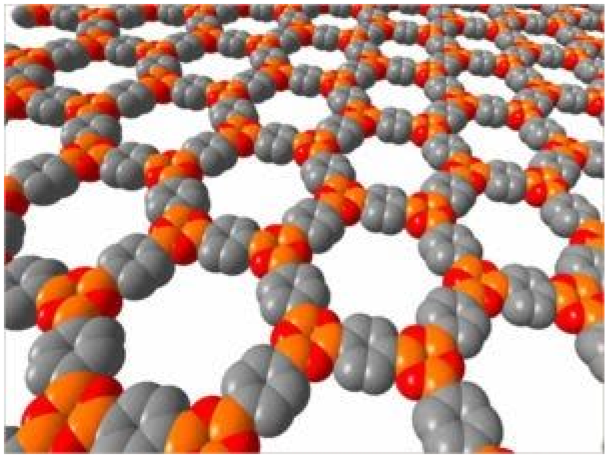
Classification of Polymers

Look around and you will see Polymers are everywhere. From the plastic bottle, you carry to school, to the silicone rubber tips on your favourite earphones. The nylon and polyester in your sneakers. Not only inanimate objects, many proteins in your body are polymers. So let us now look into the classification of polymers.

Polymers

The word "Polymer" is derived from two Greek words, 'Poly' that means many (numerous) and 'Mer' which means units. In basic terms, a polymer is a long-chain molecule that is composed of a large number of *repeating units* of identical structure. These identical structures, we understand as a unit made up of two or more molecules, join together to form a long chain.



Simply stated, a polymer is a long-chain molecule that is composed of a large number of *repeating units* of identical structure. Those monomers can be simple — just an atom or two or three — or they might be complicated ring-shaped structures containing a dozen or more atoms.

Classification Of Polymers

Since Polymers are numerous in number with different behaviours and can be naturally found or synthetically created, they can be classified in various ways. The following below are some basic ways in which we classify polymers:

1] Classification Based on Source

The first classification of polymers is based on their source of origin, Let's take a look.

(i) Natural polymers

The easiest way to classify polymers is their source of origin. Natural polymers are polymers which occur in nature and are existing in natural sources like plants and animals. Some common examples are Proteins (which are found in humans and animals alike), Cellulose and Starch (which are found in plants) or Rubber (which we harvest from the latex of a tropical plant).

(ii) Synthetic polymers

Synthetic polymers are polymers which humans can artificially create/synthesize in a lab. These are commercially produced by industries for human necessities. Some commonly produced polymers which we use day to day are Polyethylene (a mass-produced plastic which we use in packaging) or Nylon Fibers (commonly used in our clothes, fishing nets etc.)

(iii) Semi-Synthetic polymers

Semi-Synthetic polymers are polymers obtained by making modification in natural polymers artificially in a lab. These polymers formed by chemical reaction (in a controlled environment) and are of commercial importance. Example: Vulcanized Rubber (Sulphur is used in cross bonding the polymer chains found in natural rubber) Cellulose acetate (rayon) etc.

Learn different types of Polymerization here.

2] Classification Based on Structure of Polymers

Classification of polymers based on their structure can be of three types:

(i) Linear polymers:

These polymers are similar in structure to a long straight chain which identical links connected to each other. The monomers in these are linked together to form a long chain. These polymers have high melting points and are of higher density. A common example of this is PVC (Poly-vinyl chloride). This polymer is largely used for making electric cables and pipes.

(ii) Branch chain polymers:

As the title describes, the structure of these polymers is like branches originating at random points from a single linear chain. Monomers join together to form a long straight chain with some branched chains of different lengths. As a result of these branches, the polymers are not closely packed together. They are of low density having low melting points. Low-density polyethene (LDPE) used in plastic bags and general purpose containers is a common example

(iii) Crosslinked or Network polymers:

In this type of polymers, monomers are linked together to form a three-dimensional network. The monomers contain strong covalent bonds as they are composed of bi-functional and tri-functional in nature. These polymers are brittle and hard. Ex:- Bakelite (used in electrical insulators), Melamine etc.

3] Based on Mode of Polymerisation

Polymerization is the process by which monomer molecules are reacted together in a chemical reaction to form a polymer chain (or three-dimensional networks). Based on the type of polymerization, polymers can be classified as:

i) Addition polymers:

These type of polymers are formed by the repeated addition of monomer molecules. The polymer is formed by polymerization of monomers with double or triple bonds (unsaturated compounds). Note, in this process, there is no elimination of small molecules like water or alcohol etc (no by-product of the process). Addition polymers always have their empirical formulas same as their monomers. Example: ethene n($CH_2=CH_2$) to polyethene -(CH_2-CH_2)n-.

ii) Condensation polymers:

These polymers are formed by the combination of monomers, with the elimination of small molecules like water, alcohol etc. The monomers in these types of condensation reactions are bi-functional or tri-functional in nature. A common example is the polymerization of Hexamethylenediamine and adipic acid. to give Nylon – 66, where molecules of water are eliminated in the process.

Read about Polymers of Commercial Importance.

4] Classification Based on Molecular Forces

Intramolecular forces are the *forces* that hold atoms together within a *molecule*. In Polymers, strong covalent bonds join atoms to each other in individual polymer molecules. *Intermolecular forces* (between the molecules) attract polymer molecules towards each other.

Note that the properties exhibited by solid materials like polymers depend largely on the strength of the forces between these molecules. Using this, Polymers can be classified into 4 types:

i) Elastomers:

Elastomers are rubber-like solid polymers, that are elastic in nature. When we say elastic, we basically mean that the polymer can be easily stretched by applying a little force.

The most common example of this can be seen in rubber bands(or hair bands). Applying a little stress elongates the band. The polymer chains are held by the weakest intermolecular forces, hence allowing the polymer to be stretched. But as you notice removing that stress also results in the rubber band taking up its original form. This happens as we introduce crosslinks between the polymer chains which help it in retracting to its original position, and taking its original form. Our car tyres are made of Vulcanized rubber. This is when we introduce sulphur to cross bond the polymer chains.

ii) Thermoplastics:

Thermoplastic polymers are long-chain polymers in which inter-molecules forces (Van der Waal's forces) hold the polymer chains together. These polymers when heated are softened (thick fluid like) and hardened when they are allowed to cool down, forming a hard mass. They do not contain any cross bond and can easily be shaped by heating and using moulds. A common example is Polystyrene or PVC (which is used in making pipes).

iii) Thermosetting:

Thermosetting plastics are polymers which are semi-fluid in nature with low molecular masses. When heated, they start cross-linking between polymer chains, hence becoming hard and infusible. They form a three-dimensional structure on the application of heat. This reaction is irreversible in nature. The most common example of a thermosetting polymer is that of Bakelite, which is used in making electrical insulation.

iv) Fibres:

In the classification of polymers, these are a class of polymers which are a thread like in nature, and can easily be woven. They have strong inter-molecules forces between the chains giving them less elasticity and high tensile strength. The intermolecular forces may be hydrogen bonds or dipole-dipole interaction. Fibres have sharp and high melting points. A common example is that of Nylon-66, which is used in carpets and apparels.

The above was the general ways to classify polymers. Another category of polymers is that of Biopolymers. Biopolymers are polymers which are obtained from living organisms. They are biodegradable and have a very well defined structure. Various biomolecules like carbohydrates and proteins are a part of the category.

Solved Example for You

Q: Which of these polymers occur naturally?

a. Starch and nylon
b. Cellulose and Starch
c. Proteins and PVC
d. Nylon and Proteins

Sol: The correct option is “B”. On the basis of classification of polymers based on their sources, we know that Nylon and PVC are synthetic polymers. While starch and cellulose are naturally occurring polymers.

Q: Which catalyst is used for the Polymerisation of olefins?

Find the answer by learning Polymers of Commercial Importance.

Types of Polymerization

You are perhaps already aware of various polymers such as PVC, nylon, Bakelite etc. As you will notice although all these are polymers, they have very distinctly different physical appearance and properties. This is due to the difference in their monomers and their polymerization. So let us study a bit more about condensation and addition polymerization.

Polymerization

By now you are familiar with the concept of polymers. They are huge chains or sometimes even 3D structures of repeating units known as monomers. The monomer is the basic unit of a polymer. These monomers can bond to each other on each side, potentially forever.

So this reaction of combining these monomers to form long chains or three-dimensional networks is known as polymerization. Broadly polymerization can be classified into two categories,

- Step-Growth or Condensation Polymerization
- Chain-Growth or Addition Polymerization

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Addition Polymerization

As the name suggests addition polymers form when an addition reaction occurs. The repeating monomers form a linear or branch structure depending on the type of monomer. During addition polymerization, the monomers rearrange themselves to form a new structure. But there is no loss of an atom or a molecule. Again there are four types of addition polymerizations which are

- *Free Radical Polymerization*: Here the addition polymer forms by addition of atoms with a free electron in its valence shells. These are known as free radicals. They join in a successive chain during free radical polymerization.
- *Cationic polymerization*: A polymerization where a cation is formed causing a chain reaction. It results in forming a long chain of repeating monomers
- *Anionic Vinyl Polymerization*: Involves the polymerization of particularly vinyl polymers with a strong electronegative group to form a chain reaction'
- *Coordination Polymerization*: This method was invented by two scientists Ziegler and Natta who won a Nobel Prize for their work. They developed a catalyst which let us control the free radical polymerization. It produces a polymer which has more density and strength.

Condensation Polymerization

Condensation polymers form from the step growth polymerization. Here when molecules of monomers react to form a bond they replace certain molecules. These molecules are the by-product of the reaction. In most cases, this by-product is a water molecule.

The type of polymers that result from a condensation polymerization depends on the monomers. If the monomer has only one reactive group, the polymers that form have low molecular weight. When monomers have two reactive end groups we get linear polymers. And monomers with higher than two reactive groups results in a polymer with a three-dimensional network.

Polyester and nylon are two common condensation polymers. Even Proteins and Carbohydrates are a result of condensation polymerization.

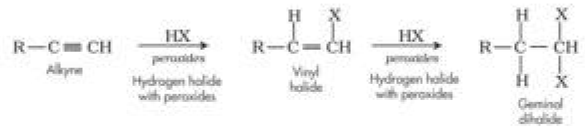
Addition Polymerization vs. Condensation Polymerization

Let us do a comparative analysis of the two types of polymerization to understand them better.

- In addition polymerization monomers only join at the active site of the chain. But in condensation polymerization, any molecule can react with any other.
- In addition polymerization, there are three distinct steps. Initiation, propagation and finally termination. In condensation polymerization, there is no termination step. The end groups remain reactive through the entire process.
- Addition polymerization results in homo-chain polymers whereas condensation polymerization results in hetro-chain polymers.
- The most significant difference is that in addition polymers there is no loss of atom. But in condensation reaction, there is a loss of a molecule of water, ammonia etc as a by-product.

Solved Question for You

Q: Here, product follows which of the following



a. Free radical substitution mechanism
b. Free radical addition mechanism
c. Electrophilic substitution mechanism
d. None of the above

Ans: The correct answer is “B”. Free radical addition occurs when halide reacts with alkynes in the presence of peroxides. Two anti-Markovnikov additions occur leading to a geminal dihalide product.

Rubber

Have a look around you and you will find at least five things made out of rubber. From your car tyres to erasers use rubber as their main ingredient. Rubber is the most vastly used polymer by mankind. Let us learn some interesting facts about natural and synthetic rubber.

Natural Rubber

We have commonly been using rubber for industrial and household purposes for over a 1000 years. Natural rubber is a plant polymer, we harvest it from rubber plants in the form of *Latex.* An average plant will produce about 19 pounds of latex annually.

Natural rubbers are also known as elastomers (hydrocarbon polymer) due to its high elasticity. It is made up of a thick stretchy white liquid which is latex and some suspended solid particles which are impurities. The monomer for synthesis of natural rubber is commonly known as *Isoprene,* that is 2-methyl-1,3-butadiene.

The natural form is always in cis-configuration which is cis – 1, 4 – polyisoprene. This polyisoprene molecule has a coil structure. Various chains link together with weak Van der Waals bond to give it this coil formation. Hence this structure is responsible for its elasticity and tensile strength.

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Vulcanisation

Natural Rubber in its raw form does not have ideal properties or qualities. It is extremely brittle at temperatures below 283 K. And at higher temperatures of above 335 K, it turns too soft and gluey. It also has the propensity to absorb water molecules and hence reducing its strength.

To improve the features of rubber and increase is elasticity it undergoes a chemical process, Vulcanization. Here we heat a mixture of raw rubber and sulfur (or another such accelerator) to temperatures between 373 k and 415 K. Here the sulfur chemically combines with the polymers and forms bridges (cross-links) between long-chain molecules. This helps with the elasticity and tensile strength.

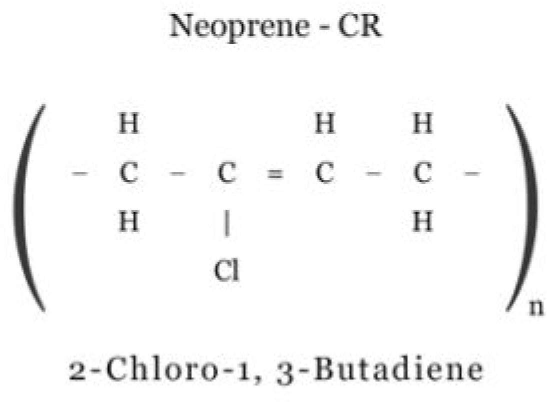
Synthetic Rubbers

Synthetic rubbers are artificial polymers. It is man-made rubber which industries produce by synthesizing it from crude oil or petroleum and other such minerals and by-products. Its main property is its elasticity or deformation under stress or external force. But it also has the ability to return to its original shape and size without any permanent change or damage.

Unlike natural latex which only has one chemical type, there are about 20 types of chemically synthesized rubbers. However, synthetic rubbers are generally homopolymers of 1, 3-butadiene derivatives or copolymers of 1, 3-butadiene with another unsaturated monomer.

Let us take a closer look at the preparation of two important synthetic rubbers.

1] Neoprene



(Source: Mantanline.com)

Also known as *Polychloroprene* it is said to be the first synthetic rubber developed in 1931. It is one of the most important rubbers in the world and has an annual consumption of 300000 tons. It is formed by the free radical polymerization of chloroprene.

Neoprene has good mechanical strength. Neoprene is also highly resistant to heat and chemical interference. It has many applications and is widely used for cables. moulded goods, conveyor belts, gaskets etc.

2] Styrene Butadiene Rubbers

Butadiene rubbers are known to be the most elastic rubbers. It was produced in the United States and Europe during the World War I days due to a shortage of natural rubber. Copolymerization of two compounds, in this case, styrene and butadiene, in the presence of a catalyst give us this elastomer. The ratio of styrene to butadiene is about 25:75. It has a heat resistance superior to natural rubber, but lower tensile strength.

Styrene Butadiene Rubbers main purpose is to make tyres for automobiles. It is also used in adhesives, shoe soles and floor tile.

Solved Example for You

Q: Dicarboxylic acids react with diols to form which type of copolymer?

Sol: Dicarboxylic acids react with diols to form alternating types of a copolymer. They form polyesters such as glyptal, daozon. They are alternating copolymer because there is alternating one carboxylic acid and one alcoholic unit.

Biodegradable Polymers

Polymers are everywhere — and therein lies the problem. Most of the polymers we use on an everyday basis are from petroleum-based products (the plastic grocery bags to the buckets in our homes) and although they're durable in use, they're also durable in waste. And the solution to this is biodegradable polymers!

Biodegradable Polymer

These are those polymers which can decompose under aerobic or anaerobic conditions, as a result of the action of microorganism/enzymes. The materials develop it like starch, cellulose, and polyesters. Aliphatic polyesters are the most commonly used polymers of this type. Some examples are given as follows:-

- Poly β-hydroxybutyrate – co-β-hydroxy valerate (PHBV):- It is derived by combining 3-hydroxy butanoic acid and 3-hydroxy pentanoic acid, in which monomers are cross-linked by an ester linkage. It decomposes to form carbon dioxide and water. It is brittle in nature, and it can be used in the production of drugs and manufacturing of bottles.

- Nylon 2–nylon 6:- It is a polyamide copolymerisation of glycine (H_2N-CH_2-COOH) and aminocaproic acid ($H_2N-(CH_2)_5-COOH$).
- Polyhydroxy butyrate (PHB):- It is formed by the condensation of hydroxybutyric acid (3-hydroxy butanoic acid) molecules.

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Non-Biodegradable Polymer

These polymers are resistant to environmental degradation thus end up to accumulate in form of waste. These are polymers which have long chains consisting of Carbon and Hydrogen atoms. The interatomic bonding of these polymers is very strong and adamant, hence making them resistant to microbes which try to break their bonds and digest them.

All kind of plastics and synthetic fiber are non-biodegradable in nature. Some common examples of non- biodegradable polymers are:

- polyethene (PE), which is primarily used in packaging
- polystyrene (PS), which is a rigid, economical plastic, used mainly for producing disposable plastic cutlery and dinnerware
- polycarbonate (PC) whose Transparency, excellent toughness, thermal stability make it suitable for Compact discs, riot shields, vandal proof glazing, baby feeding bottles, electrical components, safety helmets

Uses of Biodegradable Polymers

An estimated 86% of all plastic packaging is used only once before it is discarded, producing a stream of waste that persists in waterways and landfill, releases pollutants and harms wildlife.

Conventional polymers such as polyethene and polypropylene are durable in nature can persist for many years after disposal. They are appropriate when used for products which require a long lifespan (Example plastic tables and chairs), but seem inappropriate for applications in which plastics are used for short time periods and then disposed of (Example: packaging items).

Furthermore, plastics are often soiled by food and other biological substances, making physical recycling of these materials impractical and generally undesirable. In contrast, biodegradable polymers (BPs) can be disposed of in prepared bioactive environments to undergo degradation by the enzymatic actions of microorganisms (bacteria, algae and fungi)

Their polymer chains may also be broken down by nonenzymatic processes such as chemical hydrolysis. BPs are often derived from plant processing of atmospheric CO_2. Biodegradation converts them to

CO_2, CH_4, water, biomass, humic matter, and other natural substances. BPs are thus naturally recycled by biological processes

Biodegradable polymers contain polymer chains that are hydrolytically or enzymatically cleaved, resulting in, soluble degradation products. Biodegradability is particularly desired in biomedical applications, in which degradation of the polymer ensures clearance from the body and eliminates the need for retrieval or explant. Biodegradable polymers have applications in:

- Controlled/sustained release drug delivery approaches
- Tissue engineering scaffolds
- Temporary prosthetic implant

Solved Example for You

Q: The average molecular mass and mass average molecular mass of a polymer are 30,000 and 40.000 respectively. The PDI of the polymer is

a. < 1
b. > 1

c. 1

d. 0

Sol: The correct answer is “B”. Polydispersity Index (PDI) is the ratio of the mass average molecular mass to the number average molecular mass

PDI = 40000 ÷ 30000 = 1.33

Polymers of Commercial Importance

In today’s day, Polymers are widely used materials, which are found almost in every material used in our routine life. The importance of polymers has become much more emphasized as its applications are numerous and varied. Let us now explore some polymers of commercial importance.

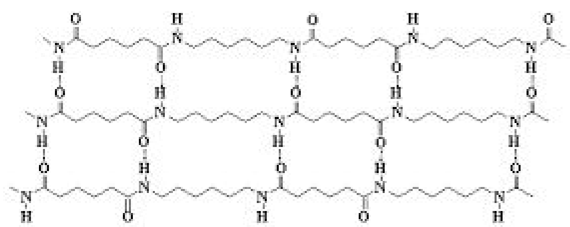
Polymers of Commercial Importance

There are various polymers of commercial importance, which are used in so many different dominions of sciences, industry and technology. Some are listed below:

Nylon

Nylon is a synthetic polymer prepared in labs and produced by industries for its commercial importance. It is commonly used in the textile and fabric industry. Nylon comes under the family of linear polyamides.

Nylon 6 and nylon 6,6 are 2 commonly used types of nylon. In fact, Nylon 6,6 (widely used as fibres) is made from adipic acid and hexamethylene diamine.They have a compact molecular structure exhibiting excellent abrasion resistance. The monomers are joined by hydrogen bonding. Nylon’s characteristics which make it such a valuable material can be attributed to its strength, lustre, elasticity and resistance to damage by oil and chemicals.



In nylon 6,6, the carbonyl oxygens and amide hydrogens can hydrogen bond with each other. This allows the chains to line up in an orderly fashion to form fibers.

Hydrogen bonding in Nylon 6,6.

Nylon Fiber: Nylon Fibre is used in clothing/apparels in shirts, underwear, raincoats lingeries etc. Industrial uses of Nylon are the production of Conveyer and seat belts, nets and ropes, parachutes and tents.

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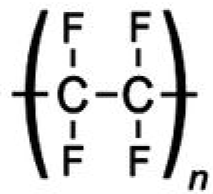
Polytetrafluoroethylene

It is commonly known as PTFE is a synthetic fluoropolymer of tetrafluoroethylene. It is of high molecular weight and made up of mainly carbon and fluorine.The best-known brand name of PTFE-based formulas is Teflon which is extensively used in cook-wares such as non-stick pans.

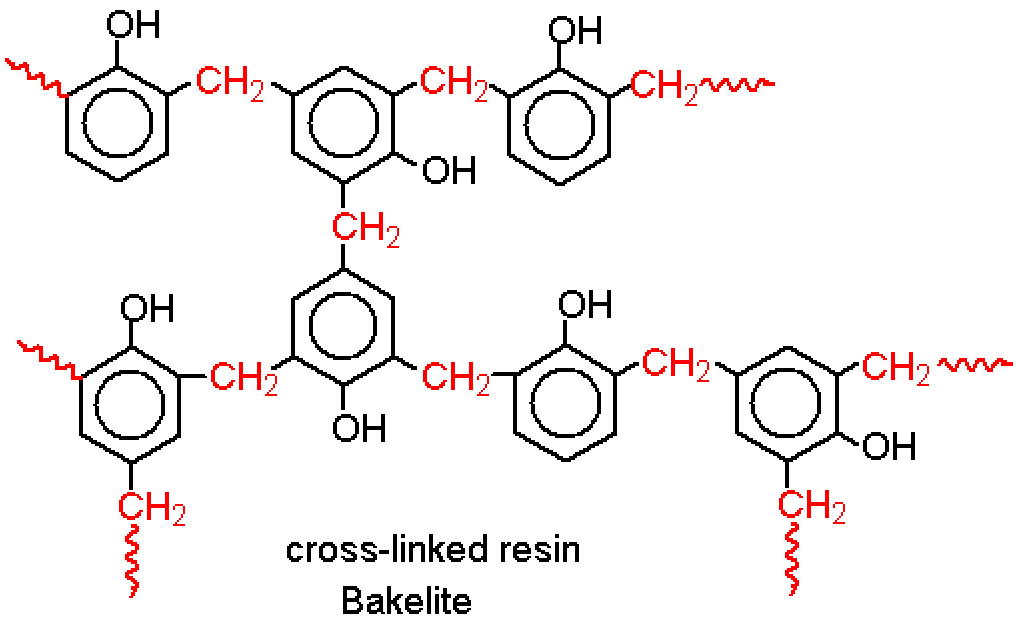


Structure of PTFE

Bakelite

Bakelite is one of the oldest polymers that was synthesized by man. It is a thermosetting polymer and has high strength and retains its shape after moulding. It is one of the first polymer/plastic created in a laboratory. The polymer is formed by condensation of formaldehyde with phenol. Its chemical formula is $(C_6H_6O \cdot CH_2O)_n$.

Bakelite has a high resistance to heat and chemicals and also has a low electrical conductivity due to which it is most commonly used for making electrical switches Bakelite is also used to make the handles of a variety of utensils. It is one of the most important and extensively used polymers for making components and parts of various items. Other uses of this polymer are seen in pipe stems.



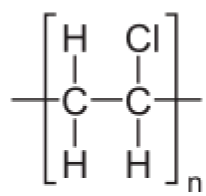
cross-linked resin
Bakelite

Polyvinyl Chloride (PVC)

When talking about polymers of commercial importance we must discuss PVC. It is one of the most widely used polymers in the world. PVC is used extensively across a broad range of applications (used in building, transport, packaging, electrical etc. products), and this can be attributed to its highly versatile nature.

PVC is a highly durable and long-lasting material. It is thermoplastic in nature.It is formed after polymerization of vinyl chloride monomer. It is a very durable and long-lasting material which can be used in a variety of applications, either rigid or flexible, white black or a range of colours in between.

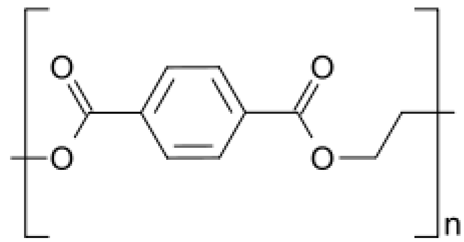
Some common commercial products which use the polymer PV Care window frames, drainage pipe, medical devices, cable and wire insulation. Credit cards and vinyl records are also made using PVC. Recently PVC has also found a place in the textile industry.



Structure of PVC.

Polyethylene Terephthalate

Commonly called PET is a thermoplastic polymer which is extensively used in containers of all kinds. PET consists of polymerized units of the monomer ethylene terephthalate, with its repeating unit as ($C_{10}H_8O_4$). PET bottles are commonly recycled, making it very cost effective. This is why it is one of the most important polymers of commercial importance.

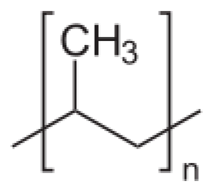


Structure of PET

Polypropylene

Polypropylene is one of the most versatile polymers produced commercially, with applications both as a plastic and fibre.It is a thermoplastic polymer which is translucent and possesses good chemical and heat resistance. Now, Polypropylene (PP) is a linear hydrocarbon polymer, and its empirical formula is expressed as -(C_nH_{2n})-. The Monomer propylene polymerizes to form polypropylene

Polypropylene is commonly used in consumer products as Furniture, Luggage, Toys, Battery Cases and other "durable" items for the home, garden or leisure use. It is also widely used in packaging (also reusable containers) and textiles.

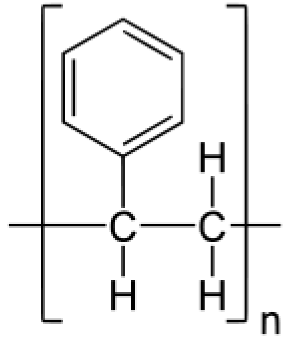


Structure of polypropylene

Polystyrene

Polystyrene is a synthetic aromatic polymer which is formed by the polymerization of styrene monomers. And Polystyrene can be solid or foamed. As a hard solid plastic, it is commonly used in rigid a packaging, toys, bottles, lids, refrigerator trays and boxes, disposable cutlery etc.

Foam polystyrene is made in a way where it can have 95 percent air present and is widely used to make home and appliance insulation, surfboards, lightweight protective packaging and food packaging.

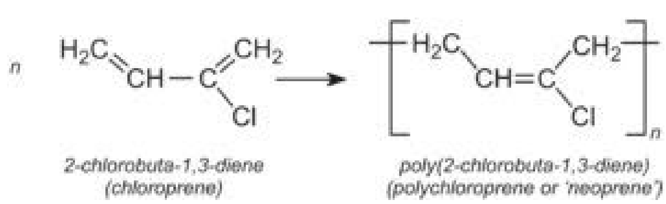


Structure of polystyrene

Neoprene

Neoprene, also called polychloroprene or chloroprene rubber is an addition homopolymer, with rubber-like structure and properties. It is a synthetic rubber produced by the polymerization of chloroprene.

Neoprene as a polymer has good chemical stability and is able to maintain flexibility over a wide temperature range. It is used in a wide variety of application, some of the common ones being laptop sleeves, orthopaedic braces and electrical insulation.



(Source: EssentialChemicalIndustry)

Solved Example for You

Q: The catalyst used for the polymerisation of olefins is which of the following?

a. Ziegler Natta catalyst
b. Wilkinson's Catalyst
c. Pd-catalyst
d. None of the above

Sol: The correct answer is option "A".Ziegler-Natta catalysts are mixtures of titanium compounds like titanium(III) chloride ($TiCl_3$) or Titanium (IV) Chloride ($TiCl_4$) and compounds of Aluminium like Aluminium triethyl $Al(C_2H_5)_3$. They are used in the synthesis of polymers of 1-alkenes (alpha-olefins). So to polymerize olefins we must use Zeigler Natta catalyst.

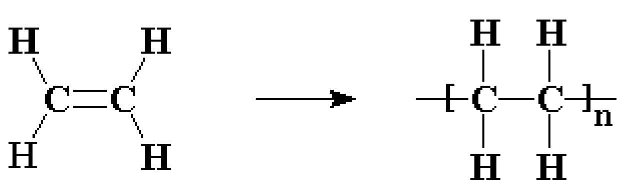
Condensation Polymerization or Step Growth Polymerization

Now that we have learnt about polymers and their types, let us learn about polymerization. Polymerization is the process by which monomer molecule undergoes chemical reaction to form polymer chains. Here we will look at condensation polymerization and step growth polymerization.

Addition Polymerization

Polymers can be classified into 2 types as per their preparation process they undergo – Addition polymerization and Condensation Polymerization. In addition polymerization, the entire monomer molecule becomes a part of the polymer.

For example, when ethylene is polymerized to make polyethene, every atom (present in the monomer) of ethylene becomes a part of the polymer.



Ethylene has two carbon atoms and four hydrogen atoms, and the polyethylene repeat structure has two carbon atoms and four hydrogen atoms. None gained, none lost.

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Condensation Polymerization

On the other hand, in Condensation polymerization, a part of the monomers is eliminated when the monomer becomes a part of the polymer. The part that is eliminated is usually a small molecule like water or HCl gas. Such small molecules (which are like by-products of a reaction) ***condense*** on things as tiny droplets, hence giving the name condensation polymerization.

For better understanding let us consider the preparation of Nylon 6,6:

Nylon 6,6 is prepared using two monomers, each of which contains 6 carbon (thus giving the polymer the name as Nylon 6,6), adipoyl chloride and hexamethylene diamine.When these two compounds polymerize, the chlorine atoms from the adipoyl chloride along with one of the amine hydrogen atoms, are eliminated/expelled in the form of HCl gas.

Characteristics of Condensation Polymers

- Condensation polymers form more slowly than addition polymers and often require suitable lab environments, like the addition of heat.
- The polymers are generally lower in molecular weight.
- Often, the terminal functional groups on the polymer's chain remain active.In the late stages of polymerization, groups of shorter chains end up combining into longer chains.
- The presence of polar functional groups on the polymer chains enhances the chain-to-chain attraction (especially in the cases of hydrogen bonding).This attributes to the crystallinity and tensile strength of the polymer.

Step-Growth and Chain Growth

The other system by which we can classify the type of polymerizations involved is divided into 2 types – Chain Growth Polymerizations and Step Growth Polymerizations. In simple terms, during the process of Chain Growth polymerization, monomers become a part of the polymer one at a time. The growth only happens at the end of the chains. It is the addition of monomers to an ever-growing chain.

The process of Step-growth polymerization is a little more complicated than chain-growth polymerization.Now let us look at an example for Step-Growth Polymerization for better understanding. Let us consider the process of making Polyester called polyethylene terephthalate.

- The two monomers which are terephthaloyl chloride and ethylene glycol react to form a dimer-ester dimer. A dimer is two structurally same or similar monomers attached to each other by bonds that can be either strong, weak, covalent or intermolecular.
- In this stage of a chain growth system, a third monomer would add to the dimer to form a trimer, then a fourth to form a tetramer, and continue so forth. But this is not the case when it comes to Step-growth polymerization.

- The dimer in this instance during step-growth polymer can undergo different changes. It can react with one of the monomers to form a trimer.
- That was one possibility. The dimer can also attach to another dimer to form a tetramer:
- The dimer may also bond with a trimer to form a pentamer.
- Making things more complicated, these newly formed tetramers and pentamers can undergo reaction to form even bigger oligomers. This process may continue, resulting in growth of these oligomers and eventually the oligomers are big enough to be classified as polymers.

Difference Between Two Processes

In a step-growth reaction, the growing chains can react with each other to form longer chains. This holds true for chains of all lengths. But in an addition polymerization, only the monomers can react with growing chains. Two growing chains can't join together the way they can in a step-growth polymerization.

An important point to understand is, polymerizations can step growth or chain growth, and they can be condensation or addition. All step-growth polymerizations may not necessarily condensation polymerization, while not all chain growth polymerizations are addition polymerization.The two systems should not be reconciled.

Solved Example for You

Q: Formaldehyde is the starting material for the manufacture of which of the following?

a. Bakelite
b. Caprolactum
c. Rayon
d. None of the above

Sol: The correct answer is option “A”. Bakelite is a trade name for various synthetic resins of which phenol-formaldehyde resins are amongst the most widely known.