

## Unit-1

Polymer: Polymers are class of natural or synthetic substances composed of very large molecules, known as macromolecules is called polymers.

### Monomer:

Def: Monomer is defined as a simple molecule with two or more binding sites through which forms covalent linkages with other monomer to form macromolecule is called monomer.

-> Monomers are building block of polymers.  
(or)

Def: The repeating units of polymers forms a large molecule called monomer.

Ex: water, ethanol etc.

Monomer	polymer
Ethylen e	poly thene.
propylen e	poly propylene.
butadiene	poly buta diene.
vinyl chloride	poly vinyl chloride.

### \* Repeat units

Def: A repeat unit, or repeating unit is a part of polymer, where repetition produce the complete polymer chain. It is called repeat units.

→ A repeat unit sometimes called as 'mer'.

### \* Degree of polymerisation :-

Def: The no. of repeating units in a polymer chain is called degree of polymerisation.

Molecular weight of polymer

$$\text{Degree of polymerisation} = \frac{\text{Molecular weight of polymer}}{\text{Molecular weight of monomer}}$$

→ The polymers with high DP called high polymer.

→ The polymers with low DP called oligo-polymers.  
→ Molecular weight range 10,000/-10,00,000.

### \* Classification of polymers

#### 1. Based on occurrence

→ Polymers are again divided into three types

1. Natural polymers: They are found naturally

in plants and animals, resins, etc.

2. Semi-synthetic polymers: They are modified version of natural rubber. Rubber is treated with chemicals to make semi-synthetic polymer.

3. Synthetic polymer: They are completely man-made polymers called synthetic polymers.

Ex: polythene, nylon 66, etc.

## (2) Based on structure

→ # polymers again divided into three types.

1. Linear polymers: They are long and straight chain of monomer. Pvc is a linear polymer.

2. Branched polymer: They are linear polymers contains some branches.

3. Network polymer: The polymer which formed from bi-directional or tri-directional monomer called Network polymer etc.

## 3. Based on Morphology

### A. crystalline

In which molecule folding in regular.

Ex: Nylon, polyester.

### B. Amorphous

In which molecule folding in random.

Ex: polystyrene etc.

## 4. Based on usage

1. Thermoplastics: Thermoplastic polymers can be softened on heating and harden on cooling. called Thermoplastic polymers.

2. Thermosetting polymers: Thermosetting polymer is a permanent setting polymer as it gets hardened and cannot be softened again. called Thermosetting polymers.

3. Fibers: Fibers are made of macro molecules refined as polymer. → polymer fibers are subset of artificial fibers.

4. Elastomers: Elastomer are polymers that have viscosity and elasticity, known as viscoelasticity.

→ Molecules are held together.

## \* polymerisation method

Def: The chemical reaction by which the monomer are combined to form polymers is called polymerisation.

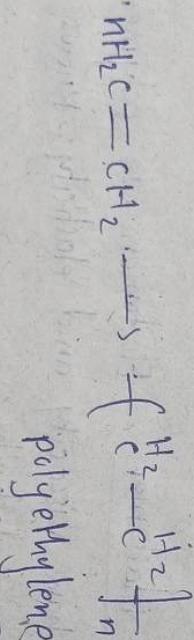
- Types of polymerisation.

### 1) Addition polymerisation

The process in which same monomer is added to the chain to form a polymer is called Addition polymerisation.

→ The molecular weight of polymer is an integral multiple of monomer.

Ex: polymerisation of ethylene



### ii) condensation polymerisation

It is a form of a step-growth polymerisation where smaller molecules react with each other to form larger structural units called as condensation polymerisation.

→ It is also known as step growth polymerisation.

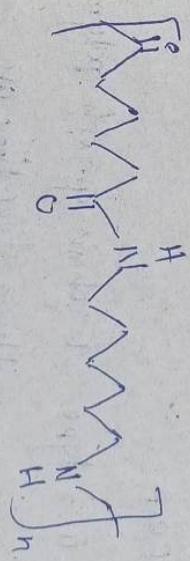
→ The molecular weight of an polymer is not an integral multiple of the molecular weight of monomers.

Ex: Nylon 6-6.

### 3) Co-polymerisation

when two or more different monomer undergo simultaneously polymerisation, is called co-polymerisation.

Ex: Nylon 6-6.



#### ④ Free-radical polymerisation :

Def: A free radical polymerisation is a polymerizing approach by which successive addition of free radicals takes place to form a polymer unit, is called.

F.R.P.

→ It is of two types

1. Cationic polymerisation.

2. Anionic polymerisation.

→ It is of three steps, they are

o Initiation

o Propagation.

o Termination.

o Initiation: Initiation is the foremost

step in polymerisation.

→ One or two radicles created in this, and

transfer to second step.

o Propagation: A polymer spends most of the

time in propagation after initiation.

o Termination: Termination is the final step

in polymerisation.

#### ⑤ Ionic polymerisation :

Def: Ionic polymerisation is a chain-growth polymerisation in which active centers are ions.

1. Cationic polymerisation

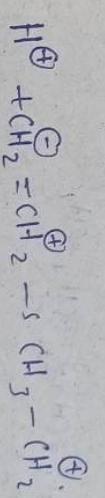
2. Anionic polymerisation.

1. Cationic polymerisation: It is a chain growth polymerisation in which cations transfer charge to monomer, this process is known as cationic polymerisation.

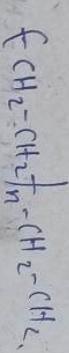
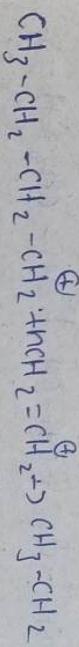
→ In cationic polymerisation three steps

are involved they are

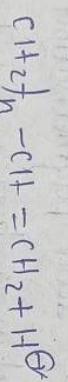
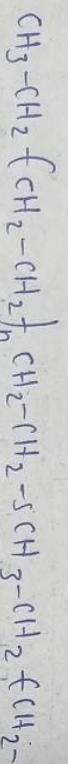
(1) chain initiation.



(2) chain propagation.



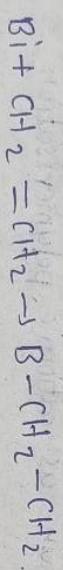
### 3 chain termination



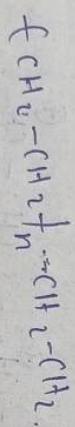
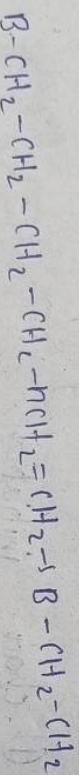
### (2) Anionic polymerisation:

Anionic polymerisation is a form of chain growth polymerisation or addition polymerisation, in which anions transfer charge to monomers. This process is known as anionic polymerisation.

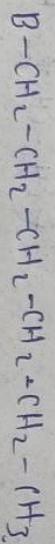
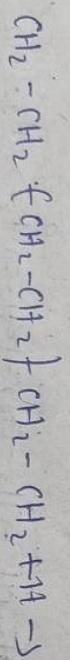
#### 1. Initiation



#### 2. Propagation



#### 3. Chain Termination



## (6) coordination polymerisation

Def.: coordination polymerisation is another variant of addition polymerisation, which is neither free radical, nor ionic. It is called c.p.

→ It is spatially arranged.

→ It is also called as stereospecific polymerisation.

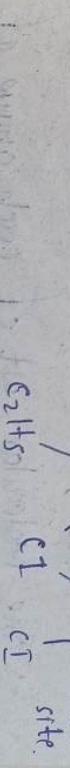
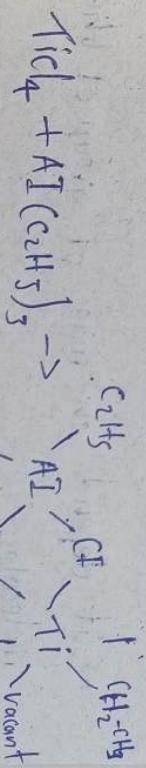
→ Ziegler-Natta polymerisation. Catalyst is used.

→ Coordination polymerisation is used to obtain polymer with very high co-ordination.

-! Coordinative polymerisation is of two types.

a. Heterogeneous - Ziegler Natta polymerisation

b. Homogeneous - Ziegler Natta



## \* Average molecular weight concept.

### 1. Number Average molecular weight

→ It is defined as total weight of polymer molecule to the total no. of molecules is called NAMW.

→ It is denoted by  $\bar{M}_n$ .

$$\bar{M}_n = \frac{\text{wt. of polymer same molecule}}{\text{Total no. of molecules}}$$

$$\bar{M}_n = \frac{n_1m_1 + n_2m_2 + \dots + n_im_i}{n_1 + n_2 + \dots + n_i}$$

$$\bar{M}_n = \frac{\sum m_i n_i}{\sum n_i}$$

### ② Weight Average molecular weight:

→ It depends on mass of group of the molecules.

→ The molecular wt. of each group of molecule is divided by the total mass of the polymer.

→ It is denoted by  $M_w$ .

$$n_1m_1, n_2m_2, n_3m_3, \dots, n_im_i$$

$M_w = \frac{\text{wt. of polymer molecule (molecular wt. of polymer molecule)}}{\text{wt. of polymer molecule}}$

$$M_w = \frac{\sum m_i^2 n_i}{\sum m_i n_i}$$

### ③ Viscosity Average molecular weight

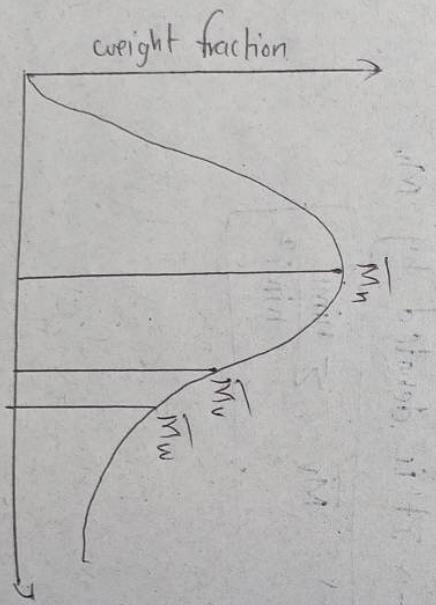
→ Viscosity of polymer depend on concentration and molecular weight of the polymers.

→ It is used to measure molecular weight.

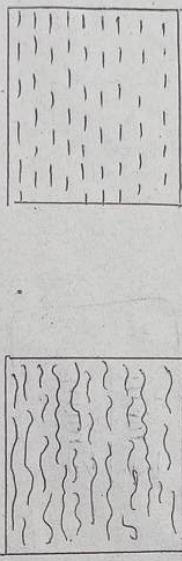
→ It is denoted by  $\bar{M}_v$

$$\bar{M}_v = \frac{\sum n_i m_i^3}{\sum n_i m_i^2}$$

## \* polydispersity and molecular weight distribution



- > In monodispersed all molecules are in same size.
- > In polydisperse all molecules are in different size.

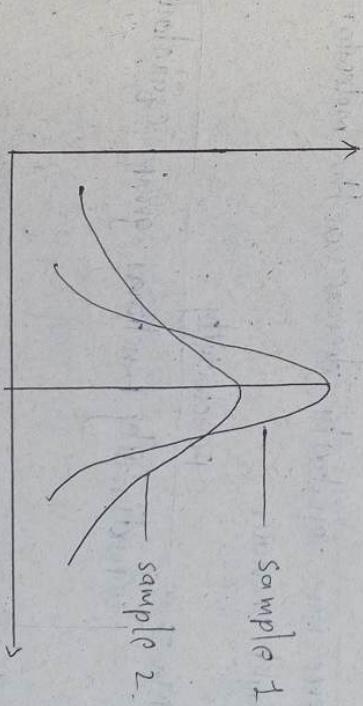


Monodispersed system. polydispersed system.

Polydispersity: It is defined as ratio of weight average molecular weight to the number average molecular weight is called polydispersity.

- > polydispersity gives an idea of the lowest and highest molecular weight.
- > polydispersity is very important parameter.
- > To obtain degree of polydispersity, we can determine  $M_w$  and  $M_n$ .

Molecular weight distribution



→ Fig:

molecular weight distribution of two hypothetical polymer samples having same number of weight but average molecular weight but different polydispersities.

## \* Measurement of molecular weight

### \* End group

- > The end group analysis is a chemical method used to determine the no. average molecular weight of polymers.
- > Ex: carboxyl terminates polybutadiene, hydroxyl terminates polybutadiene.
- > This method is limited to the determination of polymers with a molecular weight of less than 20,000 dalton.
- > Here more sensitivity decreases as the molecular weight increases.

### -> $M_n = \frac{\text{Functionality}}{\text{Unfunctional functional group equivalent}}$

- > values of  $k$  and  $\alpha$  are available for known polymers.
- > By using values of  $k$  and  $\alpha$ , we can determine intrinsic viscosity using eq(1)

## \* Viscosity method

-> The molecular weight obtained by this technique is the viscosity avg. molecular weight.

-> The relation b/w viscosity of a polymer and molecular weight is given by

$$[\eta] = kM^a \quad (1)$$

where  $\eta$  = Intrinsic viscosity

$M$  = Molecular weight

$a$  and  $k$  are constant.

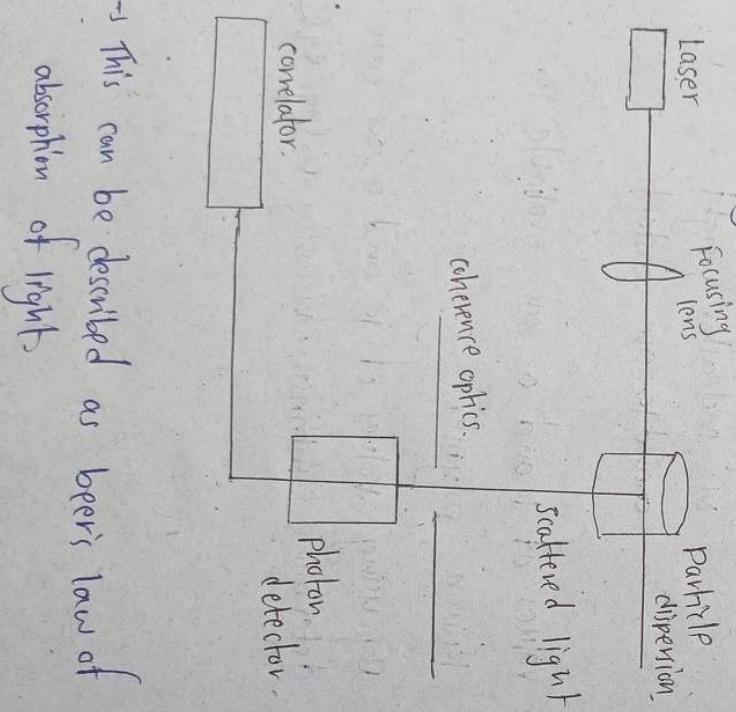
## \* Light scattering

→ Light scattering methods are used for determine weight avg molecular weight (Mw).

→ The light scattering method depends on light.

→ when polarizable particles are placed in oscillating electric field of beam light, then light scattering occurs.

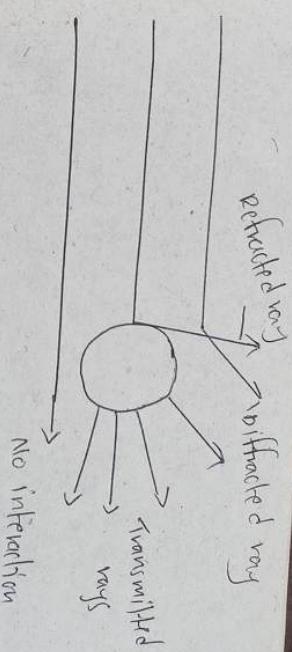
→ Block diagram.



→ This can be described as beer's law of absorption of light.

## \* polymer testing and Analysis

Def polymer testing and analysis employs both physical and analytical methods to verify the chemical, mechanical, and thermal properties of polymeric material



## ①. Degree of polymerisation:

Degree of polymerisation is defined as the no. of monomer units in the polymers is called degree of polymerisation.

$$\text{Degree of polymerisation} = \frac{\text{molecular weight of polymer}}{\text{molecular weight of monomer}}$$

→ weight average molecular weight:

→ It depends on the mass of group of the molecules.

→ The molecular weight of each group of molecule divided by total mass of the polymer.

→ It is denoted by  $M_w$

→  $n_1$  molecule having molecular weight =  $M_1$

$n_2$  "

$n_3$  "

"

"

" " " =  $M_2$

" " " =  $M_3$

## unit-2 (Synthetic polymers)

→ Differences b/w Addition and condensation polymerisation:

Addition polymerisation	condensation polymerisation
→ Addition polymerization produces addition polymers	→ condensation polymerization produces condensation polymers.
→ produces thermo plastic	→ produces thermo setting plastic.
→ Reaction proceeds in a fast manner.	→ Reaction proceeds in a slow manner.
→ proceeds by chain growth mechanism	→ proceeds by step growth mechanism.
→ Involves one monomer	→ Involves two different monomers.
→ Results in homo-chain polymers	→ Results in hetero-chain polymer.
→ No by product.	→ By product produces
→ Ex: PVC, Teflon	→ Ex: Nylon, G.C, Bakelite

## Synthetic polymers

-> Synthetic polymer are derived from petroleum oil, and made by scientist and engineer known as synthetic polymers.

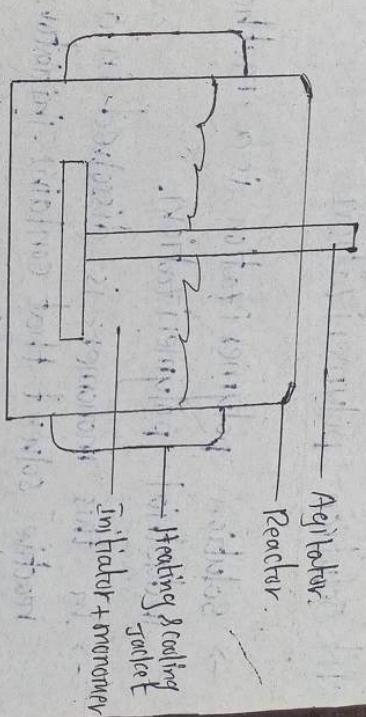
Ex: Nylon, polyethylene, polystyrene etc.

### Polymerisation

-> Polymerization is a process in which small molecule called monomers, combines chemically to form large molecule called polymer, this whole process is called polymerization.

### i) Bulk polymerization

-> Bulk polymerization carried out by adding a soluble initiator to pure monomer in liquid state. is called Bulk polymerization.  
-> Bulk polymerization is also called as mass polymerization.  
-> This method is used for polymerization of liquid state monomers.



### > Advantages

- > simplicity
- > pure polymer is obtained.
- > Disadvantage
- > Highly exothermic
- > very low molecular weight obtained.

### iii) Solution polymerization

- Solution polymerization is a method of industrial polymerization.
  - In this monomer is dissolved in a non-reactive solvent that contains initiator.
  - Finally the result is a polymer.
  - Some disadvantages of bulk polymerization are eliminated by using solution polymerization.
  - It is used in large industrial scale.
  - Below figure shows solution polymerization
- 
- The diagram illustrates a laboratory setup for solution polymerization. A beaker labeled "solution" contains a clear liquid. Three separate additions are shown: "catalyst" is added from a small beaker, "initiator" is added from another small beaker, and "monomer" is added from a third small beaker. Arrows point from each addition point to its respective label.

### Suspension polymerization

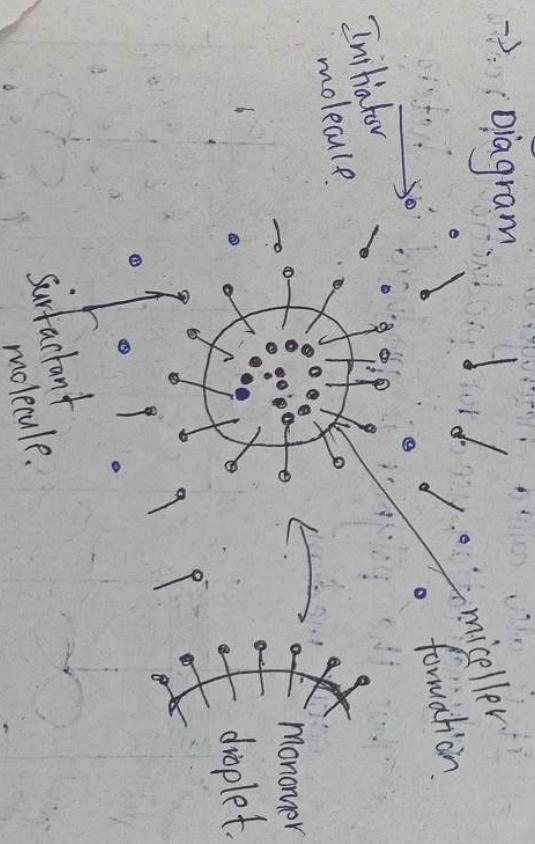
- Emulsion polymerization is the most important technique used for addition polymerization.
- Fine droplets in a large amount of water.

→ The solution is stabilized by the addition of soap (or) detergent.



→ Interact with monomer and resulting polymer.

→ Diagram



### Advantage

- Temperature control is easy → Decrease of monomer
- Stirring is also easy → Environmental pollution.

### Disadvantages

- Explain diagram

→ Advantage

→ Heat can be easily controlled.

→ The rate of polymerization is high.

→ Disadvantages

→ costly

→ Impurity levels are high.

#### IV Suspension polymerization

→ Suspension polymerization is the most

Important technique used for addition

Polymerization

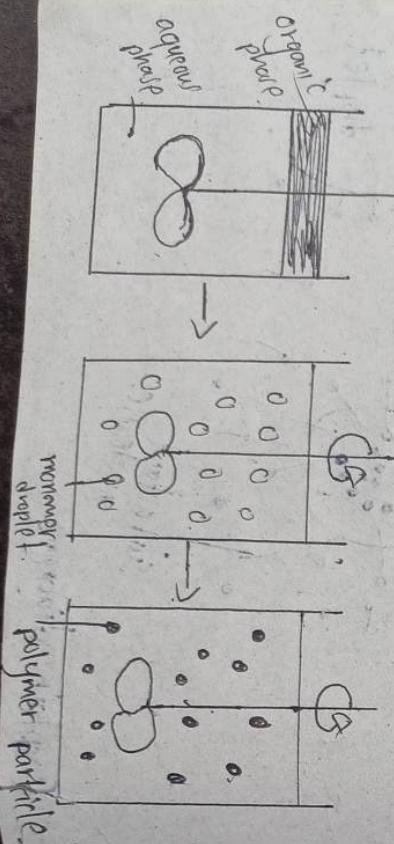
→ The disadvantages of emulsion polymerization

can be eliminated by suspension polymerization

→ It is also called heterogeneous radical polymerization used for production of resins

→ Thus the polymer is produced in hetero-

genous medium.



→ Above diagram shows suspension polymerization process.

→ Advantages

→ Heat can be easily controlled.

→ polymer.

→ Economical

→ Beard size disadvantage.

→ Control of particle size is difficult

→ Applicable water as insoluble monomer

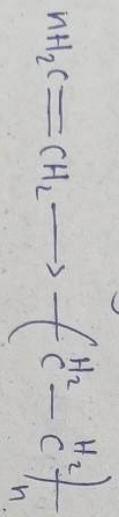
#### Classification of polymers based on physical properties

→ The classification of polymers is classified into four types:

1. Thermoplastics
2. Thermosetting plastics
3. Fibers
4. Elastomers

## 1. Thermo plastics

- > Thermoplastics can be broadly classified as amorphous or crystalline.
- > Molecules in Thermoplastics are held together.
- > Thermoplastics are soft, if they heated after some time, they get their original shape.
- > Thermoplastics are soften by heating and harden by cooling.
- > Thermo plastics are produced by chain polymerization.
- > preparation of thermoplastics.
  - o preparation of polythene



polythene

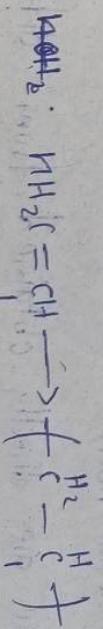
-> polythene used in packaging film, garbage bags, grocery bags, in wires & cables, bottles, toys etc.

## 2. Thermo setting plastics

- > Thermosetting plastics are also known as thermosets or thermosetting plastics.
- > Heavy branched molecules present in Thermosetting plastics.
- > Thermosetting plastics are hard, if they heated up, becomes soft and again becomes very hard.
- > High degree of cross linking bw polymer chains.
- > Network polymer.



- > Thermosets are strong and durable.
- > preparation of vinyl chloride.



CT

PVC

CI

→ vinyl chloride used in windows, roofing, fencing, flooring, wall coverings, etc.

→ general applications: insulators, panels, cooler handles, pistons, etc.

### 3. Fibers

→ Fibers can be generally defined thread-like structure, that are thin, long, flexible, etc.

→ Sources of fibers are: plants, animals.

→ classification of fibers.

on the basis of sources of fibers, they can be classified into two types, they are

#### 1. Natural fibers 2. Man-made fibers

1. Natural fibers: The fibers obtained normally from both plants and animals are known as natural fibers

→ These are directly obtained from different plants and animals.

2. Man-made Fibers: The fibers, which artificially made by human beings are called man-made fibers.

→ The best examples of man-made fibers are: rayon, nylon, polyester, etc.

→ Significance of fiber

o soluble fiber may reduce blood cholesterol and sugar.

o soluble fiber improve blood glucose

Ex:- o Elastomeric materials

o Thermoplastics

o polythene

### → Applications

- o Textiles
- o Industrial Applications
- o Sports Applications
- o Aerospace Applications

#### ④ Elastomers

-> Elastomers are polymers that have viscosity and elasticity.

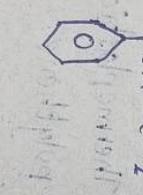
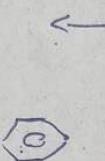
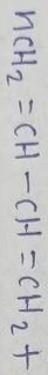
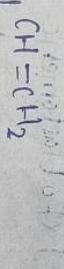
-> Elastomers get back their original shape and size after stretching.

Ex: BUNA-S, BUNA-N

BUNA-S

-> Several properties - high abrasion resistance,

high bearing capacity

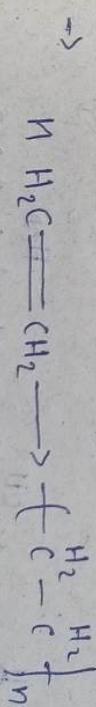


\* Preparation of polymers based on different types of monomer

1. olefin monomers

-> polymerization of polythene

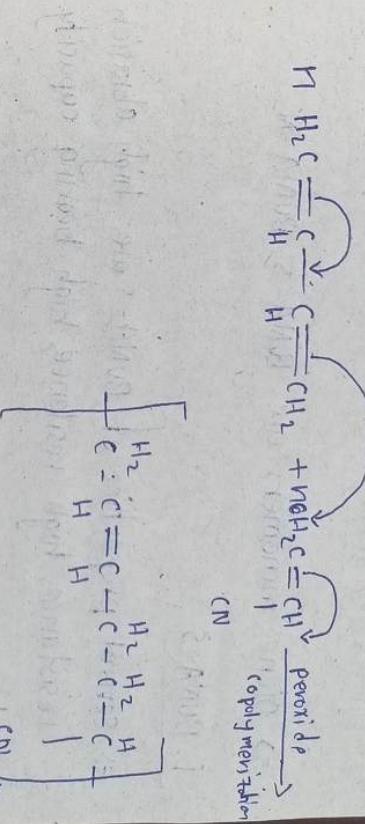
-> To prepare polythene the monomer ethylene is first converted into a polymer.



-> BUNA-N is a synthetic rubber prepared by co-polymerization.

-> catalyst used - peroxide.

-> product formed - co polymer.



## 2. Diene monomers

-> Diene monomers are BUNA-S, BUNA-N.

### i) BUNA-S :

-> Several properties of BUNA-S are, high abrasion resistance, high resilience, high bearing capacity etc.

### ii) BUNA-N

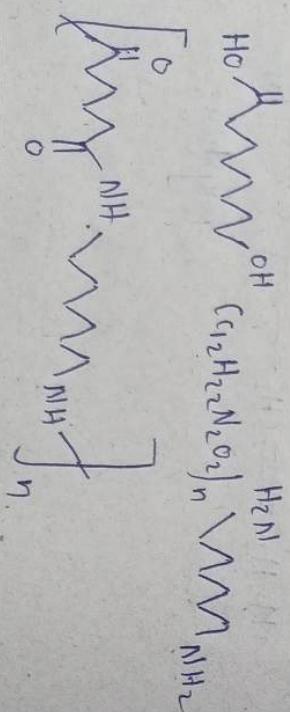
Answer in last page

### (3) Nylons:

-> When two or more different types of monomers undergo polymerization is called co-polymerization.

-> The properties of co-polymer and individual polymer are different.

-> Eg: Nylon 6-6.

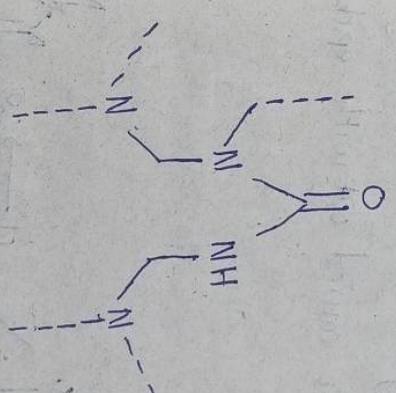


## 4. Urea-formaldehyde

-> Urea-formaldehyde is a class of synthetic resins obtained by chemical combination of urea and formaldehyde.

-> Urea-formaldehydes are used as adhesives.

### -> chemical structure



### (5) phenol-formaldehyde

-> Bakelite is obtained the condensation of phenol and formaldehyde in the presence of acid.

-> Chemical formula -  $\text{C}_8\text{H}_6\text{O}_2$ .

-> It is a synthetic polymer.

-> The reaction of phenol and formaldehyde produces thermosetting polymers.

→ Applications

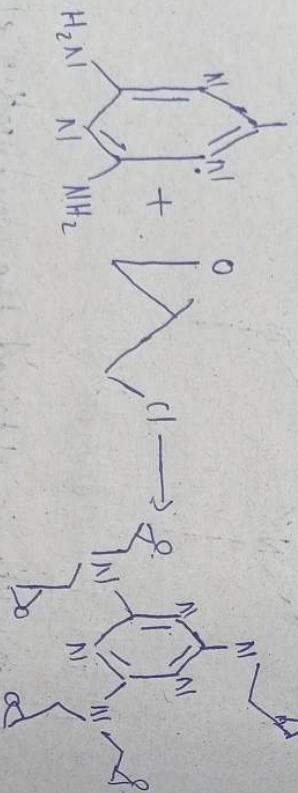
- o Vacuum cleaner.
- o Cameras
- o Handles
- o Buttons etc

(6) Melamine Epoxy

- The Epoxy polymers are basically polyethers.
- The reaction is carried out with epichlorohydrin.

- preparation.

NH<sub>2</sub>



(1) cation exchange resin

cation exchange resins contain positively charged functional groups, which attract negatively charged ions in solution.

→ They contain amine functional group.

\* Ion exchange resins

Def An Ion exchange resin (or) Ion exchange polymer is a resin (or) polymer that act as medium for Ion exchange.

→ The Ion exchange resin is a insoluble matrix.

→ It is a white or yellowish in colour.

→ It is in small size.

→ Ion exchange resins are used in separation, purification, decontamination etc.

→ Types of ion exchange resins

1. cation exchange resin.
2. Anion exchange resin.

→ It is again classified into two types

- o strong acid cation resins: They are made up of polystyrene and sulfonate functional group.
  - charged with  $H^+$  and  $Na^+$  ions.
  - o weak acid anion resins: They consist of polystyrene matrix acrylic polymer with carboxylic functional groups.
- ② Anion exchange resins: Anion exchange resins contains negatively charged functional groups which attract freely charged ions in solution.
- It is again classified into two types:
  - o strong base anion resins: They consist of polystyrene matrix.
  - o weak base anion resins: They are also consist of polystyrene matrix. Regulated and controlled by pH of the solution.

→ Ion exchange resins Applications

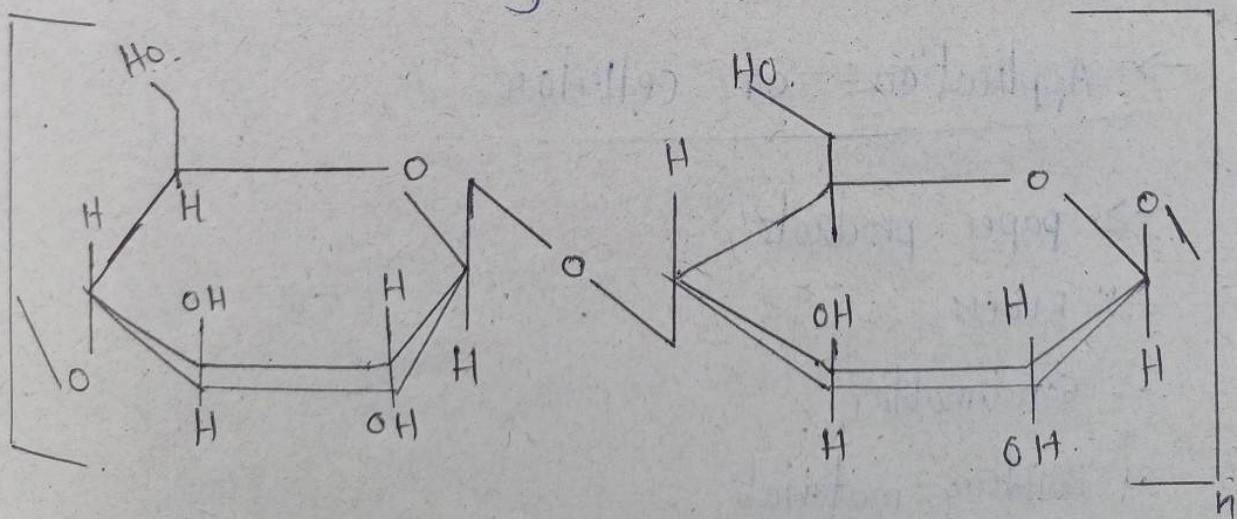
- o Ion exchange resins have wide range of Applications.
- o Biodeisel filtration
- o water softening
- o removing impurities
- o Demineralization
- o catalysts
- o metal separation etc.

## UNIT-3 (PART-1)

Natural polymers Natural polymers are defined as, they are found naturally in nature like plants, animals, and resins etc called natural polymers.

### I cellulose :

- cellulose first discovered by french chemist payen,
- cellulose is the organic compound on the earth.
- cellulose  $(C_6H_{10}O_5)_n$ .
- cellulose consist of oxygen, carbon, hydrogen and it is tasteless and no odour.
- Main sources of cellulose - Bamboo, cotton, jute etc.
- chemical and physical structure.



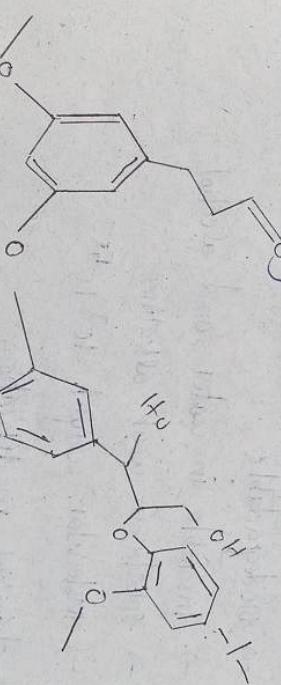
## -> Properties of cellulose

- > properties of cellulose depends on degree of polymerisation.
- > odourless.
- > Tasteless.
- > Insoluble in water.
- > Biodegradable polymer.
- > physical state - white powder.
- > Chemical modifications.
- o Ethyl cellulose formation
  - > when cellulose and alkali and ethyl chloride react together at 100°C cellulose is formed
- > Ethyl cellulose is a tough and flexible polymer.
- > less inflammable.

- ## -> Applications of cellulose
- > paper products
  - > fibers.
  - > Consumables
  - > Building materials

## 2. Lignin

- > chemical and physical structure.



-> Lignin is a class of complex organic polymer.

-> Lignin is present in wood to provide structural support.

-> Lignin is a hydrophobic, it requires efficient water.

-> Main source of Lignin.

Biomass sources can be hard wood, softwood, herbaceous plants.

## o properties

- > Colourless or white colour.
- > Biodegradable.
- > Insoluble in water and alcohol.
- > Soluble in weak alkalines.
- > Molecular weight  $10^3$  -  $10^5$ .

## o chemical modifications

- > The he lignin can be easily modified for the development of new materials.
- > lignin can be used with GPT without chemical modification.

## o Applications

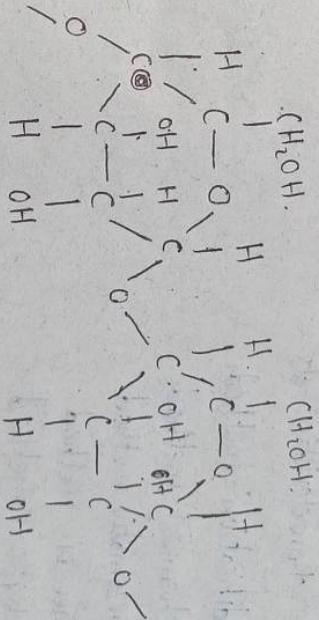
- > for power generation.
- > Fuel combustion.

- > Nanoparticles.
- > super capacitor.
- > polycatalyst, etc.

## 3. Starch

-> starch is a complex carbohydrate that exist in many foods including, vegetables, fruits etc.

## -> Structure of starch



-> The main sources of starch are maize, tapioca, wheat, potatoes etc.

## o properties

- > High viscosity.
- > good swelling power.
- > good iodine binding ability.
- > lower water absorption capacity.
- > Act as Emulsifier.
- > Easily digestible.
- > tasteless
- > odourless

## Chemical modification

- > ~~starch~~. In starch, if chemical modification is done, properties will increase.
- > For example, increased digestion, emulsifying gel characteristics etc.
- > Modification methods
  - o chemical method
  - o Enzymatic method
  - o Genetic method
  - o physical method

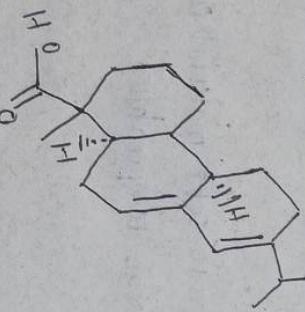
## Applications

- > Applications are of three types.
- o Applications of Native starch.
- o Applications of hydrolysed starch.
- c. " modified starch.

## Properties

- > Rosin is brittle and flammable.
- > It is typically glassy solid.
- > Soluble in alcohol, benzene, chloroform etc.

## Structure



- o Applications
  - > used in soap, soda, wax, varnishes etc.
  - > In medical - lenses
  - > In soft drinks
  - > ointments.

## (4) Rosin

- > Rosin is a form of resin obtained from plant, pines etc.
- > It is typically glassy solid.
- > Rosin contains different resin acids.

## (5) Shellac

- o shellac is a resin substance obtained from the lac insect, used for varnish it is called shellac.

### o structure of shellac

- > shellac is refined from polyester type of resin.
- > shellac is also called as shellacite.
- > shellac colour is lacquer.
- > shellac is a natural polyester.

### o Main source

- > shellac main source is lac insect.

See lac.

- > shellac is soft material and becomes rigid at room temperature.

### o properties

- > It is a natural form of plastic.
- > Biodegradable polymer.
- > synthetic polymer,
- > It is soft material

- > Non conductor.
- > oil resistance.
- > Insoluble in water.

### o chemical modification

→ modification of lac has been increased its

properties.

- > performance increases.
- > modified with various oils.

### o Applications

- > used as 'wax'
- > Food coatings
- > cosmetics
- > varnishes
- > tannin blocker
- > odour-blocker

## (6) vegetable oils

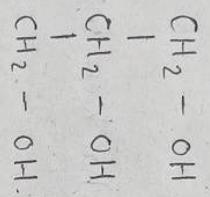
- > vegetable oils are extracted from various types of fruits, nut, and grains.

- > The most consumed oils are, sunflower, palm, coconut, corn, peanut, cottonseed etc.

- > vegetable oils are used to cook food.

## o Structure of vegetable oil

-> Ex: Triglyceride



## o Applications

- o Main source
  - > Vegetable oil main source is seeds, fruit, nuts, grains etc.
- o properties
  - > Vegetable oils composed of triglycerides.
  - > used in making food, and for hair growth.
  - > vegetable oils are liquid sticky oils.
  - > The fatty acids in triglycerides may be same or different.

## o paints.

-> For cooking food.

## (7) Gums:

-> Gums can be derived from plant endosperm, plant exudates etc.

-> Gums are wasteage of plant.

## o structure of gums.

-> The fats and oils obtained from their resources are used directly but, chemical modification is done for refinement.

- > gums are produced by duct structure.
- > gums don't have any particular shape.
- > from plant gums arrive like liquid drops.

## - Typical modifications

### o Alkaline Hydrolysis

### o Hydrogenation

### o Transesterification

but after coming out from wood, becomes hard.

→ when plant got injury, gums will come out.

### o Main source

→ Gums are mainly always derived from plant, only.

### o properties

- Soluble in water.
- forms as gel.
- High molar mass
- Gums are complex carbohydrates.
- Black or Brown in colour.
- sticky nature.

### o chemical modification

- Gums are naturally occurring component in plants
- Gums are cheap and plentiful
- Gums to be modified to alter their properties

## o Applications

- o protein drug delivery
- o Transdermal drug delivery
- o Anti-hypertensive drug delivery
- o Colon targeted drug delivery

## ⑧ proteins:

- proteins are polypeptide structures consisting of one or more long chains of amino acid residues is called proteins
- proteins are naturally occurring, complex substance.
- proteins present in all living organisms.

### o structure of proteins

→ The scientist Lindstrom suggested protein structure with four levels, they are.

- o The primary structure
- o The secondary structure
- o The tertiary structure
- o The quaternary structure

## o Main source

- > chicken, duck, turkey, seafood, fish, birds, prawns, crab, eggs, mille cheese etc

## o properties of proteins.

- > forms colloidal solutions in water.
- > solubility depends on electrostatic charges.
- > Net charge depends on number
- > molecular weight
- > shape
- > colour reactions of proteins.
- o chemical modifications
- > In proteins - chemical modification increases the properties of proteins.
- > proteins helpful for growth and strong and healthy health.
- > Acetylation, glycosylation are some of well known examples within the process.
- o Applications:
  - > Emulsification
  - > Solubility

## Unit - 3 (PART-II)

### Ethyl cellulose

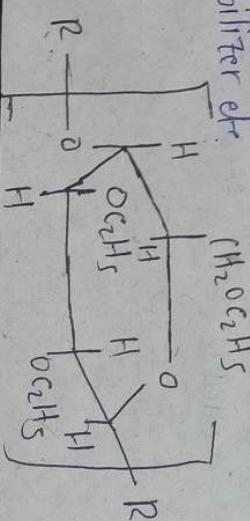
-> Ethyl cellulose is a derivative of cellulose in which some of hydroxyl groups are converted into ethyl ether groups called Ethyl cellulose

-> The No. of ethyl groups can vary depending on manufacturer.

-> Ethyl cellulose is also used as an emulsifier.

-> Ethyl cellulose is used as coating material for tablets and capsules.

-> Ethyl cellulose is used as binder, thickener and stabilizer etc.

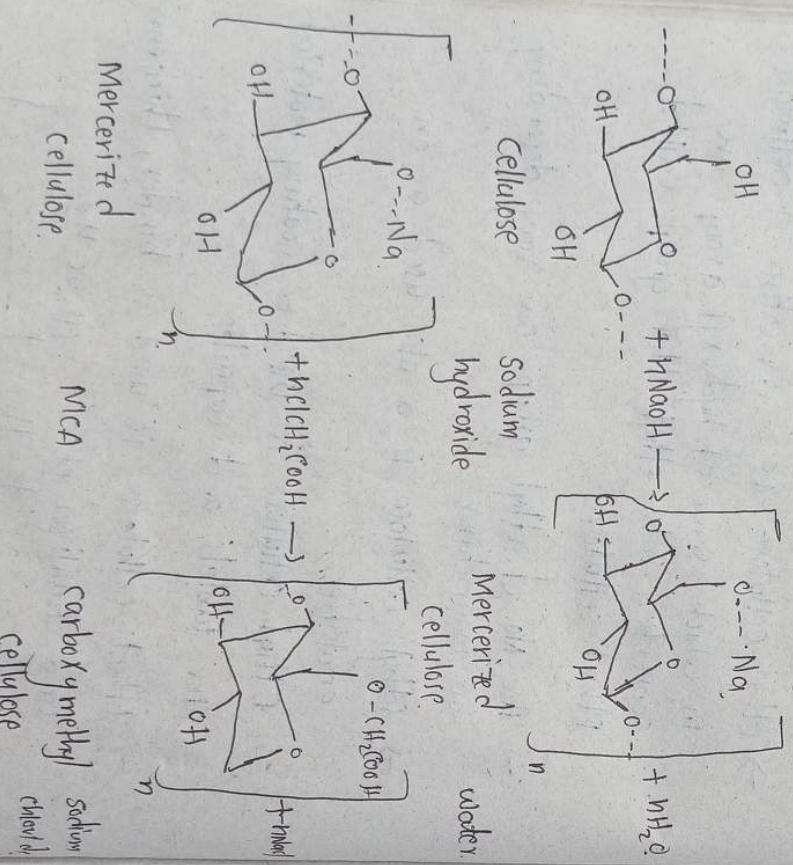


- > surface hydrophobicity
- > molecular weight.
- > melting point.
- > etc.

## \* CMC (Carboxymethyl cellulose)

- CMC stands for carboxymethyl cellulose.
- CMC is an anionic water soluble polymer.
- CMC is also called as cellulose gum.
- CMC is used as sodium carboxymethyl cellulose.

## \* Preparation



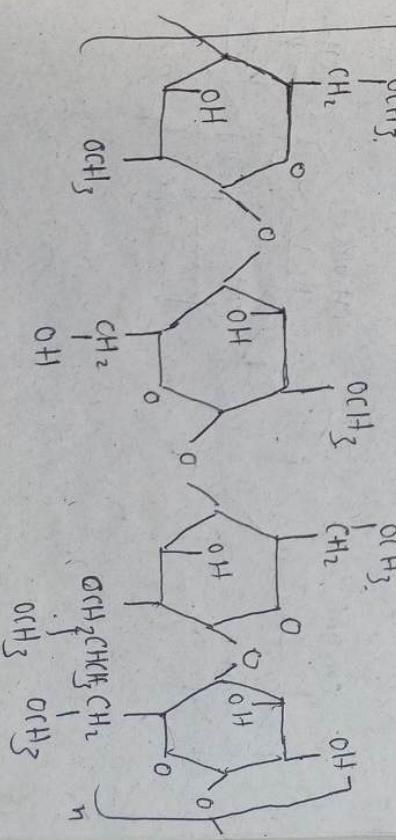
→ cellulose react with sodium hydroxide,

result in mercerized cellulose.

→ mercerized cellulose react with water and MCA finally forms an carboxymethyl cellulose.

## \* HPMC

- HPMC stands for hydroxypropyl methylcellulose polymer.
- HPMC used in eye drops.
- HPMC also used in oral medicines.
- Hypromellose is an emulsifier, thickening, suspending agent.
- process involve, alkaline treatment, etherification, washing, neutralization, purification, drying etc.



## \* cellulose Acetate :

→ Cellulose Acetate is an non-flammable thermoplastic polymer made by acetylating cellulose is called cellulose acetate.

→ Cellulose Acetate is an biomass material.

→ Cellulose is better than petroleum-based plastic.

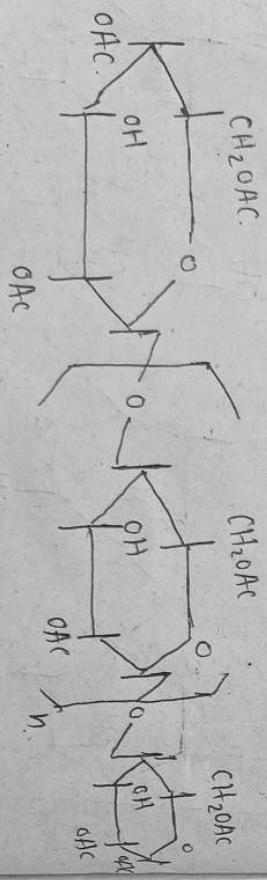
→ Cellulose acetate is not pure cellulose compound.

→ Cellulose acetate fibres are two types

- o Acetate fibres

- o Triacetate fibres

→ Acetate fibre and Triacetate fibre are similar in many properties but differ in chemical compounds.



## \* Liquid crystalline polymers; specially plastics.

Poly PES, PAES, PEEL, PEAIC.

### \* 1. PES

→ PES stands for poly ether sulfone sulfones.

→ polysulfones are high performance thermoplastic.

→ PES raw materials are high cost.

→ Three polysulfones used are

- o poly sulfone

- o poly ether sulfone

- o poly phenylene sulfone

→ polysulfones are rigid, high-strength, and transparent

→ properties of PES

- o High strength & stiffness.

- o Temperature 100°C and 200°C.

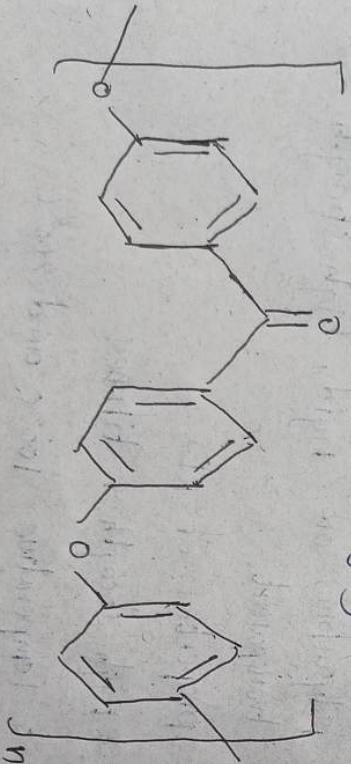
- o pH range - 2 to 13.

### Applications

- o Membranes - hemodialysis, waste water recovery.
- o Materials - glass fibers, composite material.

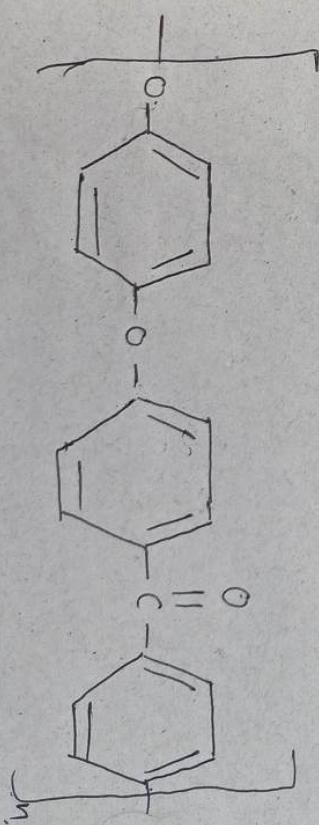
## \* PEEK

- PEEK - stands for polyether ether ketone.
- PEEK is a colourless organic thermoplastic polymer in PEKE family.
- PEKE is a semicrystalline thermoplastic with excellent mechanical and chemical resistance.
- PEKE young's modulus 3.6 GPa.
- PEKE tensile strength 90 to 100 MPa.
- PEKE glass transition temperature is around 143°C. and melts around 343°C.
- This technology has expanded to applications in orthopaedic surgery.



## \* PEAK

- PEAK stands for poly ether-aryl ketone.
- PEAK is a family of semi crystalline thermoplastics.
- PEAK has high temperature stability and mechanical strength.
- PEAK contains ketone ( $R-C(=O)-R'$ ) and ether groups ( $R-O-R'$ ).
- PEAK has continuous operating temperature of 250°C. and melts at 350°C.
- PEAK have good chemical resistance.
- Applications - oil drilling components - seals, compressor rings, valve parts, gears, bearings, wire coatings, medical devices etc.



## UNIT - 4

### \* Definition of Hydrogel

Def: Hydrogel is a polymeric material, that can change its structure acc. to its environment such as local temperature, pH, salt and water concentration is called Hydrogel.

- > Hydrogels are made from polymer.
- > Hydrogels have softness, toughness, stretchability, decent deformability, biocompatibility etc.

### \* Classification of hydrogel products :-

-> The hydrogel products can be classified on different basis. as.

#### ① classification based on source :-

-> Hydrogels can be classified into two groups based on their natural & synthetic origins.

## 2. classification according to polymeric:-

a) Homopolymeric hydrogels : These are refined

as polymer network derived from single monomer.

-> This may have cross-linked skeletal structure.

b) Copolymeric hydrogels : This is referred as

polymer network derived from two or more different monomers.

### ③ classification based on configuration

-> classified as follows

a. Amorphous. (non crystalline)

b. Semicrystalline

c. Crystalline

### ④ classification based on type of cross-linking

-> classified as follows

a) Chemically cross-linked : They may have

permanent junctions.

b) Physical cross-linked : They may have han-

sition junctions.

## (5). classification based on Appearance

-> Hydrogels appearance as

a. Matrix

b. Microsphere

⑥. classification based on network electrical charge

a. Non ionic

b. Ionic

c. Amphoteric electrolyte

d. Zwitterionic

### \* properties of Hydrogels

1. Mechanical property : mechanical properties

are very important for pharmaceutical applications

-> Ex:- maintaining its physical texture during the drug delivery.

2. Biocompatible properties : It is important

for the hydrogels to be biocompatible and nontoxic in order to applicable in biomedical field.

-> can be used to elevate the toxicity of hydrogels

3. Swelling property: Hydrogels are the swollen polymeric networks occupied by drug molecules.

-> Swelling property is influenced by:

o Type and composition of monomers.

o Temperature, pH, etc.

o Cross-linking.

$$R_s = (W_s - W_d) / W_d$$

where  $R_s$  = swelling ratio.

$W_s$  = weight of swollen hydrogel

$W_d$  = weight of dried hydrogel.

\* Method to produce hydrogel

1. physical cross-linking: physical cross-

linking hydrogels are formed by molecular entanglement and (or) secondary forces including H-bonding or hydrophobic forces.

-> There has been increased interest in

physical (or) reversible gels.

## \* Network polymer

Def: Network polymer is a three dimensional structure of chains linked by chemical (or) physical crosslinks. It is called network polymer.

-> interpenetrating polymer networks (IPNs) are special type of polymers designed to obtain compatible materials either miscible (or) immiscible.

-> IPNs are refers to elastomers.

-> Hydrogen IPNs, which use water as solvent.

Types of Network polymers

1. physically cross-linked (Type I)

-> physically cross linking is the formation of bond b/w polymer chains through physical interactions

-> This interactions including coordination bonding, hydrogen bonding, van der waals interactions.

2. Covalently cross linked (type II)

- $\rightarrow$  physically or chemically cross-linked  
shape memory multiresponsive

→ shape-memory polymers attract  
fam. both industrial and acad.

due to their mechanical functionality.

### 3. Composites as multifunctional materials

(type III).

-> multifunctional composites are designed through microstructural modification

## \* Advanced delivery systems

- > Advanced drug delivery system refers to innovative technologies and formulations.
  - > It is used to improve delivering the drug into the human body for particular organs.
  - > Advanced drug delivery system reduces side effect.
  - > Examples of advanced drug delivery systems
  - o Nanoparticles: Nanoparticle-based drug delivery systems utilizes nanoscale carriers such as liposomes, polymeric nanoparticles, inorganic nanoparticles.
  - > Advantages - increased drug solubility, targeted delivery etc.

## Applications

- Automotive parts
  - damping materials
  - medical devices etc

## o polymeric micelles:

- > polymeric micelles are self-assembling nanoscale structures formed by amphiphilic co-polymers.

- > used in cancer therapy and EPR.

## o Liposomes

- > liposomes are lipid-based vesicles.
- > liposomes encapsulate both hydrophilic and hydrophobic drugs.

- > Advantages offers - biocompatibility, versatility

cancer therapy, gene & vaccine delivery etc.

## o polymeric nanogels:

- > polymeric & nanogels are three-dimensional hydrogel networks with nanoscale dimensions
- > polymeric nanogels can encapsulate drugs and release them in controlled manner.
- > Advantages - Biocompatibility, high drug loading capacity, etc.

## o Gene delivery systems:

- > Gene delivery systems are designed to deliver nucleic acids like DNA or RNA, to target

cells for gene therapy.

- > This is advanced drug delivery system and rapidly growing field.

## \* Control Release:

- > A dose is simply a specific amount medication. i.e administered at one time

- > Ideally blood levels of any drug should be constant and controlled.

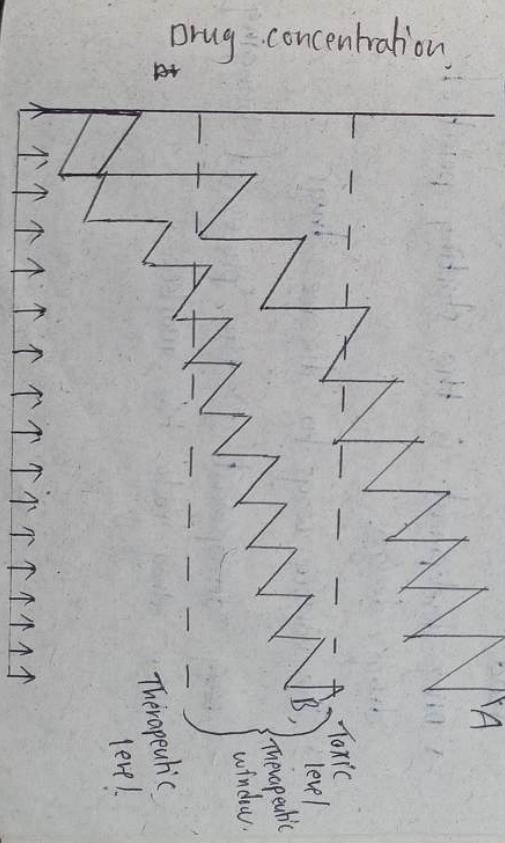
- > usually drugs are taken at regular time interval.

- > If the doses are designed to keep the blood levels of drugs should be constant

- > If the drugs are not high level to be toxic.

- > If the drugs are minimum level to be infective

Ex.



-> Dose regimen A quickly reaches therapeutic level

but continuous to hit reaches toxic level.

-> dose regimen B involves half amount.

drug provided with same freq.

-> drug regimen C exist b/w toxic and

therapeutic level.

-> drug development includes four steps

o Discovery

o preclinical studies

o clinical development

o Market approval

-> drug delivery refers to approaches, formulations, technologies

-> drug delivery modify drug release profile.

-> drug release is a form of diffusion, swelling, degradation, etc.

-> Types

1. Spatial drug delivery: Targeting a drug to particular organ or tissue.

2. Temporal drug delivery: The drug delivery rate to the target tissue is controlled.

o Sustained release drug delivery system.

o controlled release drug delivery system.

o Targeted drug delivery.

-> The various ways to discover drugs

-> drug development is the process of bringing

new drug into the market.

o Nanosomes.

o Nano particles

- o. microspheres
  - o. liposomes
- Limitations
1. physiological factors, pH, gastric absorption drug from system.
  2. The slow release of drug.
  3. Drugs with half life of thr.
  4. Difficult to secure the therapy.

### \* Absorption:

Def: The process of getting drug from its dosage form into the body is called absorption.

→ Rate of absorption  $\propto$  conc. of drug at absorption site.

→ Absorption can be controlled by site of drug particle, solubility, pH value etc.

→ Drugs penetrate through following mechanisms.

o. passive diffusion: water and water soluble molecules such as O<sub>2</sub>, CO<sub>2</sub>, urea etc.

- High molecular weight & lipid soluble compounds i.e. steroids will dissolve.
- o facilitated diffusion: substances are carried out by without using energy.

o Active diffusion: substances are carried out by using energy i.e. from lower to higher concentration.

o Endocytosis: substances are transported across the cell membrane, and drug across the cell.

### \* Drug from formulations (Dosage forms)

Def: Drug formulation is the process of combining various chemical substances with one active drug to form final medicinal product is called drug formulation.

→ A drug from formulation can be given to the patient in various forms like solid, liquid etc.

→ problems with direct use of API.

- o difficult to handle
- o chemical instability
- o May cause irritation

- o May cause toxicity.
- o unpleasant qualities.

### → Solid formulations

Tablets - A tablet is usually a disc shaped compressed preparation that contain 5-10% drug, 80% filler etc.

Enteric coated Tablet: These are tablets are hard coated with disintegrate in acidic but in alkaline.

Controlled release tablet: It is designed to release specific amount of drug over a specified period of time!

Capsules: A capsule is a gelatinous substance.

It can be hard or soft.

- > Hard capsule contain drug in solid form.
- > soft capsule contain drug in liquid form.

## \* Routes of drug Administration:

\* Routes of drug administration is suitable ways for treatment of a disease cureing is called routes of drug administration.

### -> Types of drug administration.

1. Enteral
2. parenteral
3. topical

#### Topical

- Nasal administration
- Inhalation.
- Dermal application
- Enteral
- Vaginal.

#### Routes of drug administration

##### parenteral

- Intradermal injection
- subcutaneous injection
- Intramuscular.
- Intravenous.
- Intraarterial
- Intrathecal
- Intracardiac
- Intraarticular
- Intrapertitoneal

##### Enteral

- oral
- Nasogastric
- Buccal.
- sublingual.
- Rectal
- colon.

1 Enteral Administration of drug in suitable formulation into gastrointestinal tract is called enteral Enteral route of administration.

→ It is further divided into Intero oral,  
Naso Nasogastric, Buccal, sublingual, Rectal,  
colon etc.

2 parenteral : Introduction of drug into the body by other than enteral route is called parenteral route of administration.

→ It is further divided into Intradermal  
Injection, subcutaneous injection, Intramuscular,  
Intravenous, Intraarterial, Intrathecal,  
Intracardiac, etc, Intraarticular, Intraperitoneal,  
etc

3 Topical : Administration of drug in the form of solution like, lotion, gel, sprays, vapour, etc. are called Topical administration.

→ It is further divided into: Nasal  
administration, Inhalation, Dermal application,  
Iontophoresis, vaginal, etc.

## unit - 5

### X surface tension

Def: surface tension is a phenomenon, that occurs when the surface of a liquid is in contact with another phase.

- > Here surface of the liquid behaves like an elastic sheet.
- > surface tension depends on force of attraction b/w particles, solid, liquid, gas etc.
- > surface tension of various liquids.

liquid	surface tension
Hydrogen	2.4
Helium	0.16
water	0.072.
Ethanol	22.0
sodium chloride	114

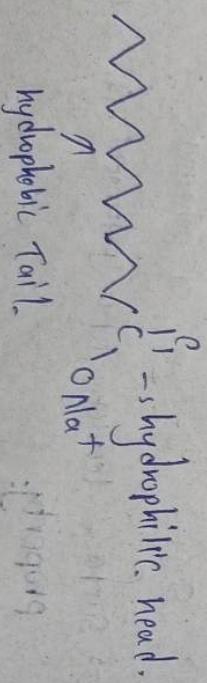
- > surface tension of polymers.
- > Surface tension of a polymers is a (critical) property.

- Surface tension refers to energy required to increase surface area of a liquid.
- Surface tension exist in solid, liquid & gas.
- Polymers typically have lower surface tension
- Surface tension of polymer is critical in many applications.

### \* Micells

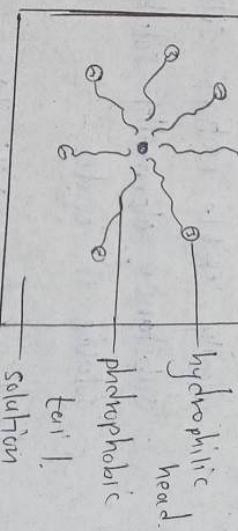
- Def: polymeric micelles are nanoscopic shell structures formed by amphiphilic block copolymers.
- Micells are formed by cumulative formation of amphiphilic molecules in solution.
  - In simple, when array of solubles are added to water, micelle is formed.
  - A typical micelle in water forms an aggregate.

Ex:  $\text{C}_17\text{H}_{35}\text{COONa}$ .



### \* Reverse micells

- Reverse micells are approximately in spherical shape.
- And also in ellipse, bilayers are possible.
- Reverse micells are water droplets, that are obtained from sulphates in water.
- Reverse micells are nanometer (1-10nm).
- Reverse micells are thermodynamically stable molecules.
- Reverse micells are surfactant atoms.



### Application of micells

- used in electrophoresis and chromatography.
- used to remove fats in human body.
- In detergents, tipped lipophilic materials.

## \* Solubilization

Def: It is the formation of a thermodynamically stable, isotropic solution of a substance. Normally soluble or slightly soluble in water.

→ Factors of solubilization.

- o Separation of solvent molecules.
- o Interaction b/w the solvent and solute molecules.
- o Breaking of inter-ionic or intermolecular bonds.
- o Separation of solute molecules provide space.
- o Molecules of solids break away from bulk.

## \* photoelectron spectroscopy:

Def: PES is a valuable analytical technique used in various fields including physics, chemistry, material science etc. is called PES.

→ Applications of PES.

### 1. Chemical analysis:

- PES can determine the elemental composition and chemical state of atoms.
- PES can provide info about electronic structure of atoms and molecules.

### 2. Surface science:

- PES can widely used to study the surface of materials, including semiconductors, catalysts, thin films etc.
- Surface science is the study of physical and chemical phenomena.
- It occurs b/w two phases.

### 3. Material characterization:

- > PES can be used to investigate the electronic structure of various materials including metals, insulators, polymers, nanoparticles etc.
- > It gives details like surface energy levels etc.

### 4. Semiconductor physics:

- > PES can be used to study the electronic properties of semiconductors.
- > This information is essential for developing semiconductor devices.

### (5) Environmental science

- > PES can be used to study the composition and reactivity of environmental samples.
- > Environmental science is the study of interaction b/w physical, chemical and biological components of Environment.

### 6. Nanotechnology

- > PES can be used to study the characterization of nanomaterials.
- > Now days nanotechnology rapidly increasing day by day.

- > Nanotechnology is the designing large devices with components like small in size with same properties.

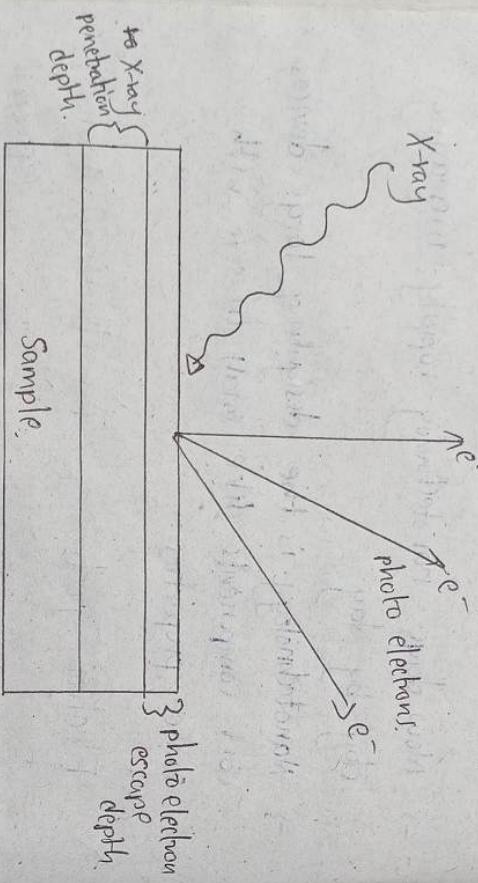
\* Electron Spectroscopy for Chemical Analysis (ESCA)

Def: Electron Spectroscopy for chemical analysis (ESCA) is also known as X-ray photo-electron spectroscopy (XPS), it is a analytical technique for determining the elemental composition and chemical state of material's surface.

- > The basic principle of ESCA or XPS is based around the X-rays, photo electric effect, Emission of photo electrons, spectral analysis, chemical analysis etc.

→ ESCA is a surface analysis technique.

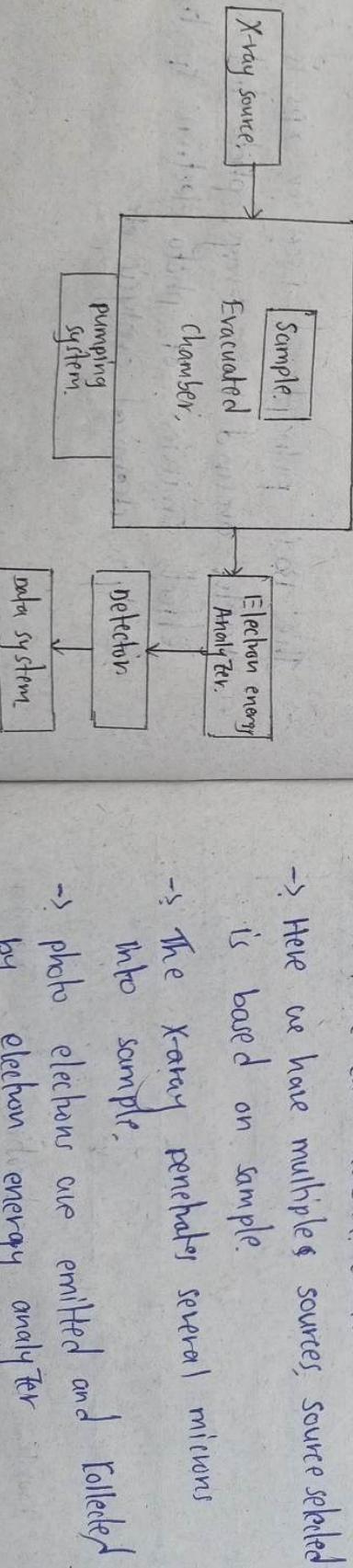
→ Surface analysis block diagram.



→ Here, the process done by sample with monochromatic X-ray.

→ photo electron emission is multiple, directions.

#### Instrumentation of ESCA



→ Instrumentation of ESCA on XPS includes

o X-ray source: ESCA typically uses high energy X-ray source, such as monochromatic

X-ray.

o sample chamber: Here sample is under the investigation, and also contains manipulator.

o Electron Analyzer: The emitted photo electrons are energy analyzed using electron analyzer,

o Detector: The electron analyzer is coupled with detector. That captures energy.

o Data system: The signals from detector are recorded by data system.

#### Working of ESCA

→ In ESCA, we use X-ray monochromatic beam.

→ Here, we can measure emitted electrons.

→ Here we have multiple sources, source selected is based on sample.

→ The X-ray penetrates several microns into sample.

→ photo electrons are emitted and collected by electron energy analyzer

-> detector detects the electron from Analyzer.

-> Finally data stored in data system.

## \* Auger Spectroscopy

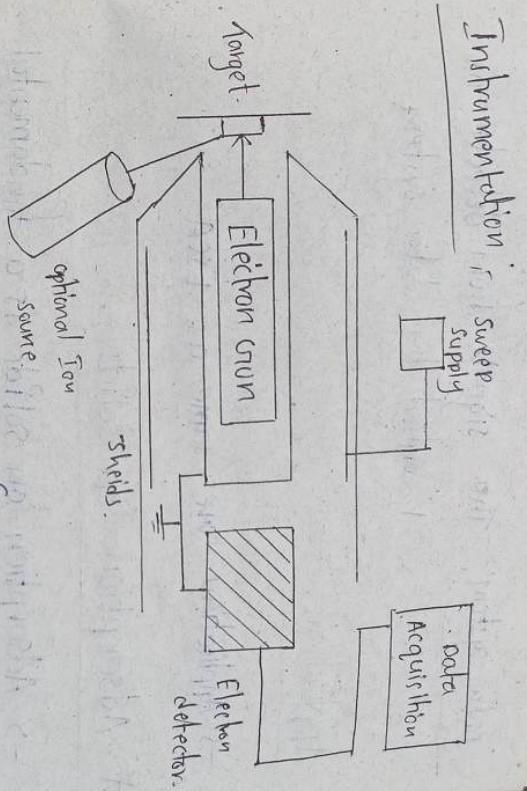
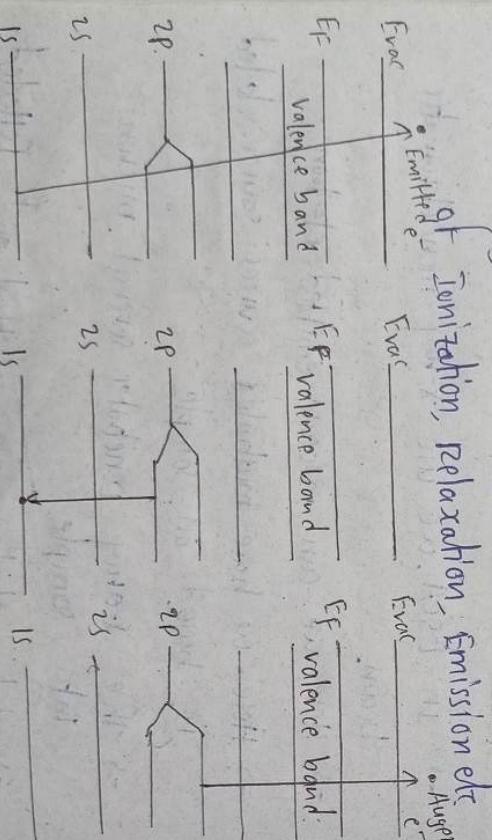
Def: Auger electron spectroscopy (or AES)

(or) simply Auger is a surface analysis technique, it uses an electron beam to excite electrons in the particle.

-> The electron beam can emit "Auger electrons".

-> Auger spectroscopy measures kinetic energy of the emitted electrons.

principle Auger spectroscopy based on principles



-> The instrumentation of AES includes.

o Electron gun: AES uses an electron gun to generate focused beam of electrons.

-> These electrons go towards surface of the sample.

o Sample chamber: Here the sample is under investigation and also user manipulation.

o Energy Analyzer: The emitted electrons are energy-analyzed using electron energy analyzer.

o Detector: The electron analyzer is coupled with detector and capture the energy and intensity of emitted Auger electrons.

J ionization Relaxation Emission

Data system: The signals from detector are recorded by data system.

### Applications

→ Applications are same as ESCA.

- chemical adsorption is strong.
- It is irreversible.

### \* Adsorption on solids

→ Adsorption on solids is a fundamental process.

→ This phenomena have great importance in scientific and engineering fields.

### Types of adsorption

1. physical adsorption
- physical adsorption is also known as physisorption.

→ In chemical adsorption, the formation of bonds occur between adsorbate molecule and surface atoms.

Surface area: Materials with high surface area, such as nanoparticles.

Surface chemistry: The chemical composition and reactivity of solid surface that occur with adsorbate molecules.

Temperature & pressure: Absorption behaviour is influenced by temperature and pressure.

### Applications:

- Here involves weak interactions such as van der waals forces, dipole-dipole interactions, etc.
- physisorption is reversible and occurs at low temperatures.

### 2. chemical adsorption

→ In chemical adsorption, the formation of bonds occur between adsorbate molecule and surface atoms.

- chemical adsorption is strong.
- It is irreversible.

### Factors influencing adsorption

## Polymer adsorption on solids

-> polymer adsorption on solids is a phenomena where polymer molecules adhere to surface.

-> understanding polymer adsorption on solids is crucial material science, surface engineering.

-> key points to consider:

- o polymer properties
- o Adsorption mechanism.
- o Adsorption kinetics.
- o Surface modification etc.

## Applications

-> understanding polymer adsorption on various solids including:

- o separation process.
- o coatings
- o adhesives.
- o prevent fouling
- o enhance adhesion etc.

## \* Electrical phenomena at interfaces, including electrokinetics:

Electrical phenomena at interfaces, including electrokinetics play vital role in understanding behaviour and application of polymers.

1. Electrophoresis: This is movement of charged particles, such as polymer molecules.

2. Electroosmosis: This is movement of a solvent through porous material under electric field.

3. Zeta potential: This is a key parameter in electrokinetic phenomena, it represents electrical potential.

4. Dielectric properties: polymers exhibit dielectric properties, that influence electric fields.

5. Electroactive polymers: EAPs are class of polymers that can undergo change in size, shape or conductivity in electrical stimulation.

6. Electrospinning: Electrospinning is a technique used to produce polymer nanofibers.