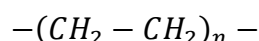


2. Plastics, rubbers and fibres. (14 hours)

Preparation, properties and applications of - Plastics: Polyethylene, Polyvinylchloride, polymethyl methacrylate, polyethylene terphthalate, Teflon, Bakelite. Rubbers: natural and synthetic rubbers – polybutadiene, polyisobutylene, butyl rubber, nitrile rubber, BUNA-S, BUNA N, neoprene rubber. Synthetic fibres : Nylon 66, Nylon 6, Rayon.

Polyethylene

Polyethylene is the simplest hydrocarbon polymer and has the following structure



It is a very commonly used polymer and was first produced in England by the Imperial Chemical Industries (ICI) in 1933 by polymerizing the ethylene monomer. Ethylene can be prepared either by the hydrogenation of acetylene or by the dehydration of the ethanol. In some countries it is produced from petroleum products by the process of cracking. Ethylene is a gas at room temperature. It has a boiling point of $-104\text{ }^{\circ}\text{C}$.

There are three varieties of polyethylene low density (LDPE), linear low density (LLDPE) high density (HDPE). Low density of polyethylene consists of molecules with branches, linear low density polyethylene consist of polymer chains with large number of short branches, which are shorter and more abundant than those of LDPE where as the high density variety is essential linear.

Low density polyethylene (LDPE) is produced by the high pressure polymerization of ethylene using oxygen as the initiator. The reaction occurs at pressure as high as 1.5×10^8 pascal (~ 1500 atm) and in the temperature range of $180\text{-}250\text{ }^{\circ}\text{C}$. It is interesting to note that even an extremely small quantity of oxygen, say, 0.1 %, is sufficient to initiate the polymerization. Apart from oxygen, other initiators include peroxides, hydroperoxides and azo compounds. Ethylene can be polymerized by solution or bulk polymerization techniques. For the solution method, the solvent employed are benzene, chlorobenzene, and so on. The reaction conditions are such that the polymer as well as the monomer dissolves in the solvent and follows true solution polymerization technique.

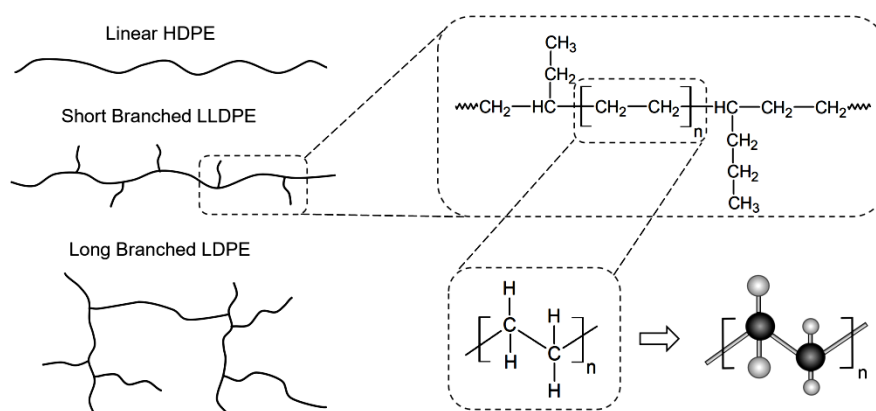
Low density polyethylene melts at $110\text{-}125\text{ }^{\circ}\text{C}$ and is only around 40 % crystalline. The density is around $0.91\text{-}0.92\text{ g/cc}$. While practically no solvent dissolves it at room temperature, several solvents can do so at high temperature.

resistance to breakage is made use of in 'squeeze bottles and in many attractive containers. Pipes made of LDPE are used for both agricultural, irrigation and domestic water line connections. The non-polar nature of the polymer makes it ideal for providing insulations to electric cables.

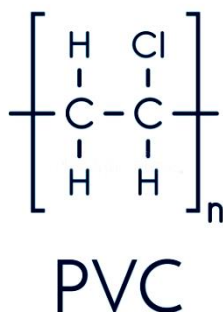
LLDPE

The production of LLDPE is initiated by transition metal catalysts, particularly Ziegler or Philips types of catalyst. The actual polymerization process can be done either in solution phase or in gas phase reactors. Usually, octene is the co-monomer in solution phase while butene and hexene are copolymerized with ethylene in a gas phase reactor. LLDPE has similar strength as HDPE but is much more flexible. The polymer chains have a large number of short branches, which are shorter and more abundant than those of LDPE. It also has a narrower molecular weight distribution than LDPE. Both increases the degree of crystallinity which results in higher tensile and impact strength and greater puncture resistance compared to LDPE. This type of low density polyethylene can be processed into thinner films with better environmental stress and crack resistance than HDPE and LDPE.

LLDPE has penetrated almost all traditional markets for polyethylene; it is used for plastic bags and sheets (where it allows using lower thickness than comparable LDPE), plastic wrap, stretch wrap, pouches, toys, covers, lids, pipes, buckets and containers, covering of cables and geomembranes.



Polyvinyl Chloride



PVC was synthesized in the year 1872 by German chemist Eugen Baumann. Later in the 20th century PVC was commercially used by the Russian chemists Ivan Ostromislensky and Fritz Klatte. They found it difficult to process this rigid polymer, and sometimes the entire process would go in vain. In 1926 the method of processing PVC was proposed by Waldo Semon and the B.F. Goodrich Company. In this process, a flexible PVC was obtained by the addition of various additives. Later PVC was commercialized and has been used widely in various sectors. Resin is the main component in the production of PVC. It is white, brittle solid material available in powder form or granules. PVC is now replacing traditional constructional materials like ceramics, metal, concrete, wood, rubber and many more. PVC is produced by the process of polymerization of the vinyl chloride monomer. PVC is amorphous in nature, and hence it is easily combined with other chemicals/substances. Depending on additives used in manufacturing with PVC, many qualities can be imbued in products including anti-mist, different colours, elasticity, fire retarding, flexibility, impact resistance and microbe prevention.

The monomer, vinyl chloride boils at -14°C . Industrial polymerization of vinyl chloride is carried out either in suspension or emulsion. Limited quantities of PVC are also made by bulk polymerization. Redox initiators are used for emulsion systems, while azo compounds are employed in bulk and suspension polymerization. The emulsion system has the advantage that the polymerization could be done at low temperatures (20°C) while higher temperatures are required for the for the suspension and bulk polymerization. Since the monomer is a gas at these temperatures, polymerization has to be conducted in a pressure reactor or autoclave.

Structurally the PVC molecule is partially syndiotactic and does not have a completely regular structure. This is why PVC has low crystallinity. The polymer molecules are either

linear or slightly branched. PVC is insoluble in water, alcohol and hydrocarbons. Acids and alkalis have practically no effect on PVC at least to up to 20 °C. PVC however dissolves in acetone and carbon disulphide is found to be an excellent solvent for PVC.

Properties of PVC

- By nature, PVC is a lightweight, sturdy and abrasion-resistant material.
- This versatile thermoplastic polymer is resistant to the action of all inorganic chemicals.
- PVC is an excellent material for insulation due to its high dielectric strength and vapour barrier capacity.
- It can withstand extreme climatic conditions, shock and is free from corrosion. Hence, it is the preferred method for several outdoor applications.
- Since the durability is more, long-life is assured.
- PVC products are self-extinguishing due to high chlorine content.
- PVC can be made more flexible and softer by adding plasticizers such as phthalate and can be bent as per requirement.
- PVC is an intrinsic flame retardant.
- It offers good tensile strength and is rigid by nature.
- It is economical and is an affordable solution.
- It demands less maintenance and offers resistance to grease and oil.

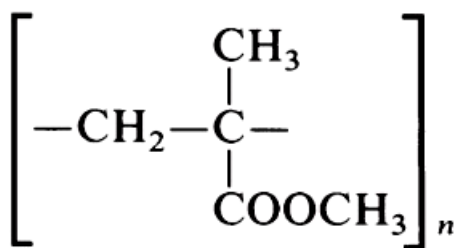
Applications

- Plasticized PVC is used in flooring or (PVC-U) unplasticized PVC is used in making window frames.
- It is used in making sewage pipes and other pipe applications where cost or vulnerability to corrosion limits the use of metal.
- Used in construction fields for insulation on electrical wires or in flooring for hospitals, schools, homes, and other areas where a sterile environment is a priority.
- It is used in various industries like building, electronics, electrical, automotive, medical and packaging.
- PVC fabric is used in the manufacture of aprons shower curtains, raincoats, jackets and sports bags.
- It is used in the garden hose and imitation leather upholstery.

Polymethyl Methacrylate

Polymethyl methacrylate was discovered in the early 1930s by British chemists Rowland Hill and John Crawford at Imperial Chemical Industries (ICI) in the United Kingdom. ICI registered the product under the trademark Perspex. About the same time, chemist and industrialist Otto Röhm of Rohm and Haas AG in Germany attempted to produce safety glass by polymerizing methyl methacrylate between two layers of glass. The polymer separated from the glass as a clear plastic sheet, which Röhm gave the trademarked name Plexiglas in 1933.

Methyl methacrylate, in bulk liquid form or suspended as fine droplets in water, is polymerized (its molecules linked together in large numbers) under the influence of free-radical initiators to form solid PMMA. The structure of the polymer repeating unit is:



Uses

- PMMA has a good degree of compatibility with human tissue, and it is used in the manufacture of rigid intraocular lenses which are implanted in the eye when the original lens has been removed in the treatment of cataracts.
- Eyeglass lenses are commonly made from PMMA.
- Historically, hard contact lenses were frequently made of this material. Soft contact lenses are often made of a related polymer, where acrylate monomers containing one or more hydroxyl groups make them hydrophilic.
- In orthopedic surgery, PMMA bone cement is used to affix implants and to remodel lost bone. It is supplied as a powder with liquid methyl methacrylate (MMA). Although PMMA is biologically compatible, MMA is considered to be an irritant and a possible carcinogen. PMMA has also been linked to cardiopulmonary events in the operating room due to hypotension. Bone cement acts like a grout and not so much

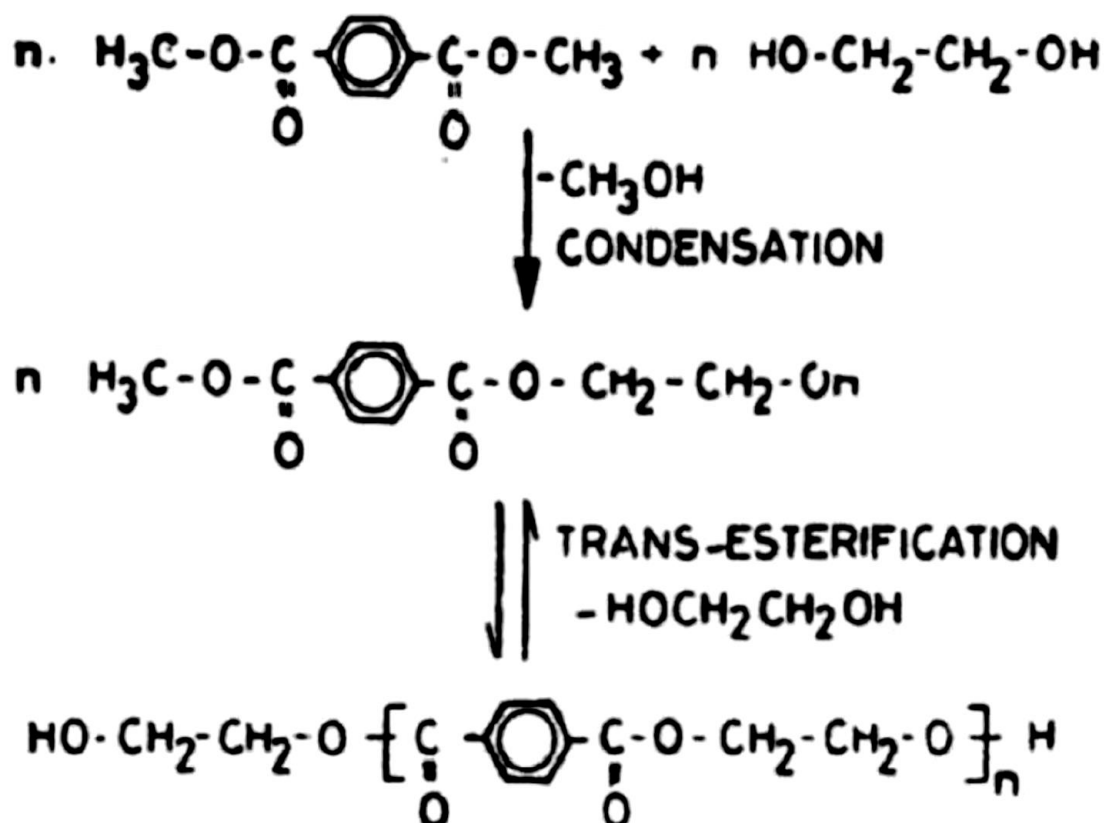
like a glue in arthroplasty. Although sticky, it does not bond to either the bone or the implant; rather, it primarily fills the spaces between the prosthesis and the bone preventing motion. A disadvantage of this bone cement is that it heats up to 82.5 °C (180.5 °F) while setting that may cause thermal necrosis of neighboring tissue. A careful balance of initiators and monomers is needed to reduce the rate of polymerization, and thus the heat generated.

- In cosmetic surgery, tiny PMMA microspheres suspended in some biological fluid are injected as a soft-tissue filler under the skin to reduce wrinkles or scars permanently. PMMA as a soft-tissue filler was widely used in the beginning of the century to restore volume in patients with HIV-related facial wasting. PMMA is used illegally to shape muscles by some bodybuilders.
- Bioprocess chromatography columns use cast acrylic tubes as an alternative to glass and stainless steel. These are pressure rated and satisfy stringent requirements of materials for biocompatibility, toxicity, and extractables.

Polyethylene terephthalate (PET)

PET was first synthesized in North America in the mid-1940s by DuPont chemists searching for new synthetic fibers. DuPont later branded its PET fiber as "Dacron." Today, more than half of the world's synthetic fiber is made from PET, which is called "polyester" when used for fiber or fabric applications. When used for containers and other purposes, it is called PET or PET resin. PET is a clear, strong, and lightweight plastic that is widely used for packaging foods and beverages, especially convenience-sized soft drinks, juices and water. Virtually all single-serving and 2-liter bottles of carbonated soft drinks and water sold in the U.S. are made from PET.

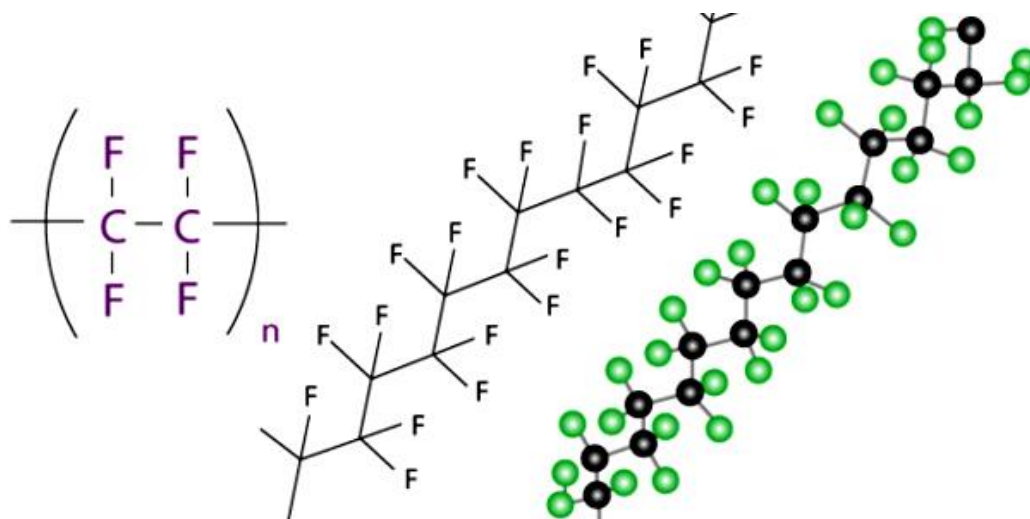
The starting materials for PET are ethylene glycol and terephthalic acid. In commercial practice, however, dimethyl terephthalate (DMT) is taken in place of terephthalic acid. DMT is melt condensed with ethylene glycol to give PET.



The first stage of the reaction (condensation) is carried out at the reflux temperature of ethylene glycol with a low vacuum, when methanol is recovered. The second stage (trans-esterification) is carried out at high temperatures around 200-250 °C, under a very high vacuum, so that the ethylene glycol can be effectively removed to push the reaction in the forward direction. Polyethylene terephthalate melt at round 265 °C and is resistant to heat and moisture. This polyester is virtually; unattacked by many chemicals. It is extensively used to make textile fibers. It has good mechanical strength up to 175 °C. Garments made from its fibers resist wrinkles. PET is also made into films which are used in the manufacturing of magnetic tapes.

Polytetrafluoroethylene

Polytetrafluoroethylene (PTFE), also known as 'Teflon' in trade, may be visualized as polyethylene with all its hydrogen atoms substituted by fluorine, as shown:



Polytetrafluoroethylene was accidentally discovered in 1938 by Roy J. Plunkett while he was working in New Jersey for DuPont. As Plunkett attempted to make a new chlorofluorocarbon refrigerant, the tetrafluoroethylene gas in its pressure bottle stopped flowing before the bottle's weight had dropped to the point signaling "empty". Since Plunkett was measuring the amount of gas used by weighing the bottle, he became curious as to the source of the weight, and finally resorted to sawing the bottle apart. He found the bottle's interior coated with a waxy white material that was oddly slippery. Analysis showed that it was polymerized perfluoroethylene, with the iron from the inside of the container having acted as a catalyst at high pressure.

Polymerisation is carried out by the emulsion method using peroxide initiators. TFE can also be polymerised with redox initiators such as hydrogen peroxide and ferrous sulphate. In some cases, oxygen is used as the initiator. The polymerization is associated with the release of large quantities of heat and if sufficient precautions are not taken, this can result in violent explosions.

The compound is used as the coating for non-stick pans as they are hydrophobic and has a high resistance capacity to heat. Known as a polymer thermoplastic and has a density of 2200 kg/m^3 while appearing as a white solid at normal temperature. The melting point is 327°C .

Teflon is nonstick in nature and has low friction and good dielectric properties. As a result, Teflon is used for many purposes. A few application areas of Teflon are listed below:

- Cookware: The nonstick property of Teflon has been used in the manufacture of cookware ever since the discovery of this material. It's extremely low frictional properties and high heat resistance have made Teflon cookware very popular.
- Machine parts: The extremely low friction of Teflon makes it ideal for making machine parts, such as gears, bearings, pipe linings, joints, slide plates, bushings, O-rings, and saw blades. There is a lot of sliding action in the working of such machine parts. The low friction and self-lubricating property of Teflon decreases wear and tear and increases the life of machinery.
- Fabric and carpet industry: The nonstick property of Teflon is also used in fabrics and carpets for improving their stain-resistant qualities.
- Insulator: Teflon has excellent dielectric properties, especially at high radio frequencies. This property is useful for its use as an insulator in cables and connector assemblies.
- Medicine: The chemical inertness of Teflon makes it apt for making artificial body parts.
- Armor-piercing bullets: Teflon is used to coat specific types of hardened armor-piercing bullets. This coating helps decrease the wear and tear on the firearm's rifling.
- Electrets: Electrets are electrostatic analogs of magnets. Teflon has a very high bulk resistivity. This property is responsible for the use of Teflon in the manufacture of electrets.

Bakelite

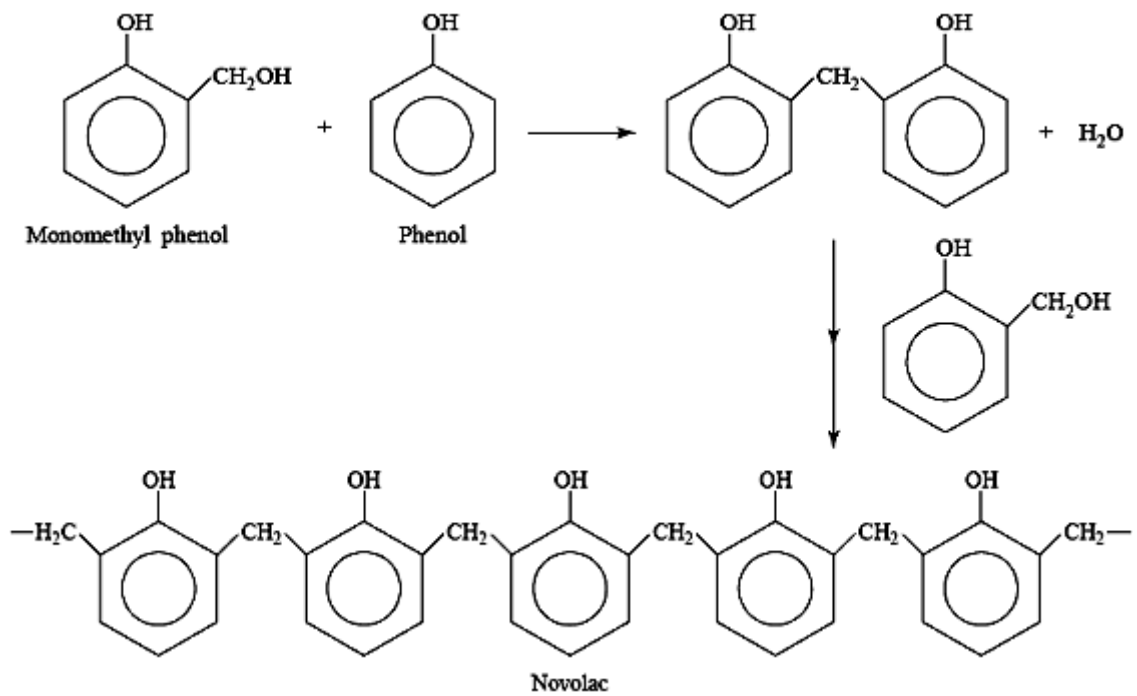
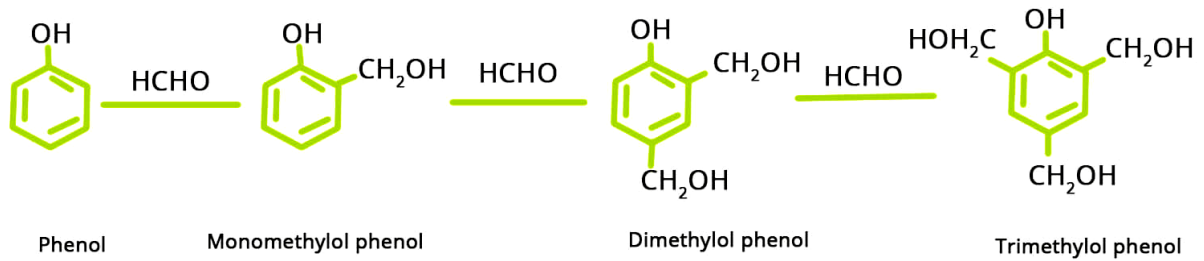
We live in the 21st century where the world is full of plastics. Nowadays it is hard to imagine our life without plastic. We use it in our daily life in homes, offices, schools, electric sockets, plugs, devices, buckets, etc. Leo Bakeland, a Belgian chemist, successfully developed the first synthetic molding plastic called Bakelite between 1907-1909.

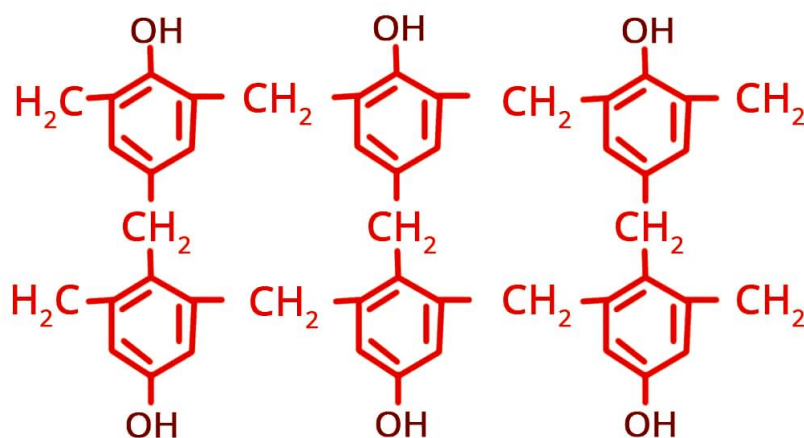
Plastics are divided into two types i.e. Thermoplastic and Thermosets. Bakelite comes under the category of thermosetting plastic. Bakelite is a polymer that is made up of monomer phenol and formaldehyde. Bakelite is also known as polyoxybenzyl methylene glycol anhydride. It is one of the oldest polymers which were created by humans.

Preparation of Bakelite

When phenol is taken in excess under an acidic medium then the product of this condensation reaction is acidic. The quantity of formaldehyde is considered as more than the quantity of

phenol in the mixture and the reaction occurs as a basic medium and the product formed is known as Resol. The reaction that takes place is highly exothermic





Bakelite

Bakelite Properties

Bakelite is a material of a thousand uses. Many things like plastic handles of utensils, bangles, and automobile parts are made up of Bakelite.

The important properties of a Bakelite are:

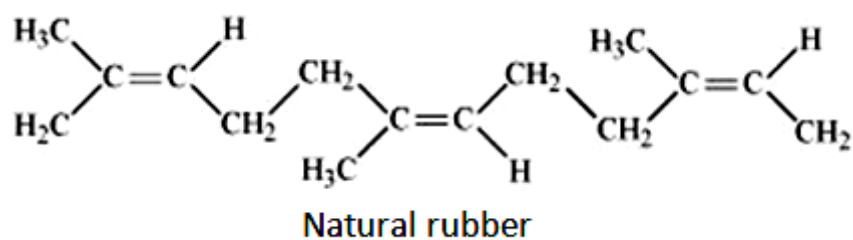
1. It is the commercial name for phenol-formaldehyde resin.
2. It can be made into a variety of bright colors.
3. Bakelite can be quickly molded.
4. It is malleable and liquefiable when heated and becomes permanently hard after cooling. So it is also known as thermosetting plastic.
5. It has high resistance towards electricity heat and other chemical action. So it is preferred to make electronic gadgets, switches, and automobile parts from the bakelite.
6. It is resistant to electric current due to its low electrical conductivity.

Bakelite Uses

1. Bakelite is a good insulator used in non-conducting parts of radio and electric devices like switches, automobile distribution caps, insulation of wires, Sockets, etc.
2. It is used to make clocks, buttons, washing machines, toys, kitchenware, etc.
3. It can be made into different colors so it is used in producing vibrant and attractive products.

Natural rubber

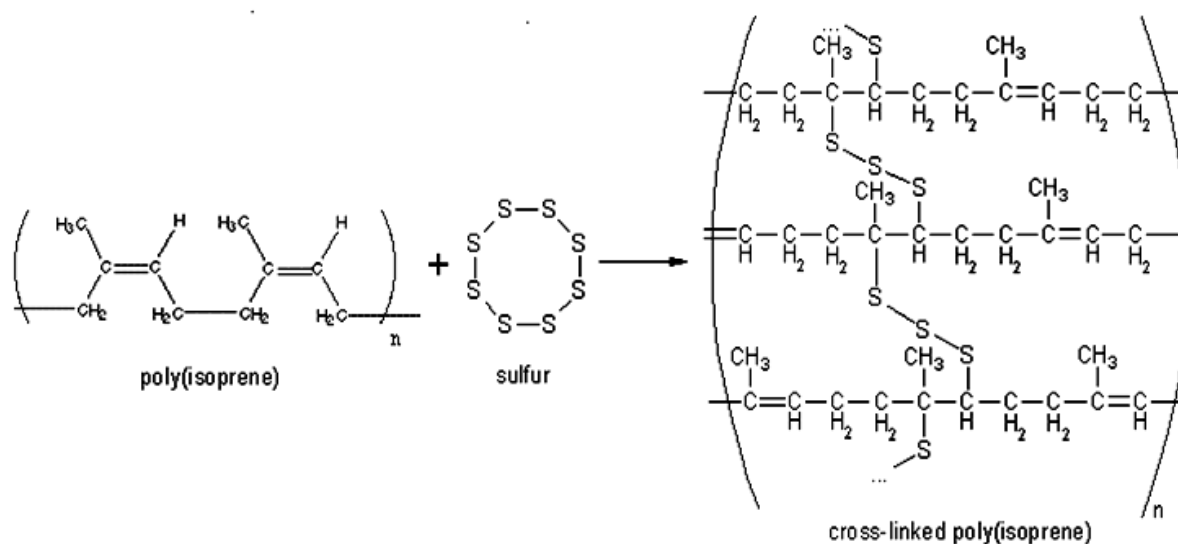
These are the elastomers which are obtained naturally. Natural rubber is made up of solid particles suspended in a milky white liquid (called latex) that drips from the bark of certain tropical and subtropical trees. This latex rubber is mainly found in countries like Brazil, India, Indonesia, Malaysia, and Sri Lanka. It is made by the polymerization of isoprene (2-methyl-1,3-butadiene) which has a chemical formula $(C_5H_8)_n$ and it is known as cis-1,4-polyisoprene. In simple words, we can say that they are made by loosely joining the monomers of isoprene (C_5H_8) in the form of a long tangled chain.



Preparation of Natural Rubber:

- Rubber tapping – The milky white liquid latex is collected from the rubber trees in a cup by making a slight V-cut on the tree bark. The collected latex is washed, filtered and reacted with acids to congeal the rubber particles.
- Mastication – The rubber obtained from the tapping process is still not ready to be used. When it is cold it is very brittle in nature and when warmed up it becomes very gluey. To remove the brittle nature and strong odour of the rubber, it is allowed to pass through the rollers and is pressed to make it softer and flexible to work. This process is repeated based on the properties that are required for the rubber. In this process, extra chemical ingredients are also added to enhance the properties of rubber.
- Calendering is a process which is mainly performed to provide shape to the rubber using rollers (after proper mixing of the chemical ingredients).
- The final product obtained is then extruded to make hollow tubes by passing them through specially designed holes in an extrusion machine.
- Vulcanization – Performing all the steps listed above will not yield rubber that is strong or hard enough to be used in items like car tires and machinery. To enhance all

these properties, sulphur is added to the rubber and it is heated at a temperature ranging from 373 K to 415 K. This process is known as vulcanization. The sulphur acts as a cross-linking agent and after vulcanization, rubber gets cross-linked and becomes hard.

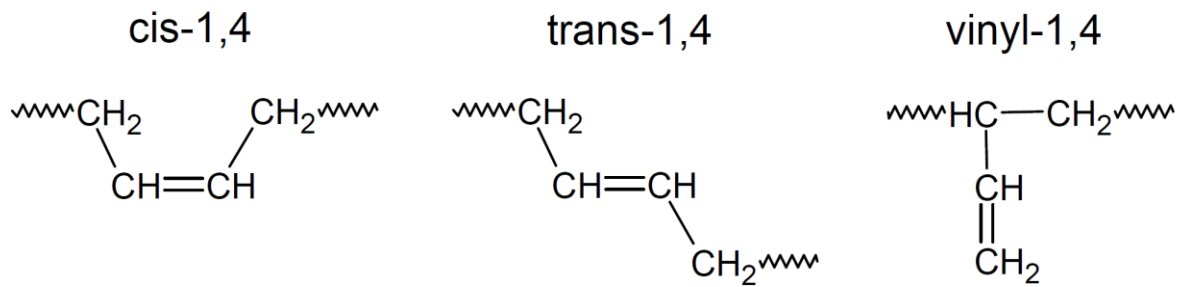


Vulcanisation

Synthetic rubbers

Polybutadiene rubber

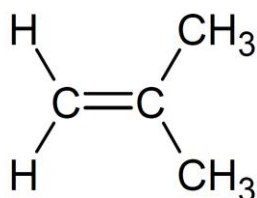
Polybutadiene rubber (BR, PBD) is one of the cheapest and largest-volume synthetic general-purpose elastomers which is sometimes used as a substitute for natural rubber (NR). It is produced either by anionic polymerization or by coordination polymerization of 1,3-butadiene typically in a non-polar solvent. The latter is often the method of choice because it allows for both tight control of the molecular weight (MW) and excellent stereoregularity. The 1,3-butadiene can enter the growing polymer chain in three different ways yielding the three structural isomers cis-1,4, trans-1,4 and vinyl-1,2, as shown in the figure below.



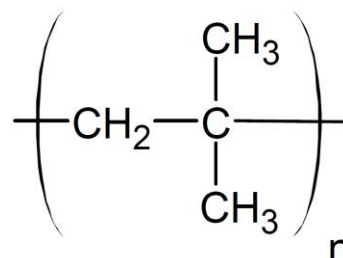
Both cis-1,4- and trans-1,4-polybutadiene have a similar low glass transition temperature (T_g) of approximately -107 °C whereas 1,2-vinyl has a much higher T_g of about 0°C and thus is not suitable for most elastomer applications. The cis and trans PBD have very different mechanical properties and uses. For example, cis-1,4 rich PBD has very low crystallinity, and the lowest melting point, whereas polybutadiene with a high trans-1,4 content has much higher crystallinity and is much harder and less flexible.

Butadiene rubbers are typically cured by sulfur systems and are often compounded with other polymers and additives such as oils, fillers, crosslinking agents, and antioxidants, which allows for a versatile variation of the elastomeric properties.

Some major manufacturers of polybutadiene rubbers are Firestone, Cray Valley, AsahiKasei, GoodYear, and Lanxess. Three types of polybutadiene are available: high-cis, medium-cis, and low-cis. Among these, medium-cis rubber is the most popular grade. The major use of cis polybutadiene rubber is in tires. It goes into side walls and treads. To optimize performance such as traction, rolling and abrasion resistance, it is typically compounded with other elastomers such as natural rubber and SBR. Other applications are golf ball cores, inner tubes of hoses for sandblasting, and covers for pneumatic and water hoses.

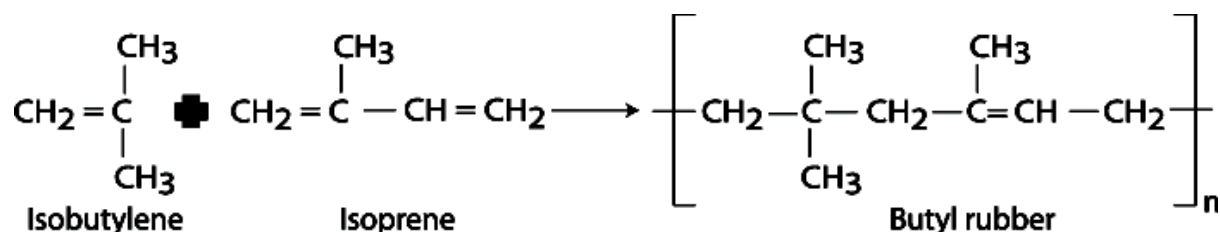
Polyisobutylene**Isobutylene**

Polymerization \longrightarrow

Polyisobutylene

It is produced by cationic polymerization of isobutylene using BF_3 and AlCl_3 catalyst in a suitable solvent such as hexane or methylene dichloride at -80°C . The polymer dissolves in many hydrocarbons. Polyisobutylene is chemically one of the most inert polymers known so far. Moisture, acids, and alkalis have practically no effect on this polymer.

Polyisobutylene is widely used as an insulation material in the electrical industry. It is also added to motor oils to suppress the sharp fall in the viscosity with increase temperature. A copolymer of isobutylene with 2-5 % of isoprene is made under the commercial name of **butyl rubber**.



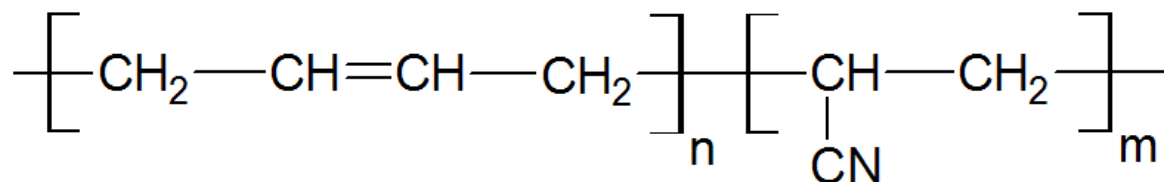
Butyl rubber, also known as Isobutylene-isoprene (IIR), is a synthetic elastomer produced by low temperature cationic copolymerization of 1,1-dimethylethylene (isobutylene) with about 0.5 to 2 percent 1-methyl-1-butenylene (isoprene) using Lewis catalysts in chlorocarbon solvents. The isoprene provides the necessary unsaturation sites for crosslinking (vulcanization). Butyl elastomers can be vulcanized with sulfur.

Butyl rubber has unique elastomeric properties that makes it a good choice for a wide variety of rubber goods. Its low gas permeability together with its flexibility makes it the ideal material for inner tubes of tires and other high pressure tubes. Other applications include diaphragms, gaskets, wire and cable insulations, liners, O-rings, seals, weather stripping, and

bottle closures. It's very low resilience makes it also suitable for shock absorption, vibration damping and insulation applications.

Acrylonitrile butadiene rubber (NBR)

Acrylonitrile butadiene rubber (NBR), usually shortened to nitrile, is a unique elastomer. It can be produced by free-radical emulsion polymerization of butadiene with 15 to 45 percent acrylonitrile either hot (hot rubber) or cold (cold rubber): It is also called Butadiene Acrylonitrile (**Buna-N**, Bu for butadiene and Na for sodium (natrium in several languages including Latin, German, and Dutch), and **N** for nitrile) rubber which has prepared by using sodium metal as radical initiator.



NBR grades with high acrylonitrile content have better oil and abrasion resistance, whereas grades with low acrylonitrile content have better low temperature flexibility and resilience. In general, nitrile rubbers have only moderate physical properties but good abrasion and excellent oil and hydrocarbon solvent resistance. However, they are not suitable for use with polar solvents. Nitrile rubbers also have low gas permeability particularly those with high nitrile content but poor ozone and modest heat resistance. To improve the physical properties, nitrile rubbers are sometimes carboxylated (XNBR) or hydrogenated which improves their temperature resistance.

Many properties can be adjusted by varying the acrylonitrile content in the nitrile rubber. The higher the nitrile content, the higher the resistance to aromatic hydrocarbons and the lower the nitrile content, the better the low temperature flexibility.

- High Nitrile: > 45 % acrylonitrile
- Medium Nitrile: 30 - 45%
- Low Nitrile: < 30%

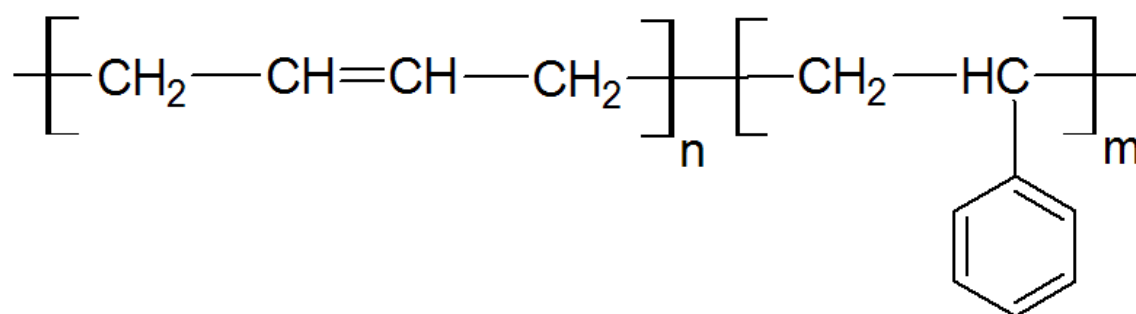
The best overall balance for most applications is a medium nitrile content.

NBR's are used where excellent oil resistance is required. They are widely used in sealing applications, particularly for oils and gasoline (aliphatic and aromatic hydrocarbons). Major applications include gaskets, seals, diaphragms, gasoline hoses, liners, tubing, O-rings and cable jacketing. Carboxylated grades find also uses as rubber tougheners in many epoxy formulations.

Styrene butadiene rubber (SBR, BUNA-S)

Styrene butadiene rubber (SBR) is one of the cheaper synthetic general purpose elastomers that is sometimes used as a substitute for natural rubber (NR). It can be produced by free-radical solution polymerization by using sodium metal.

The material was initially marketed with the brand name **Buna S**. Its name derives Bu for butadiene and Na for sodium (natrium in several languages including Latin, German, and Dutch), and S for styrene. Buna S is an addition copolymer. SBR is a highly random copolymer of butadiene and 10 to 25 percent styrene.



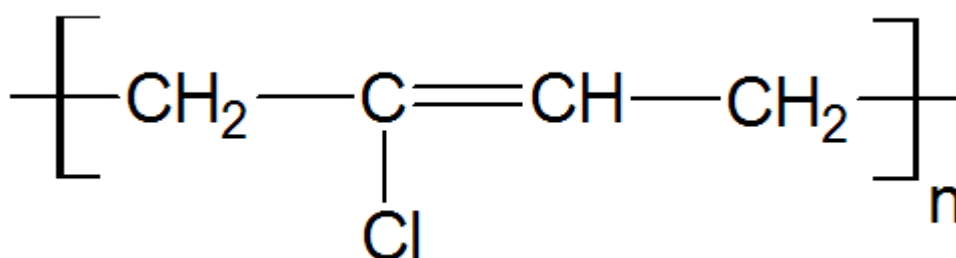
Styrene butadiene rubber (SBR) is the highest volume general purpose synthetic rubber. It can be used in similar applications as NR (natural rubber)/ IR (isoprene rubber) elastomers, except in severe dynamic application due to the inferior fatigue resistance. Typical applications include drive couplings, haul-off pads, conveyor belts, shoe soles and heels, adhesives, roll coverings and car tires (but not truck tires) and various other molded rubber goods. The typical working temperature range is -25°C to +100°C for static sealing.

The difference between Buna-N and Buna-S are tabulated below

Buna – N	Buna- S
The monomers of Buna – N is 1,3-butadiene and acrylonitrile.	The monomers of Buna – S is 1,3 butadiene and styrene.
An alternative name is Nitrile-Butadiene-Rubber	An alternative name is Styrene-Butadiene Rubber.
Buna – N is synthesised by the polymerization of 1,3-butadiene and acrylonitrile in the presence of sodium.	Buna – S is synthesised by the polymerization of 1,3-butadiene and styrene in the ratio 3:1 in the presence of sodium.
It is used in belts, sealing of oils etc.	It is used in automobile industries

Neoprene or Chloroprene Rubber (CR)

Chloroprene Rubber (CR), also known as chlorobutadiene rubber, is an important diene-based elastomer. The name Neoprene was a registered trademark of DuPont Performance Elastomers. The commercial grades are mostly trans-1,4-polychloroprene produced by free-radical emulsion polymerization of 2-chloro-1,3-butadiene.



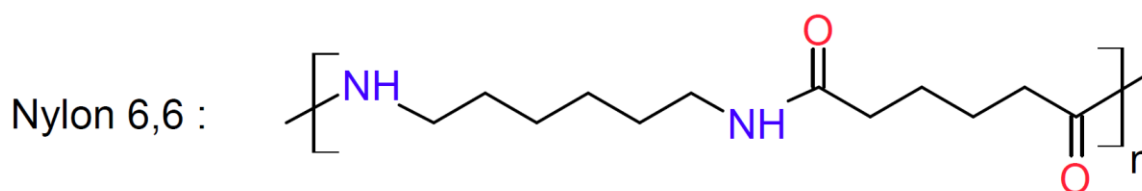
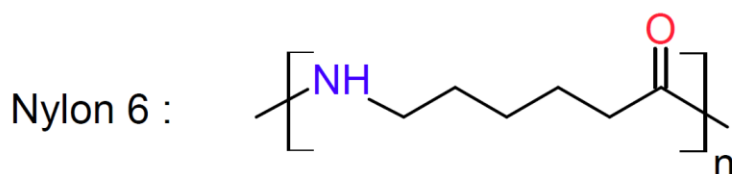
Chloroprene is used primarily for gaskets, cable jackets, tubing, seals, O-rings, tire-sidewalls, gasoline hoses and weather-resistant products such as wet suits and orthopedic braces. It is

also used as a base resin in adhesives, electrical insulations and coatings. It has many useful properties and a reasonable price.

Nylone 66

Nylon is a generic name for a family of synthetic aliphatic and semi-aromatic polyamides. Nylon 66 is synthesized by polycondensation of hexamethylenediamine and adipic acid. Equivalent amounts of hexamethylenediamine and adipic acid are combined with water in a reactor. This is crystallized to make nylon salt, an ammonium/carboxylate mixture. The other most important polyamide is polycaprolactam (**Nylon 6**). Nylon 6 is synthesized by ring-opening polymerization of caprolactam. Caprolactam has 6 carbons, hence *Nylon 6*. When caprolactam is heated at about 533 K in an inert atmosphere of nitrogen for about 4–5 hours, the ring breaks and undergoes polymerization. Then the molten mass is passed through spinnerets to form fibres of nylon 6.

Both are amorphous or only moderately crystalline when injection molded whereas films and fibers have a high degree of crystallinity due to mechanical stretching during processing. Nylon 6,6 is usually more crystalline and more ordered than Nylon 6 resulting in slightly different physical properties such as higher melting point, higher modulus, and lower moisture absorption, whereas Nylon 6 has somewhat better ductility and impact resistance. Both types of Nylon have excellent mechanical properties including high tensile strength, high flexibility, good resilience, low creep and high impact strength (toughness). Due to their high melting point of about 500 - 540 K (225 - 265°C) and good fluid resistance, they maintain excellent strength and toughness during exposure to hot, aggressive automotive fluids and to hot air whether humid or dry.



Nylon is used in the garment and home furnishing industry. However, due to its higher price and lesser wrinkle resistance, it has been replaced by polyester in many garment products. Yet, it remains an important fiber for more demanding applications, including tire cords, ropes, seat belts, hoses, conveyer belts, carpets, parachutes, racket strings, sleeping bags, tents, and various civil engineering materials.

Rayon

Rayon is also known as viscose is in fact, regenerated cellulose. The initial step is the production of alkali cellulose. This is prepared by treating cellulose obtained from wood pulp with strong alkali at relatively low temperatures. The alkali cellulose thus obtained is further treated with carbon disulphide to produce what is known as cellulose xanthate. Representing cellulose as Cell-OH its reactions involved can be written as follows

