What is a Fluoropolymer?

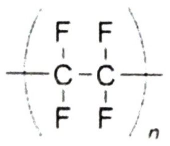
A fluoropolymer is a fluorocarbon-based polymer with multiple **carbon-fluorine** bonds which is produced from alkenes in which one or more hydrogen atoms is replaced by fluorine. Fluoro polymers have high resistance to solvents, acids, and bases that's why it is used in making kitchenware and industry wares.

Following is the common example of Fluoropolymers:

Polytetrafluoroethyene (PTFE) or Teflon

Polytetrafluoroethylene (PTFE) or Teflon is a synthetic **fluoropolymer** that is made by polymerizing tetrafluoroethylene. It is chiefly used to coat non-stick cooking utensils and to make seals and bearings.

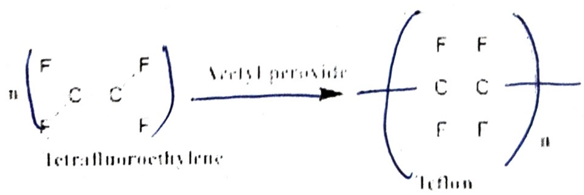
Structure of Polytetrafluoroethylene (PTFE) or Teflon



Preparation of Teflon

Teflon is prepared by heating **tetrafluoroethylene** in the presence of peroxides or ammonium persulphate catalyst at high pressures.

Preparation of Polytetrafluoroethylene (PTFE) or Teflon



Properties of Teflon

1. Teflon is flexible and inert to solvents and boiling acids even to aqua regia and is stable up to **598K** temperature.

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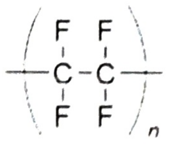

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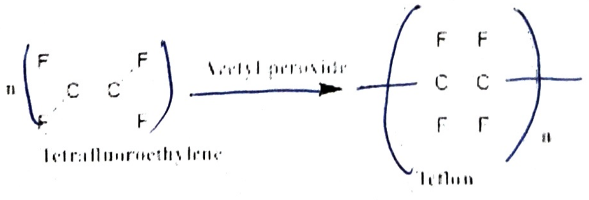


Properties of Teflon

1. Teflon is flexible and inert to solvents and boiling acids even to aqua regia and is stable up to **598K** temperature.

2. It has a low coefficient of friction and low dielectric constant due to the highly symmetric structure of the macromolecules.

3. It has good insulating power in hot and wet environments.

4. Teflon maintains high strength, toughness, and self-lubrication at low temperatures of -**268.15 ℃**.

Applications of Teflon

1. Teflon is used for making non-stick utensils due to its great chemical inertness and high thermal stability.

2. It is also used for making gaskets, pump packings, valves, seals, non-lubricated bearings, filter cloth, etc.

3. It is also used as electrical insulations in connector assemblies, cables, and in printed circuit boards.

4. Teflon film is also widely used in the production of **carbon fiber composites** as well as fiberglass composites.

What is Polyvinyl Chloride (PVC)?

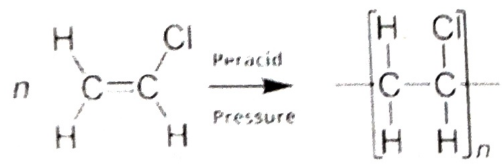
Polyvinyl Chloride (PVC) is the third most widely used thermoplastic polymer after polyethylene and polypropylene. It is prepared by radical polymerization of vinyl chloride to produce material composed of an average of 10,000 to 24,000 monomer units.

It is atactic and therefore amorphous, but it has a relatively high glass transition temperature (Tg) because of the large size of its molecules and its polar carbon-chlorine bond.

Preparation of Polyvinyl Chloride (PVC)

The monomer vinyl chloride is treated with peracid under pressure to obtain Polyvinyl Chloride (PVC)

Preparation of Polyvinyl Chloride (PVC)



Properties of Polyvinyl Chloride (PVC)

1. It is a linear polymer and thermoplastic in nature.

2. It is a white brittle solid, hard, rigid material which tends to stick to the metallic surface.

3. It is insoluble in all hydrocarbon solvents.

4. It has a melting point of 212 and glass transition temperature (Tg) is 80.

Applications of Polyvinyl Chloride (PVC)

1. When PVC is plasticized with high boiling esters such as di-n-butyl phthalate, it is used for making raincoats, handbags, shower curtains, vinyl flooring, water pipes, etc.

2. Around the world, over 50 % of PVC manufactured is used in construction. As a building material, it is cheap, durable, and very easy to assemble. It is a rigid material and is used to make pipes, panels, and molded objects.

3. PVC is commonly used as insulation on electric wires.

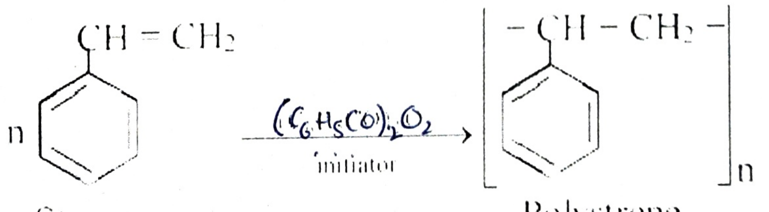
4. PVC is used in the healthcare sector for the manufacturing of blood collection, ostomy, and urine collection products.

What is Polystyrene ?

Polystyrene, also known as **Polyvinyl benzene** is hard, brilliantly transparent, stiff resin which is produced by the **free radical addition polymerization** of styrene in the presence of benzoyl peroxide. Polystyrene is non-biodegradable and widely used in the food-service industry as rigid trays, containers, disposable eating plates, bowls, etc.

Preparation of Polystyrene

Polystyrene is prepared by **free radical addition polymerization** of styrene in the presence of benzoyl peroxide as a catalyst.



Styrene   Polystrene

Properties of Polystyrene

1. Polystyrene exists in an **amorphous** state due to the presence of bulky phenyl groups which makes packing of Polystyrene inefficient.

2. Polystyrene is non-polar having a melting point of **240 °C**.

3. Polystyrene is a transparent polymer having a good optical property that allows high transmission of all wavelengths.

4. Polystyrene is hard but brittle due to the chain-shifting effect of the benzene ring.

5. Polystyrene has **good insulation** properties. That's why it is used in making Polystyrene insulation products.

Applications of Polystyrene

1. Polystyrene is used in making **'throw away'** drinking cups, soft drinks, and baby feeding bottles.

2. By adding color and filler, it can be used for making toys and household items.

3. When gas is blown into Polystyrene liquid, it foams and hardens to form **styrofoam** which is used for making ice chests and disposable coffee cups.

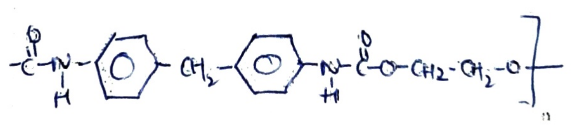
4. Polystyrene is also used as packing material for shipping instruments and appliances, and it is widely used for home insulation.

5. Medically it is used for sterilizing test tubes, diagnostic components, and other medical devices.

What is Polyurethane?

Polyurethane (PU) is a polymer having organic units joined by **urethane** (also known as carbamate). Urethane is a compound that has an O-R group and an NH-R group bonded to the same carbonyl carbon.

Structure of Polyurethane



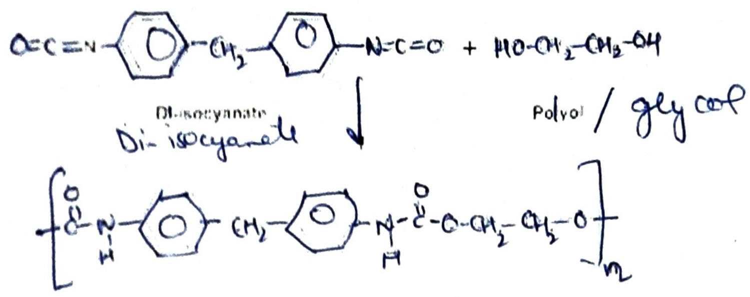
Polyurethane

Polyurethanes are thermosetting polymers but their thermoplastic variants are also available in the market. Polyurethanes are prepared by the polymerization of **toluene-2,6-di-isocyanate** and **ethylene glycol.** If the reaction is carried out in the presence of a blowing agent, the product is polyurethane foam.

Preparation of Polyurethanes

Polyurethanes are formed by reacting a **polyol** (an alcohol with more than two reactive hydroxyl groups per molecule like ethylene glycol) and **di-isocyanate** or a polymeric isocyanate in the presence of suitable catalyst and additives.

Preparation of Polyurethane



Polyurethane

Properties of Polyurethanes

1. Polyurethane has high load capacity in both tension and compression that may change shape under heavy load but will return to its original shape once the load is removed with little compression.

2. Polyurethanes possess **high fear resistance** along with high tensile properties.

3. Polyurethane material will remain stable with minimal swelling in water, oil, and grease.

4. Polyurethanes exhibit good electrical insulating properties.

Applications of Polyurethanes

1. Polyurethane foam is used for furniture stuffing, carpet backings, and insulation.

2. One of the most important uses of polyurethanes is in fabrics with elastic properties, such as spandex.

3. Polyurethane materials are commonly formulated as **paints** and **varnishes** for finishing coats t protect or seal the wood.

4. Polyurethane is also used in making solid tires and garments.

What are Conducting Polymers?

As the name suggests organic polymers that conduct electricity are known as conducting polymers. They are also known as **intrinsically conducting polymers (ICPs)** and they have alternating single and double bonds along the polymer backbone (conjugated bonds) or that are composed of aromatic rings such as Phenylene, naphthalene, anthracene, pyrrole, and thiophene which are connected through carbon-carbon single bonds.

Examples: **Polyacetylene, Polypyrrole, Polyaniline, etc**

What is the reason behind conducting nature of these polymers?

Conducting polymers comes in two forms that are doped conducting polymers and non-doped conducting polymers. The conductivity of non-doped conjugated polymers is due to the existence of a conductivity band similar to a metal.

In a conjugated polymer, three of the four valence electrons form strong sigma bonds through sp^2 hybridization where electrons are strongly localized.

The remaining unpaired electron of each carbon atom remains in a P_z orbital. It overlaps with a neighboring P_z orbital to form a pi bond.

The pi electrons of these **conjugated P_z orbitals** overlap to form an extended P_z orbital system through which electrons can move free (delocalization of pi electrons). However, the conductivity of non-doped polymers is low.

In the case of doped conjugated polymers, an electron is removed from the valence band by oxidation (p-doping) or is added to the conducting band by reduction (n-doping).

P-doping increases the mobility of electrons in these delocalized orbitals and the polymer becomes highly conductive.

Properties of Conducting Polymers

1. Conductivity polymers have high melting and softening points because the mobility of the repeat units is highly restricted due to the presence of a fully aromatic ring structure and the absence of free rotating groups.
2. Conductivity polymers show excellent chemical, thermal and oxidative stability due to low hydrogen content and aromatic structure.
3. They can be processed into a highly ordered crystalline thin film that is electrically conducting upon doping.
4. They are insoluble in many common solvents.

Applications of Conducting Polymers

1. They are used in the manufacturing of chemical sensors, electro-magnetic shielding, antistatic coatings, corrosion inhibitors, etc.
2. They are also used in compact electronic devices such as polymer-based transitions, light-emitted diode (LEDs), and lasers.
3. They are used for microwave-absorbent coating particularly radar-absorptive coatings on stealth aircraft.
4. They are used in the manufacturing of printed circuit board because it protects the copper from corrosion and prevents its solderability.

Following are some common examples of conducting polymers:

Examples of Conducting Polymers

1. Polyacetylene

Polyacetylene or Polyethyne having a repeating unit **$(C_2H_2)_n$**, is a rigid, rod-like polymer that consists of long carbon chains with alternating single and double bonds between the carbon atoms.

It is a conducting polymer whose electrical conductivity was dissolved by **Hideki Shirakawa**, **Alan Heeger**, and **Alan MacDiarmid** who received Nobel Prize in chemistry in 2000 for their work.

Properties of Polyaniline

1. It has great electrical conductivity in the range of 10^{-10} to 10^{2} **s/cm**.
2. It has band gapes of **4.3** and **2.7 ev** in its reduced and oxidized forms respectively.
3. It has high chemical stability.
4. Polyaniline-based composition can withstand high temperatures like **230-240 ℃** without significant change in electrical properties.

Applications of Polyaniline

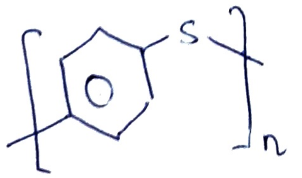
1. It is used in the manufacturing of printed circuit boards.
2. Polyaniline and its derivatives are used as the base element for the production of N-doped carbon materials.
3. The color change of polyaniline in different oxidation states can be used in sensors and electrochromic devices.
4. Printed emeraldine polyaniline-based sensors have wide application in the electronic sector.

3. Poly-p-phenylene sulphide

Poly-p-phenylene sulphide (PPS) is an organic polymer consisting of aromatic rings linked by sulphides. Though poly-p-phenylene sulphide is insulating in nature, it can be converted into a semiconducting polymer through oxidation or the use of dopants.

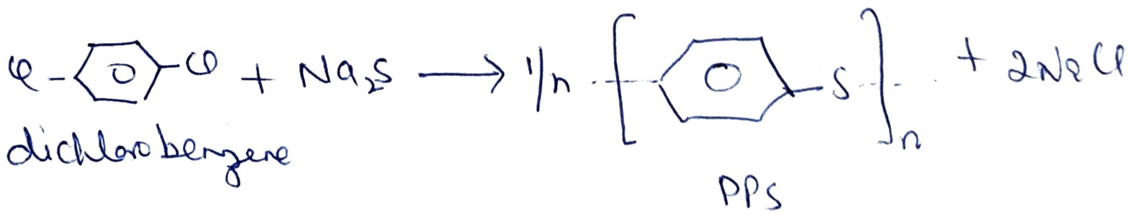
PPS is a rigid and opaque polymer with a high melting point **(280 ℃)**. That's why it can be used in filter fabric for coal boilers, film capacitors, and gaskets.

Structure of Poly-p-phenylene sulphide (PPS)



Preparation of Poly-p-Phenylene Sulphide (PPS)

Poly-p-Phenylene Sulphide (PPS) is produced by the reaction of **sodium sulphide** and **dichlorobenzene** in a polar solvent such as N-methyl pyrrolidone at high temperature (250 ℃).

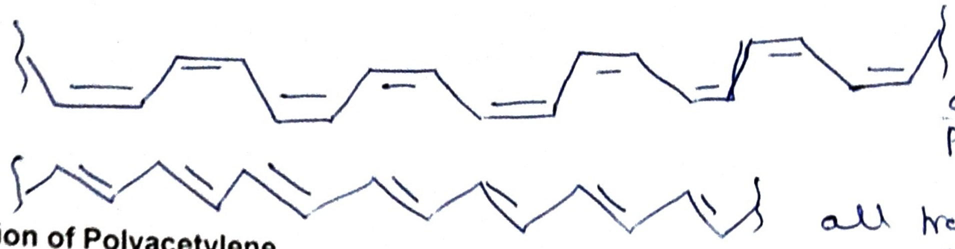


Properties of Poly-p-Phenylene Sulphide (PPS)

1. It is resistant to heat, acids, alkalies, bleaches, sunlight, and abrasion.
2. It absorbs only a small amount of solvent and resists dyeing.
3. It has good conducting properties if doped with dopants or by oxidation.
4. It has exceptional mechanical strength and good dimensional stability.

Structure of Polyacetylene

There are two types of structure of Polyacetylene that is cis- and trans-polyacetylenes.



Preparation of Polyacetylene

$HC\equiv CH$

$Et_3Al/Ti(OBu)_4$ | $(Et)_3Al/Ti(OBu)_4$

$-78°C$, toluene ↓ | ↓ $150°C$, hexadecane

all cis polyacetylene copper coloured | all trans polyacetylene silver-colored

Properties of Polyacetylene

1. Films of cis-polyacetylene are flexible and can be readily stretched while trans-polyacetylene is much more brittle
2. Both cis and trans-polyacetylene show high thermal stability.
3. They are insoluble in common solvents

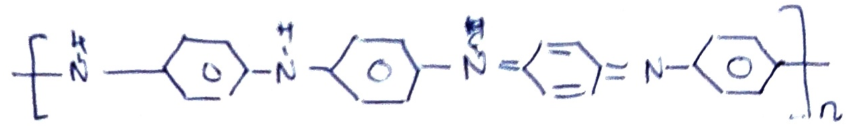
Applications of Polyacetylene

1. Doped polyacetylene offers a particularly high electrical conductivity therefore it can be used in electric wiring or electrode material in lightweight rechargeable batteries.
2. Tri-iodide oxidized polyacetylene can be used as a sensor to measure glucose concentration

2. Polyaniline

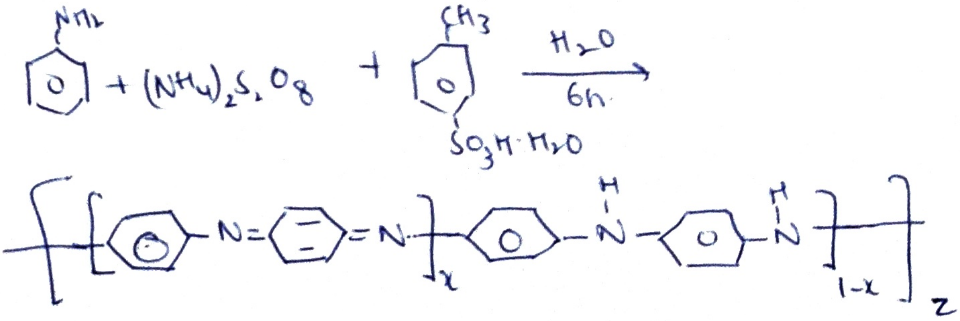
Polyaniline (PANI) is a conducting polymer of the semi-flexible rod polymer family which was discovered in the early **1860s** by lightfoot through oxidation of aniline. It behaves like an organic semiconductor that has good electrical conductivity measured in the units **s/cm.**

Structure of Polyaniline



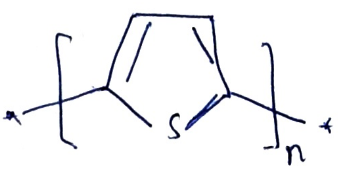
Preparation of Polyaniline

Polyaniline is synthesized by oxidative polymerization of aniline.



The development of polythiophenes was done by Nobel prize winners (2000), Alan J.Heeger, Alan MacDiarmid, and Hideki Shirakawa.

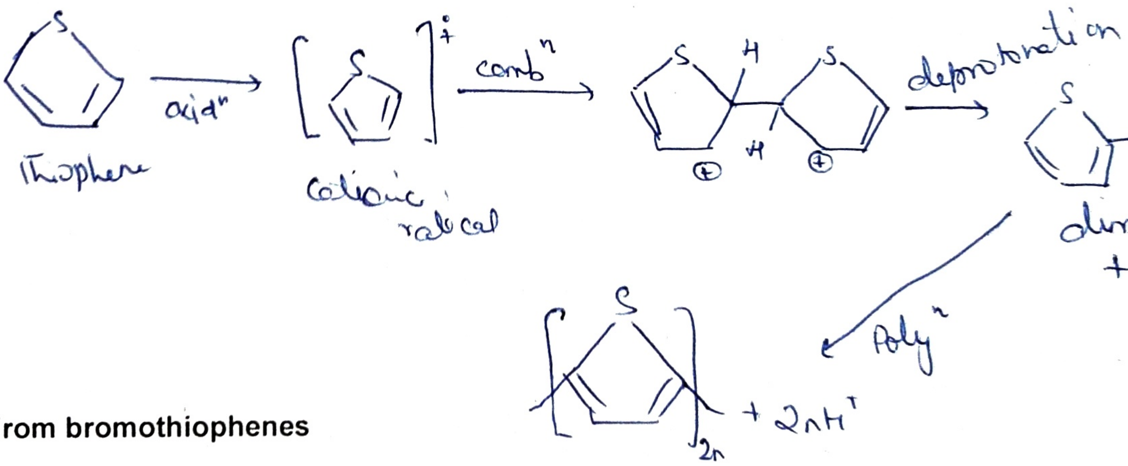
Structure of Polythiophene



Preparation of Polythiophene

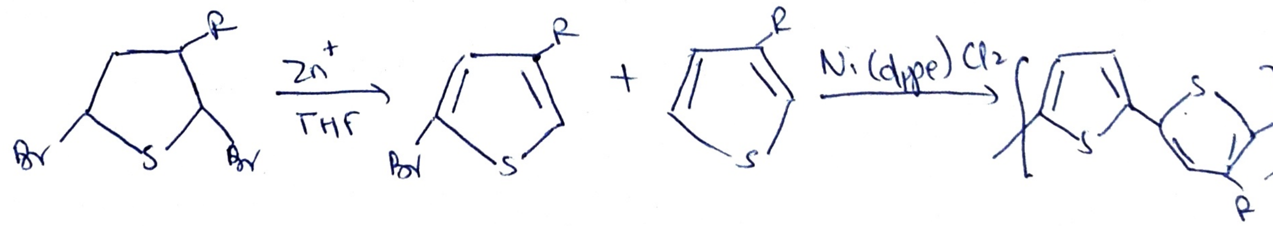
1. Electrochemical Synthesis

Polythiophene can be prepared by **electrochemical polymerization** of a solution containing thiophene and an electrolyte. Through this method, a conductive polythiophene film gets produced on the anode.



2. From bromothiophenes

2,5-dibromo-3-alkyl thiophene is treated with highly reactive Rieke Zinc to form a mixture of organometallic isomers. Then, the addition of a catalytic amount of **Pd** $(\mathbf{PPh_3})_4$ produces a regiorandom polymer, but treatment with Ni(dppe)Cl_2 yields regioregular polythiophene.



$R = C_6H_{13}$

Applications of Poly-p-Phenylene Sulphide (PPS)

1. It is used in automotive industries for the manufacturing of fuel injection systems, water pump impellers, electric brakes, bulb housing, etc.
2. It is used in electronic industries for the manufacturing of connectors, hard disk drives, sockets, switches, etc.
3. It is used in the medical industry like surgical instruments, medical fibers, and membranes.
4. It is used in fiber extrusion and non-stick and chemical-resistant coatings.

4. Polypyrrole

Polypyrrole (PPy) is an organic polymer having the chemical formula $H(C_4H_2NH)_nH$ which is obtained by oxidative polymerization of pyrrole. It is an **intrinsically conducting polymer** that is used in electronics, optical, biological, and medical fields.

Structure of Polypyrrole

Preparation of Polypyrrole

Polypyrrole can be produced by oxidative polymerization of pyrrole.

Properties of Polypyrrole

1. It is an insulator but its oxidized derivatives are good electrical conductors having conductivity in the range of **2** to **1000 s/cm.**
2. It attains good thermal stability if treated with an acid or base like sulphuric acid and sodium hydroxide.
3. It is corrosion resistant and also chemically stable due to cross-linking.
4. Its glass transition temperature is **160-170** °C.

Applications of Polypyrrole

1. Polypyrrole and its related polymers are used in electronic devices and chemical sensors.
2. It can be used as a potential vehicle for drug delivery
3. It can be used as catalyst support for fuel cells.
4. It is used to coat silica and reverse-phase silica to yield a material capable of anion exchange.

5. Polythiophene

Polythiophene (PT) having the general formula $(C_4H_2S)_n$, is a conductivity polymer whose conductivity exceeds **100 s/cm**. The electrical conductivity of polythiophene is due to the delocalization of electrons along the polymer backbone.

Doping of Polythiophene

Polythiophene is an ordinary polymer that becomes electrically conductive upon treatment with an oxidizing agent (electron-acceptors). A variety of reagents have been used to dope polythiophenes like Iodine and Bromine.

Properties of Polythiophene

1. It is an excellent intrinsic conducting polymer having conjugated double bonds in the backbone.
2. It has high environmental and thermal stability.
3. It is a colored solid but tends to be soluble in organic solvents.
4. It is transparent having good optical properties.

Applications of Polythiophene

1. They are widely used in solar cells due to their ability to form better contact with metal electrodes.
2. They are also used in polymer batteries and electrochromic devices.
3. They can also work with receptors for detecting metal ions or chiral molecules.
4. They show potential in the treatment of prion diseases.

Polyamides- Definition, Types, Properties and Applications

December 17, 2021

What are Polyamides?

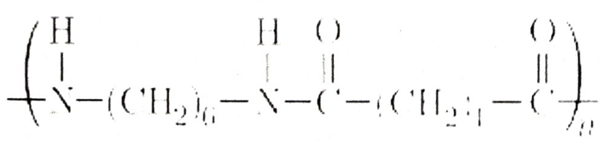
Polymers that have amide linkages are called **polyamides.** These are prepared by condensation polymerization of dibasic acids with diamines or their equivalents.

Polyamides occur both naturally and artificially like proteins, such as wool and silk are naturally occurring polyamides whereas nylons, aramids and sodium poly(aspartate) is artificially manufactured polyamides.

Following are some famous polyamides:

1. Nylon 6,6

Nylon 6,6 is a type of polyamide that is made of two monomers that is **hexamethylenediamine** and **adipic acid** each containing 6 carbon atoms. That's why it is called nylon 6,6.



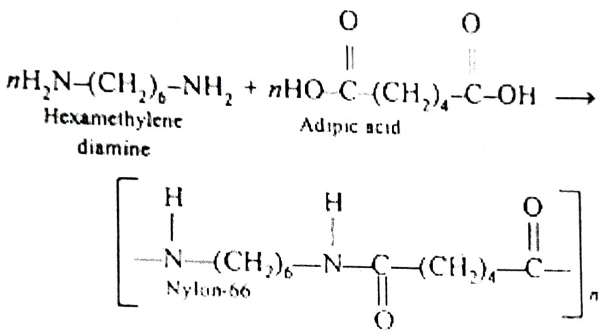
Nylon 66

parts, airbags, ropes, conveyor belts, etc.

Preparation of Nylon 6,6

It is prepared by the condensation polymerization of adipic acid and hexamethylenediamine. The acid and the amine first react to form a salt which when heated to **525 K** under pressure, undergoes polymerization with the elimination of water as steam and the nylon is produced in the molten state.

Preparation of Nylon-66



Properties of Nylon 6, 6

1. It has a high melting point and high heat deflection temperature.

2. It offers better resistance to acids and has high stain cleanability.

3. It is more difficult to color due to **dense structure** with small and evenly spaced pores.

4. It exhibits greater mold shrinkage, lower expansion, and improved thermal and electrical conductivity.

Applications of Nylon 6,6

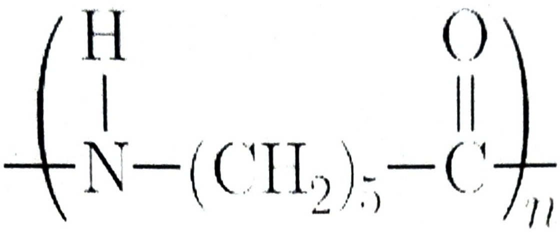
1. It is used for making swimwear, hoses, and machine parts due to its waterproof property.

2. It is also used for making glass-reinforced laminates, fasteners, and conveyor belts.

3. It is used in fibers for textiles, carpets, and molded parts.

4. It is also used for making surgical sutures and strings for musical instruments.

polymerization of monomer caprolactam.

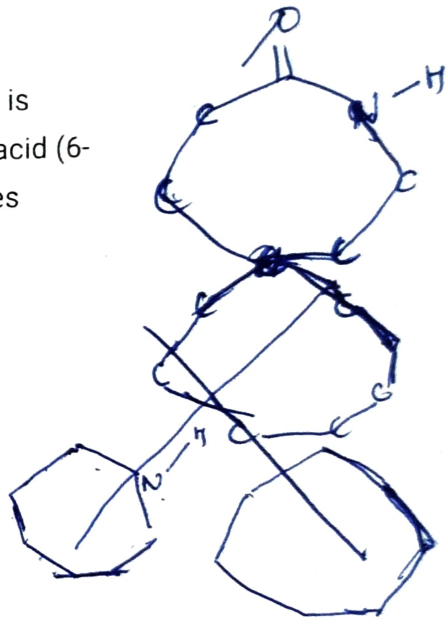


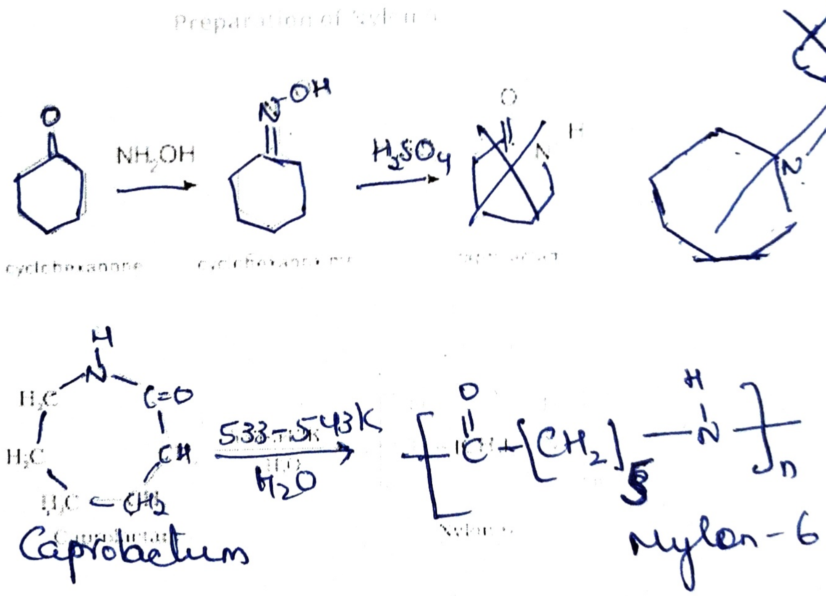
Nylon 6

Nylon 6 is tough, elastic, and lustrous possessing high tensile strength. That's why it is used for the manufacture of type cords, fabrics, and mountaineering ropes.

Preparation of Nylon 6

The monomer caprolactam on heating with water at high-temperature polymerization gives nylon 6. When caprolactam is heated with a trace of water, it hydrolyses to E-aminocaproic acid (6-aminohexanoic acid) which upon continued heating undergoes polymerization to give nylon-6.





Properties of Nylon 6

1. It has a lower melting point and lower heat deflection temperature.
2. It has a **lustrous surface** finish which makes it easy to color.
3. It has poor chemical resistance to acids and has a high water

1. It is widely used for gears, fitting, and bearings in the automotive industry.

2. It is used as a thread in bristles of toothbrushes and strings for acoustic and classical musical instruments.

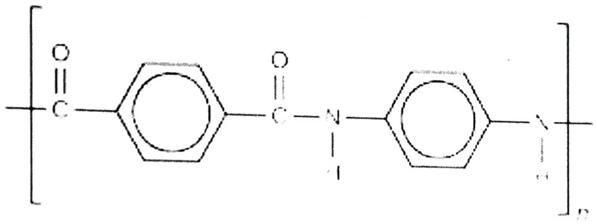
3. It is also used for manufacturing threads, ropes, filaments, and nets.

4. It is also used for the manufacturing of gun frames.

3. Kevlar

Kevlar is heat resistant and strong synthetic fiber which is an aromatic polyamide, also known as **aramids.**

Structure of Kevlar

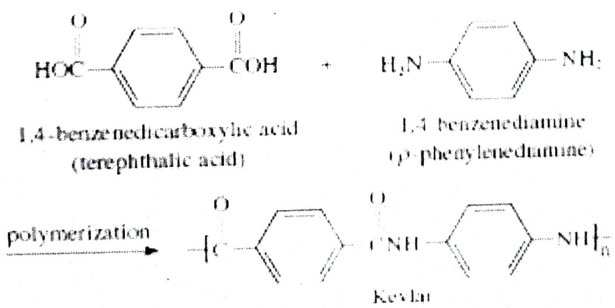


It is a polymer of 1,4-benzene-dicarboxylic acid and 1,4-diaminobenzene which have hydrogen-bonded chains, giving it a sheet-like structure.

Preparation of Kevlar

Kevlar is prepared in a solution from monomers **1,4-benzene-dicarboxylic acid** and **1,4-diaminobenzene** in a condensation reaction yielding HCl as a by-product.

Preparation of Kevlar



2. It has high heat stability and flexibility.

3. It has very **high rigidity** due to delocalized bonding which causes benzene rings to be inflexible.

4. There is a high electron chain density in Kevlar.

Applications of Kevlar

1. Army helmets are made of Kevlar. It is also used for lightweight bulletproof vests and high-performance skis.

2. It is used in the protective clothing worn by firefighters because it is stable at a very high temperature.

3. It is used as a protective outer shield for optical fiber cable.

4. It is widely used in the manufacturing of motorcycle helmets, car parks, brakes, clutch lining, etc.

Polymer Chemistry

Popular Posts

Conducting Polymers: Definition, Examples, Properties and Applications

March 22, 2022

Types of Rubber, their Properties and Applications

April 12, 2022

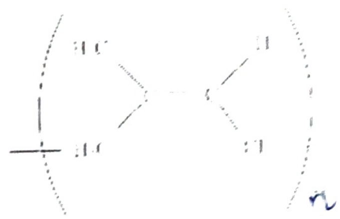
Chemical Manufacturing Experts

sed chemical solution

1. Natural Rubber

Natural rubber is a natural polymer that is manufactured from **latex** which is a colloidal solution of rubber particles in water. Latex is obtained by making cuts in the bark of rubber trees like Hevea brasiliensis, found in tropical and semi-tropical countries such as southern.

Structure of natural rubber

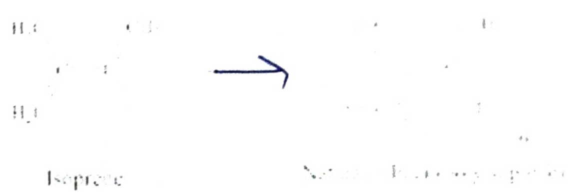


India, Indonesia, Malaysia, Sri Lanka, South America, etc. The natural rubber has remarkable elasticity and undergoes long-range reversible extension even under a relatively small applied force.

Preparation of natural rubber

Natural rubber is a linear **1,4-addition polymer** of isoprene.

Preparation of natural rubber



Isoprene

Since each repeating unit in polyisoprene contains a double bond having cis-stereochemistry. That's why natural rubber is cis-polyisoprene.

Prop:
Natural rubber has no polar gps & hence Intermol. forces of are only weak Vander Walls interaction
Cis-pp

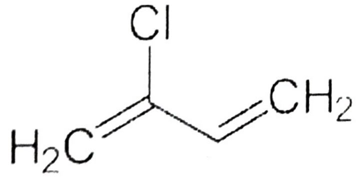
crystalline.

Important Examples of Synthetic Rubbers

1. Chloroprene

Chloroprene is a monomer of neoprene. It is prepared by the **addition of HCl to vinylacetylene.** The solution takes place on the triple bond as per Markovnikov's rule.

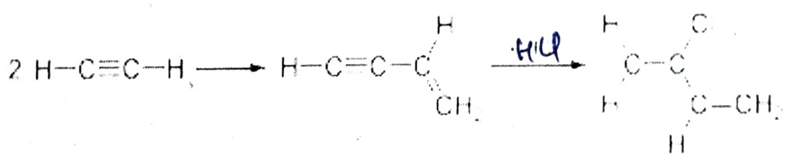
Structure of Chloroprene



Preparation of Chloroprene

Vinylacetylene needed for the purpose is prepared by dimerization of acetylene by passing it through an aqueous solution of ammonium chloride and cuprous chloride at **343 K**.

Preparation of Chloroprene



2. Neoprene

Neoprene (also known as **polychloroprene**), is a synthetic rubber that is made by polymerization of chloroprene. It is harder and stronger than natural rubber and resistant to water.

Structure of Neoprene

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1. Natural Rubber

Natural rubber is a natural polymer that is manufactured from **latex** which is a colloidal solution of rubber particles in water. Latex is obtained by making cuts in the bark of rubber trees like Hevea brasiliensis, found in tropical and semi-tropical countries such as southern.

India, Indonesia, Malaysia, Sri Lanka, South America, etc. The natural rubber has remarkable elasticity and undergoes long-range reversible extension even under a relatively small applied force.

Preparation of natural rubber

Natural rubber is a linear **1,4-addition polymer** of isoprene.

Since each repeating unit in polyisoprene contains a double bond having cis-stereochemistry. That's why natural rubber is cis-polyisoprene.

Properties of Natural rubber

1. Natural rubber has no polar groups and hence intermolecular forces of attraction are only weak van der Waals interactions.
2. Cis-polyisoprene does not have a straight-chain but has a coiled structure. As a result, it can be stretched like a spring.
3. Due to the coiled structure, natural rubber does not fit properly in the crystal lattice and hence is considered to be non-crystalline.

Applications of Natural rubber

1. It has engineering applications like anti-vibration mounts, drive couplings, springs, bearings, rubber bands, etc.
2. It is widely used in high-performance tires for race cars, buses, and aircraft due to its heat-resistant properties.
3. It is used in hoses, automotive parts, foam mattresses, and battery boxes.
4. Raw rubber is sometimes used for adhesives and as a part of shoe soles.

2. Synthetic Rubbers

Synthetic Rubber may be defined as any vulcanizable rubber-like polymer which is capable of getting stretched to twice its length. However, it returns to its original shape and size when the stretching force is taken out.

Most of these rubbers are derived from butadiene derivatives and contain carbon-carbon double bonds so that they can also be vulcanized. Thus, synthetic rubbers are either homopolymers of **1,3-butadiene** or its derivatives or are copolymers of 1,3-butadiene or its derivatives with another unsaturated monomer.

Properties of Synthetic rubber

1. Due to the trans orientation of double bonds, synthetic rubber has a highly regular zig-zag structure that cannot be stretched much. Hence, it is considered to be non-elastic.
2. Due to the highly regular zig-zag structure, synthetic rubber fits closely in the crystal lattice and hence is considered to be crystalline.

Important Examples of Synthetic Rubbers

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Preparation of Chloroprene

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Neoprene (also known as **polychloroprene**), is a synthetic rubber that is made by polymerization of chloroprene. It is harder and stronger than natural rubber and resistant to water.

That's why it is used in the manufacture of hoses, gaskets, shoe heels, stoppers, etc.

Preparation of Neoprene

It is prepared by polymerization of chloroprene in which it polymerizes very readily (700 times faster than isoprene). The reaction occurs by **1,4-addition** of one chloroprene molecule to the other where no specific catalyst is needed but the polymerization is slower in absence of oxygen.

Properties of Neoprene

1. It has much more oil resistance than natural rubber It is not oxidized by air.
2. It has high tensile strength
3. It has acceptable chemical stability and maintains flexibility over a wide temperatures.
4. It is resistant to sun, climate, and ozone determination.

Applications of Neoprene

1. It is used as an insulator and for making conveyor belts and printing rollers.
2. It is used in the manufacture of hoses. gaskets, shoe heels. stoppers, etc.
3. During Covid-19, Neoprene is actively used to make face masks having **99.9 %** filtration efficiency.
4. It is a popular material in making protective clothing for aqua activities like scuba diving, swimming, etc.