Module – 7: Polymers

- Difference between thermoplastics and thermosetting plastics; Engineering application of plastics – ABS, PVC, PTFE and Bakelite

- Compounding of plastics: moulding of plastics for Car parts, bottle caps (Injection moulding), Pipes, Hoses (Extrusion moulding), Mobile Phone Cases, Battery Trays, (Compression moulding), Fibre reinforced polymers, Composites (Transfer moulding), PET bottles (blow moulding)

- Conducting polymers – Polyacetylene – Mechanism of conduction – applications (polymers in sensors, self-cleaning windows)

Introduction to Polymers

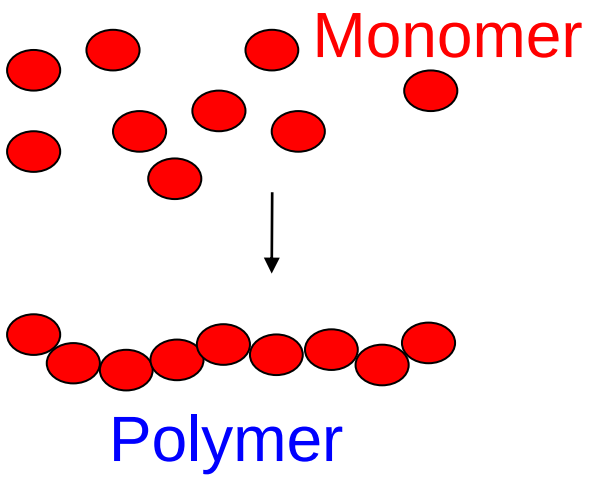
Polymers: Poly + mers

Poly means **many**

mers means **units** or **parts**

Polymers - **Many repeated parts**

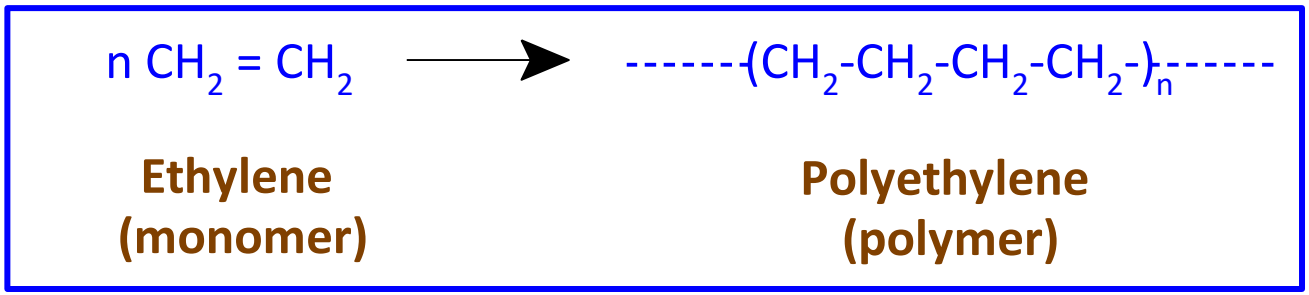
- or **many repeated units**



Definition of Polymer

Polymers are macromolecules (giant molecules of higher molecular weight) formed by the repeated linking of large number of small molecules called **monomers**.

Example:

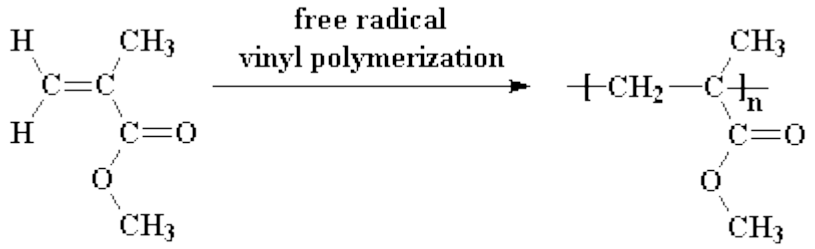


Definition

Polymers are materials made of long, repeating chains of molecules. The materials have unique properties, depending on the type of molecules being bonded and how they are bonded.

Terminology

Monomer	**: one unit**	**(A)**
Dimer	**: two units**	**(A-A)**
Trimer	**: three units**	**(A-A-A)**
Tetramer	**: four units**	**(A-A-A-A)**
Polymer	**: many units**	**(-A-A-A-A-A-A-A-A-A-A-)$_n$**



methyl methacrylate

poly(methyl methacrylate)

Polymer – Classification

Polymers are classified based on different parameters

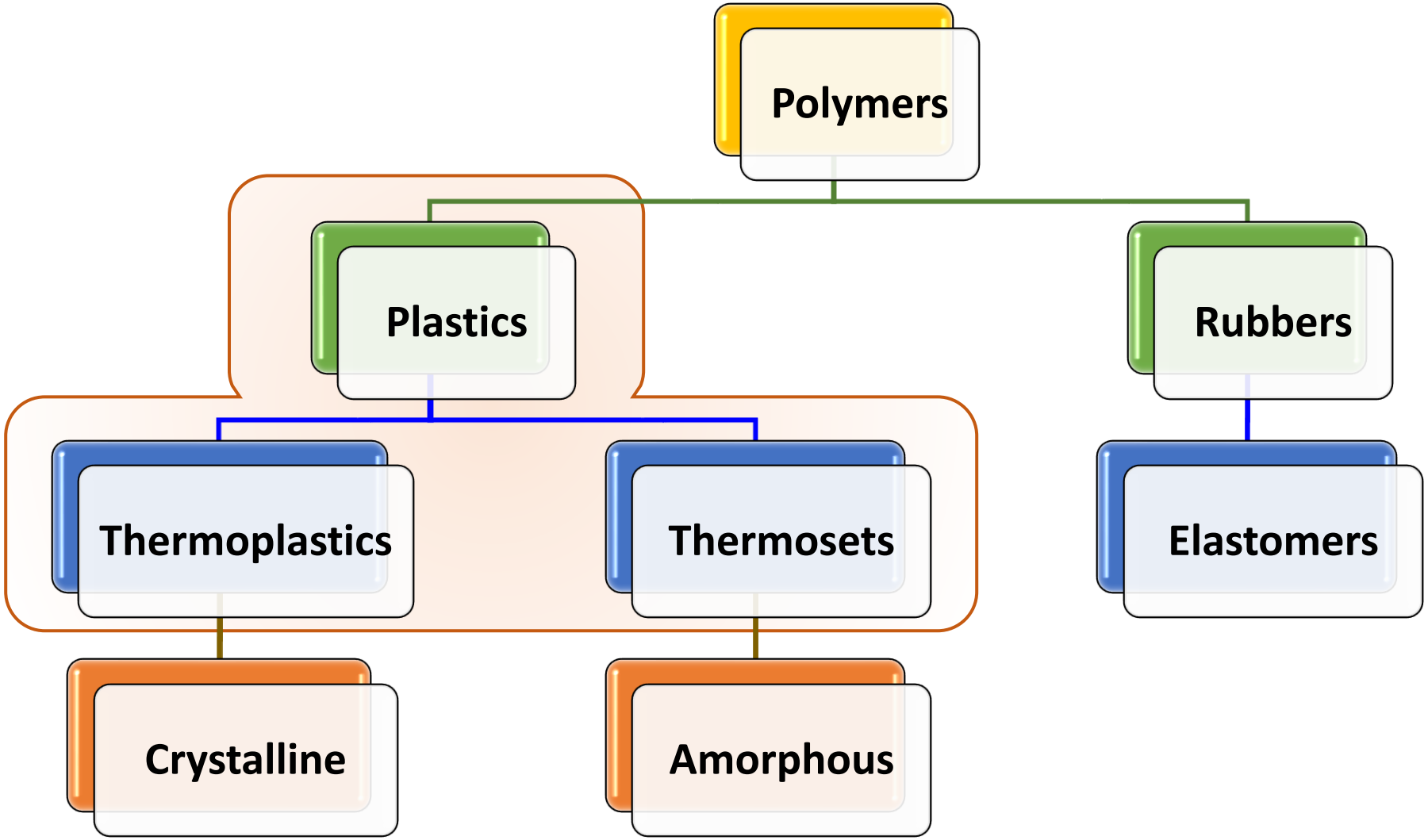
1. Based on "**Occurrence**"
   - Natural polymers (e.g. Silk)
   - Synthetic polymers (e.g. Nylon)

2. Based on "**Type of polymerization**"
   - Addition polymers (e.g. Polyethylene)
   - Condensation polymers (e.g. Polyester)

3. Based on "**Monomeric units**"
   - Homopolymers (e.g. Polypropylene)
   - Co-polymers (e.g. Styrene butadiene rubber)

4. Based on "**Thermal Effect**"
   - Plastics (e.g. Polyvinyl chloride)
   - Rubbers (e.g. Butyl rubber)

Classification – Thermal Effect



Plastics

- Plastics are high molecular weight organic polymer materials, that can be moulded into any desired shape by applying heat and pressure

- Plastics or resins are classified into two types

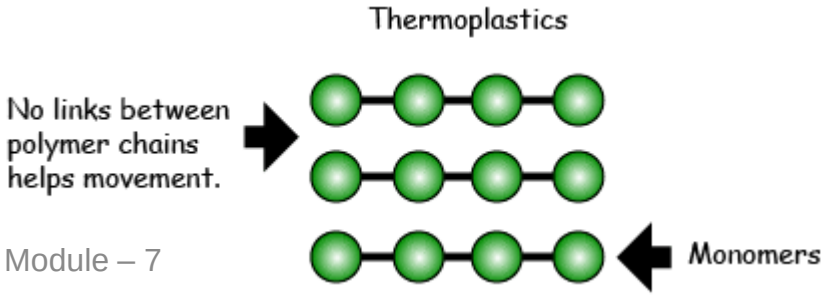
(A) Thermoplastic resins

(B) Thermosetting resins

(A) Thermoplastic resins

- They are prepared by **addition polymerisation**.
- They are straight chain (or) slightly branched polymers and various chains are held together by weak van der Waal's forces of attraction.
- Thermoplastics can be **softened on heating and hardened on cooling**.
- They are generally soluble in organic solvents

e.g. Polyethyene, Polyvinyl chloride

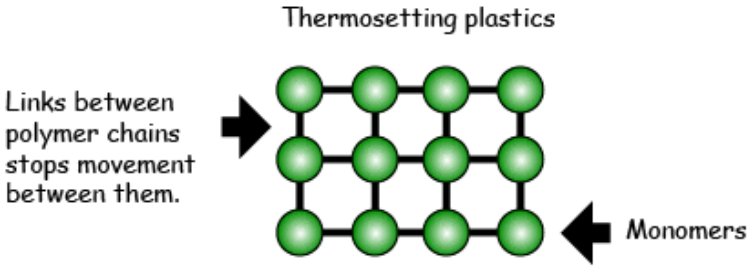


- Heated & Re-moulded 100's of times!!!
- Can also be recycles

(B) Thermosetting resins

- Thermosetting resins (or) Thermosets
- They are prepared by **condensation polymerisation**
- Various polymer chains are held together by strong covalent bonds (cross links)
- Thermosetting plastics get **harden on heating and once harden, they cannot be softened again**
- They are almost insoluble in organic solvents.

e.g. Bakelite, Polyester



Can not be softened

Thermoplastic Vs Thermosetting plastic

Thermoplastic resins	Thermosetting resins
They are formed by **addition polymerisation**	They are formed by **condensation polymerisation**
They consists of **Linear long chain polymers**	They consists of **three dimensional network structures**
All the polymer chains are held together by **weak van der Waals forces**	All the polymer chains are linked by **strong covalent bonds**
They are **weak, soft and less brittle**	They are **strong, hard and more brittle**
They **soften on heating** and harden on cooling	They **do not soften on heating**
They **can be remoulded**	They **cannot be remoulded**
They have **low molecular weights**	They have **high molecular weights**
They are **soluble in organic solvents**	They are **insoluble in organic solvents**
e.g. PE, PVC	e.g. Bakelite, polyester

Plastics - Examples

- Properties & Engineering application of plastics

i. **ABS = Acrylonitrile butadiene styrene**

ii. **PVC = Polyvinyl Chloride**

iii. **PTFE = Polytetrafuloroethylene**

iv. **Bakelite**

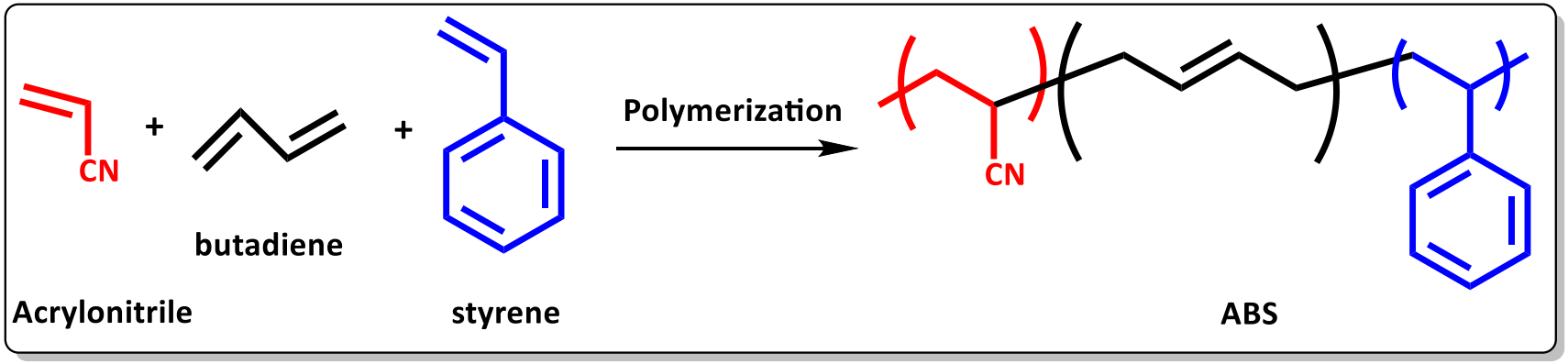
Preparation

Properties

Uses

i. ABS - Preparation

- ABS (**Acrylonitrile butadiene styrene**) is a ter-polymer
- It is polymerized by the polymerization of acrylonitrile, butadiene and styrene



- It is an amorphous and thermoplastic polymer
- Mainly ABS can be prepared in two different grades: 1. for extrusion and 2. for injection moulding.

i. ABS – Properties & Application

- **Properties of ABS**
  - Cost effective
  - Good Impact Strength
  - Good Chemical Resistance
  - High Gloss Surface Finish
  - Good Flexural Properties
  - Can prepare in different grades as per the requirement

ABS can be recycled

- **Applications of ABS**
  - musical instruments (recorders, plastic clarinets, and piano movements)
  - automotive trim components, automotive bumper bars
  - medical devices for blood access
  - White-water canoes
  - buffer edging for furniture and joinery panels
  - luggage and protective carrying cases
  - small kitchen appliances
  - Keyboard keycaps
  - toys, including Lego and Kre-O bricks
  - golf club heads (because of its good shock absorbance)
  - Household and consumer goods

i. ABS – Advantages & Limitations

Advantages

- ✓ Good impact resistance with toughness and rigidity
- ✓ Metal coatings have excellent adhesion to ABS
- ✓ Formed by conventional thermoplastic methods
- ✓ A light-weight plastic

Disadvantages and Limitations

- ○ Poor solvent resistance
- ○ Low dielectric strength
- ○ Only low elongations available
- ○ Low continuous service temperature

Typical Engineering Applications

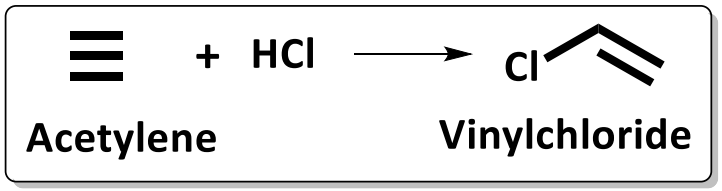
- ➢ Automotive hardware (used in electroplated metal coatings for decorative hardware), appliance cases, pipe, plated items.

ii. PVC – Preparation

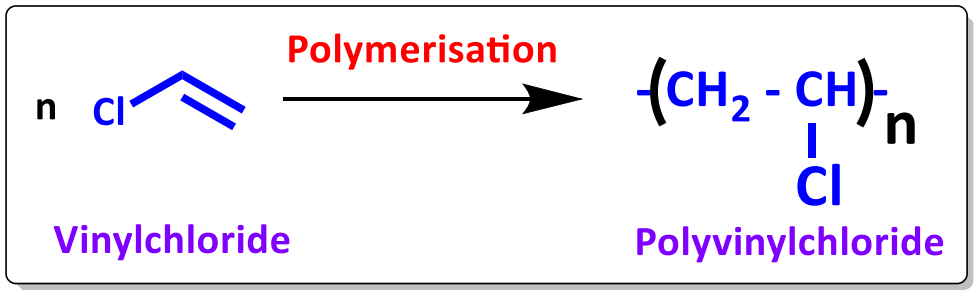
Polyvinyl Chloride (PVC)

Preparation: Preparation of PVC involves the following two steps

Step-1: Vinyl chloride is prepared by treating acetylene with hydrochloric acid at 60-80 ^{o}C in the presence of metal chloride as catalyst



Step-2: Polyvinylchloride is obtained by heating water emission of vinyl chloride in presence of benzoyl peroxide (or) hydrogen peroxide under pressure

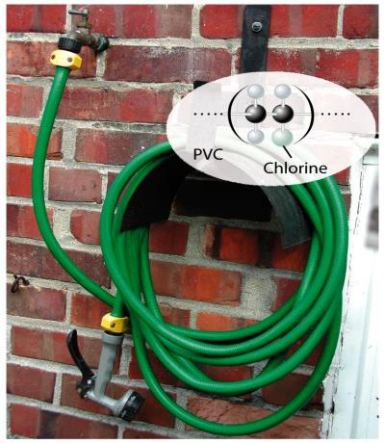


ii. PVC – Properties & Uses

Properties of PVC

1. PVC is colourless, odourless and chemically inert powder
2. It is insoluble in inorganic acids and alkalis, but soluble in hot chlorinated hydrocarbons such as ethyl chloride
3. It undergoes degradation in presence of heat (or) light

Polyvinylchloride (PVC)



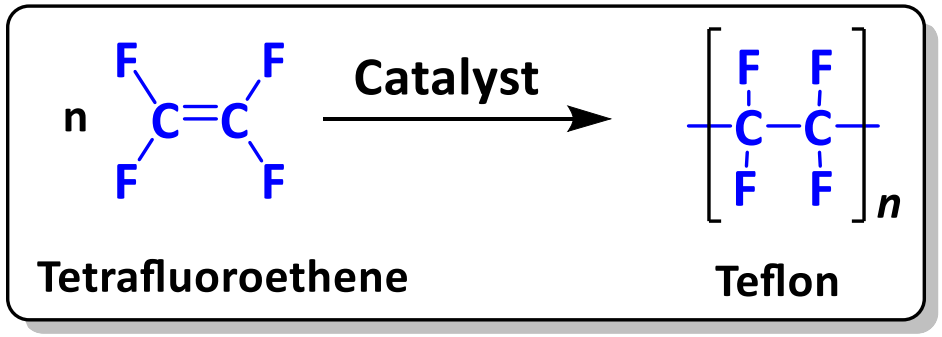
Uses of PVC

1. It is used in the production of pipes, cable insulations, table covers and rain-coats etc.
2. It is also used for making sheets, which are employed for tank-linings, light fittings, refrigerator components, etc.

iii. PTFE – Preparation & Properties

TEFLON

- **The trivial name of PTFE (polytetrafuloroethylene) is Teflon.**
- Teflon is made by the polymerization of tetrafluoroethene as shown bellow.



Properties of TEFLON

- This polymer is a hard, strong, chemically resistant compound with a high melting point and very low surface friction.
- Hydrophobic polymer
- Lowest coefficient of friction against any solids

iii. PTFE – Uses

Uses of TEFLON

- In motors, transformers coils, capacitors, pipes, tanks and storage of chemicals
- Non-stick appliances
- Where TEFLON is used as a lubricant, it reduces friction, wear and energy consumption of machinery.

iv. Bakelite – Preparation

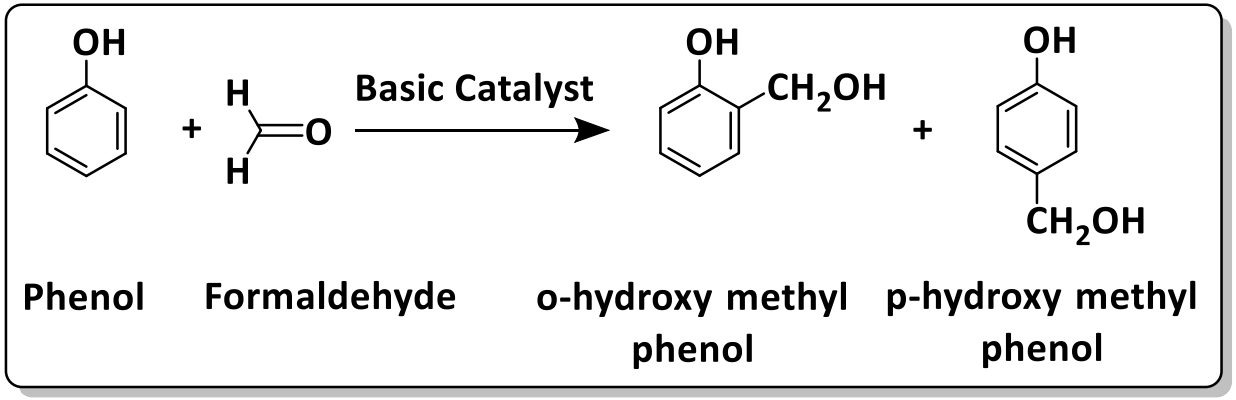
Bekalite is obtained by the condensation polymerisation of phenol and formaldehyde in the presence of acid or alkali catalyst

Preparation

The reaction involves the following **3 steps**

Step-1

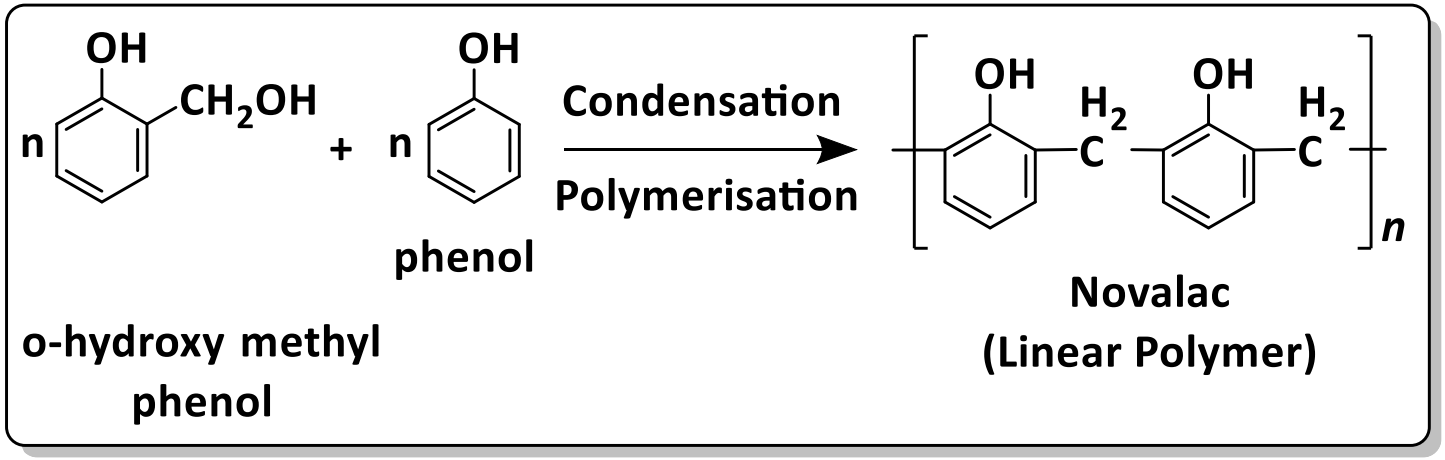
The first step is the reaction between phenol and formaldehyde to produce methylol phenols (mono, di and tri-methylol phenols)



iv. Bakelite – Preparation

Step-2: Synthesis of linear polymer Novolac

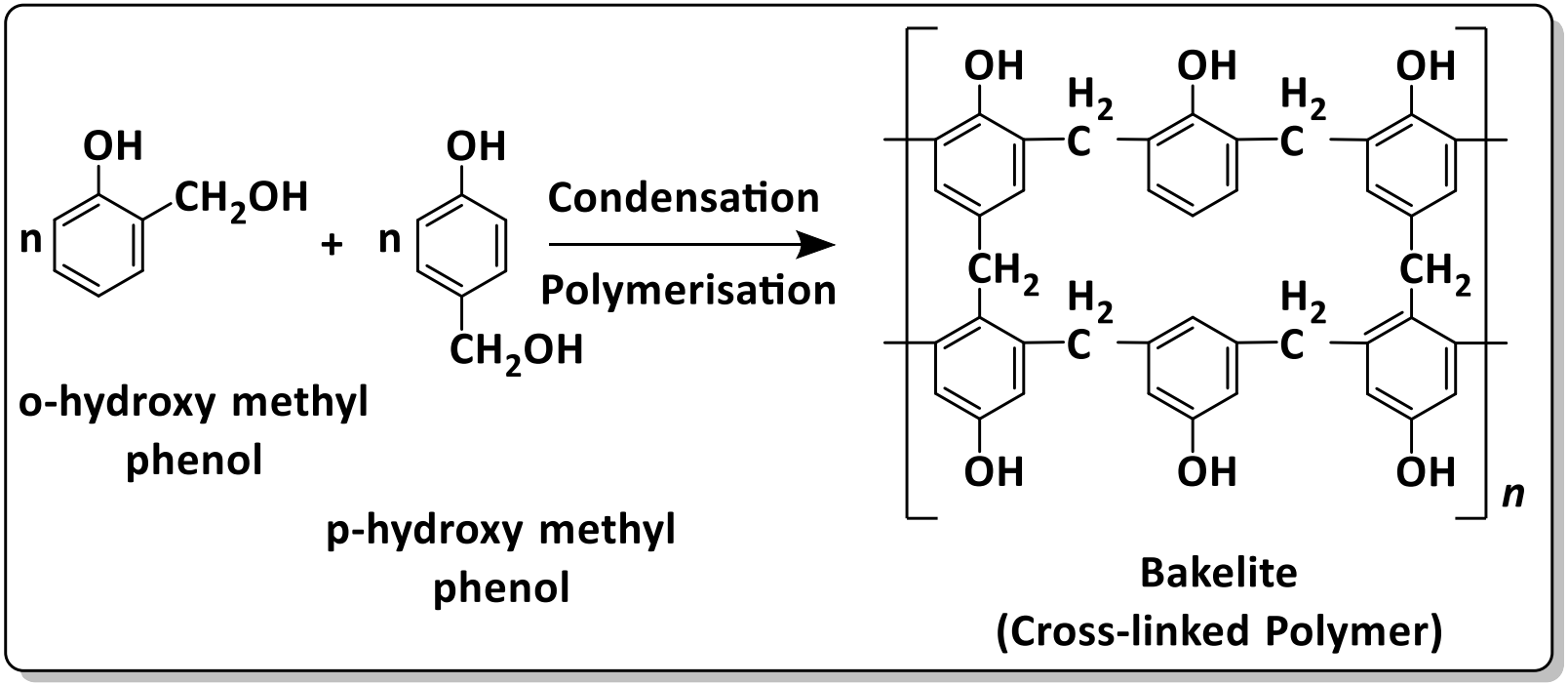
- When methylol phenols are heated with excess of phenol in presence of alkaline catalyst. The methylol phenols condense either through methylene linkages or through ether linkages to form resoles.
- Resole is a low molecular weight linear polymer. It is completely soluble in alkaline solution



iv. Bakelite – Preparation

Step-3: Synthesis of cross linked polymer Bakelite or phenol formaldehyde resin

- By reacting the methylol pheonls in the presence of a curing agent (hexamethylene tetramine) produces hard, rigid, infusible, cross-linked polymer called **bakelite**



iv. Bakelite – Properties & Uses

Properties of Bakelite

- Bakelite is resistant to acids, salts and most organic solvents, but it is attacked by alkalis because of the presence of –OH groups
- It possesses excellent electrical insulating property

Uses of Bakelite

- Bakelite is used as an adhesive in plywood laminations & grinding wheels, etc.
- It is also widely used in paints, varnishes
- Cooker with **Bakelite** Handles
- It is used for making electrical insulator parts like plugs, switches, heater handles, etc.