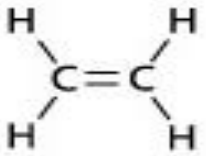
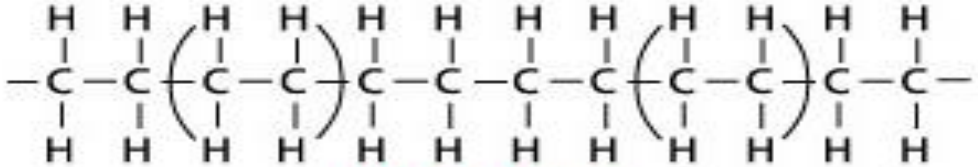
POLYMERS

Carbon-based compounds

Polymers ARE CHAINS OF Monomers joined together.

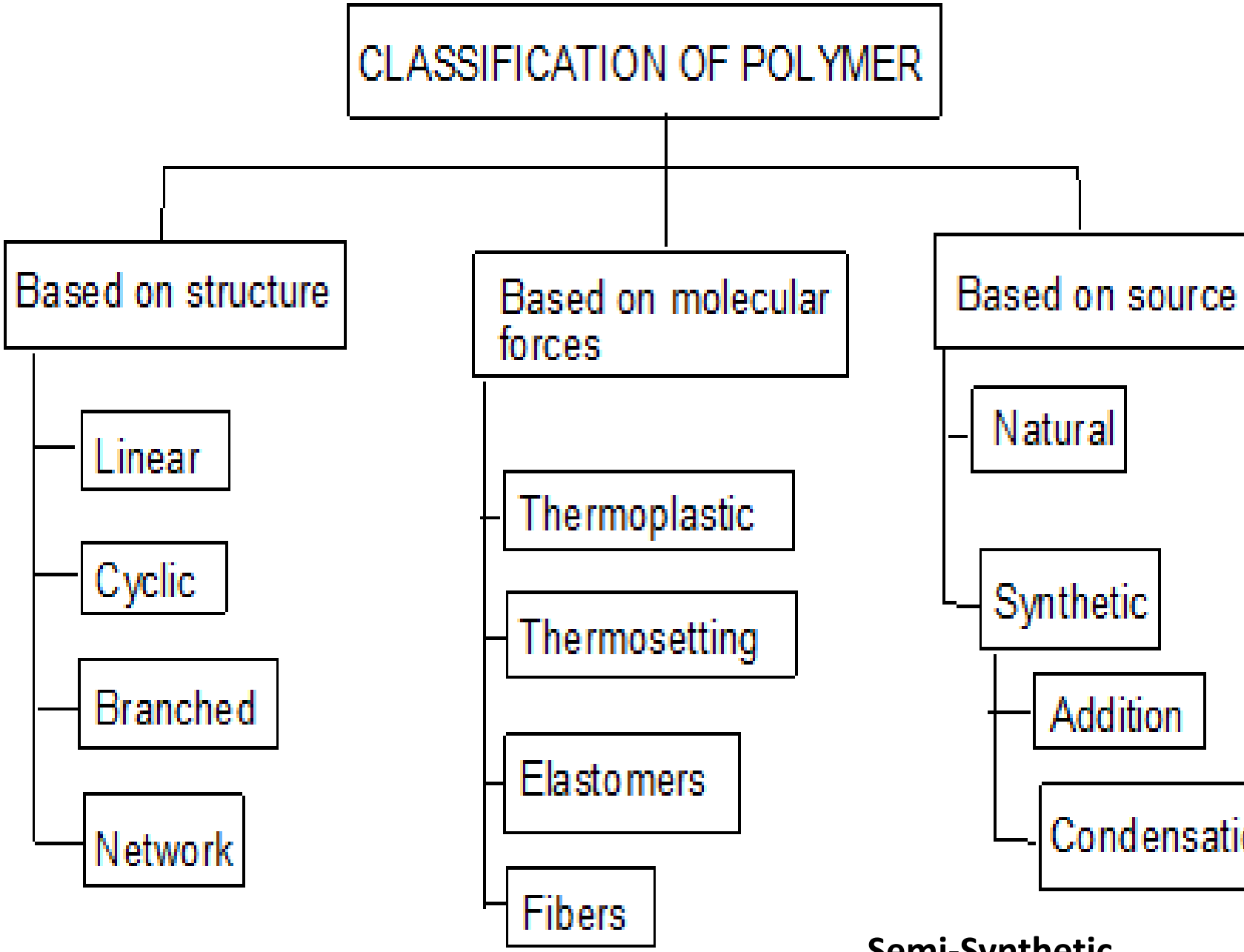


ethylene



polyethylene

- A polymer is a macromolecule with high molecular mass ranging from 5000 to one million, which are formed by combination of one or more low molecular weight compound/ s. The unit substance from which polymer is obtained is called monomer.
- The process by which polymers are obtained is called polymerization
- For e.g. polyethylene is obtained by repeating ethylene unit as a result of polymerization.



Semi-Synthetic

- Polymers can be separated into plastics and rubbers (fibres not included here)
- As engineering materials, it is appropriate to divide them into the following three categories:

1. Thermoplastic polymers
2. Thermosetting polymers
3. Elastomers where (1) and (2) are plastics and (3) are rubbers

Thermoplastic Polymers - Thermoplastics (TP)

- Solid materials at room temperature but viscous liquids when heated to temperatures of only a few hundred degrees
- This characteristic allows them to be easily and economically shaped into products
- They can be subjected to heating and cooling cycles repeatedly without significant degradation

Thermosetting Polymers - Thermosets (TS)

- Cannot tolerate repeated heating cycles as thermoplastics can

When initially heated, they soften and flow for molding

But elevated temperatures also produce a chemical reaction that hardens the material into an infusible solid

If reheated, thermosets degrade and char rather than soften

Elastomers: Polymers that exhibit extreme elastic extensibility when subjected to relatively low mechanical stress

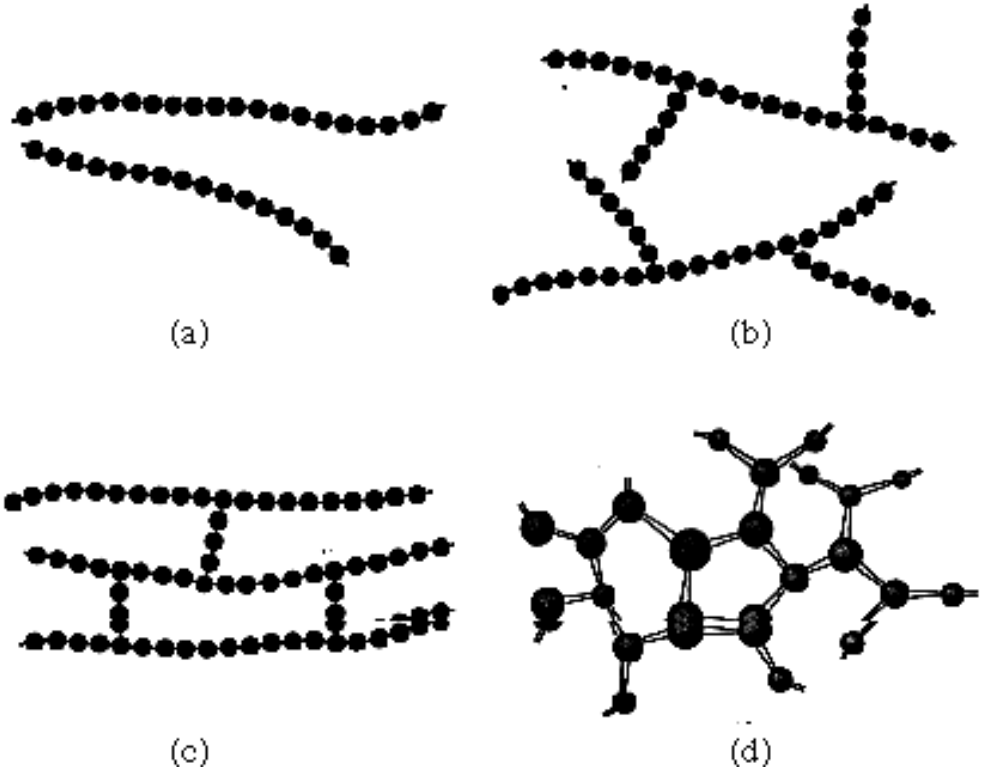
- Also known as rubber
- Some elastomers can be stretched by a factor of 10 and yet completely recover to their original shape
- Although their properties are quite different from thermosets, they share a similar molecular structure that is different from the thermoplastics

Examples of Polymers

- Thermoplastics: Polyethylene, polyvinylchloride, polypropylene, polystyrene, etc.
- Thermosets: Phenolics, epoxides, and certain polyesters
- Elastomers: Natural rubber, (vulcanized) Synthetic rubbers, which exceed the tonnage of natural rubber

Linear, Branched, and Cross-linked Polymers

- Linear structure –chain-like structure Characteristic of thermoplastic polymers
- Branched structure –chain-like but with side branches Also found in thermoplastic polymers
- Cross-linked structure -Loosely cross-linked, as in an elastomer Tightly cross-linked, as in a thermoset



ii) On the basis of nature of monomer

- Homopolymers (comprise of monomers of the same type)
  - Linear (homochain or heterochain)
  - Branched
  - Cross-linked
- Heteropolymers/ Copolymers (Different repeating units)
  - Linear; Branched; Graft (regular/irregular); Block (regular/irregular)

iii) On the basis of chemical nature

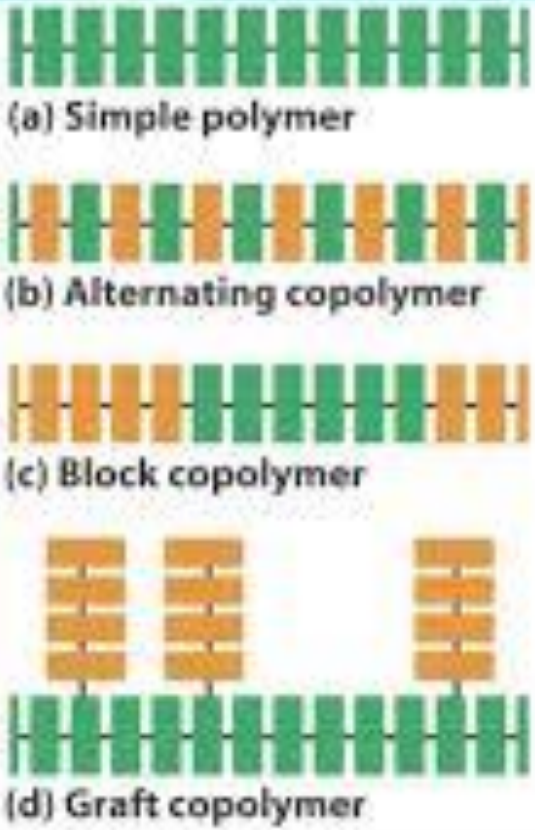
- Organic (polymer backbone chain made up of carbon atom)
- Inorganic (No carbon atoms in the backbone chain, eg., Silicone rubbers)

a)Homopolymer

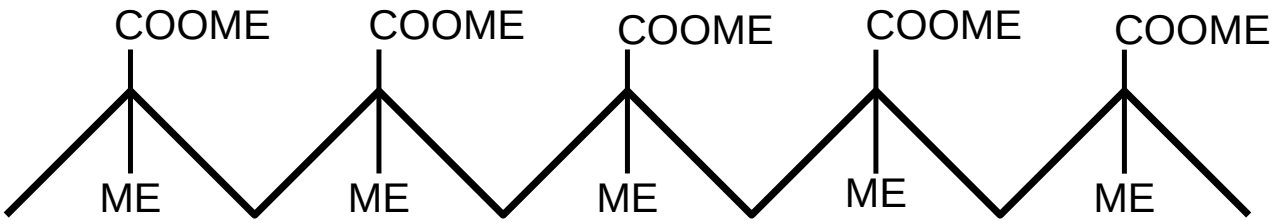
b)Copolymer

c) Block copolymer

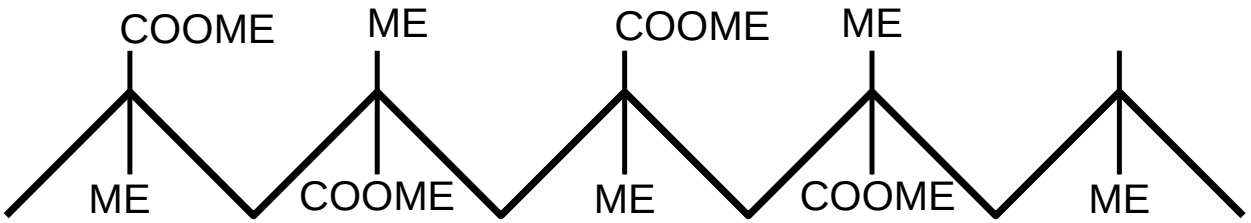
d) Graft copolymer



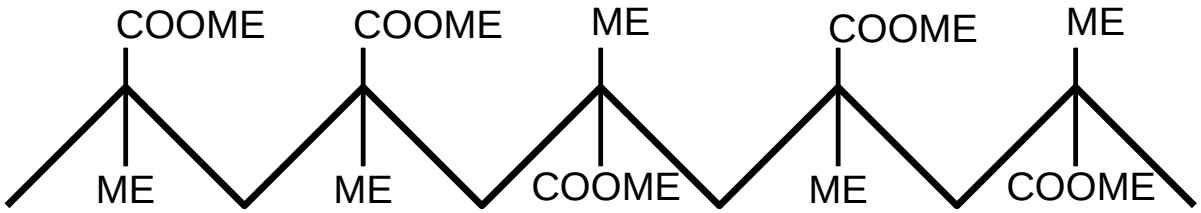
- ***Depending on tacticity:***
- Isotactic – similar groups on same side of chain



- Syndiotactic – two groups alternate



- Atatactic – displays no regular pattern



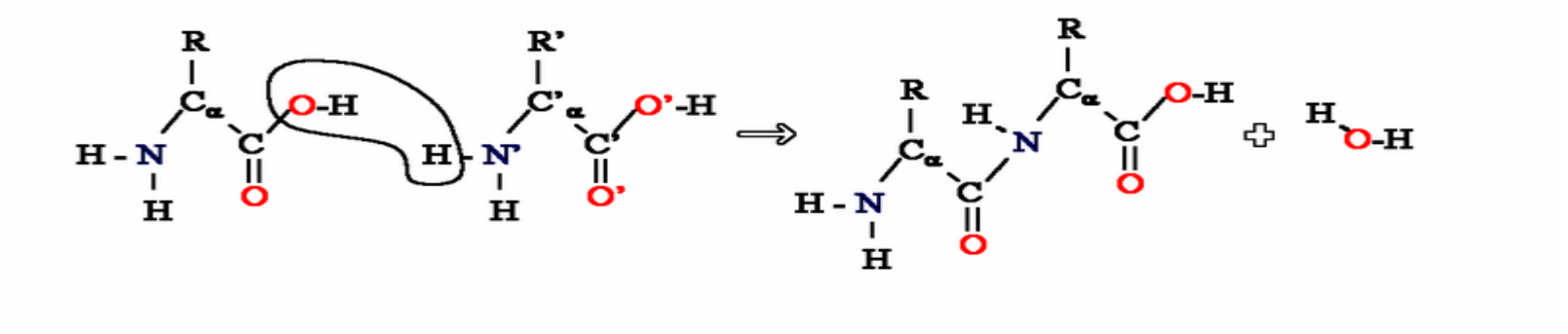
❖ Every other carbon in the chain is a steriocenter

Classification based Polymerization

- **Addition Polymerization:** A polymer formed by direct repeated addition of monomers is called addition polymerization. In this types of polymers monomers are unsaturated compounds or derivatives of alkenes.

Fig 1: The polymerisation of ethene in to poly(ethene)

- **Condensation Polymerization:** Condensation polymerization involves condensation of two different monomers which are normally bi functional group. During the process there is loss of small molecule such as water



- Effect of Branching on Properties
  - Thermoplastic polymers always possess linear or branched structures, or a mixture of the two
- - Branches increase entanglement among the molecules, which makes the polymer: Stronger in the solid state. More viscous at a given temperature in the plastic or liquid state

- Effect of Cross-Linking on Properties
- •Thermosets possess a high degree of cross-linking, while elastomers possess a low degree of cross-linking
- •Thermosets are hard and brittle, while elastomers are elastic and resilient
- •Cross-linking causes the polymer to become chemically set The reaction cannot be reversed The polymer structure is permanently changed; if heated, it degrades or burns rather than melt

- Mechanical Properties of Thermoplastics
- •Low modulus of elasticity (stiffness) E is two or three orders of magnitude lower than metals and ceramics
- •Low tensile strength TS is about 10% of the metal
- •Much lower hardness than metals or ceramics
- •Greater ductility on average Tremendous range of values, from 1% elongation for polystyrene to 500% or more for polypropylene

- **Physical Properties of Thermoplastics**
- •Lower densities than metals or ceramics Typical specific gravity for polymers are 1.2 Ceramics specific gravity = 2.5 Metals specific gravity = 7.0
- •Much higher coefficient of thermal expansion Roughly five times the value for metals and 10 times the value for ceramics
- •Much lower melting temperatures
- •Specific heats two to four times those of metals and ceramics
- •Thermal conductivities about three orders of magnitude lower than those of metals
- •Insulating electrical properties

- General Properties and Characteristics of Thermosets
- •Rigid - modulus of elasticity is two to three times greater than TP
- •Brittle, virtually no ductility
- •Less soluble than TP in common solvents
- •Capable of higher service temperatures than TP
- •Cannot be remelted - instead they degrade or burn

CHARACTERISTICS OF IDEAL POLYMER

- Should be inert and compatible with the environment.
- Should be non-toxic.
- Should be easily administered.
- Should be easy and inexpensive to fabricate.
- Should have good mechanical strength.

Why are polymers/ plastics extensively used-

- Plastics are strong, light weight, flexible and durable.
- Plastics show superior optical properties (clarity, gloss and color).
- Plastics can be easily moulded into a variety of shapes and sizes.
- Plastics have excellent mechanical strength (tensile properties, tear resistance and impact resistance).

- Plastics are relatively cheap compared to tin, glass and steel.
- Plastics are reusable and recyclable.
- Plastics have long use life.

- Plastics are good electrical / heat insulators.
- Plastics do not corrode or decay.
- Plastics are cheap and dispensable.
- Plastics are resistant to chemicals, water or grease.

- ***Compounding of polymer***
- Polymer and Additives

➢ Usually, polymers are mixed with added ingredients (serve a variety of purposes)
•Properties of a polymer can often be beneficially changed by combining it with additives

➢ 2 types of additives
  ➢ Modifying additives
  ➢ Protective additives

- Fillers
  – Reinforcing fillers- to toughen polymers. e.g. carbon black added to rubber; improvement in abrasion resistance
  – Non-reinforcing fillers- are in powder, added to cheapen the mix (usually these additives do not enhance the properties). e.g. calcium carbonate.
- Plasticizer- usually non-volatile liquids, desired to increase the flexibility. e.g. flexible plasticized PVC, eg. Tricresyl phosphate, triphenyl phosphate, etc.
- Binders- Hold the constituents together. Eg. Cellulose derivatives. Influence properties of plastics.

- Types of Additives by Function
- •Resin- main constituent.
- Fillers –to strengthen polymer or reduce cost
- •Plasticizers –to soften polymer and improve flow
- •Colorants –pigments or dyes
- •Lubricants –to reduce friction and improve flow, eg. Vegetable oil, soaps, etc.
- •Flame retardents –to reduce flammability of plastic
- •Cross-linking agents –for thermosets
- Stabilizers- Ultraviolet light absorbers –to reduce degradation from sunlight, Antioxidants –to reduce oxidation damage
- Pigments- used to colour the product, eg. Titanium oxide- white color, iron oxide red color, etc.
- Catalyst- accelearate polymerisation, eg. H2O2, benzoyl peroxide, etc.

Fabrication/ Moulding

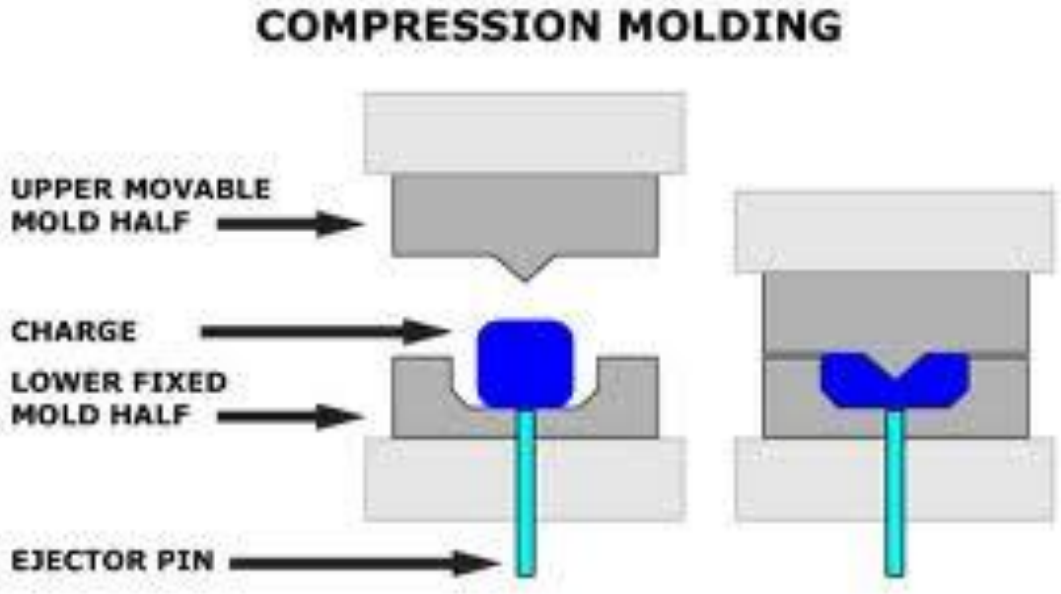
Molding or **moulding** is the process of manufacturing by shaping liquid or pliable raw material using a rigid frame called a mold or matrix. This itself may have been made using a pattern or model of the final object.

A **mold** or **mould** is a hollowed-out block that is filled with a liquid or pliable material like plastic, glass, metal, or ceramic raw materials. The liquid hardens or sets inside the mold, adopting its shape. A mold is the counterpart to a cast. The very common bi-valve molding process uses two molds, one for each half of the object.

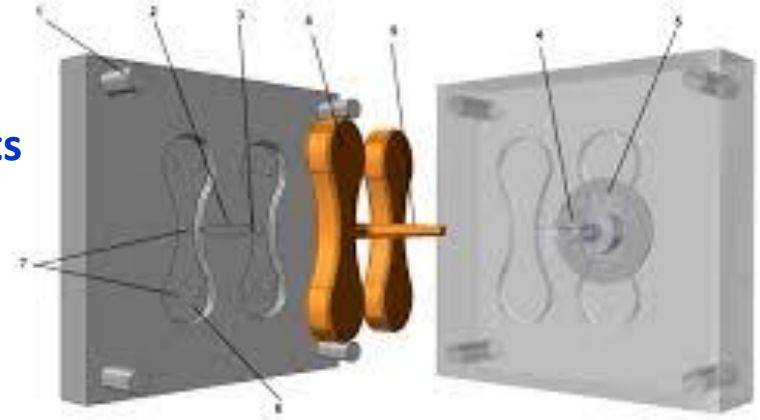
Compression Molding is a process in which a molding polymer is squeezed into a preheated mold taking a shape of the mold cavity and performing curing due to heat and pressure applied to the material.

The method is used mostly for molding **thermosetting resins (thermosets)**, but some thermoplastic parts may also be produced by Compression Molding.

The method uses a split mold mounted in a hydraulic press



Thermoplastic and thermosets



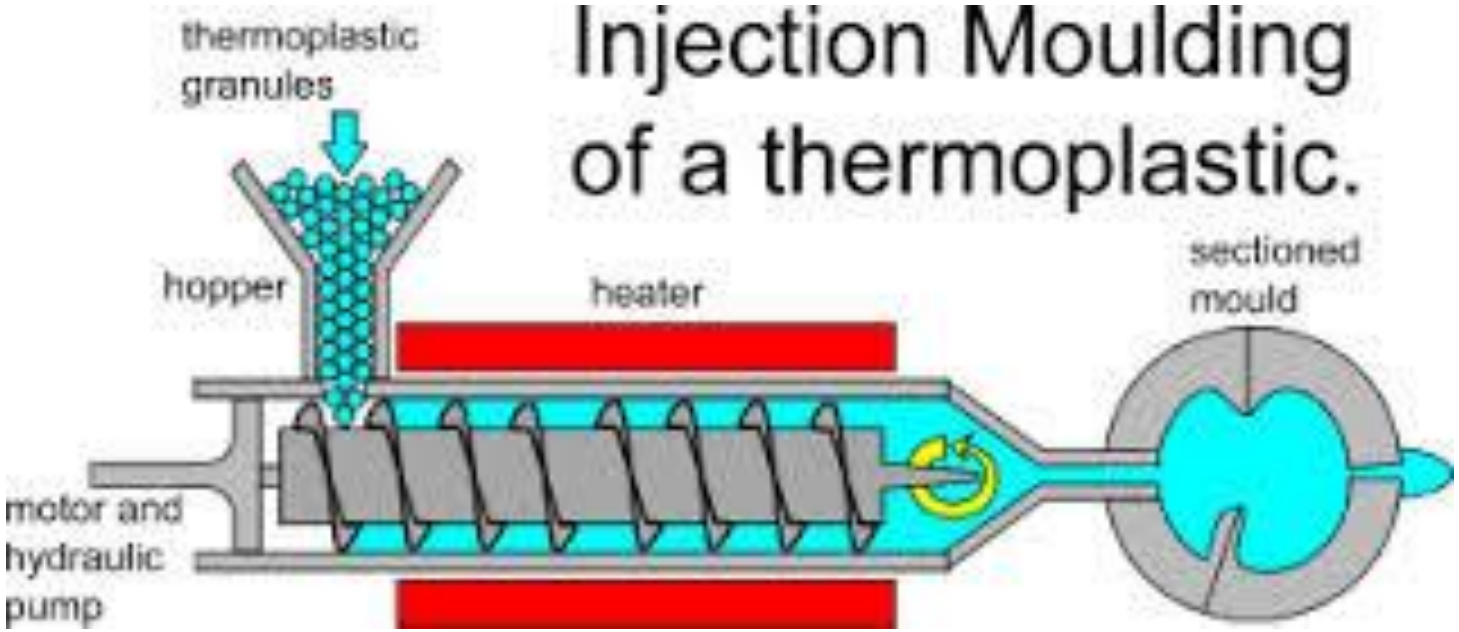
https://www.youtube.com/watch?v=GqE93pbV_9I

Injection molding

- Injection molding is a method to obtain molded products by injecting plastic materials molten by heat into a mold, and then cooling and solidifying them.
  The method is suitable for the mass production of products with complicated shapes, and takes a large part in the area of plastic processing.

Advantages of Injection Molding

- High production rates
- Wide range of materials can be used
- Low labor costs
- Minimal scrap losses



Thermoplastic

https://www.youtube.com/watch?v=b1U9W4iNDiQ

Transfer Molding

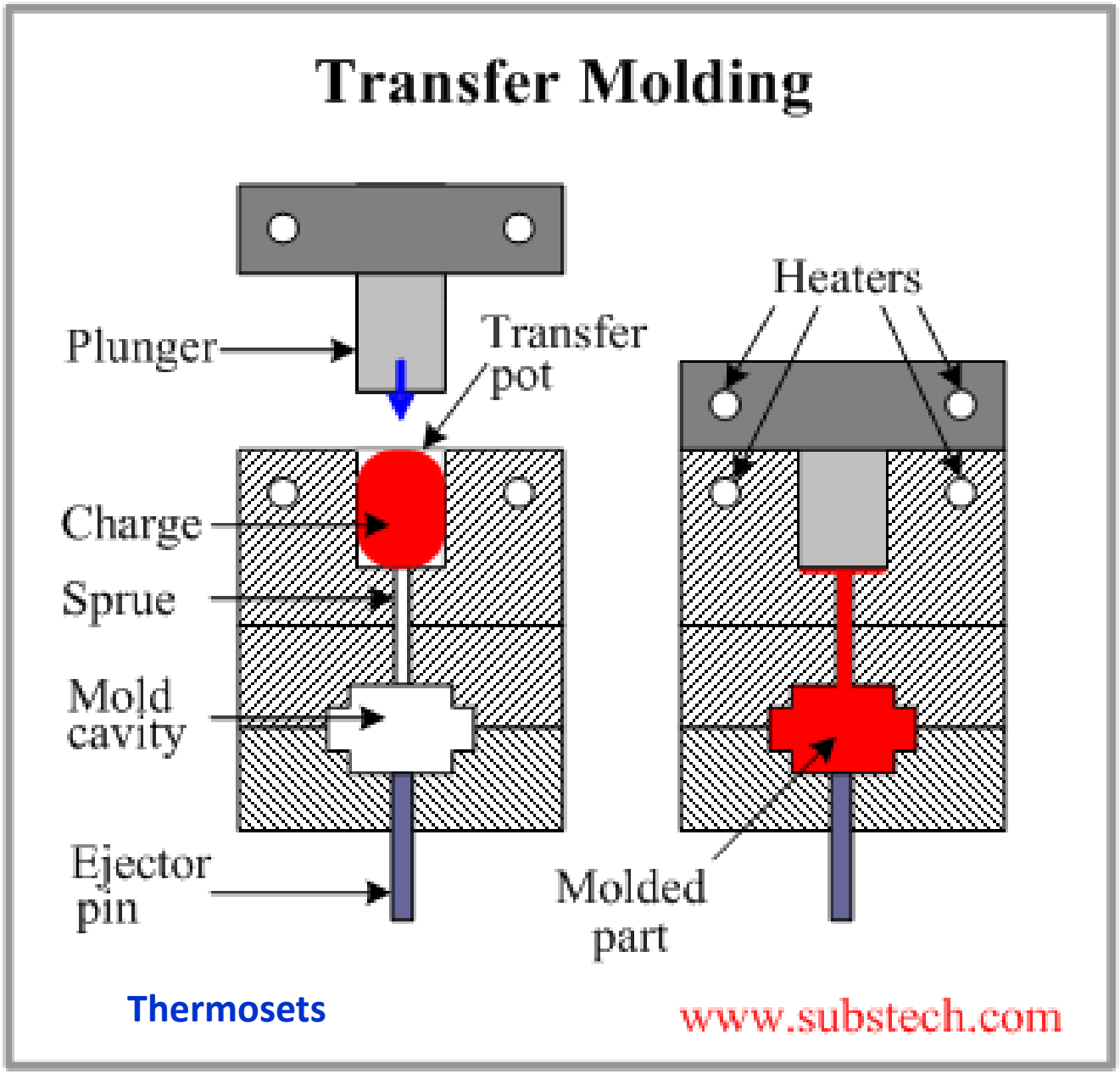
The method is used primarily for molding thermosetting resins (thermosets), but some thermoplastic parts may also be produced by Transfer Molding

The method combines features of both Compression Molding (hydraulic pressing and the same molding materials - thermosets) and Injection Molding (ram-plunger and filling the mold through a sprcue).

TS charge is loaded into a chamber immediately ahead of mold cavity, where it is heated; pressure is then applied to force soft polymer to flow into heated mold where it cures

Two variants:

- Pot transfer molding - charge is injected from a "pot" through a vertical sprue channel into cavity
- Plunger transfer molding – plunger injects charge from a heated well through channels into cavity.



https://www.youtube.com/watch?v=Lp7go_TMe28

Extrusion Molding-

Thermoplastic granules are fed from a hopper by a rotating screw through a heated cylinder.

The tapered shape of the screw compacts the plastic as it becomes plasticized. This part of the process is similar to the heating and compacting stages in the injection moulding process. The difference being that the softened material is allowed to flow out through a die in a continuous stream

(Extrusion moulding) rather than be pumped intermittently in measured amounts into a mould.(Injection moulding)

The die which is fitted to the end of the extruder barrel determines the cross-section of the extrusion.

Widely used for thermoplastics and elastomers to mass produce items such as tubing, pipes, hose, structural shapes, sheet and film, continuous filaments, and coated electrical wire

Carried out as a continuous process; *extrudate* is then cut into desired lengths

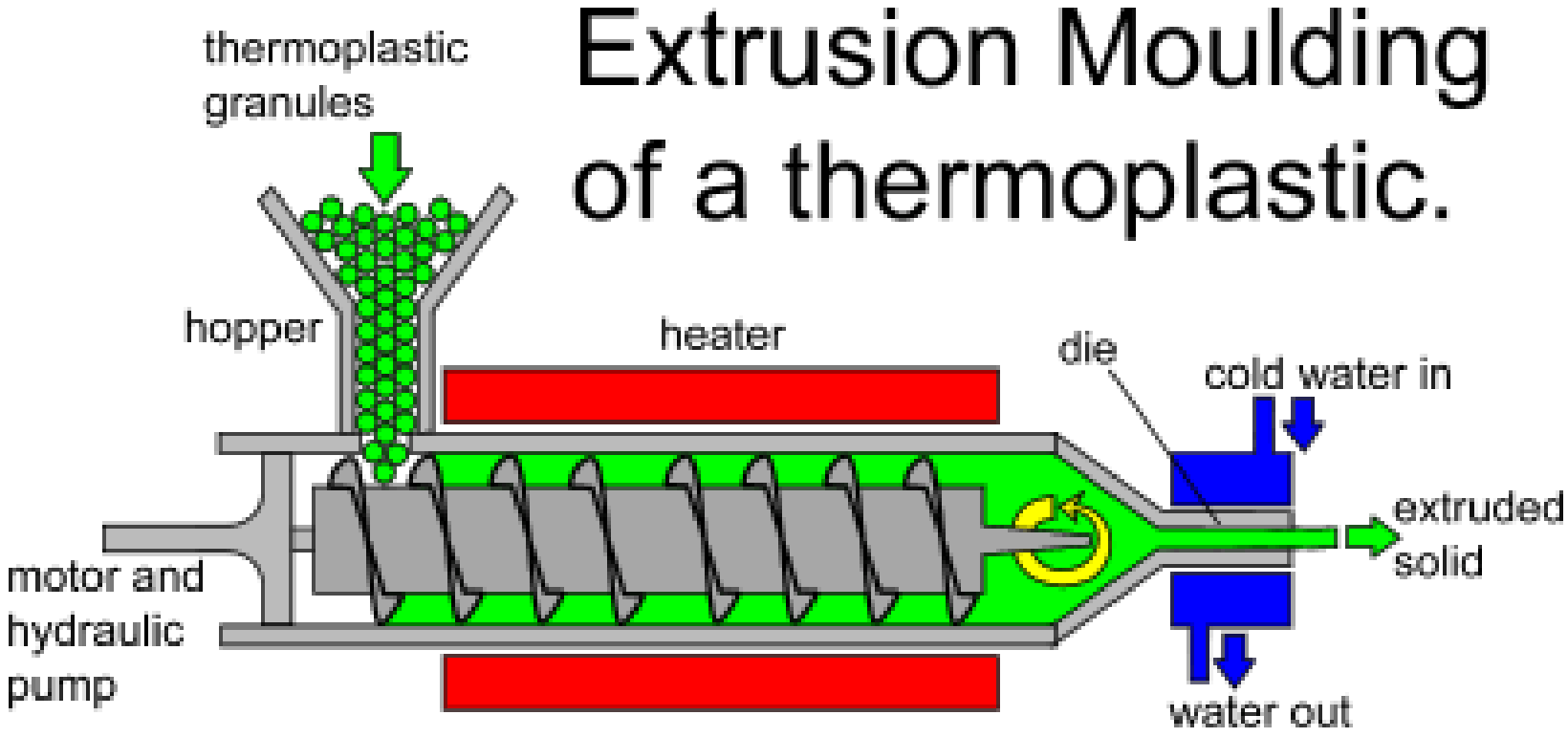
Extrusion

This process can be compared to squeezing toothpaste from a tube. It is a continuous

process used to produce both solid and hollow products that have a constant

cross-section. E.g. window frames, hose pipe, curtain track, garden trellis.

Extrusion Moulding of a thermoplastic.



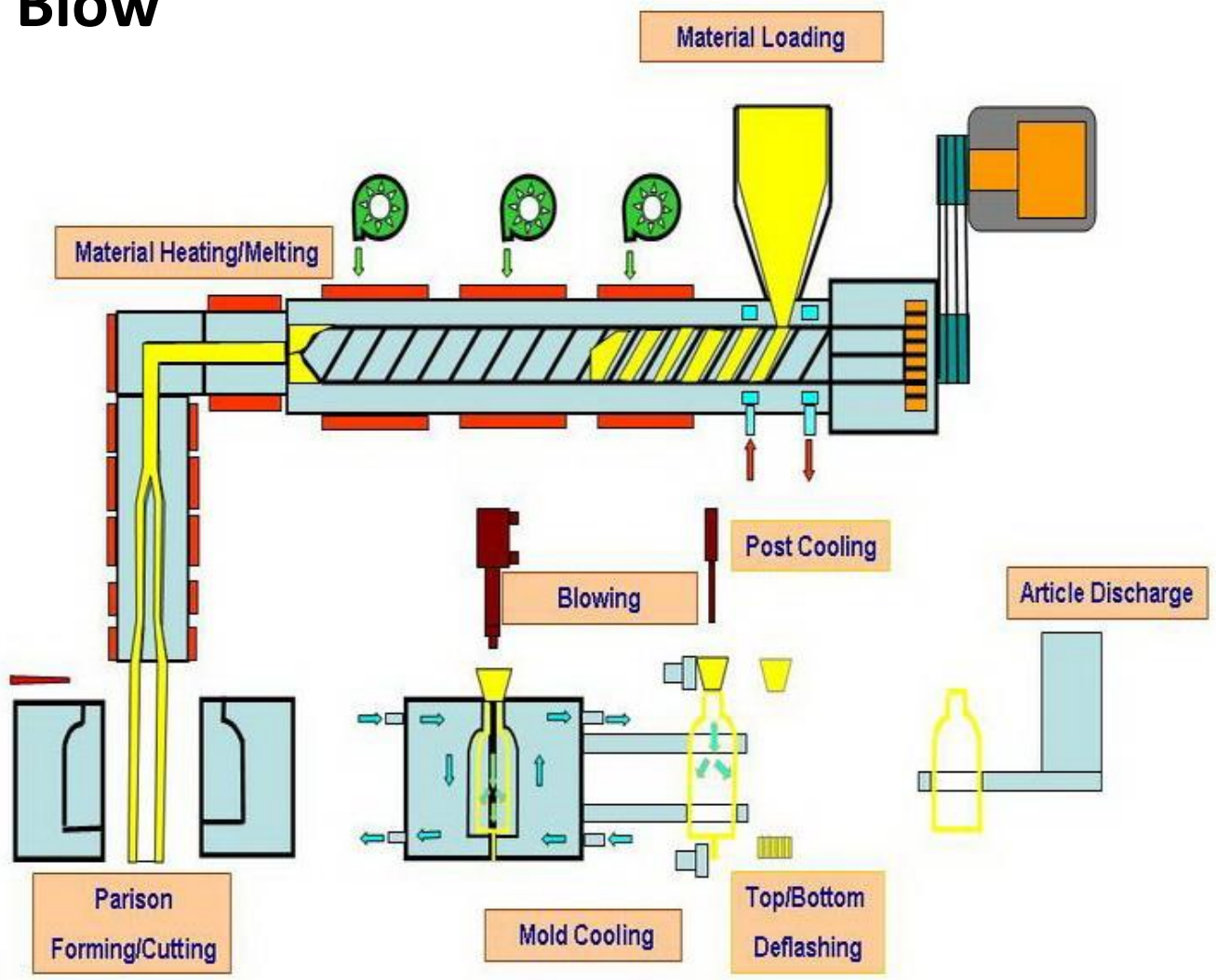
Thermoplastic

- ***Horizontal***

https://www.youtube.com/watch?v=Tp2Rdx69SSo

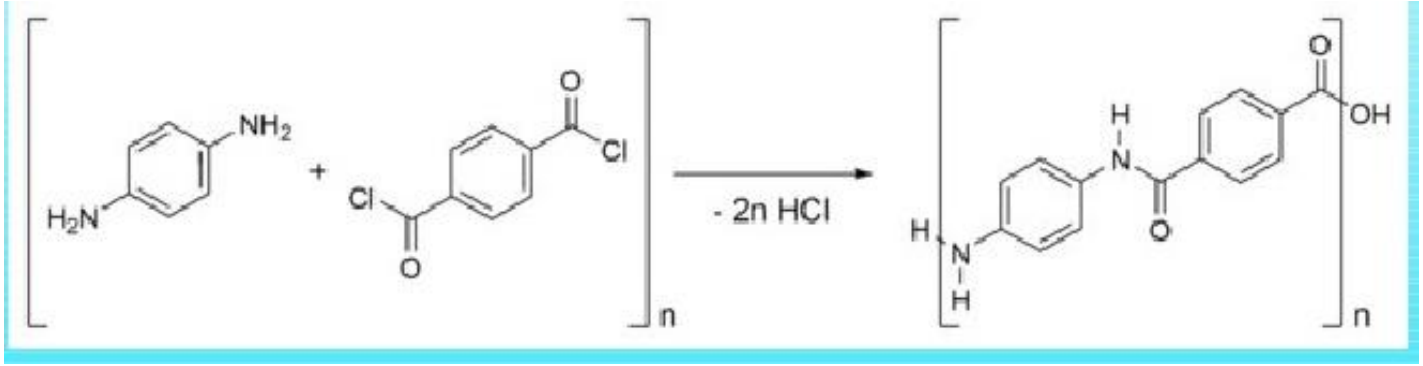
Also called as ‘Extrusion Blow Molding’.

Vertical



https://www.youtube.com/watch?v=xJtyn0vumQU

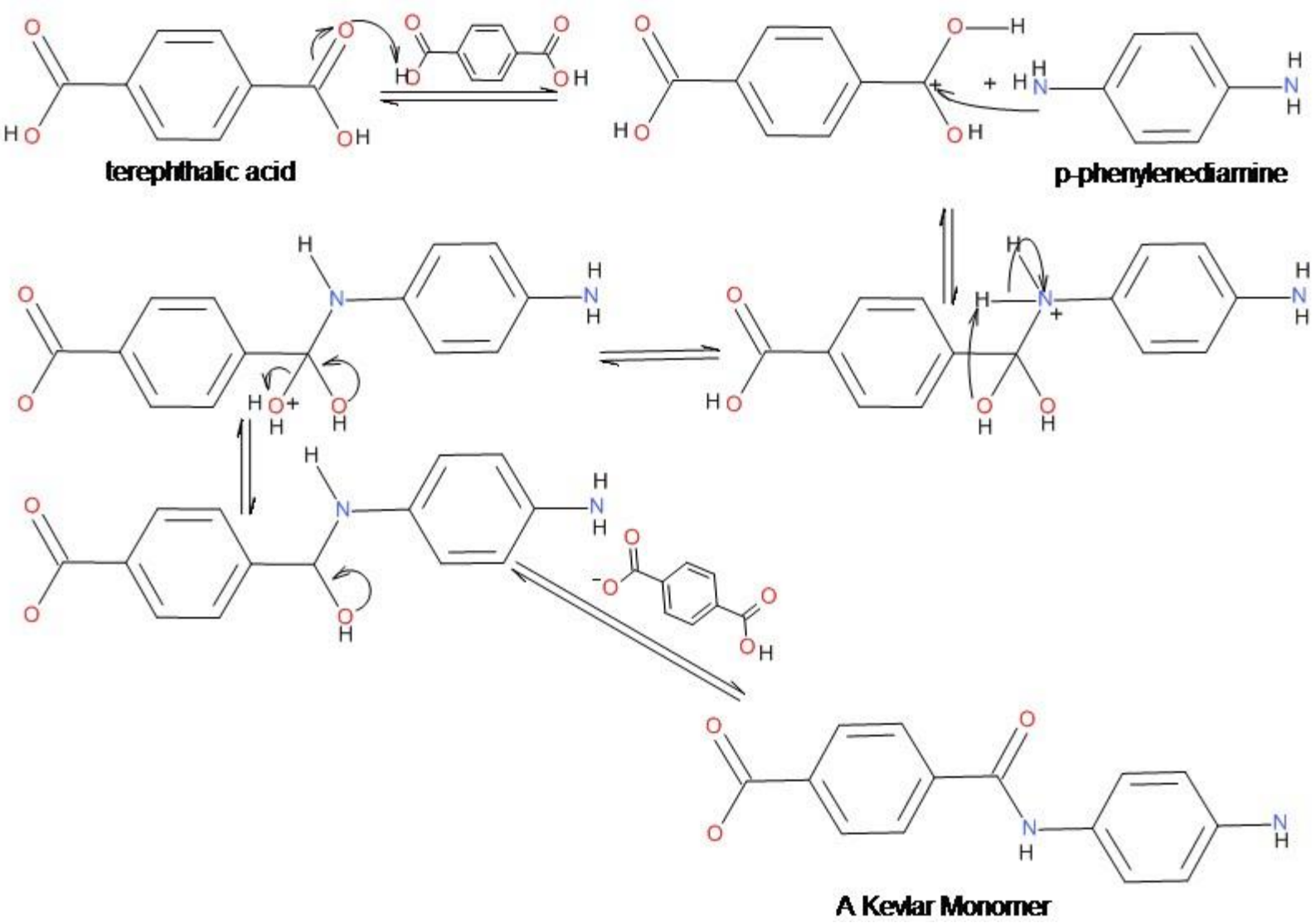
Synthesis of some important polymers- Kevlar



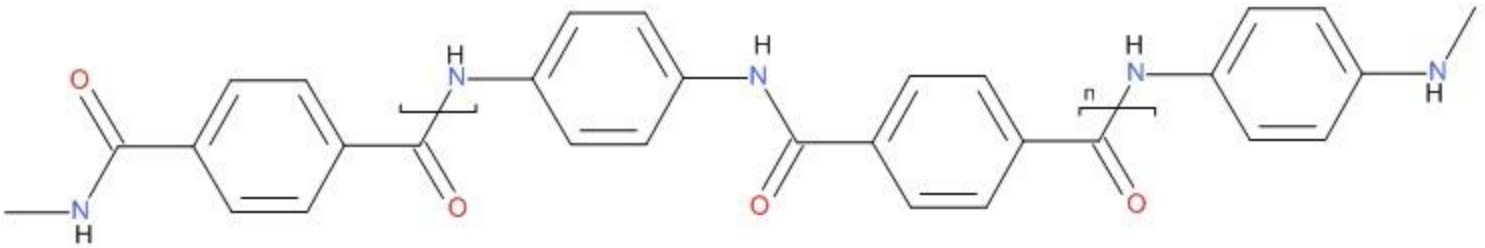
This is a amide co-polymer synthesized by condensation polymerisation of phenylene diamine and terpthaloyl chloride.

Terepthalic acid is used for manufacture of Kevlar but as terepthaloyl chloride is more active than the terephthalic acid, terepthalic aid is converted to terepthalic chloride which is used to manufacture Kevlar.

Condensation mechanism-



Polymerisation



Kevlar

Basic Information

- Kevlar is a high strength material first used in the 1970's.
- It has the iupac name poly(imino-p-phenyleneimino= terephthaloyl)
- Its molecular formula is [-CO-C6H4-CO-NH-C6H4-NH-]n
- It is made up of the monomers 4-phenylene-diamine (*para*-phenylenediamine) and terephthaloyl chloride

- Kevlar's relative molecular mass is 238.241g.
- The glass transition temperature of kevlar is 170 degrees Celsius
- Kevlar is insoluble in water