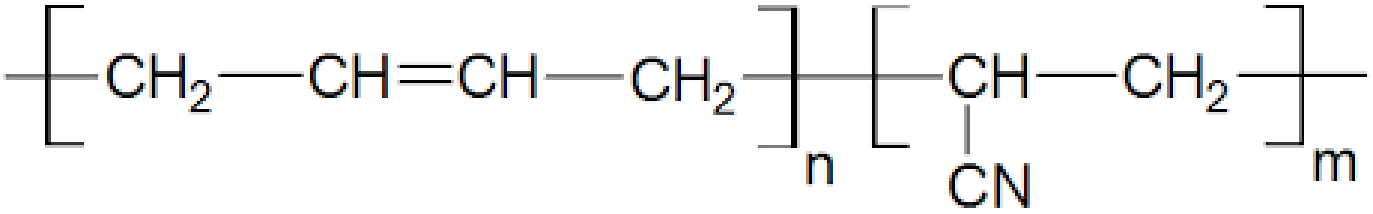
Graft Copolymer

Styrene Butadiene Rubbere (SBR) : A Copolymer of Styrene and Butadiene



Butadiene Styrene

Nitrile Butadiene Rubbere (NBR) : A Copolymer of Acrylonitrile and Butadiene



Butadiene Acrylonitrile

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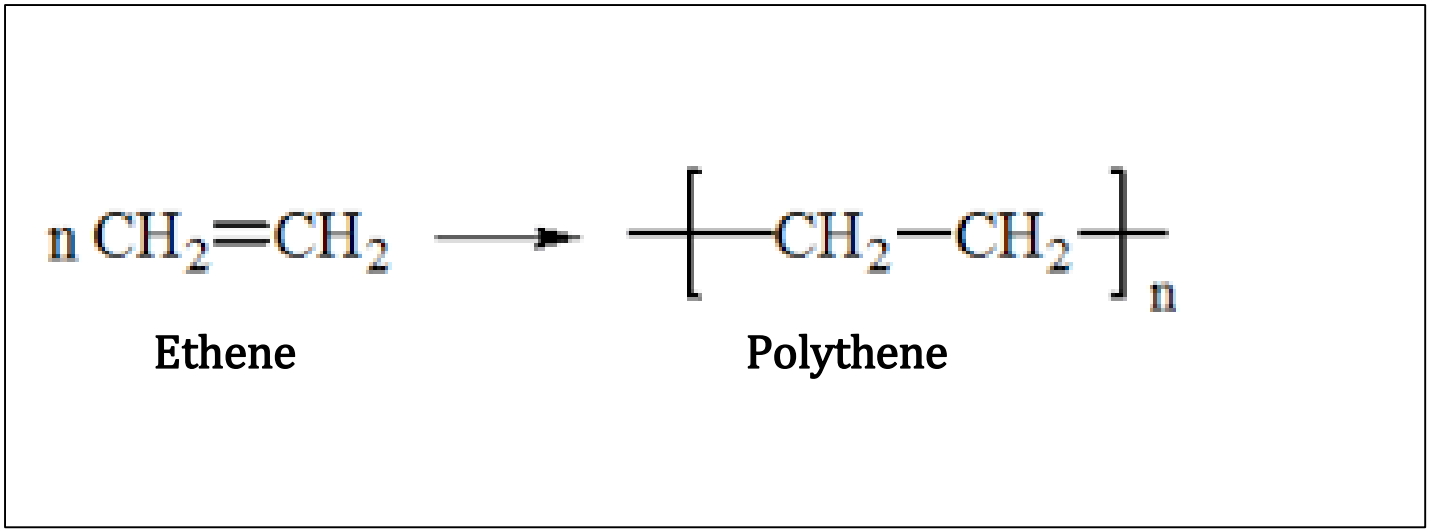
Addition & Condensation Polymers

5. Classification on the basis of mode of polymerization

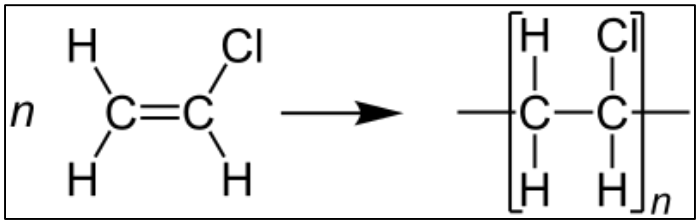
a. **Addition Polymerization (Chain Growth Polymerization)**
b. **Condensation Polymerization (Step Growth Polymerization)**

a. Addition Polymerization

They are formed by simple addition of olifinic, vinylic monomer by a chain mechanism. This process is called addition polymerization.

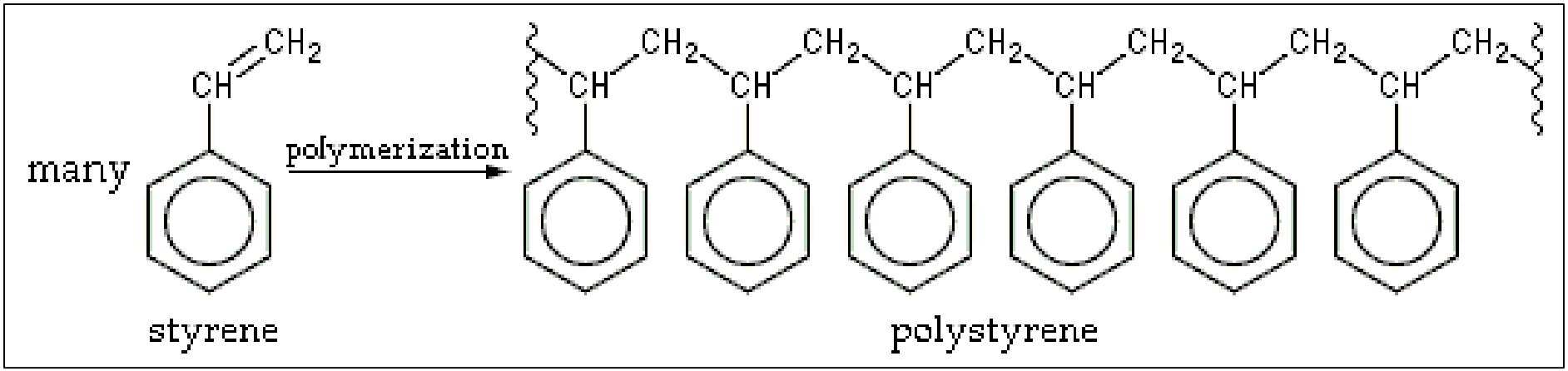


Ethene **Polythene**

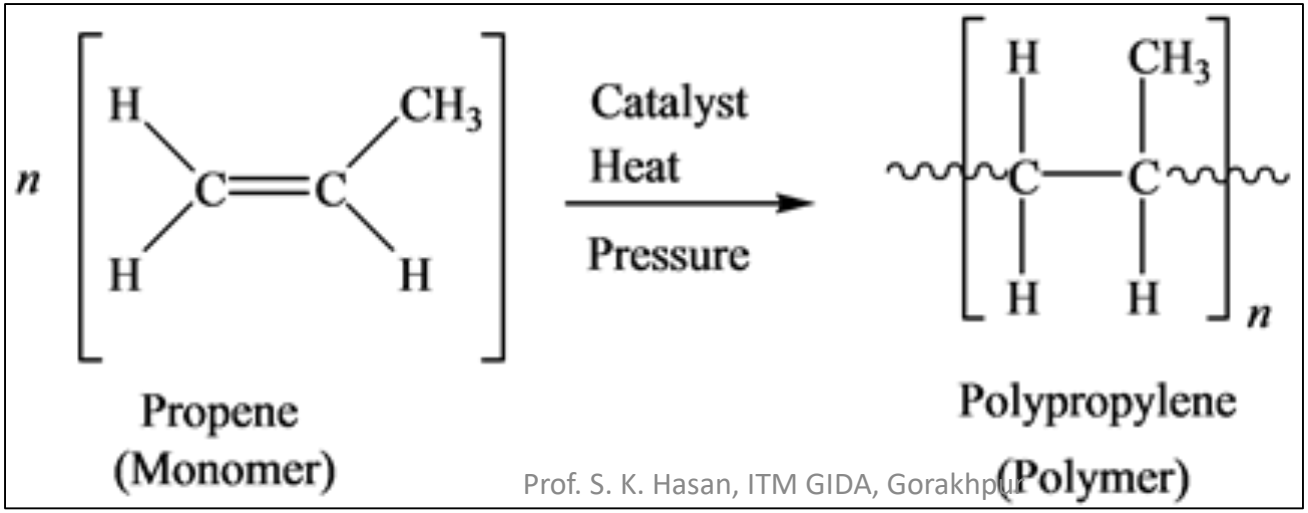


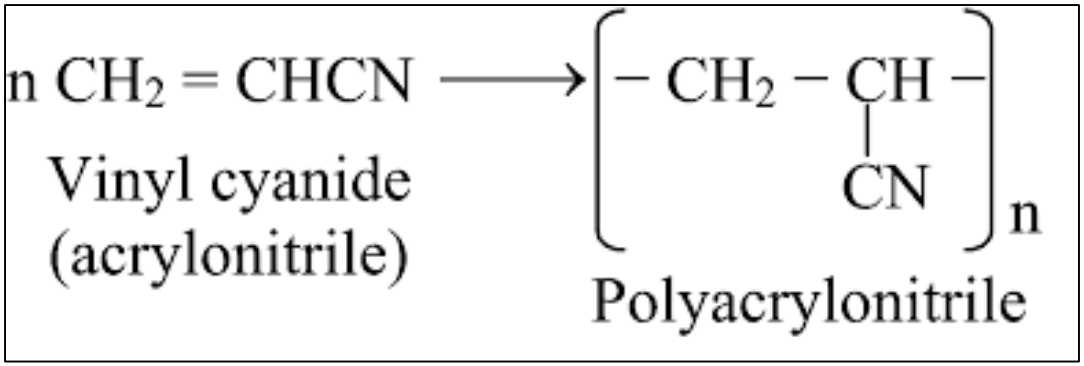
Vinyl Chloride **Polyvinyl Chloride (PVC)**

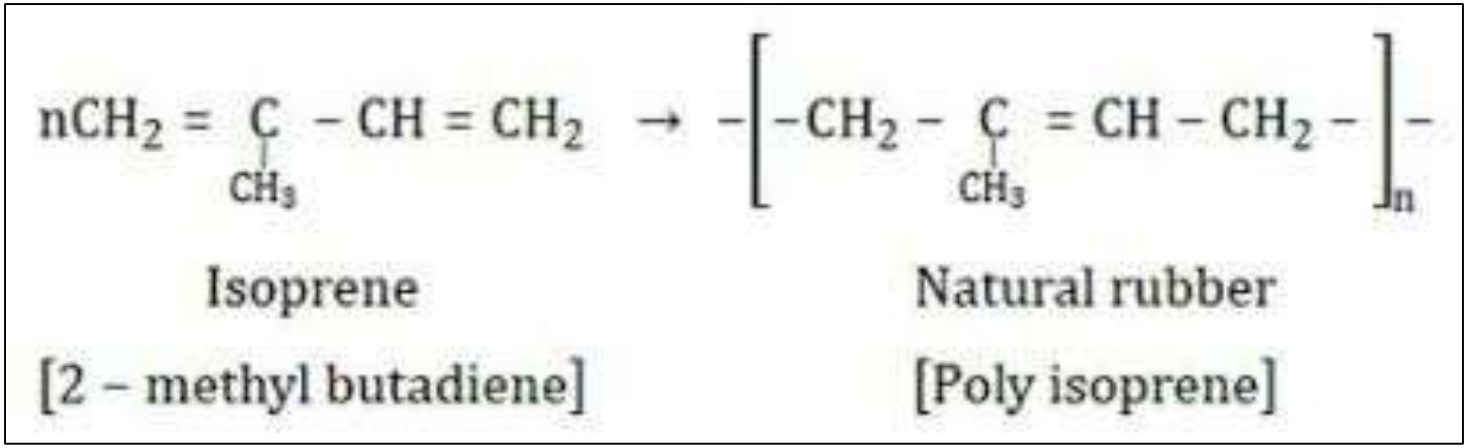
Polymer of Styrene is Polystyrene

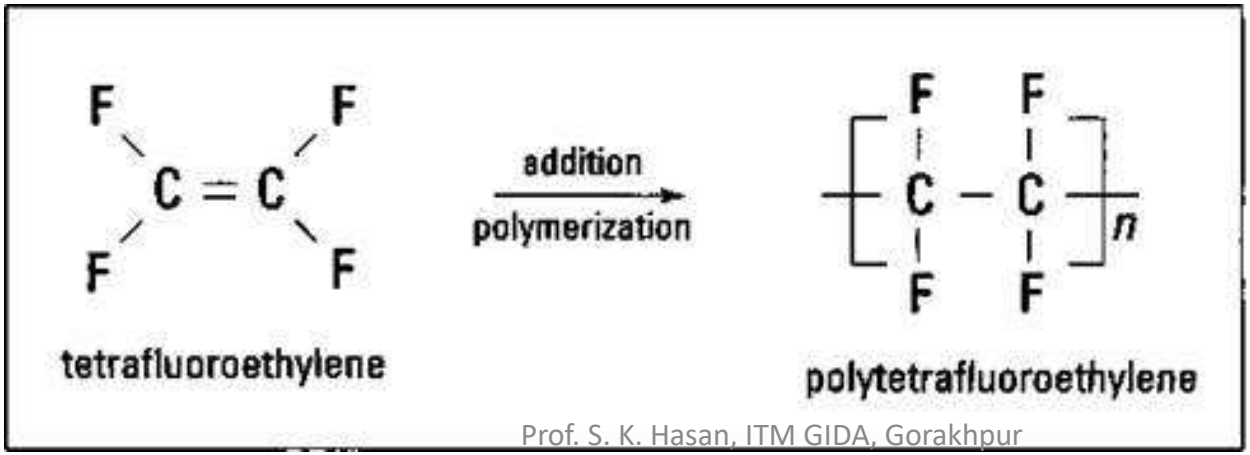


Polymer of Propylene is Polypropylene




n CH2 = CHCN
Vinyl cyanide
(acrylonitrile)
− CH2 − CH −
CN
n
Polyacrylonitrile


nCH2 = C − CH = CH2
CH3
Isoprene
[2 – methyl butadiene]
−CH2 − C = CH − CH2 −
CH3
n
Natural rubber
[Poly isoprene]


F
F
C = C
F
F
tetrafluoroethylene
addition
polymerization
F
F
C
C
F
F
n
polytetrafluoroethylene

Condensation Polymerization or Step Growth Polymerization

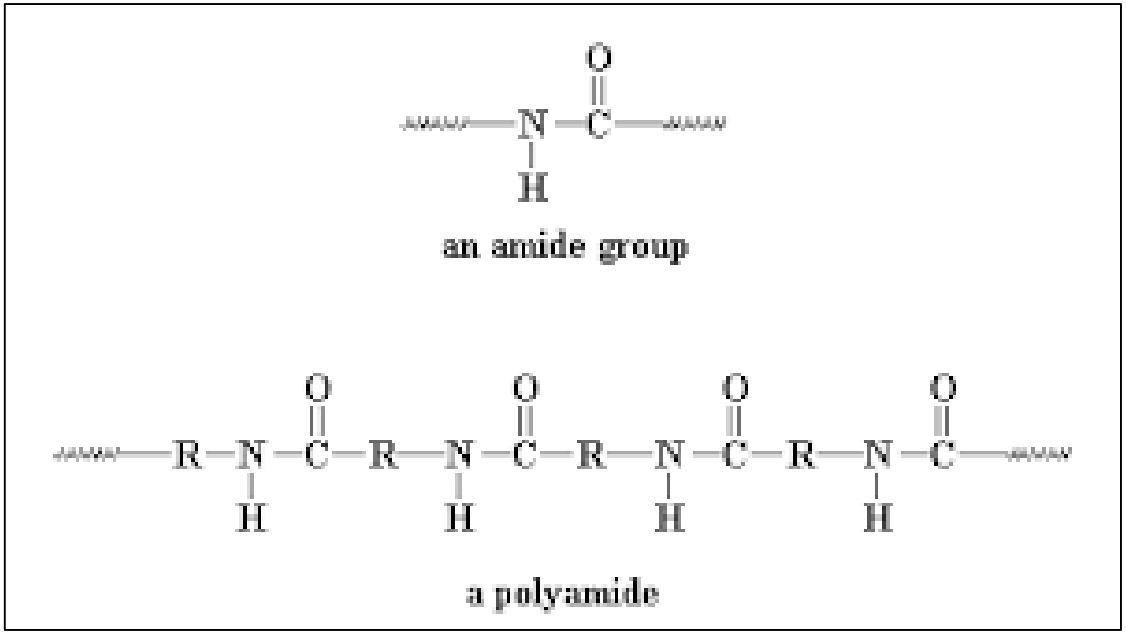
They are formed by intermolecular reactions between bi-functional or poly-functional monomer molecules having reactive functional groups such as –OH, -COOH, -NH_2, with subsequent removal of small molecules like HCl, H_2O etc..

Examples

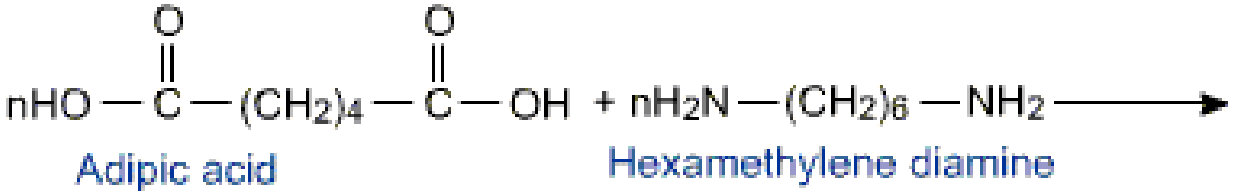
1. Polyamides polyamide is formed by polymerization of amide

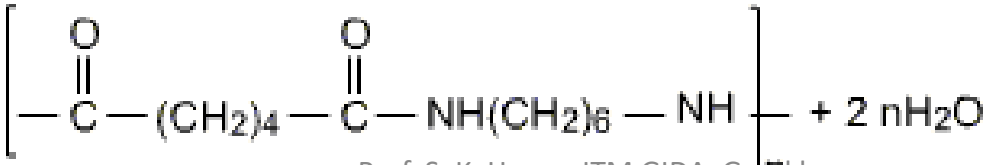
$-NH_2 + HOOC- \rightarrow -(NH-CO)- + H_2O$

Amine Carboxylic acid Amide Water



Dioic acid & Diamine (Nylon-66)

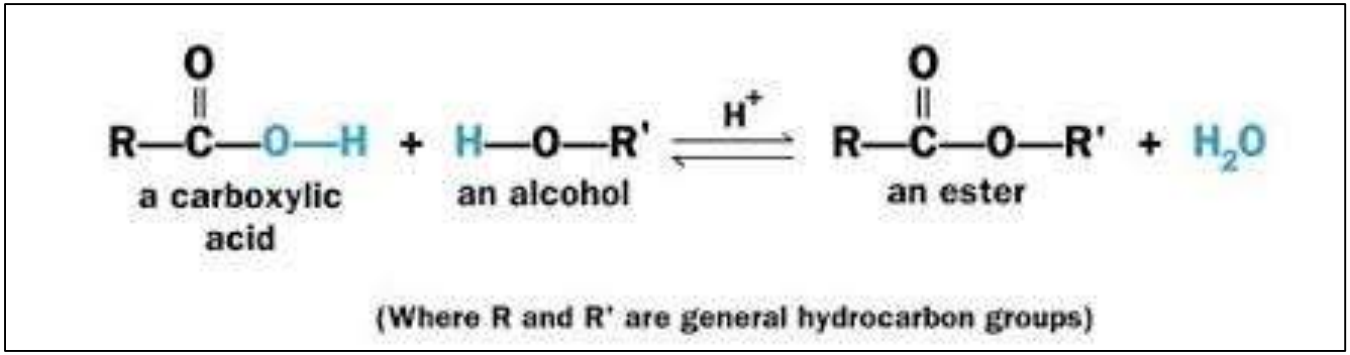


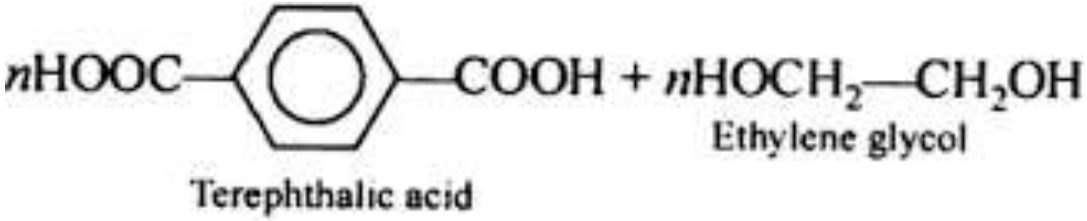


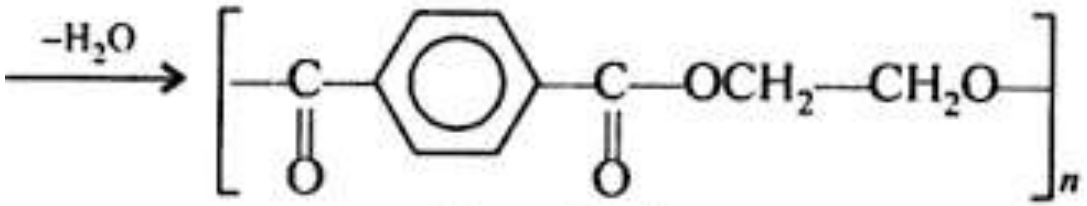
Nylon-66

Polyesters (Dacron or Terylene) - Polymer of Ester

Ester is formed by condensation of caroxylic acid and alcohol.
Polyester is formed by condensation of Dioic acid and Diols
Dacron is formed by polymerization of Terephthalic acid and ethylene glycol







Dacron (Terylene)

Difference between Addition and Condensation Polymerization

S. No.	Addition Polymerization	Condensation Polymerization
1	Formed by Chain Growth	Formed by step-growth
2	monomer must have at least a double bond or triple bond.	Must have functional groups
	It involves the linking of monomers with double bonds.	It Involves reaction between two functional groups
3	Addition Polymerization involves only one monomer	Condensation Polymerization involves two different kinds of monomers
4	It does not lead to a loss in smaller molecules e.g PVC , PS, PE, PAN and Teflon etc	It leads to loss of simple molecules like HCl etc. for example nylon, bakelite.
5	Additional polymerization reaction results in higher molecular weight polymers.	Condensation polymerization produces low molecular weight polymers as its end products.
6	Additional polymerization produces thermoplastic.	Both thermoplastics and Thermosetting Plastics are formed

Thank You

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