# SYNTHETIC FIBRES AND PLASTICS

Most clothing materials or fabrics we use in our day – to – day life are made from thin, thread-like fibres. The fibres of same fabrics such as cotton, jute, silk and wool are obtained from plants and animals. These are called **natural fibres**. Cotton and jute are examples of fibres obtained from plants. Wool and silk fibres are obtained from animals. Wool is obtained from the fleece of sheep or goat. It is also obtained from the hair rabbits, yak and camels. Silk is drawn from the cocoon of silkworm.

Fibres that are made by human beings are called **synthetic fibres**. Most of the synthetic fibres are obtained from coal, petroleum and natural gas. A synthetic fibre consists of multiple units (each of which is a chemical substance) which are formed together to form a single unit called a **polymer** (poly means many, mer means unit). Polymers are very large molecules with a high molecular mass formed by the combination of a large number of one or more types of small molecules of lower molecular mass.

**Staudinger** first hypothesized polymers in 1920 and he and others proved their existence experimentally. For this work Staudinger was awarded noble prize in 1953.

**Classification of polymers based on source of availability**
**(i) Natural Polymer**: The polymers obtained from nature (plants and animals) are called natural polymers. These are very essential for life. Example: Starch, cellulose, proteins.

**(ii) Synthetic Polymers**: The polymers which are prepared in the laboratories from chemicals are called Synthetic polymers. These are also called man-made polymers or artificial polymers. For example: polyethylene, PVC, nylon, Teflon, Bakelite.

**(iii) Semi-synthetic Polymers**: These polymers are mostly derived from naturally occurring polymers by chemical modifications. For example: Rayon, cellulose nitrate.

**Classification of polymer based on the monomer units**
**(1) Homopolymer:** When the polymer chain has only one repeating unit is called homopolymer.

$$(-A-A-A-A-A-A)$$

Example-cellulose (monomer is glucose), natural rubber (isoprene is monomer), polyethylene (ethane is monomer), PVC (vinyl chloride is monomer)

**(2) Copolymer:** When the polymer chain has two repeating units is called a copolymer.

$$(A-B-A-B-A-B-A)$$

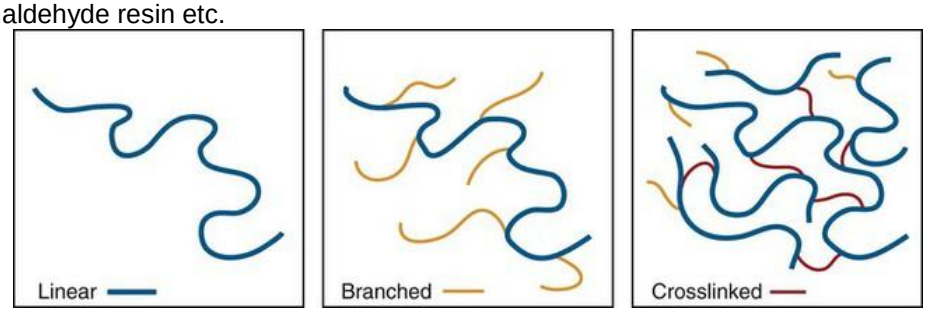
Example-bakelite (formaldehyde and phenol), polyester (ethelene glycol and terephthalic acid), melamine (melamine and formaldehyde), urea-formaldehyde resin (urea and formaldehyde)

**Classification based on structure**
This classification of polymers is based upon how the monomeric units are linked together. Based on their structure, the polymers are classified as:
Linear polymers, Branched chain polymers and Cross-linked polymers.

**1. Linear polymers:** These are the polymers in which monomeric units are linked together to form long straight chains. The polymeric chains are stacked over one another to give well packed structure. As a result of close packing, such polymers have high densities, high tensile strength and high melting points. Common examples of such type of polymers are polyethylene, nylons, polyesters, polystyrene etc.

**2. Branched chain polymers:** In this type of polymers, the monomeric units are linked to constitute, long chains (called the main-chain). These are side chains of different lengths which constitute branches. Branched chain polymers are irregularly packed and thus, they have low density, lower tensile strength and lower melting points as compared to linear polymers. Amylopectin and glycogen are common examples of this type.

**3. Cross-linked polymers:** In this type of polymers, the monomeric units are linked together to constitute a three dimensional network. The links involved are called cross links. Cross-linked polymers are hard, rigid and brittle because of their network structure. Common examples of this type of polymers are Bakelite, melamine formaldehyde resin etc.




**Classification based on synthesis of polymerization**

Depending upon the mode of synthesis or polymerization, the polymers are classified as: Addition polymers and Condensation Polymers.

**1. Addition Polymers:** The product formed when the monomer units are repeatedly added to form long chains without the elimination of any by-product molecules, is called addition polymer and the process involved is called addition polymerization. The monomer units are unsaturated compounds and are usually alkenes or the derivatives of alkenes. The molecular formula and hence the molecular mass of the addition polymer is integral multiple of that of the monomer units.

Some examples of addition polymerization are

(i) $nCH_2 = CH_2 \rightarrow \left(-CH_2 - CH_2 -\right)_n$

Ethylene polyethene

(ii) $nCH_2 = \underset{\underset{CN}{|}}{CH} \rightarrow \left( -CH_2 - \underset{\underset{CN}{|}}{CH}- \right)_n$

Acrylonitrile Orlon

**2. Condensation polymers:** The product formed when the monomers react together with the elimination of simple molecules like $H_2O$, ROH or $NH_3$ etc is called condensation polymer and the reaction or process involved is called condensation polymerization.

As the process involves the elimination of byproduct molecules, the molecular mass of the polymer is not the integral multiple of the monomer units.

Some examples of addition polymerization are:

Nylon-6,6: A polymer of hexamethylene diamine and adipic acid.

Dacron (polyester): A polymer of ethylene glycol and terephthalic acid.

Bakelite: A polymer of phenol and formaldehyde.

**Classification of polymer based on the inter molecular forces**

The utility of polymers in various fields is due to their properties like tensile strength, elasticity, toughness etc. These properties depend upon the intermolecular forces.

i) Elastomers, ii) Fibres, iii) Thermoplastics, iv) Thermo setting polymers

**I. Elastomers**: These are the polymers having very weak intermolecular forces of attraction between the polymer chains. The weak forces permit the polymers to be stretched out about 10 times the normal strength. Elastomers possess elastic character as the initially formed polymer chains are joined to form a three dimensional network structure and few bonds are introduced between the randomly coiled cross-links.

**Example**: Vulcanized rubber is a very important example. Highly vulcanized rubber containing 20-30% sulphur is called **ebonite**.

**II. Fibres:** These are the polymers which have quite strong intermolecular forces. These polymers can be used for making fibre as their molecules are long and thread like. Nylon-6,6, Polyester (terylene or Dacron) and polyacrylo nitrile (orlon) are some of the examples.
If a polymer contains only one type of monomer it is called **homopolymer**.

**Example**: Nylon – 6, polyester
If a polymer contains more than one type of monomer, it is called copolymer

**Example**: Nylon-6,6, Terylene

**Rayon**: It is not considered as true synthetic fibre as it is obtained from cellulose (which comes from wood pulp). So it is described as semi-synthetic fibre. The monomer of cellulose is glucose ($C_6H_{12}O_6$)

**Uses**:
In making shirts, tiles, home furnishing (bed sheets, curtains, table cloths, sofa covers etc) and bandages.

**Nylon**: It was first true synthetic fibre. It is a polyamide. Polymers possessing amide linkages $\left(\begin{array}{c} O \\ \| \\ -C-NH- \end{array}\right)$ are important synthetic fibers. There are different types of nylon.

i) **Nylon 6,6**:

It is copolymer of hexamethylediammine and adipic acid each of which contains 6 carbon atoms and these are represented in the name of the product 6,6.

**Uses**:
It is used in making brushes, synthetic fibres, parachutes, ropes and carpets.

**Nylon-6 or Perlon-L**: It is homopolymer of amino caproic acid. It is a polyamide.

**Uses**: It is used in making fibres, plastics, tyre cords and ropes. Nylons are insoluble in common solvents, have good strength and absorb little moisture. Due to their high strength and elasticity, nylon threads are used for making fishering nets, strings of badminton and tennis racquets.

**Polyester**: It is a polymer having an ester linkage $\left(\begin{array}{c} O \\ \| \\ -C-O- \end{array}\right)$ It is of different types, commonly used polyester is Terylene

**Terylene (Dacron):** It is copolymer of ethylene glycol and terephthalic acid.
Terrycot, a blend of terrylene and cotton has better absorbing power as compared to terylene. Terylene is blended with wool to make terrywool, which is warm in addition to the characteristics observed in polyesters.

Polyester fabrics can be washed and dried easily and quickly.

**Uses:** It is used in conveyor belts as it is very elastic. Polyester is used for making light weight sails. Polyester films are used for making recording tapes in audio cassettes, video cassettes and floppy disks.

**Acrylic**: It is homopolymer of acrylonitrile. Acrylic fibres are known as orlon and acrilan, closely resembles wool. It is warm, soft, light and flexible, resistant to moths and chemicals.

**Uses**: It is used in making sweaters, socks, shawls, carpets and blankets.

**Spandex:** It is a copolymer of polyurethane-polyurea. It's a polyamide (spandex means expands).
It has excellent elasticity, which makes it suitable for use in clothes that require (snug fitting)

**Uses**: It is used for making swimming costumes. It is often mixed with other fibres such as cotton, to get stretch fabrics used for making caps and T-shirts.

**Other useful plant fibres**

**1. Coir**: Coir is the fibre obtained from the outer covering of the fruit of coconut palm.

**Uses**: It is used for making several household products like ropes and floor coverings. Some varieties are used as a stuffing in mattresses and pillows.

**2. Silk cotton**: Another plant fibre that is commonly used as a stiffing in pillows, sleeping bags and life jackets. This fibre is known as silk cotton.

**3. Hemp**: Hemp fibres are obtained from the stem of the hemp plant. Hemp fibres are used in the production of ropes, carpets, nets, clothes and paper.

**4. Flax**: Fibres obtained from the stem of flax plant are woven to make a fibric called lines. Flax fibres are also used in the production of ropes and high-quality paper.

**III. Thermoplastics**: Linear and lightly cross-linked polymer which form a class of plastics are called thermoplastics. There are polymers in which intermolecular forces of attraction are neither very strong nor very weak. They can be moulded by heating.

**Example**: Polyethylene, polypropylene, polystyrene, PVC (poly vinyl chloride) and Teflon.

**Polyethylene or polythene**: It is homopolymer of ethylene (or ethane). It is of two different types – **HDPE** (high-density polyethylene) and **LDPE** (low-density polyethylene) depending on the density of the polymer.

**Uses of HDPE:** It is used for making containers for strong and corrosive household and industrial chemicals such as bleaches and acids.

**Uses of LDPE**: It is used for making polybags, grocery bags and packaging of foods and bread.

**Polypropylene (PP)**: It is homopolymer of propylene or propene.

**Uses**: It is used for making ketchup bottles, medicine bottles, and automobile battery casings.

**Polyethylene terephthalate (PET)**: It is copolymer of glycol and teraphthalic acid. It is a polyester.

**Uses**: It is used for making containers for microwave cooking, bottles of carbonated beverages and other food containers.

**Polyvinylchloride (PVC):** It is a homopolymer of vinyl chloride.

**Uses**: It is used for making sanitary fitting (such as water pipes).

**Polystyrene (PS):** It is used homopolymer of styrene.

**Uses**: It is used as insulator, wrapping material, and manufacturing of toys ad household articles.

**Polytetrafluoro ethylene (PTFE) or Teflon**: It is homopolymer of tetrafluoro ethylene.

**Uses:** It is used as lubricant, insulator and making cooking wares.

**IV Thermosetting polymers:** In these polymers extensive cross-links are formed between polymer chains on heating. A thermosetting polymer becomes hard on heating.

**Example**: Bakelite, urea-formaldehyde resin, melamine etc.

**Bakelite**: It is copolymer of formaldehyde and phenol.

**Uses**: It is used for making gears, protective coating and electrical fittings.

**Urea-formaldehyde resin: It** is copolymer of formaldehyde and urea.

**Uses: It** is used for making unbreakable cups and laminated sheets.

**Melamine**: It is a copolymer of melamine and formaldehyde.

**Uses**: It is used for making plastic, crockery, unbreakable cups and plates.

**Difference between thermoplastic and thermosetting polymers**

| Thermoplastic polymers | Thermosetting polymer |
|---|---|
| **1.** These soften and melt on heating. | These don't soften on heating but become hard. In case of prolonged heating is done, these start burning. |
| **2.** These can be remoulded, recasted and reshaped. | These cannot be remoulded or reshaped |
| **3. They** have usually linear structure. | These have three dimensional cross-linked structures. |
| **4.**These are formed by addition polymerization | These are formed by condensation polymerisation. |
| **5.** These are less brittle and soluble in some organic solvents. | These are more brittle and insoluble in organic Solvents. |
| **6.** Highly recyclable | Cannot be recycled |

**Uses of Plastics**

(i) Plastics are used to make toys, combs, plastic containers, polybags etc.
(ii) Bakelite is a poor conductor of heat and electricity. It is used for making electrical switches, handles of various utensils etc.
(iii) Melamine is a versatile material. It resists fire and can tolerate heat better than other plastics. It is used for making floor tiles, kitchenware and fabrics which resist fire.
(iv) Being lighter compared to metals plastics are used in cars, aircrafts and spacecrafts too.
(v) Teflon is a special plastic on which oil and water do not stick. It is used for non-stick cookware.

**Advantages of Plastics**

(i) Plastic is non-reactive. They do not react with air and water.
(ii) They are not corroded easily.
(iii) Plastic is light, strong, durable and can be moulded into different shapes and sizes.
(iv) Plastics are generally cheaper then metals. They are widely used in industries and for household articles.
(v) Plastics are poor conductors of heat and electricity. That is why electrical wires have plastic covering and handles of screw drivers are made up of plastics.

**Disadvantages of Plastics**

(i) It is difficult to dispose of.
(ii) When burnt it gives off poisonous fumes.
(iii) It is cheap to produce compared to the cost of recycling.

**Some Common Synthetic Fibres and their Uses**

| Thermoplastic | Uses |
|---|---|
| **1.** Polythene | Packaging material, carrybags bottles |
| **2.** Polypropene | Bottles, crates |
| **3.** Polyvinyl chloride (PVC) | Pipes, insulation |
| **4.** Teflon | Nonstick kitchenware |
| **5.** Polystyrene | Foam, Thermocol |
| **6.** Bakelite | Electrical insulation, buttons |
| **7.** Melamine | Crockery |
| **8.** Perspex | Windows for cars, trains and aircraft |
| **9.** Neoprene rubber | Rubber |

| Symbol | Acronym | Full name and uses |
|---|---|---|
|  | PET | Polyethylene terephthalate – Fizzy drink bottles and frozen ready meal packages. |
|  | HDPE | High-density polyethylene – Milk and washing-up liquid bottles. |
|  | PVC | Polyvinyl chloride – Food trays, cling film, bottles for squash, mineral water and shampoo. |
|  | LDPE | Low density polyethylene – Carrier bags and bin liners. |
|  | PP | Polypropylene – Margarine tubs, microwaveable meal trays. |
|  | PS | Polystyrene – Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys. |
|  | Other | Any other plastics that do not fall into any of the above categories. For example melamine, often used in plastic plates and cups. |

# ASSIGNMENTS

## EXERCISE

### OBJECTIVE

1. Polymer formed by the polymerisation of adipic acid and hexa methylene di-ammine is known as
(A) Rubber (B) Thiol (C) Nylon (D) Terylene

2. Which of the following is a homo polymer
(A) Bakelite (B) Nylon 6,6 (C) Terylene (D) Neoprene.

3. Bakelite is obtained by the condensation of
(A) Formaldehyde and Phenol (B) Acetaldehyde and Phenol
(C) Formaldehyde and Acetone (D) Acetone and Phenol

4. Which one of the following parts is not correctly matched?
(A) Terylene – Condensation polymer of terphthalic acid and ethylene Glycol
(B) Teflon – Thermally stable cross linked condensation polymer
(C) Bakelite – Cross linked condensation polymer of Phenol and formaldehyde
(D) None of these

5. Match the following:

| | |
|---|---|
| i. Acrylic | a. Contains repeating ester units |
| ii. Cellulose | b. Used for making sweaters |
| iii. Polymers | c. Made up of large number of Glucose Units. |
| iv. Terylene | d. Used for making electrical switches. |
| | e. Used for manufacturing toys. |

Which of the following is the correct matching?
(A) (i) –b, (ii) –a, (iii) –d, (iv) –c (B) (i) –b, (ii) –c, (iii) –e, (iv) –a
(C) (i) –d, (ii) –b, (iii) –e, (iv) –a (D) (i) –d, (ii) –c, (iii) –b, (iv) –e

6. Match the following

| | |
|---|---|
| I. Rayon | a. Used for making socks, ropes, sleeping bags |
| II. Nylon | b. Used in making ropes, carpets, nets, clothes and paper |
| III. PET | c. Mixed with cotton to make bed sheets |
| IV. Hemp | d. In making bottles, utensils, films, coires |

Select the alternative which shows the correct matching.
(A) (i) –c, (ii) –b, (iii) –d, (iv) –c (B) (i) –c, (ii) –a, (iii) –d, (iv) –b
(C) (i) –a, (ii) –c, (iii) –b, (iv) –d (D) (i) –c, (ii) –a, (iii) –d, (iv) –b

7. The first fully synthetic fibre prepared from coal, water and air used for making socks, ropes, tents, tooth brushes etc. is
i. Nylon ii. Acrylic iii.Polythene iv. Rayon
(A) i and iv (B) ii and iii (C) iv only (D) i only

8. The example of plastics which on moulding does not get softened on heating.
i. Polythene ii. Poly vinyl Chloride iii. Bakelite iv. Melamine
(A) i and ii (B) ii and iii (C) iii and iv (D) i and iv

9. Nylon is
(A) Polyester fibre (B) Polyamide fibre
(C) Polythene derivative (D) Polyethylene methyl acrylate fibre

10. Which one is a protein fibre?
(A) Cotton (B) Rayon (C) silk (D) Polyester

11. Which one of the following statements is wrong?
(A) PVC stands for Polyvinyl Chloride (B) PTFE stands for Teflon
(C) PMMA stands for Polymethyl acrylate (D) Buna-s stands for Natural Rubber

12. Which one of the following set contains only natural polymers?
(A) Polyethylene, Polypropylene, Terylene (B) Poly ethylene, PVC, Acrilon
(C) Buna-S, Nylon, Poly butadiene (D) Bakelite, PVC , Polyethylene

13. Poly propylene is not used in
(A) Clothes (B) Ropes (C) Heat Resistant Plastics (D) Parachute Ropes

14. Dacron is an example of
(A) Polyamide (B) Polypropylene (C) Polyurethane (D) Polyester

15. Teflon, Polystyrene and Neoprene are all
(A) Copolymer (B) Condensation Polymer (C) Homopolymers (D) Monomer

16. A Plastic used for making bottles of carbonated beverages
(A) HDPE (B) PET (C) LDPE (D) PP

17. A Plastic used for making grocery bags
(A) PP (B) PS (C) LDPE (D) HDPE

18. A synthetic fibre used for making high weight sails
(A) Polyester (B) Nylon (C) Rayon (D)polythene

19. Which one of the following is an example of condensation polymerization.
(A)PVC (B) Buna-S rubber (C) Dacron (D) Lutrex

20. One of the characteristic property of polymers is
(A)High temperature stability (B) High mechanical strength (C)High elongation (D)Low hardness

21. These polymers can not be recycled
(A) Thermoplasts (B)Thermosets (C) Elastomers (D) All polymers

22 In general, strongest polymer group is _____ .
(A) Thermoplasts (B) Thermosets (C) Elastomers (D) All polymers

23. These polymers consist of coil-like polymer chains:
(A) Thermoplasts (B) Thermosets (C) Elastomers (D) All polymers

24. Strong covalent bonds exists between polymer chains in _____ .
(A) Thermoplasts (B) Thermosets (C) Elastomers (D) All polymers

25. Elastic deformation in polymers is due to _____ .
(A) Slight adjust of molecular chains (B) Slippage of molecular chains
(C) Straightening of molecular chains (D) Severe of Covalent bond

## ANSWERS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. | **C** | 2. | **D** | 3. | **A** | 4. | **B** |
| 5. | **B** | 6. | **B** | 7. | **D** | 8. | **C** |
| 9. | **B** | 10. | **C** | 11. | **D** | 12. | **D** |
| 13. | **A** | 14. | **D** | 15. | **C** | 16. | **B** |
| 17. | **C** | 18. | **A** | 19. | **C** | 20. | **B** |
| 21. | **B** | 22. | **B** | 23. | **C** | 24. | **B** |
| 25. | **A** | | | | | | |