Mustansiriyah University
Materials Engineering Department

POLYMER SCEINCE AND ENGINEERING
Course I

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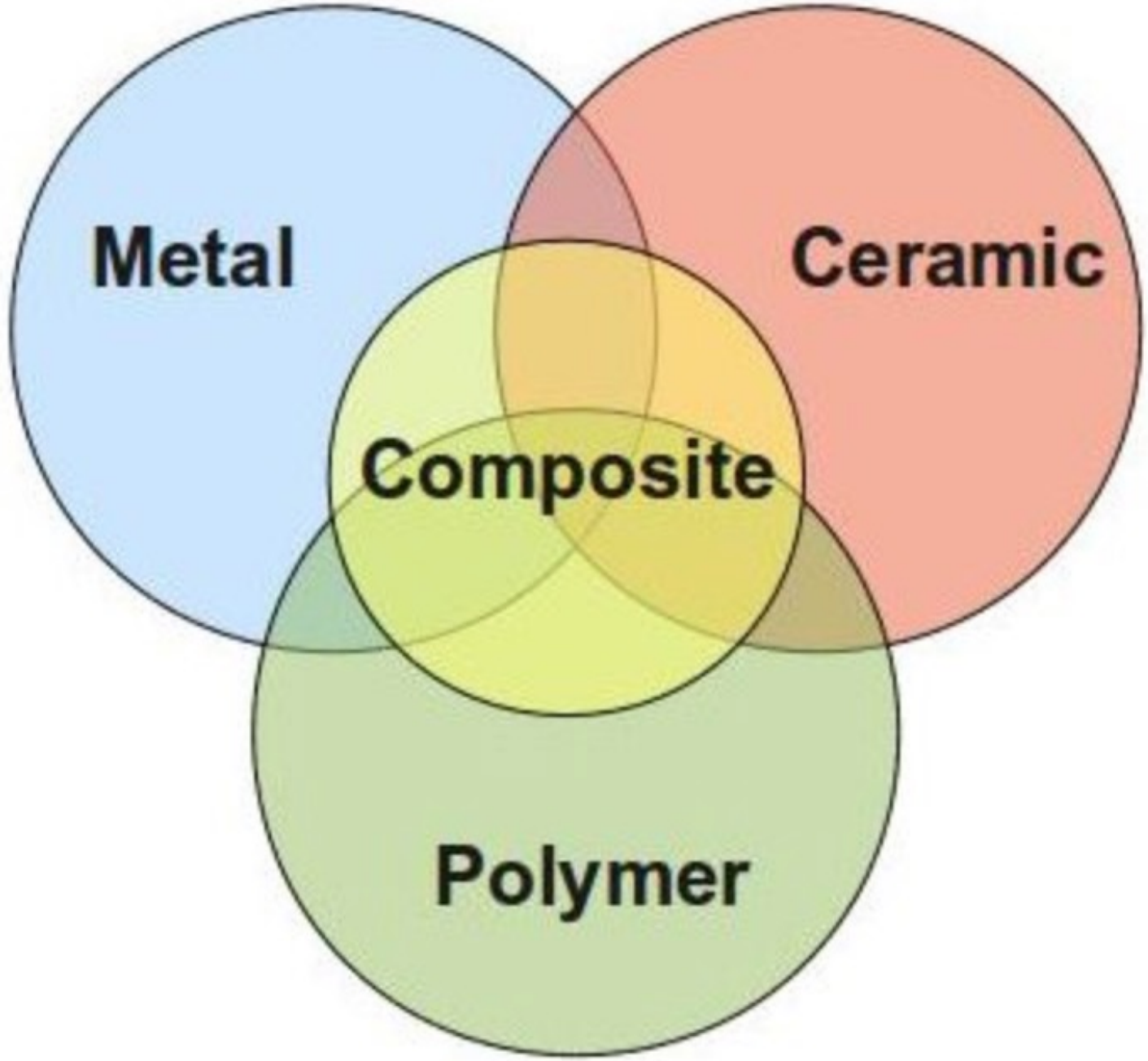
Otc. 2021


Metal
Ceramic
Composite
Polymer

Adhesives

Carpeting

Cosmetics

Fertilizers

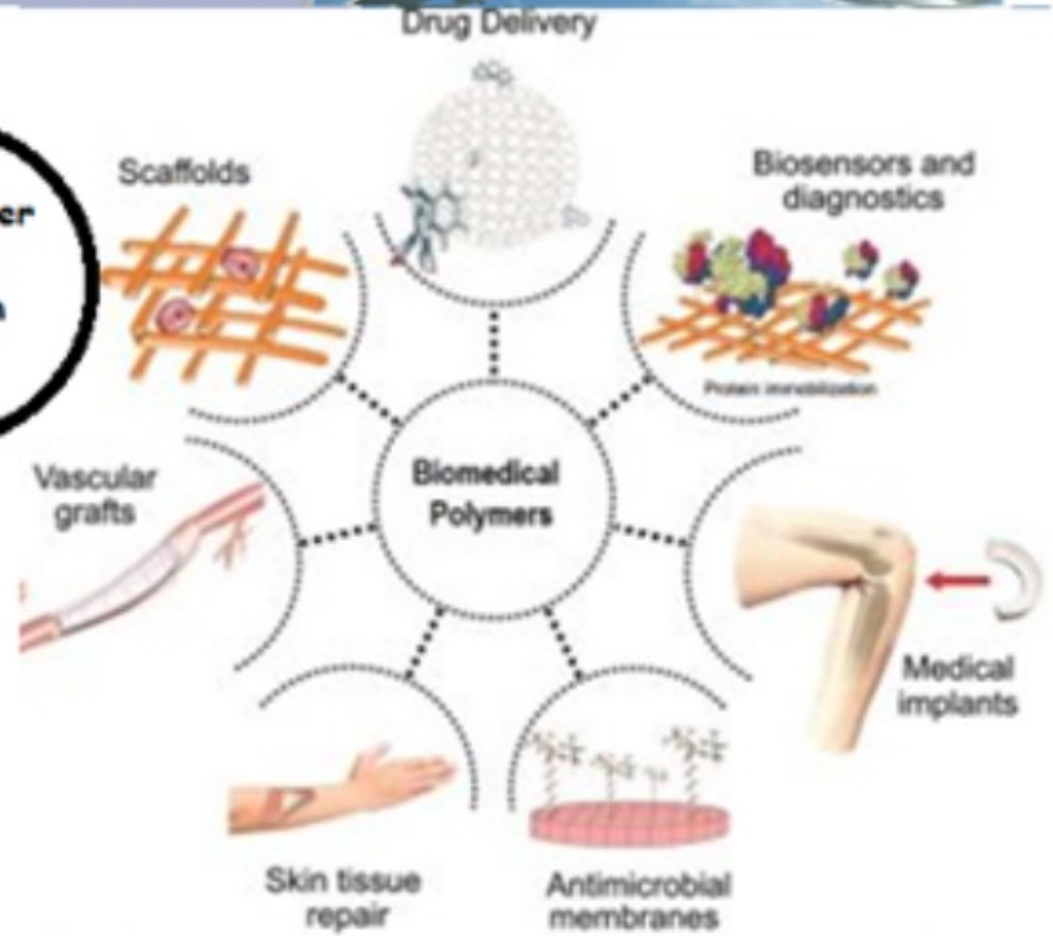
Paints

Rubber

Fabrics

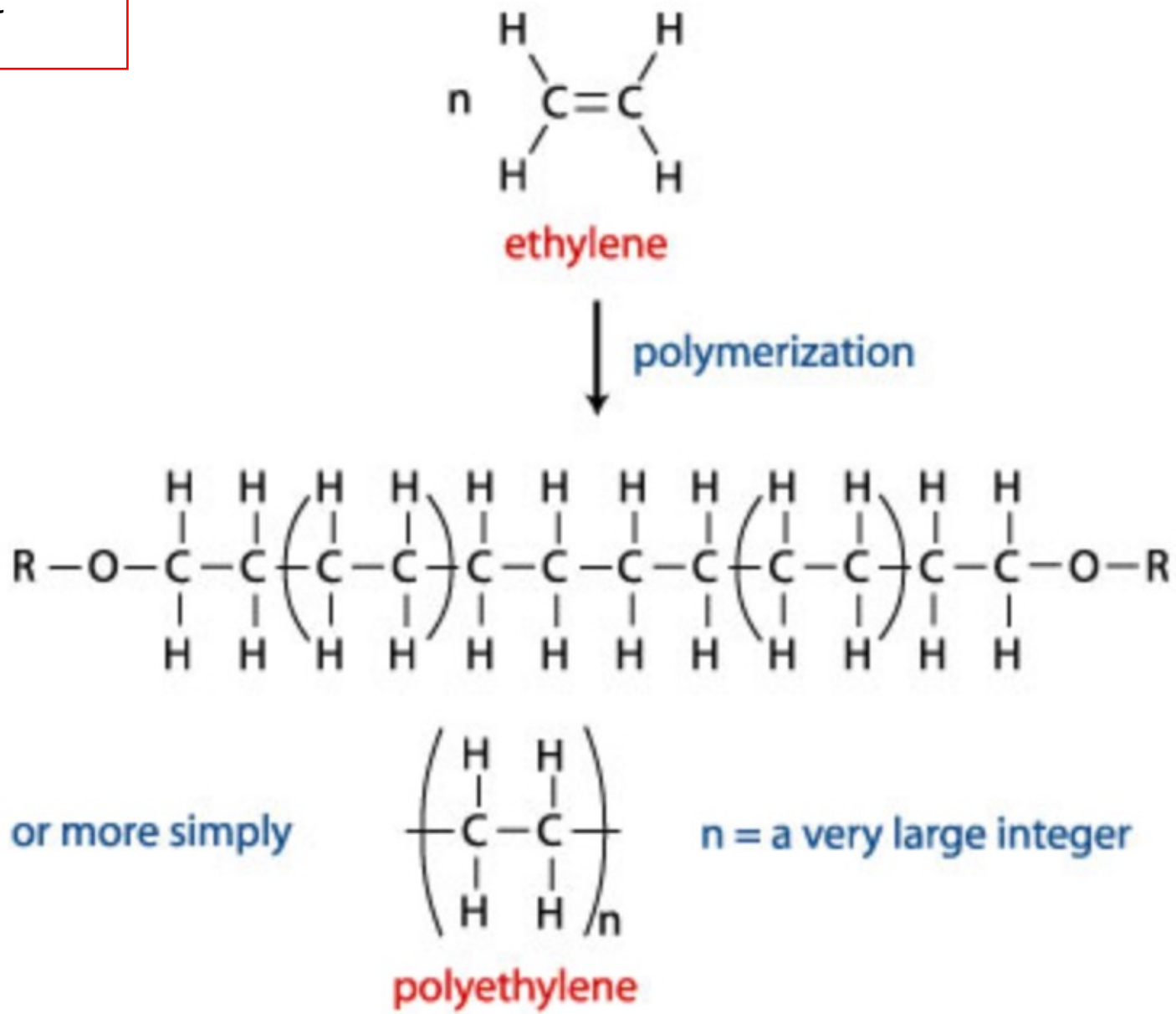
Plastics

BSc Polymer Chemistry Application Areas



Polymer = Poly (mer) ;
where Poly means many and Mer is the Building Unit

EXAMPLE



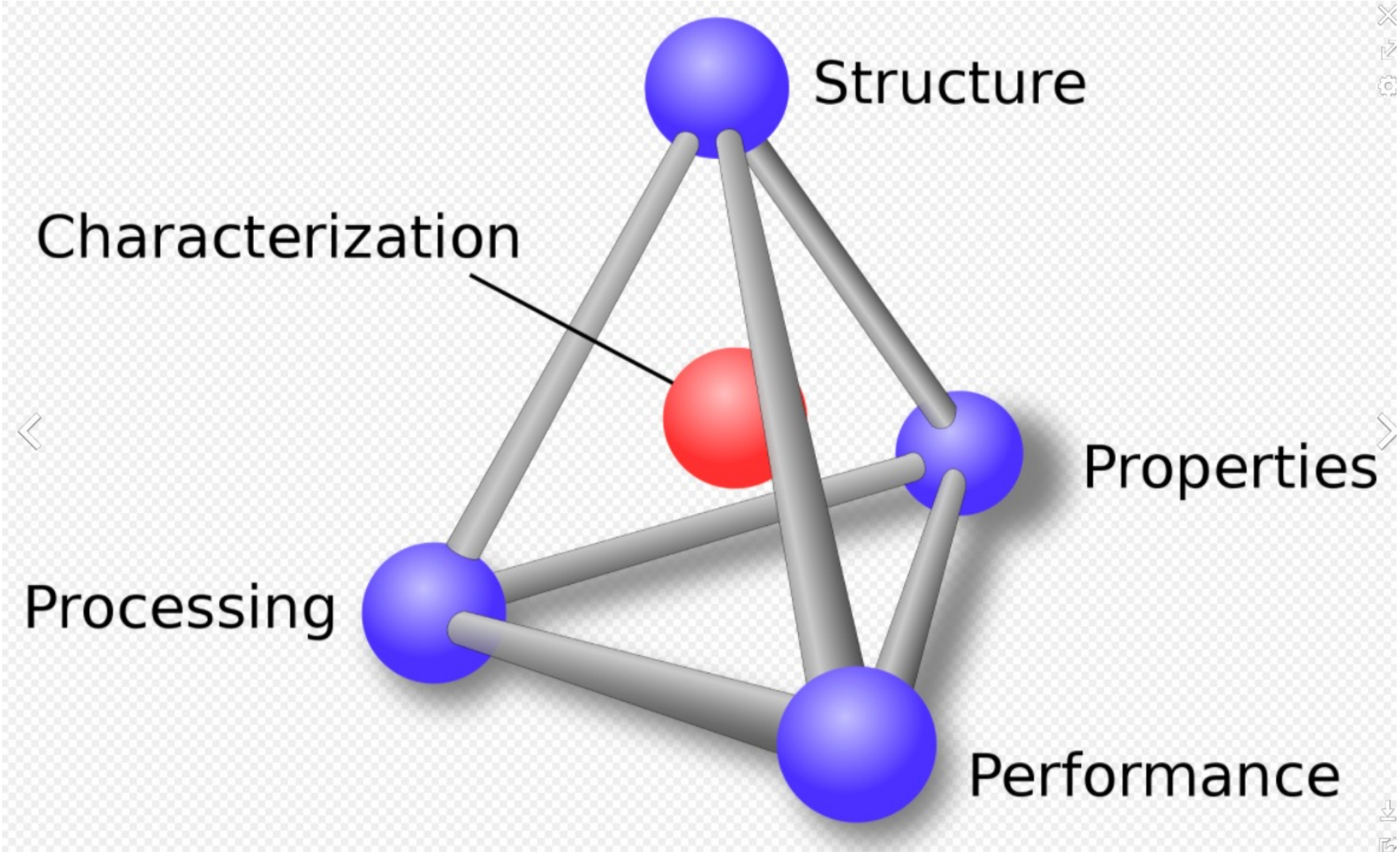


Fig.1 : The four components of the discipline of materials science and engineering

Course Outlines

1. Introductory Concepts

- Definitions and Polymer Classifications
- Polymer Molecular Weights
- Measurements of Molecular Weight and its distribution

2. Structure - Property Relationship

- Mechanical Properties of Polymer Solids and Liquids
- Thermodynamics of Polymer Mixtures
- Flow Behaviour of Polymeric Fluids
- Melting and Glass Transition Phenomena in polymer
- Diffusion in Polymer
- Polymer Defects

3. Polymer Synthesis / Polymerisation Methods

- Chain-growth polymerisation
- Copolymerization

Course activity

Activity	Percent
Mid-Course Exam	This will count for **50%** of the course grade.
Homework **oral Exam**	The total homework assignment score will count for **25%** of the course grade. **Late homework** will not be accepted unless you have a valid reason **and** you arrange it with me **in advance**.
Pop-quizzes	There will be 8 - 10 of them. Quiz questions will refer only to the recently covered material **and** not to the new material. Two or three lowest quiz scores will be dropped, and the remaining scores will count for **15%** of the course grade.
Others (posters and reports)	This includes submitting posters about solving equations using software **or** analysis an engineering problems. This will count for **10%** of the course grade.

Some Useful Sources:

1. Fried, J.R., 2014. *Polymer science and technology*. Pearson Education.
2. Kumar, A. and Gupta, R.K., 2018. *Fundamentals of polymer engineering*. CRC Press.
3. Ebewele, R.O., 2000. *Polymer science and technology*. CRC press.
4. Callister, W.D. and Rethwisch, D.G., 2018. *Materials science and engineering: an introduction*. New York: Wiley.

LECTURE NO.1

Basic Definitions , Polymer Characteristics and Classification

At the end of this lecture, you should be able to:

- Explain what is meant by polymer, monomer, polymerization process.
- Explain the main features of polymeric materials
- Classify the polymeric materials

SOME BASIC DEFINTIONS

POLYMER: A polymer is a long-chain molecule that is composed of a large number of repeating units of identical structure. The word polymer is derived from the classical Greek words poly meaning “many” and meres meaning “parts.

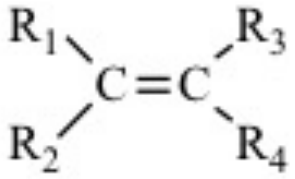
Monomer: A small individual repeating units/molecules which are connected together to form a polymer. Imagine that a monomer can be represented by the letter A. Then a polymer made of that monomer would have the structure:

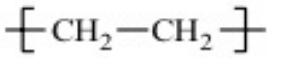
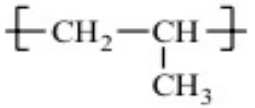
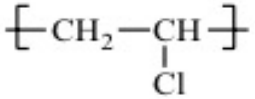
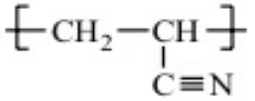
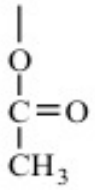
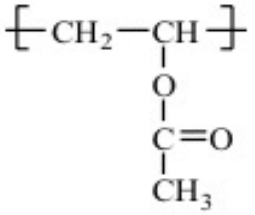
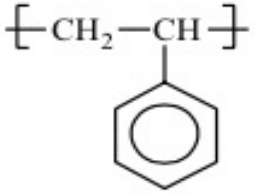
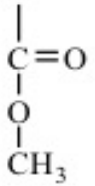
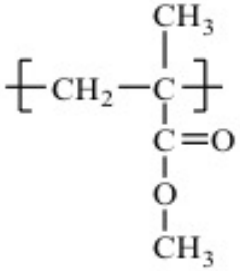
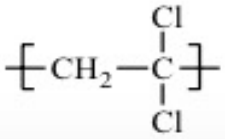
-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-A-

OLIGOMER: It is a molecular complex of chemicals that consists of a few repeating units(less than 10 units), in contrast to a polymer, where the number of monomers is infinite. Dimers, trimers, and tetramers are, for instance, oligomers composed of two, three, and four monomers, respectively.

POLYMERIZATION: It is a process in which the monomer molecules are linked through a variety of reaction mechanisms to form longer chains.

SOME EXAMPLES OF MONOMERS AND THEIR POLYMERS

Monomer = 

Polymer	R_1	R_2	R_3	R_4	Repeating Unit
Polyethylene	H	H	H	H	
Polypropylene	H	H	H	CH_3	
Poly(vinyl chloride)	H	H	H	Cl	
Polyacrylonitrile	H	H	H	$C\equiv N$	
Poly(vinyl acetate)	H	H	H		
Polystyrene	H	H	H		
Poly(methyl methacrylate)	H	H	CH_3		
Poly(vinylidene chloride)	H	H	Cl	Cl	

Polymer Characteristics

Every polymer has very distinct characteristics, but most polymers have the following general attributes.

1. Polymers can be very resistant to chemicals.

2. Polymers can be both thermal and electrical insulators.

3. Generally, polymers are very light in weight with significant degrees of strength.

4. Polymers can be processed in various ways. Extrusion produces thin fibers or heavy pipes or films or food bottles. Injection molding can produce very intricate parts or large car body panels. Plastics can be molded into drums or be mixed with solvents to become adhesives or paints.

5. **Polymers are materials with, seemingly, a limitless range of characteristics and colors.** Polymers can also make possible products that do not readily come from the natural world, such as clear sheets and flexible films.

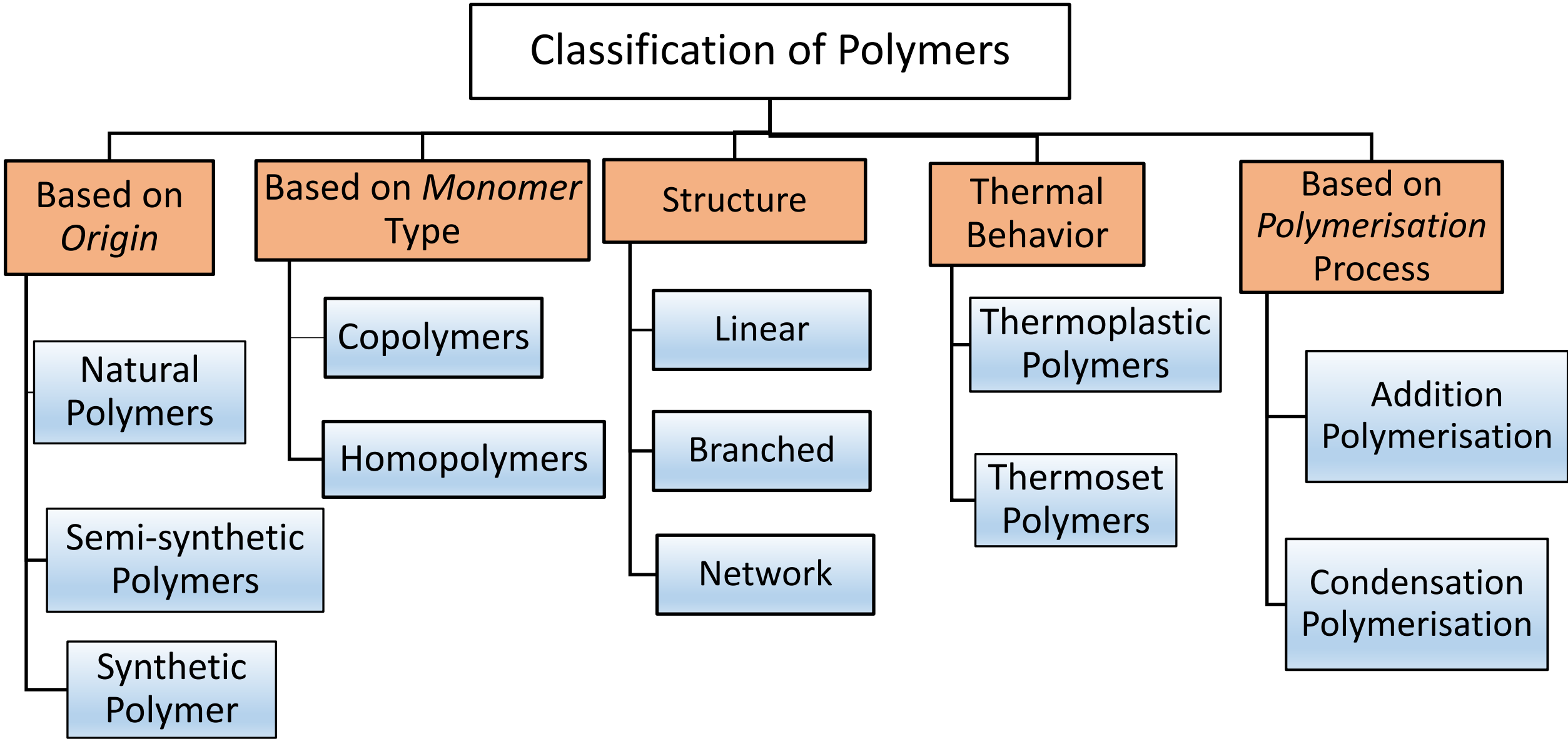
6. Polymers have some drawbacks as well such as low mechanical properties and poor temperature resistance in relation to the metallic materials.

QUESTION?

1. Polymer can be viewed as:

- Metallic Materials
- Non-metallic Materials
- Protein
- None of these

Please, write down your answer in the chat box


Classification of Polymers
Based on *Origin*
Natural Polymers
Semi-synthetic Polymers
Synthetic Polymer
Based on *Monomer* Type
Copolymers
Homopolymers
Structure
Linear
Branched
Network
Thermal Behavior
Thermoplastic Polymers
Thermoset Polymers
Based on *Polymerisation* Process
Addition Polymerisation
Condensation Polymerisation

Classification based on Origin

Natural Polymers: Those are isolated from natural materials are called as natural polymers.
E.g. Silk, Wool, Natural rubber, Cellulose, Starch, Proteins etc.

Semisynthetic Polymers: The polymers obtained by simple chemical treatment of natural polymers to improve their physical properties are called semisynthetic polymers (e.g. Cellulose acetate, Cellulose nitrate).

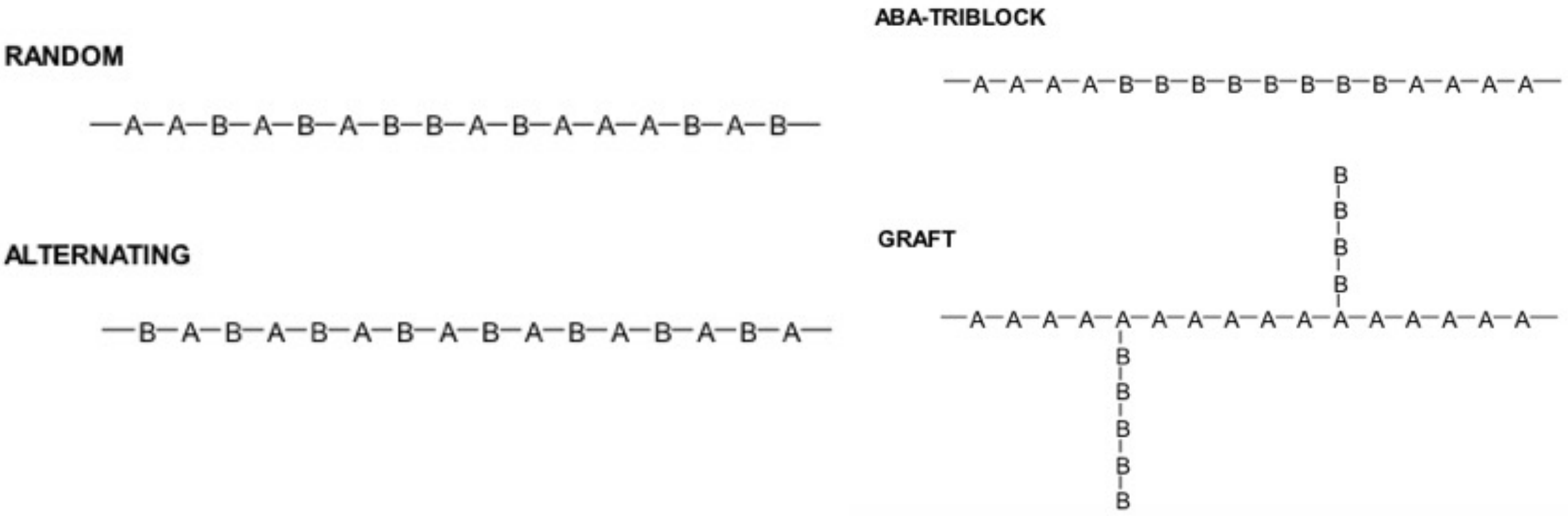
Synthetic Polymers: Polymers that are synthesized in laboratory from low molecular weight compounds, are called as, synthetic polymers. (e.g. Terylene, Polyethylene, Polystyrene, Synthetic rubber, Nylon, *PVC, *Bakelite, *Teflon etc.).

NOTE: *TEFLON = Polytetrafluoroethylene ; *PVC = Polyvinyl chloride ;
*Bakelite = polyoxybenzylmethylenglycolanhydride

Classification Based on Monomer

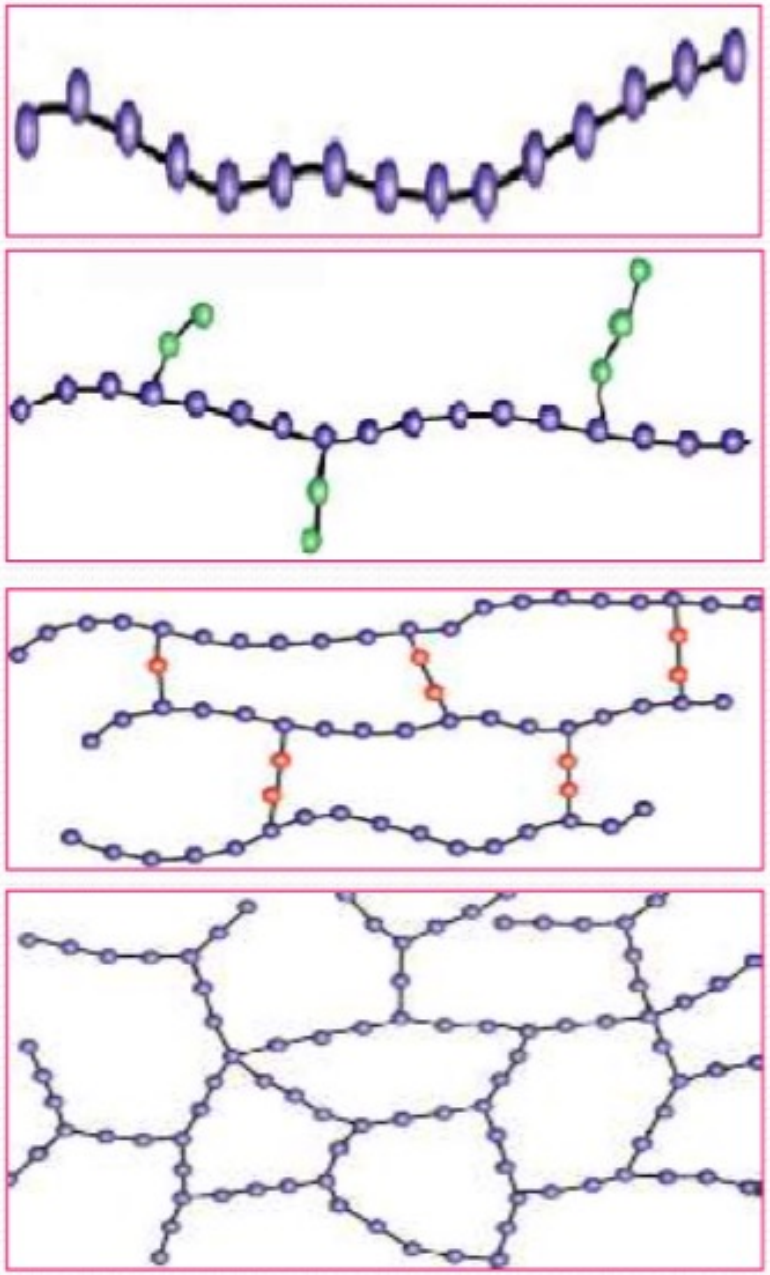
Homopolymers: A polymer consists of identical monomers is called homo polymer. (e.g. Polyethylene, PVC, Polypropylene, Nylon 6).

Copolymers : A polymer consists of monomers of different chemical structure is called copolymers (e.g. epoxy) .



Classification based on Structure

- Linear Polymer : Molecules form long chains without branches.
- Branched Polymer : Molecules having branch points that connect 3 or more segments .
- Cross-Linked Polymer : It includes interconnections between chains .
- Network Polymer : A cross linked polymer that includes numerous interconnections between chains .



Classification based on Thermal Response

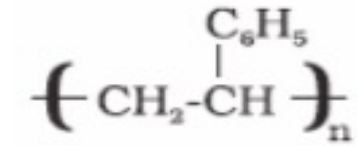
A. Thermoplastic polymers

They can be softened or plasticized repeatedly on application of thermal energy, without much change in properties if treated with certain precautions. Example of such polymers are Polyolefins, nylons, linear polyesters and polyethers, PVC, sealing wax etc.

B. Thermosetting polymers

Some polymers undergo certain chemical changes on heating and convert themselves into an infusible mass. The curing or setting process involves chemical reaction leading to further growth and cross linking of the polymer chain molecules and producing giant molecules. For example, Phenolic resins, urea, epoxy resins, diene rubbers, etc.

❖Thermoplastic Polymers



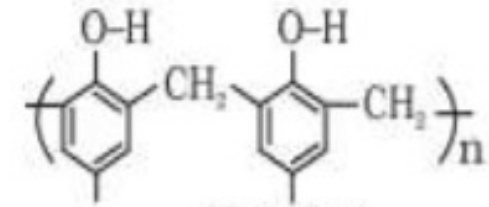
- They are easily moulded in desired shapes by heating and subsequent cooling at room temperature.
- They are soft in hot and hard on coding.
- They my be linear or branched chain polymers.

E.g. PE, PVC, PS, PP

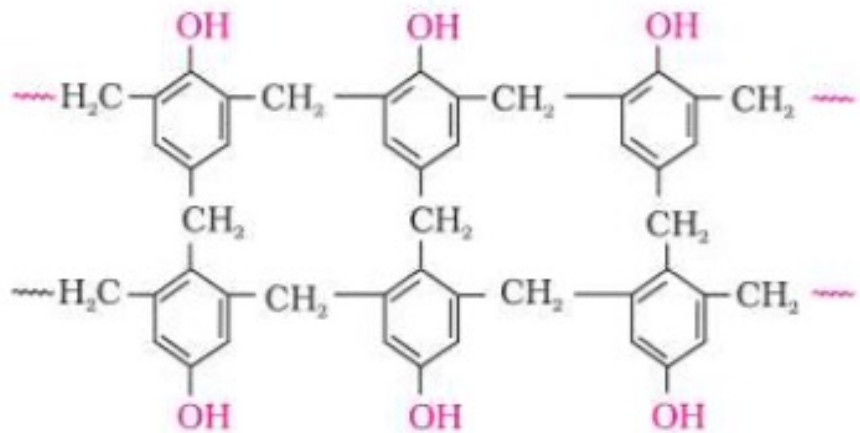
❖Thermosetting Polymers

- This polymer is hard and infusible on heating.
- These are not soft on heating under pressure and they are not remolded.
- These are cross linked polymers and are not reused.

  E.g. Bakelite



Bakelite



Bakelite

Classification based on Polymerisation Method

❖ Addition Polymers

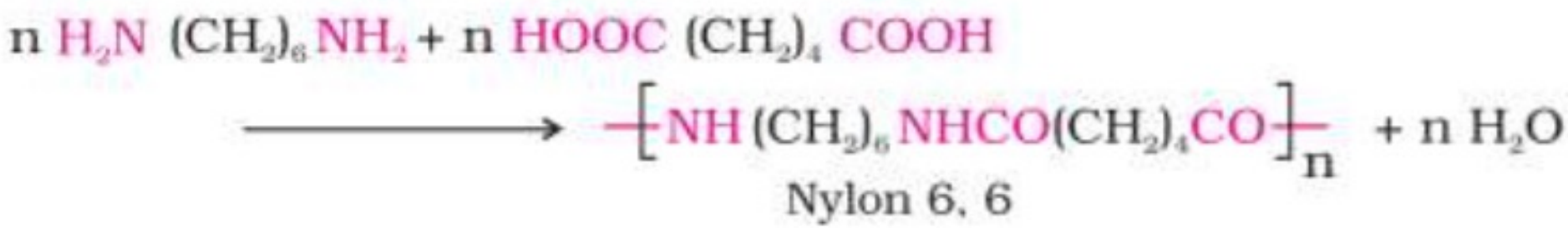
- The polymers formed by the addition of monomers repeatedly without removal of by products are called addition polymers.
- These polymers contains all the atoms of monomers hence their molecular weight are integral multiple of monomer unit.

E.g. Teflon, Polyethylene, Polypropylene, PVC.

❖Condensation Polymers

- They are formed by the combination of two monomers by removal of small molecules like H_2O, Alcohol or NH_3. Their molecular mass is not the integral multiple of monomer units.
- They have ester and amide linkage in their molecules.

E.g. Polyamides(Nylons), Polyesters(PET)



Nylon 6, 6

QUESTION?

Classify the following polymers depending on their thermal response:

Polyethylene, epoxy , polyvinyl chloride , rubber, Bakelite

Other Classification Methods

1) Based on polymer application (Elastomer, Plastics and Fibre)

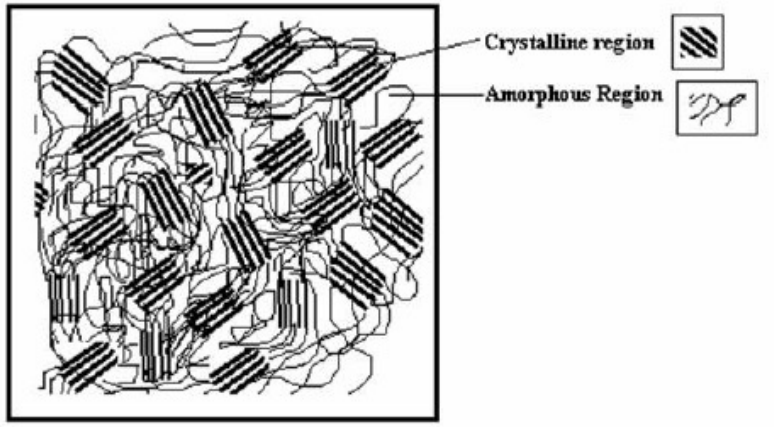
Rubber (Elastomers):- Rubber is high molecular weight polymer with long flexible chains and weak intermolecular forces. They exhibits tensile strength in the range of 300-3000 psi and elongation at break ranging between 300-1000% . Examples are natural and synthetic rubber.

Plastics:- Plastics are relatively tough substances with high molecular weight that can be molded with (or without) the application of heat. These are usually much stronger than rubbers. They exhibit tensile strength ranging between 4000-15000 psi and elongation at break ranging usually from 20 to 200% or even higher. The examples of plastics are, polyethylene, polypropylene, PVC, polystyrene, etc.

Fibers:- Fibers are long- chain polymers characterized by highly crystalline regions resulting mainly from secondary forces. They have a much lower elasticity than plastics and elastomers. They also have high tensile strength ranging between 20,000- 150,000 psi., are light weight and possess moisture absorption properties.

Polymer Type	Examples
(a) **Elastomers** (showing long – range elasticity)	Natural rubber, (1, 4 cis poly isoprene) synthetic rubbers (polybuta-diene, SBR, nitrile rubber, polychloroprene rubber, polylacrylate rubber, polyurethane rubbers, silicone rubbers etc.)
(b) **Plastics** (shapable under pressure, aided by heat)	Polyethylenes, polypropylene (isotactic), polystyrene, poly (vinyl chloride), nylon polyamides linear aromatic polyesters and polyamides, polycarbonates, acetal resins etc.
(c) Fibres (available in fibrillar or filamentous form)	Cotton (cellulose), natural silk, artificial silk (rayons), poly (ethylene terephthalate) fibre, nylon polyamide fibres etc.

2) Based on Polymer Microstructure (Amorphous or Crystalline)



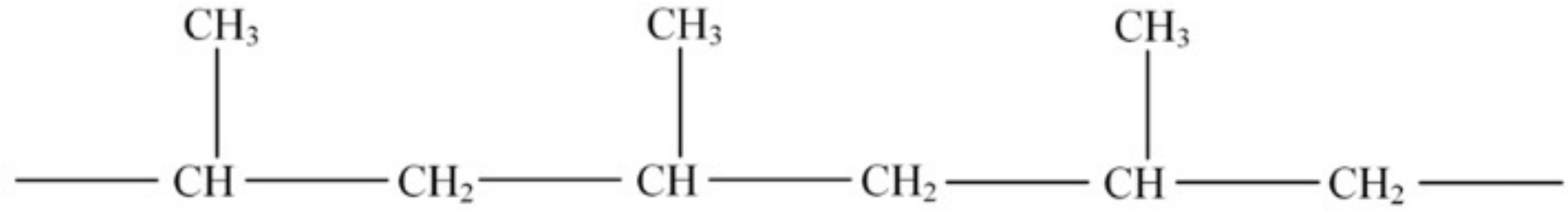
The degree of crystallinity: it is fraction of the total polymer in the crystalline regions, may vary from a few percentage points to about 90% depending on the crystallization conditions.

(a) *Crystalline* **(crystallinity, ≥ 50%)**	Polyethylene (HDPE and LDPE), polypropylene (isotactic), stretched nylon polyamides, polyoxymethylene etc. cellulose (cotton) fibre.
(b) *Semi – crystalline* **(crystallinity, 30 – 50%)**	Polybutene, cellulosics (cellulose esters (rayons) particularly if stretched), Gutta percha (1, 4 trans polyisoprene) etc.
(c) *Amorphous or non- crystalline* **(crystallinity < 25%)**	Natural rubber and most synthetic rubbers,N-alkylated(>15% alkylation) nylon polyamides, poly (methacry-lates and acrylates) poly (vinyl acetate), polystyrene etc.

3) Based on Group Orientation

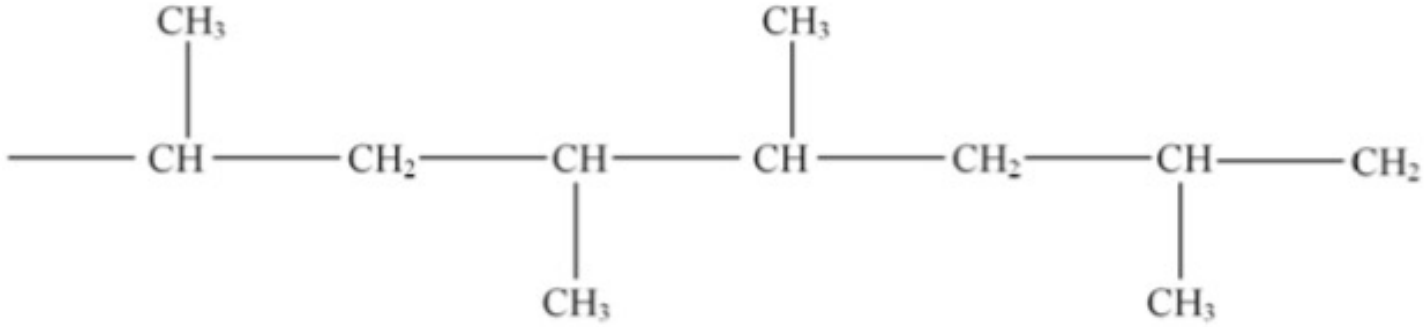
It may be defined as the geometric arrangement (orientation) of the characteristic group of monomer unit with respect to the main chain (backbone) of the polymers. On the basis of structure, polymer may be classified into three groups:-

A. Isotactic polymer:- It is the type of polymer in which the characteristic group are arranged on the same side of the main chain.



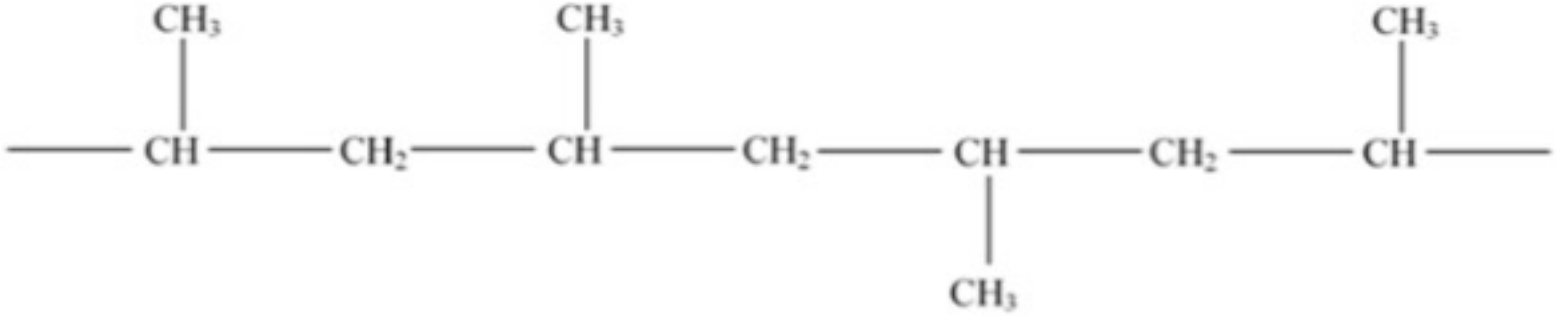
Isotactic Polypropene

B. Syndiotactic polymer:- A polymer is said to be syndiotactic if the side group (characteristic group) are arranged in an alternate fashion.



Syndiotatic Polypropene

C. Atactic polymer:- A polymer is said to be atactic, if the characteristic groups (side group) are arranged in irregular fashion (randomness) around the main chain. It has proper strength and more elasticity.



Atactic Polypropene

Thank You for your attention !