

## Introduction of Polymers

**Polymer** - The word 'polymer' is the Greek word : **poly** means many and **mer** means unit or parts, A Polymer is a large molecule that comprises repeating structural units joined by the covalent bonds.

**Monomer** – The small molecule or repeating unit or the building block in the structure of polymer is called monomer.

To be a monomer , the substance unit should have a functionality of at least two , some compounds have two functionality other have double or triple bonds in the molecule .



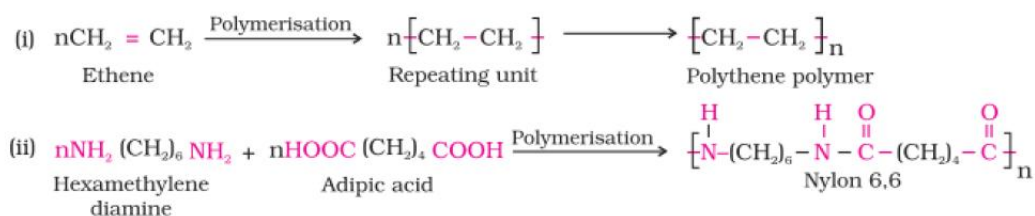
**Polymerization** – it is chemical reaction in which two or more than two molecules of one or more than one substance combine together to form a molecule of high molecular weight.

**Degree of Polymerization** – Number of monomer or repeating unit(n) in the polymer chain is called degree of polymerization (DP)

Degree of polymerization (DP) is used to calculate the average molecular weight of polymer.

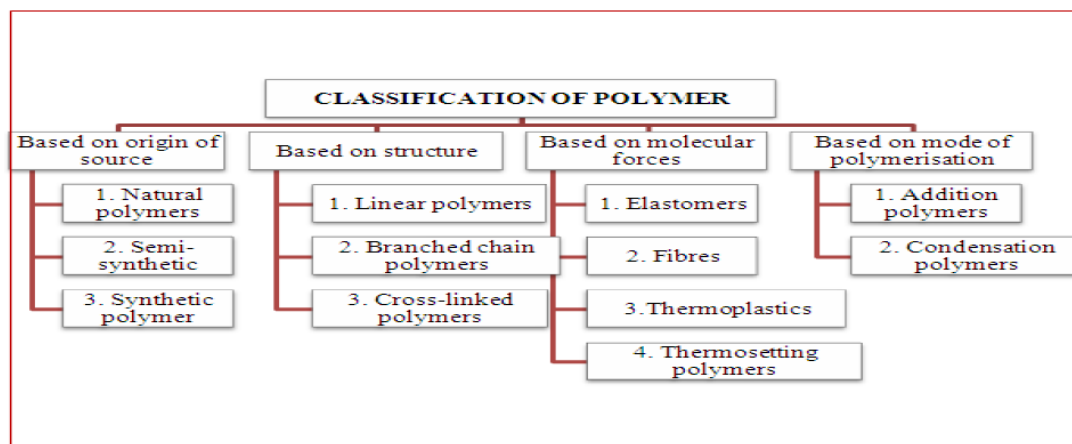
**Average molecular weight of polymer= DP X Weight of repeating unit.**

for examples of two different types of polymerization reactions.

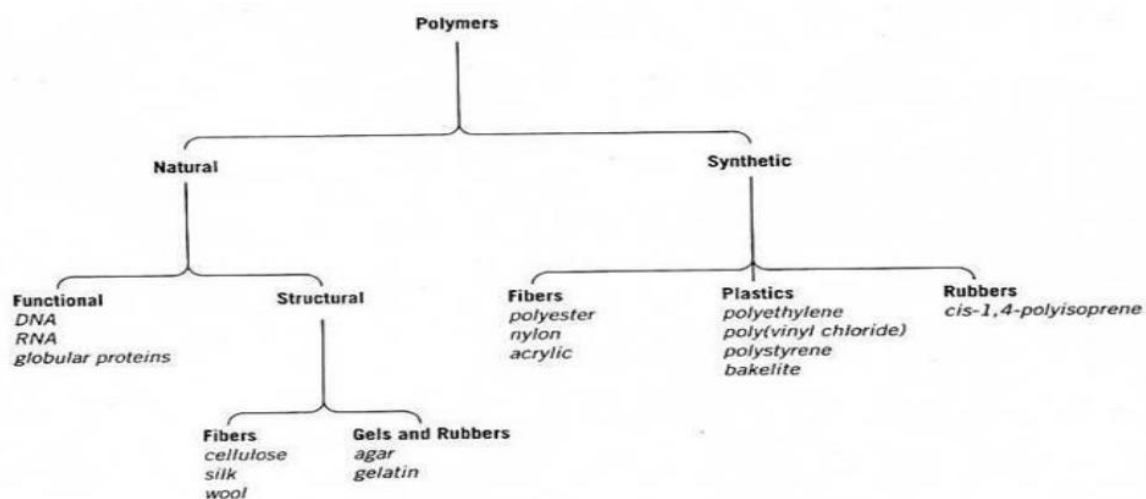


## Classification of Polymers

There are several ways of classification of polymers based on some special considerations :



**A- Classification Based on Source Under :** this type of classification, there are three sub categories. **1. Natural polymers:** These polymers are found in nature , example plants and animals. Examples are proteins, cellulose, starch, resins and rubber. **2. Semi-synthetic polymers:** The polymers obtained by simple chemical treatment of natural polymers to change their physical properties like Starch, silicones **3. Synthetic polymers:** The fibres obtained by polymerisation of simple chemical molecules in laboratory are synthetic polymers, ex.. Nylon, polyethene, polystyrene, synthetic rubber, PVC, Teflon.... etc..



### **B- Classification Based on the structure of polymers :**

There are three different types based on the structure of the polymers.

**1. Linear polymers on Structure** • In these polymers monomers are linked with each other and form a long straight chain.

- These chains has no any side chains, ex. Polyethene, PVC, Nylons, polyesters etc.
- Their molecules are closely packed and have high density, tensile strength. These are represented as:



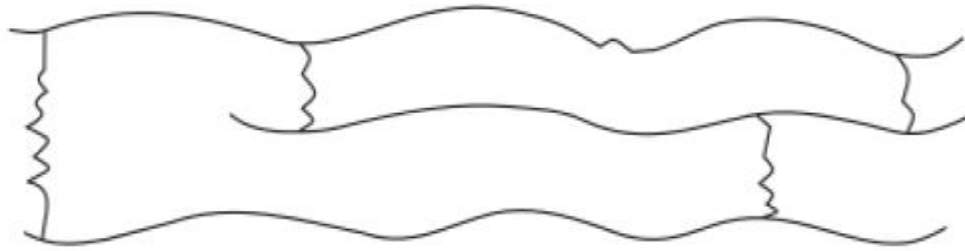
**2. Branched chain polymers** • They have a straight long chain with different side chains.

- Their molecules are irregularly packed hence they have low density, tensile strength and melting point, ex... polypropylene , amylopectin and glycogen.:



**3. Crosslinked or Network polymers** • Those polymers in which two linear chains are joined together by covalent bonds and it have three dimensional.

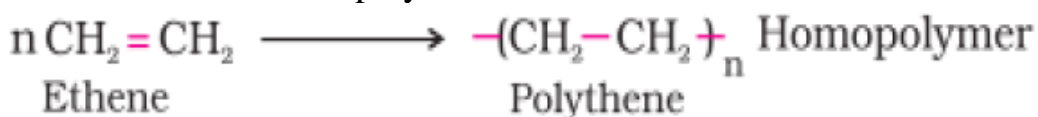
- ☐ Degree of crosslinking is a number of junction point per unit volume.
- ☐ Polymers crosslinking are hard, rigid .and brittle due to their network structure.
- ☐ Polymers Crosslinked do not dissolve in solvents because all the polymer chains are covalently tied together, but they can absorb solvents. Ex. Bakelite, melamine, formaldehyde resins, vulcanised rubber etc. These polymers are depicted as follows:



### **C- Classification Based on Mode of Polymerization**

Polymers can also be classified on the basis of mode of polymerisation into two sub groups:

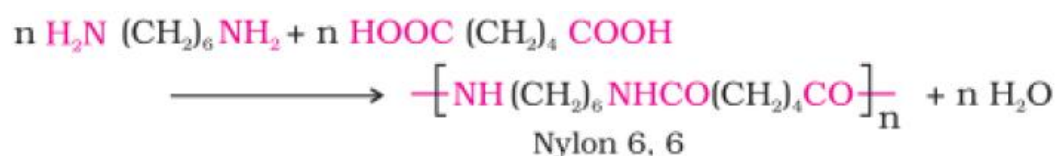
**1. Addition polymers:** The addition polymers are formed by the repeated addition of monomer molecules possessing double or triple bonds, The polymers formed by the addition of monomers repeatedly without removal of by products are called addition polymers. e.g., the formation of polythene from ethene and polypropene from propene. However, the addition polymers formed by the polymerisation of a single monomeric species are known as homopolymers.



## 2. Condensation polymers :

They are formed by the combination of two monomers by removal of small

molecules like water, alcohol or NH<sub>3</sub>.ex.. Nylon 6, 6, Nylon 6, etc. For example, nylon 6, 6 is formed by the condensation of hexamethylene diamine with adipic acid.



## D- Classification Based on Molecular Forces

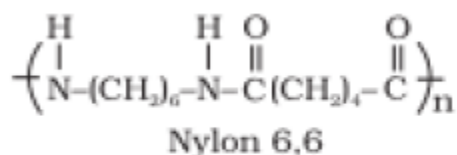
Mechanical properties of polymers like tensile strength, toughness, elasticity depends upon intermolecular forces like van-der waals forces and hydrogen bonding. On the basis of these forces they are classified as

**1. Elastomers** These are rubber – like solids with elastic properties. In these elastomeric polymers, the polymer chains are held together by the weakest intermolecular forces. These weak binding forces permit the polymer to be stretched. A few ‘crosslinks’ are introduced in between the chains, which help the polymer to retract to its original position after the force is released as in vulcanised rubber. The examples are buna-S, buna-N, neoprene, etc.



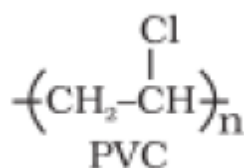
**2. Fibres :** Fibres are the thread forming solids which possess high tensile strength and high modulus. These characteristics can be attributed to the

strong intermolecular forces like hydrogen bonding. These strong forces also lead to close packing of chains and thus impart crystalline nature. used in textile industries The examples are polyamides (nylon 6, 6), polyesters (terylene), etc.



**3. Thermoplastic polymers** • These are the polymers having intermolecular forces between elastomers and fibres.

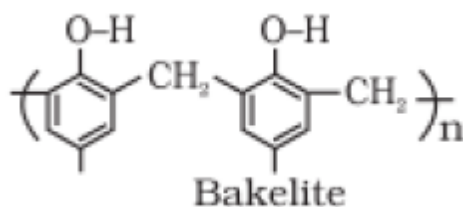
- They are those polymers which can be softened on heating and hardened on cooling room temperature.
- They may be linear or branched chain polymers.
- these polymer can be recycled many times. Ex , Polythene, polyesterne, PVC.

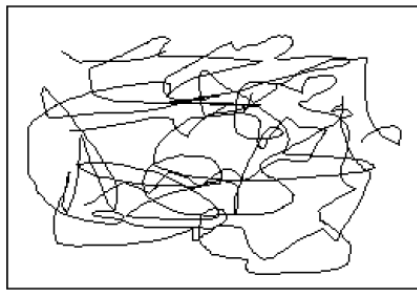


**4-Thermosetting polymers** • This polymer is hard and infusible on heating.

- These are not soft on heating under pressure and they are not remoluded.
- These polymers are cross linked or heavily branched molecules
- These polymers we cannot reused or recycle .

Ex. Some common examples are bakelite, urea-formaldelyde resins, etc.





Amorphous

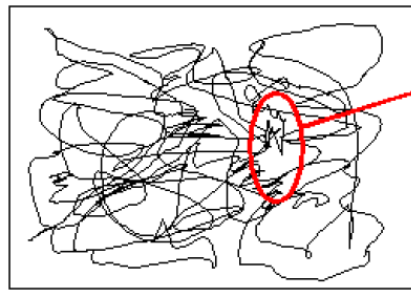
Random Structure

Broad Melting Point

Low Shrinkage

Lower Mechanical Properties

Example: ABS, PC, PS



Crystalline

Ordered Structure

Narrow Melting Point

Higher Shrinkage

Higher Mechanical Properties

Example: Nylon, Acetal, PET

### G-Classification Based On the basis of End Use:

polymers can divided into three classes:

**1-Rubbers:** They are dimensionally unstable. These polymers are characterized by long-range elasticity. The rubbery polymers are characterized by low molecular cohesion. Their mechanical properties are poor. Their tensile strength ranges between 300-1000 psi.

**2-Plastics:** these are much stronger than rubbers. They exhibit tensile strength ranges between 4000-13000 psi. some plastics are hard, stiff and dimensionally stable and some are soft and flexible.

**3-Fibres:** they are the strongest of the three different types of polymers. They exhibit tensile strength which ranges between 20000-150000 psi.

### Bonding in Polymers:

Various types of bonding may exist in polymeric material. These types and dissociation energy are:

- ☐ Primary covalent 50-200 kcal/mol - strong
- ☐ Hydrogen bonding 3-7 kcal/mol - weak
- ☐ Dipole interaction 1.5-3 kcal/mol - weak
- ☐ Van der vals forces 0.5-2 kcal/mol - weak
- ☐ Ionic 10-20 kcal/mol - weak



### Copolymers:

Those have two or more different monomer , Copolymers can be classified in the following types:

**1-Random Copolymers:** A copolymer, in which the two monomer units are placed in random manners (irregularly)(2,3)

**2-Block Copolymer:** it is a linear copolymer in which each monomer unit forms a block.(4)

**3-Graft Copolymer:** it is a branched copolymer in which one monomer unit forms backbone of the polymer and the monomer unit forms the branches(5).

