(L-1)

Date 19/Sep/2024

Syllabus

- 2 lectures per week
- 2 credit
- 4 units we have

Chemistry

UNIT-1

"Advanced Materials for smart devices"

Nanomaterial: $10^{-9}m - 10^{-7}m$

$1nm - 100nm$

(A) $\longrightarrow$ (A)
(Bulk) (Nano)

UNIT-2

"Ecofriendly Portable Energy Convertible devices"

- Electrochemistry
- Photovoltaic Cells
- Green fuel Cells (H_2O vala $H_2 + O_2$)

Environmental Chemistry

UNIT-3

"Environmental Systems"

- Segments of Environment
- Air Pollution
- Water Pollution
- Soil Pollution

UNIT-4

"Environmental Toxicology & Waste management"

- Toxicants
- Waste management
- Sustainable development

Liquid Crystals
OR
Mesomorphic Phase

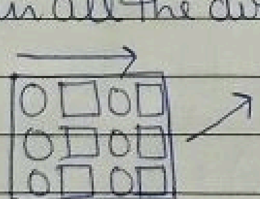
★ Liquid crystals were first observed by Freidrich Reinitzen in 1888. He was an Austrian Botanist. He was studying (p-cholestryl benzoate)

$$\underset{\substack{(C_6H_5COOC_{27}H_{45}) \\ (\text{SOLID})}}{\text{p-cholestryl benzoate}} \underset{}{\overset{145^\circ C}{\rightleftharpoons}} \underset{\substack{\text{(Liquid Crystal)} \\ \text{(hazy liquid/} \\ \text{turbid State)}}}{\text{p-cholestryl benzoate}} \overset{178^\circ C}{\rightleftharpoons} \underset{\text{(Liquid)}}{\text{p-cholestryl benzoate}}$$

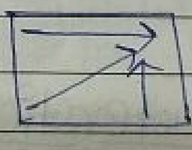
★ A State of matter that is intermediate b/w crystalline solid & isotropic liquid is known as liquid crystal or Mesomorphic State.

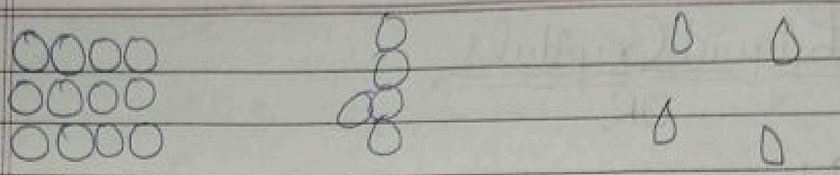
★ **Anisotropy** | **Isotropy** (Iso → Same)

→ due to fixed arrangement of particles, physical properties are different in all the directions



→ physical properties are same in all the directions

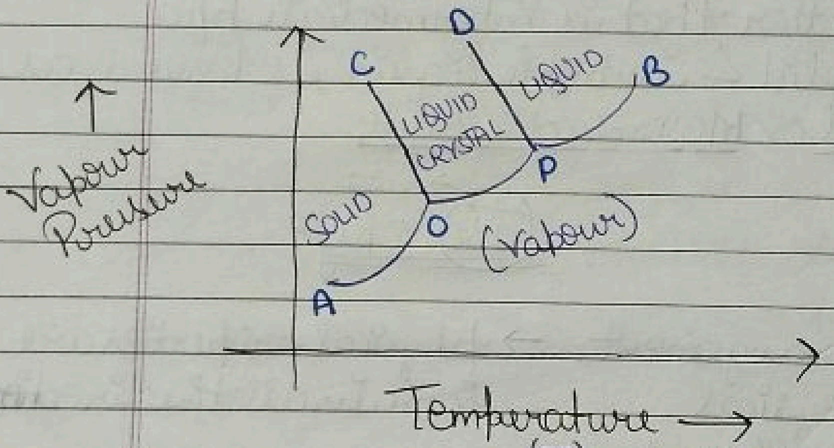




	(S)	(LC) (Liquid crystal)	(Liquid)
Positional Order	✓	×	×
Orientational Order	✓	✓	×

☆ Liquid crystals are those which have lost their positional order in order to gain their orientational order

Vapour Pressure : Temperature Curve of Liquid Crystal



~~(T) → phase transition temperature~~

Characterstics

① Triple Points: O ⟶ S ⇌ LC ⇌ V
P ⟶ LC ⇌ L ⇌ V

② Curves : ① Curve OA : Solid ⇌ Vapour
(Vapour pressure curve of Solid)

② Curve OP: LC ⇌ V (Vapour pressure curve of liquid crystal)

③ Curve PB: L ⇌ V (Vapour pressure curve of liquid)

④ Curve OC: S ⇌ LC (effect of pressure on phase transition temperature)

⑤ Curve PD: LC ⇌ L (effect of pressure on Melting point)

$$\text{Solid} \xrightarrow{\Delta} \text{liquid Crystal} \xrightarrow{\Delta} \text{liquid}$$

(phase transition temperature) (melting point)

Characterstics of Liquid Crystals

* They may flow like a liquid but their atoms may be oriented in a crystal like frame.

* Liquid Crystals may be considered to be a crystal which have lost some or all of their positional order while maintaining orientational order.

* Their atoms are oriented along a common axis known as director which leads to anisotropy. Due to anisotropy they have unique optical properties.

* They change arrangement of their molecules with

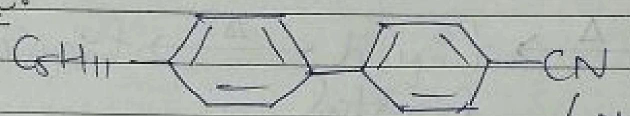
Change in surrounding of liquid crystals.

Mesogen (unit cell): fundamental unit that gives structural order to liquid crystals. Liquid crystalline molecules consist of a rigid moiety & one or more flexible parts. The rigid moiety alligns the molecule in a direction & flexible part gives flowidity.

→ each of two parts in which a thing compounded

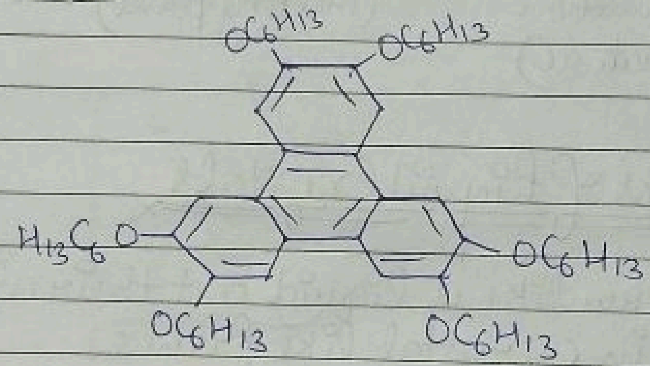
Based on Mesogen Liquid Crystal is of 2 types:

① **Calamatic:**



(Biphenyl)
(used in LCD)

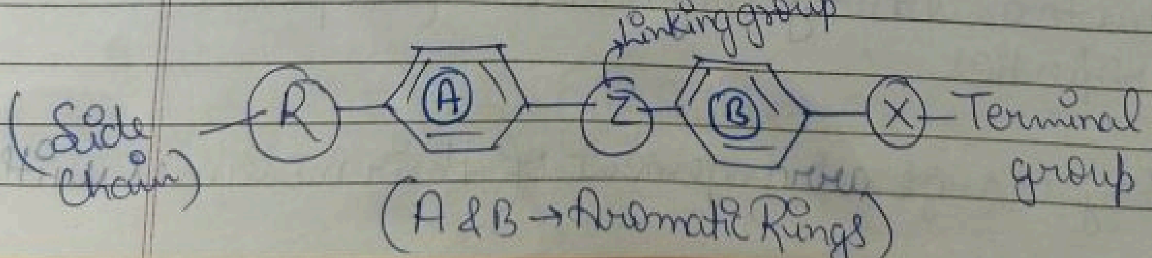
② **Discotic:**



Calamatic: In it mesogen is composed of aromatic ring connected in one direction

★ In discotic mesogen is flat shaped ring.

Chemical constitution



Classification of liquid Crystals:

$$S \underset{}{\overset{\Delta}{\rightleftharpoons}} LC \overset{\Delta}{\rightleftharpoons} L \xrightarrow{} \text{(heating)}$$
$$\xleftarrow{} \text{(cooling)}$$

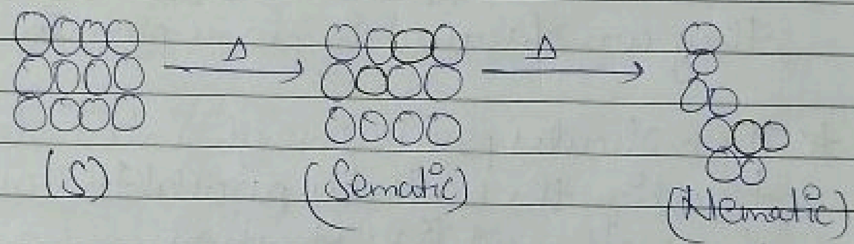
There are 2 classes

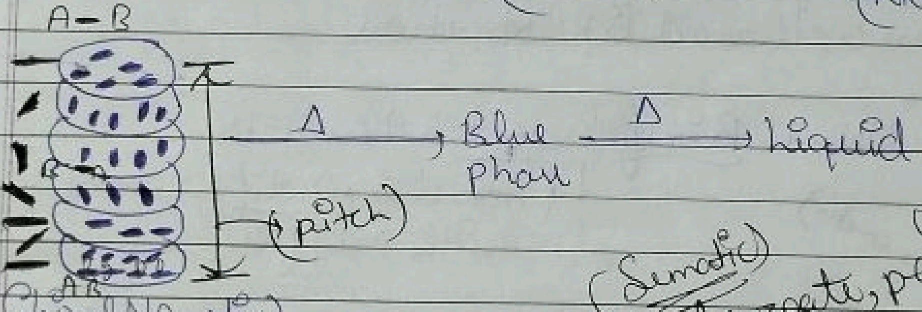
★ They show polymorphism → condn of occuring in several form

① Thermotropic: They are formed by varying temperature (either cooling the liquid or heating the solid)

② Lyotropic: They are formed by dissolving a solid in an appropriate solvent.

Thermotropic:





ex: p-azoxy benzoate (Sematic), p-azoxy anisole (Nematic)

Sematic: Their name is derived from Greek word "Smectos" ~~but~~ which means soap like.

★ They are formed at low temperature & do not flow like ordinary liquid.

★ The interlayer interactions are weaker than lateral forces so they are in form of layers that can slide over one another

★ ~~They~~ There are several categories of ~~Smetic~~ Smectic liquid crystal

Sematic (A, C, D & F) → are nonstructured
Sematic (B, E) → are structured.

In Sematic A, molecules are aligned ⊥r to layer plane.

In Sematic C, they are arranged at some arbitrary angle.

Their name.

Nematic: ★ derived from greek word "Nematos" which means thread like.

★ The molecules appear to be thread like when they are observed in plane polarised light.

★ The molecules possess enough intermolecular forces to align the molecules parallel to each other in a thread like structure.

★ It shows Birefringent behaviour.
(travel in 2 diff directions with 2 diff speeds)

(medium thermometer)

Chiral Nematic: ★ Nematic of chiral substance is known as chiral Nematic or Cholestric

★ They are in form of layers.
★ Within each layer, molecules are aligned parallel but each plane of molecule is twisted slightly with respect to the plane above and below
★ In this way the director travels on a helical path
★ The distance taken by the director to rotate one full turn in helix is known as pitch.

(L-2)

Date 23/09/2024

Chemical Bonding

The force of attraction that holds various constituents (atoms, ions, etc) together in a molecule and stabilizes them through overall reduction in energy.

Types of Bond

1) **Ionic Bond**: • NaCl

Na Cl
(2, 8, 1) (2, 8, 7)

Na^+ ---- Cl^-
(2, 8) (2, 8, 8)
(Cation) (Anion)

★ It is formed by transfer of e-s from one atom to another.

• $BaCl_2$

Cl •Ba• Cl

Cl^- --- Ba^{2+} --- Cl^-

★ EN diff > 2 → Ionic
< 2 → Covalent

Characteristics of Ionic Bond

★ High MP & BP
★ Brittle
★ Soluble in water
★ Conductor of electricity in molten state or when dissolved in water
★ non-directional

2) Covalent Bond: Bond formed by sharing of e⁻s b/w atoms.

$H_2 \Rightarrow H\cdot \; \cdot H \Rightarrow H:H \Rightarrow H-H$

One electron pair shared → Single

$CO_2 \Rightarrow \overset{\times\times}{\underset{\times\times}{O}}\!::C::\!\overset{\times\times}{\underset{\times\times}{O}} \Rightarrow O=C=O$

C_2H_2: $H-C\equiv C-H$, N_2

2 Types

Polar	Non-Polar
$H-Cl$	H_2, N_2, O_2

diff of EN $\Rightarrow$ >2 → Ionic

= 0 → Nonpolar Covalent Bond

0–2 → Polar Covalent Bond

- ☆ Soluble in organic solvents
- ☆ variable solubility in water.

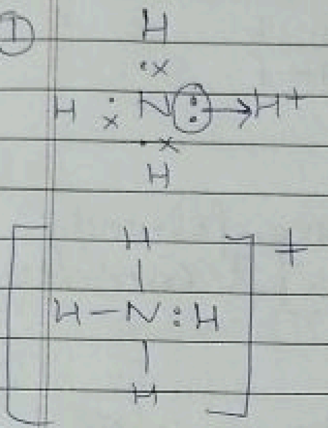
ex: $NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$

$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$

- ☆ They are directional, have definite geometric shape & show isomerism.
- ☆ BP & MP are lower than ionic compounds
- ☆ Poor conductor of heat & electricity give even when dissolved in water or in molten state

3) Co-Ordinate Bond / Dative Bond:

(1)



★ Coordinate bond is formed by sharing of e-s but shared pair of e-s is provided only by one of the bonded atoms.

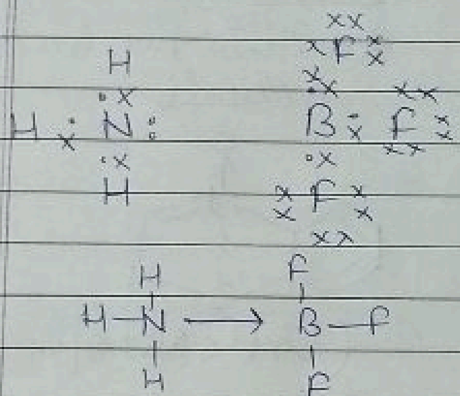
★ **Features of Co-ordinate Compounds**

↳ Their MP & BP are b/w ionic & covalent compounds

↳ They show isomerism

↳ soluble in organic solvents & slightly soluble in water.

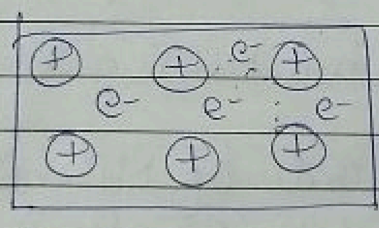
(2)



4) Metallic Bond:

★ The force of attraction holding the metal atoms together in a metallic lattice

Electron Sea Theory:



$$M \rightarrow M^{n+} + ne^-$$

(Kernels) (Valence electrons)

★ force that binds a metal cation to no. of electrons within its sphere of influence

★ metals are malleable and ductile because the individual atoms have ability to slip past one another while being firmly held together by electrostatic forces.

5) Hydrogen Bond:

$\overset{\delta+}{H} - \overset{\delta-}{F} \cdots \overset{\delta+}{H} - \overset{\delta-}{F}$

$(H-F)_x$, $(H_2O)_x$

* This is force of attraction b/w hydrogen (already bonded with electronegative atom) & EN atoms such as (FON).

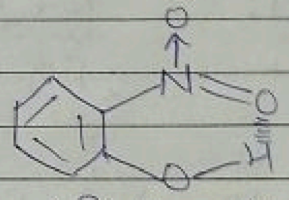
Types: Intermolecular

* b/w two molecules of same type or different type

ex: ethanol & H_2O

Intramolecular

* within the same molecule



(Ortho Nitrophenol)

* Cyclization

(Imp) Consequences:

* H_2O is liquid at ordinary Temp but H_2S is gas
* HF is liquid but HCl is gas
* In group-14 order of MP & BP $(H_2O)_x$

$CH_4 < SiH_4 < GeH_4$

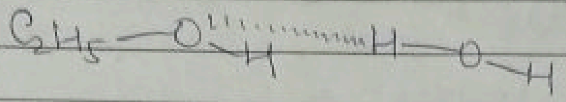
but in case of grp-15, 16, 17 the MP & BP of HF, NH_3, H_2O are exceptionally high.

Grp-14: $CH_4 < SiH_4 < GeH_4$

15 NH_3
16 H_2O
17 HF

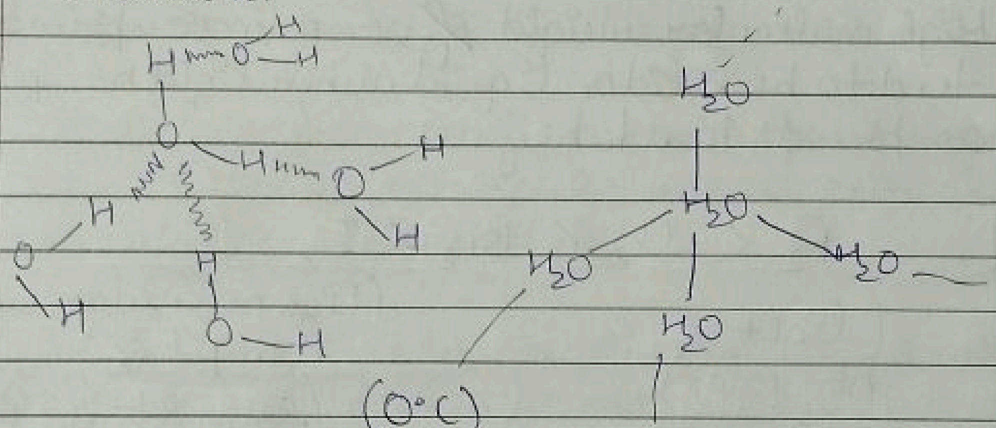
(no change in physical property of molecules)

★ Solubility : ethanol, lower aldehydes & ketones exhibit solubility in water



(Intermolecular H-bonding)

★ Anomalous behaviour of water : Ice floats on liquid water. (ρ of ice < ρ of water) bcoz of cage like Structure.



(0°C)

at 4°C → ρ is maximum

★ ρ of water increases from 0°C reaches max at 4°C then decreases further inc. of Temp.

★ T↑ → · expansion
· contraction

★ upto 4°C → Contraction dominates

(L-3)

Date 26/Sep/2024

6) Vander Wall Forces : Force of attraction b/w non polar moleculares and noble gases. It's energy is of the order 1 Kilocal per mole.

Consequences :

① Boiling point of Neon much lower than Xenon.

② Boiling point : $F_2 < Cl_2 < Br_2 < I_2$

③ High molecular weight of non polar compounds tend to be solid or liquid while light non polar compounds tend to be gases.

$F_2 < Cl_2 < Br_2 < I_2$

(light non-polar) (gas)

(high molecular weight non-polar) (solid & liquid)

Books to follow: Engineering Chem (L-4)
① Jain & Jain
② Sumita Rattan

Date 30/Sep/2024

Lyotropic Liquid Crystal: ★ They are formed by dissolving a solid in an appropriate Solvent.

★ They are formed by Amphiphilic molecules (having both hydrophilic & hydrophobic parts).

For example: Soap molecules

★ These Amphiphilic molecules mixed with an appropriate Solvent like water, their polar heads protect non polar tail forming micelle like Structure.

★ Micelles are formed only beyond a particular concentration of Solution known as critical micellization concentration.

★ As the concentration increases micelles arrange themselves into Specific pattern which Show liquid crystalline behaviour.

Importance: It can protect a drug from being destroyed in digestive tract.

Other Applications:

(i) Low molar mass liquid crystal have applications including erasable optical disk, full colour electronic Slides for computer aided drawing.

(ii) In medical application eg. Transient pressure transmitted by a walking food on the ground is measured.

($C_6H_5COOC_{27}H_{45}$ → cholestryl benzoate
cholestrol)

(iii) Thermal mapping in Solid State electronic devices to locate faults.

(iv) Used as lubricants → such as grease (capable of reducing friction, heat and wear)

(v) As polymer-composite material – mixture of Kevlar and LC is used as bullet proof vest and car body panels.

(vi) Mood rings, In Gas-liquid Chromatography

(vii) LCs are used to detect radiation and pollutants in atmosphere.

→ very small (10^{-9} m)

Nanomaterials: Characteristics & Applications

★ An American physicist Richard Feynman introduced the world to nanotechnology with his lecture, "There's Plenty of Room at the Bottom" at American Physical Society meeting on December 29, 1959.

ex: Chemical vapour deposition.

★ Society meeting on December 29, 1959. The Japanese scientist Norio Taniguchi of Tokyo university of Science was first to use the term "Nano-techno-logy" in a 1974 conference.

★ Nanomaterials represents a new class of materials having at least one dimension between 1 and 100 nm. (Materials which are of 10^{-9} m scale)

★ Smaller size (<100 nm) imparts enhanced or altered properties.

★ **Nanoscience:** is the study and manipulation of material at nanoscale.

★ **Nanotechnology:** can be defined as the application of science and scientific knowledge at nanoscale ($10^{-9}m$) for industrial and/or commercial objective/purpose

Methods of Preparation of Nanomaterials

1) Top Down Approach

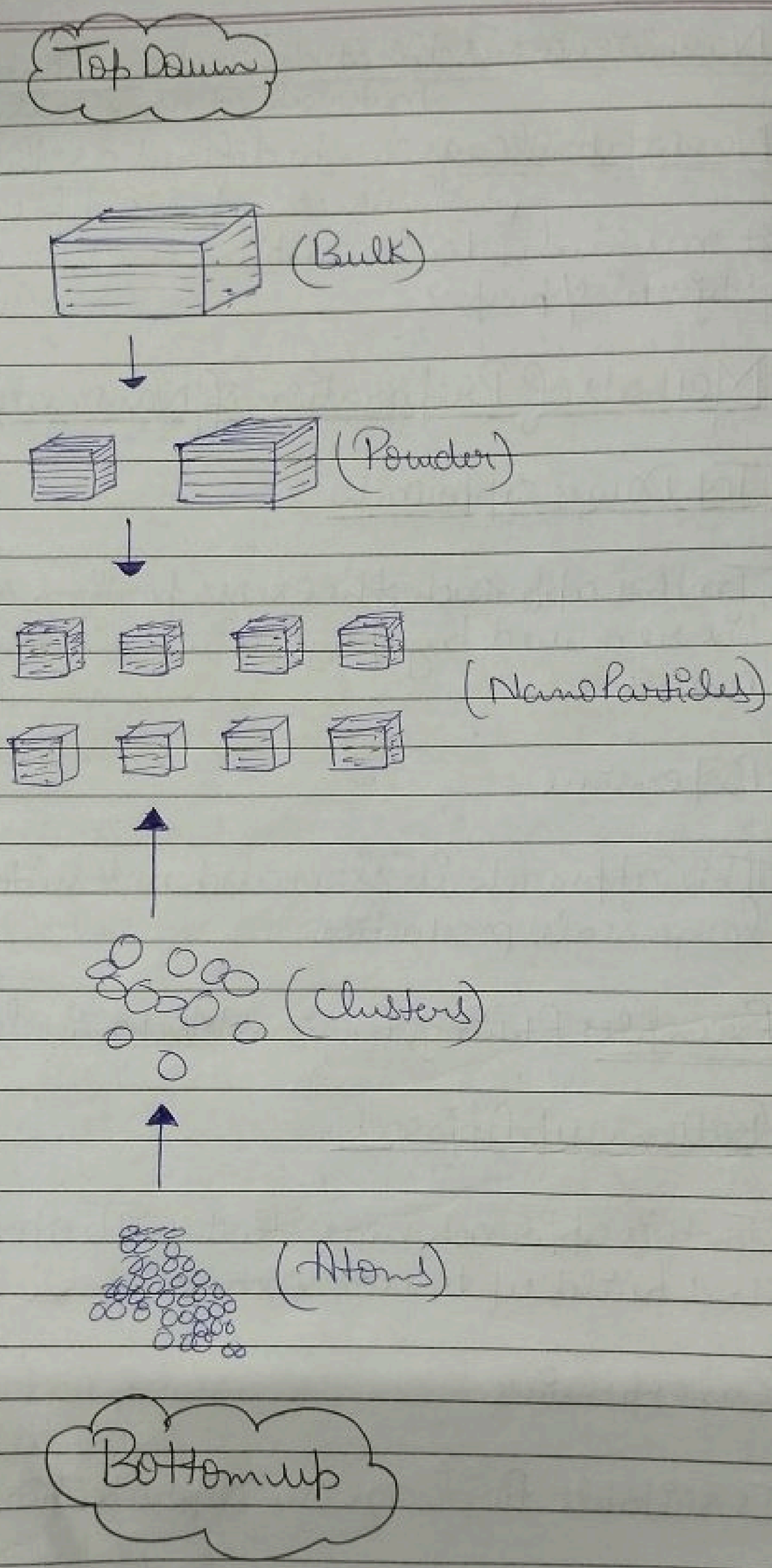
- In this approach, the excess portion of bulk material is removed by physical, chemical and mechanical means.
- Expensive
- This approach is slow and not suitable for large scale production.

Example: Etching, Erosion, Mechanical grinding.

2) Bottom up Approach

- In this approach, we start with atoms or molecules and build up to nanostructures
- Less expensive
- Is suitable for large scale production.

Example: Molecular self assembly


Top Down
(Bulk)
(Powder)
(NanoParticles)
(Clusters)
(Atoms)
Bottom up

Classification of Nanomaterials

Classified depending on no. of dimensions which lies within the nanometer range :

- **Zero-dimensional nanomaterials:** In this all dimensions are reduced to nanometer range.

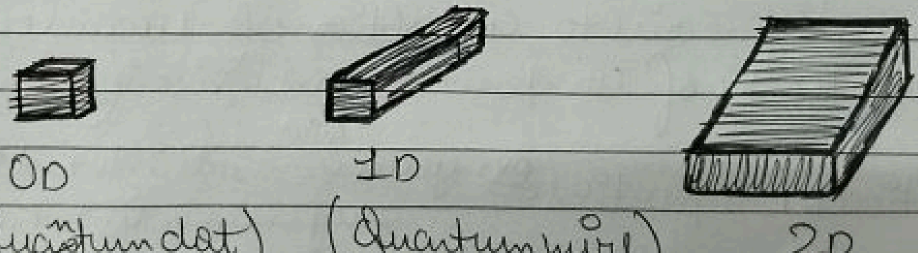
  Eg: fullerenes, Quantum-dots

- **One-dimensional nanomaterials:** In this two dimensions are reduced to nanometer range and ~~two~~ one dimension remain large

  Eg: ~~Thin films, Surface coatin~~
  Nanotubes, Nanowires

- **Two-dimensional nanomaterials:** In this one dimension is reduced to nanometer range and two dimensions remain large.

  Eg: Thin films, Surface Coating



0D (Quantum dot) 1D (Quantum wire) 2D (Quantum wall)

Properties of Nanomaterials xx

1) **Small Size:** Atleast one dimension of nanomaterial between 1-100nm.

2) **The increased relative Surface area:** In nanometer sized particles, a large portion of molecules are located at the surface as compared to interior.

3) **Size distribution:** Nanomaterials have a wide particle size distribution. To exploit the unique size dependent properties, the nanomaterials must be compound of monodispersed particles.

4) **Specific Surface feature:** Crystalline nanoparticles have enormous edges and points. Thus, their catalytic activity can be tuned (optimized) through selection of composition & their size. (control of size)

5) **Quantum size effects:** Due to quantum confinement instead of continuous energy bands such as that of bulk semiconductors, discrete energy states give rise to absorption of wavelengths characteristic of composition and size of nanoparticles.

6) Optical Properties ex: yellow gold converts into Red & grey silicon into Red due to Quantum size effects

7) Mechanical Properties: The tensile strength of CNT is 20 times of steel

8) Electrical Properties: electrical property varying from semiconductor to superconductor.

5) Quantum Size Effects

Applications

① Nano TiO_2 is used for increasing shine and life of paint

② Nano Gold & Nano silver are used for removal of arsenic from water.

③ Carbon Nanotube used as filler in composite material

④ fullerenes is a class of materials used as lubricant for delivery of medicines inside body & non-linear optical devices.

⑤ Biological nanomaterials like proteins, hormones. They show property of self assembly and specific molecular recognition.

(2-Marks) (Imp)

⑥ Medicinal Applications:

⑦ Agriculture field:

NEXTCT SYLLABUS: Complete Unit 1

Date 04/Nov/2024

POLYMERIC MATERIALS

The term 'Polymer' is derived from two greek words poly - many, mer - which means parts.
Polymers are macromolecules whose structure consist of large number of repeat units.

$$\underset{\text{(monomer)}}{nCH_2=CH_2} \xrightarrow{\text{Polymerization}} \underset{\text{(Polymer)}}{-\!\!\left(CH_2-CH_2\right)\!\!-_n}$$

Repeat unit : $-\!\left(CH_2-CH_2\right)\!-$

There is a difference between repeat unit and monomer.

Characteristics of Polymer

① **Degree of Polymerization:** n = degree of polymerization = number of monomer sites

② **functionality:** The number of active bonding site on monomer.

③ **Molecular weight of Polymers:** Polymers are polydispersed So we have to take average molecular weight.

Two types of Bonding

① Strong Covalent bonding between atoms within a polymeric chain about 1-1.5 Å.

② Weak Vander Wall forces of attraction between different polymeric chain of about 3-4 Å.

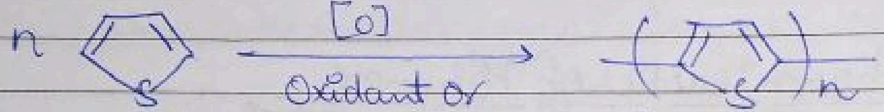
★ They have excellent corrosion resistance.

★ Act as thermal and electrical insulators.

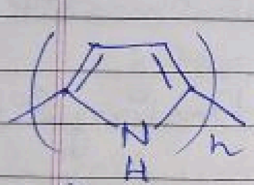
★ are semicrystalline materials.

Organic Conducting Polymers: They have long carbon based chains composed of simple repeat units derived from monomers and are capable of conducting current across the chain.

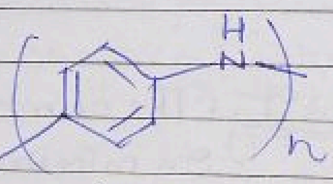
for ex:



(Thiophene) → (Polythiophene)



(Polypyrrole)
(PPy)



(polyaniline)
(PANI)

Classification

Conducting Polymers (CPs)

- Intrinsically Conducting Polymers
  - Conducting polymers having conjugation
  - doped conducting polymers
- Extrinsically Conducting Polymers
  - Conducting element filled polymers
  - Blended CP

Date:
Page:

Extrinsically Conducting Polymers

Their electrical conductivity is due to externally added ingredients

They are classified as:

★ Conductive element filled Polymers: here polymers act as a binder to hold the conducting element (carbon black, metal fibres).

The minimum concentration of conducting filler required to make the polymer Start conducting/ act as a conductor is known as Percolation threshold.

★ Blended Conducting Polymers: They are formed by blending a conventional polymer with conducting polymer. Such polymer possess better physical & chemical properties.

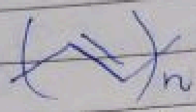
06/Nov/2024

Intrinsically Conducting Polymers

They have extensive conjugation in their backbone

(1) Conducting polymers having π e-s: Their π orbitals over the entire backbone overlap to form valence band & conduction band which are separated by significant energy gap. Electrical conductivity can occur only after thermal or photolytic activation of e-s.

eg: polyacetylene

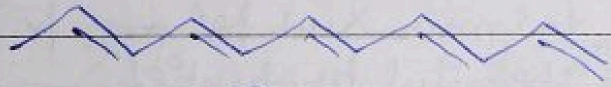
$n\,\overset{*}{C}H \equiv \overset{*}{C}H \longrightarrow$ 

(Acetylene) (polyacetylene)

$-(CH=CH)_n-$

② Doped Conducting Polymers: Polymers having conjugation can easily be oxidized & reduced.
They have low ionisation potential & high electron affinity.
Doping is done in two ways:

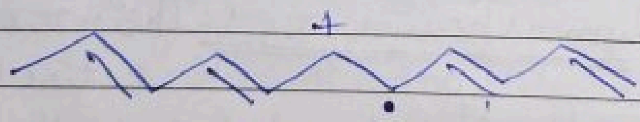
① P-Doping: It is done by oxidation process and treatment with lewis acids (e⁻ acceptor).



Polyacetylene

$* (CH)_x + LA \longrightarrow (CH)_x^+ \, LA^-$

$-e^-$ (oxidation) $\downarrow$ I_2/CCl_4



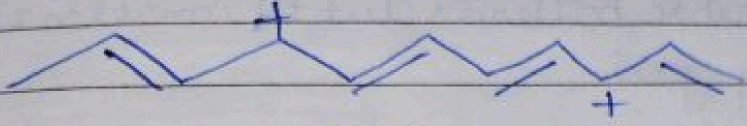
Polaron (Radical cation)

$-e^-$ (oxidation) $\downarrow$ I_2/CCl_4

Bipolaron (dication)

Bipolaron

$\downarrow$ (Segregation of cation)



(Soliton pair)

② **N-Doping**: Reduction process & it is done by treatment with Lewis base.

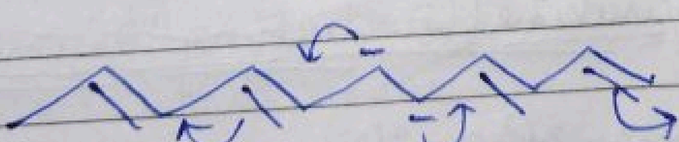
★ $(CH)_x + LB \rightarrow (CH)_x^- LB^+$

(Polyacetylene)

$+e^-$ (Reduction) $\downarrow$ $Na^+(C_{10}H_8)^-$ (Sodium Napthalide)

Polaron (Radical Anion)

$+e^-$ $\downarrow$ $Na^+(C_{10}H_8)^-$



(Bipolaron)

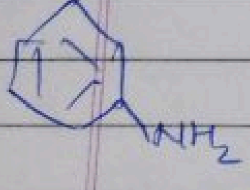
Applications of Conducting Polymers

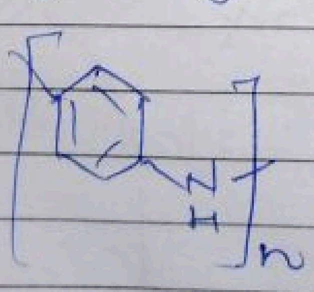
- In rechargeable batteries due to small size, long ecologically good
- Sensors for PH, O_2, SO_2, Glucose, etc
- used as electro chromic materials change colour which during electrochemical process of charge and discharge.
- Preparation of ion exchangers, Conductive paints.
- In photovoltaic devices in Al / Polymer / Au device.
- In biomedical applications, telecommunication system, microelectronic devices
- used in smart windows which can change their colours

PANI

Polyaniline (Conducting Polymer) (PANI)

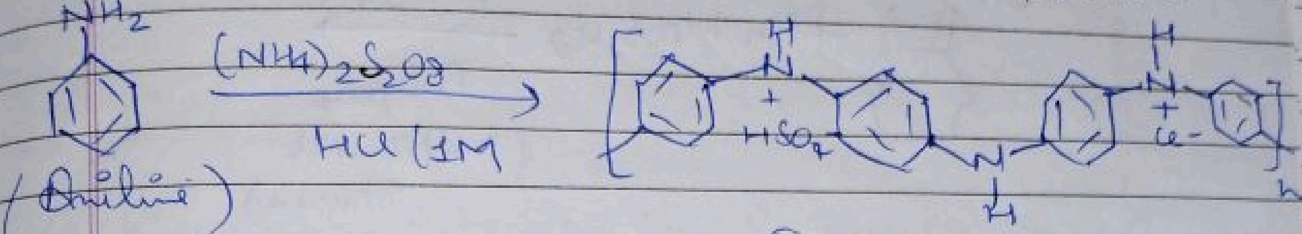
It is a polymer of aniline





Preparation:

★ addition occurring at para positions



(Aniline)

(Polyaniline)

★ PANI can be prepared by physical or chemical method. It can also be prepared by dissolving Aniline in HCl adding APS (ammonium per sulphate) and stirring for 1 hr.

Benefits:

★ It can be easily synthesized and doped, high environmental stability, biocompatibility and its electrical conductivity can be optimized.

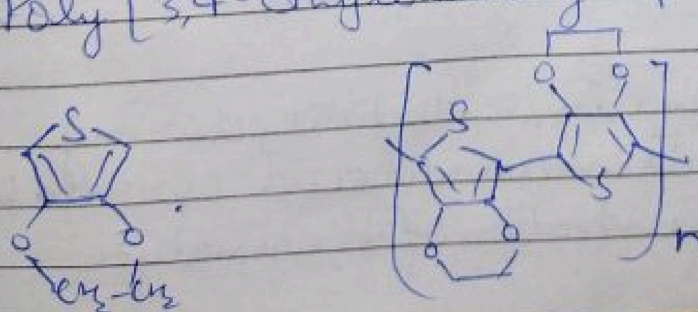
Applications:

★ Chemical vapor sensors due to electrical property.
★ electrochemical sensors with nanomaterials
★ Biological sensors for enzymes
★ Colorimetric sensors for study of bacteria in food, water
★ Ammonia Sensors.

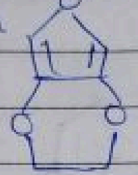
★ chemiresistive sensors
★ Transistor based sensors

(PEDOT) PEDOT

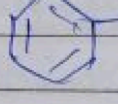
Poly [3,4-ethylenedioxythiophene) Conducting polymer

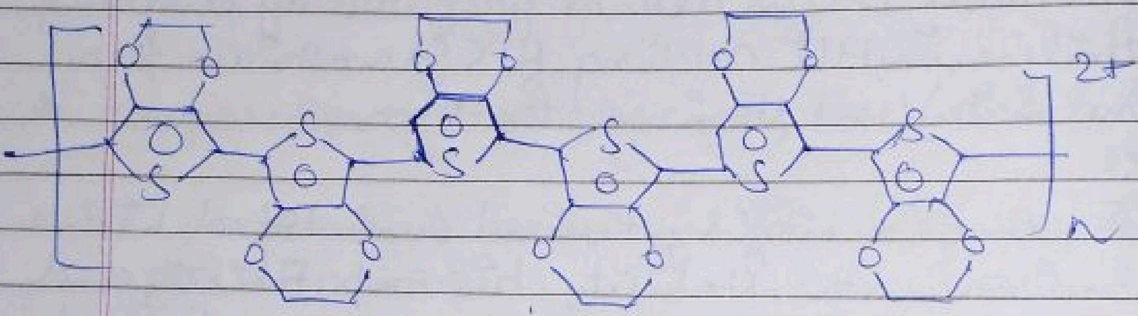


Preparation:

6n  $+ 14n\, Na_2S_2O_8 \xrightarrow{Fe_2(SO_4)_3}$

PSS poly
(sulphonated styrene)

 $-CH=CH_2$ (Styrene)



$+14n\, SO_4^{2-} + 14n\, Na^+ + 12n\, H^+$

★ The monomer EDOT are joined at 2,5-positions of each 5 membered thiophene ring to create linear polymer chains

USES:
- ★ Conductometric Sensors
- ★ Pressure and Strain Sensors
- ★ Temperature Sensors
- ★ Optical Sensors.

1) Chemical Sensors

Conductometric Sensors: change in conductivity during experiment is measured and correlated to the concentration of the analyte

Electrochemical Sensors: using Redox rxns presence of biomolecules or biopollutants is detected

2) Biosensors

1) Biomolecule detection: by functionalization of PEDOT with specific biomolecules biosensors can be created.

3) Pressure & Strain Sensors

* Flexible Sensors

* ~~Vari~~ Wearable Sensors

4) Temperature Sensors: change in Temperature affects conductivity. In this way PEDOT can be used as a temperature sensor

Advantages of PEDOT

1) High Conductivity:

2) Stability:

3) Flexibility:

4) Ease of functionalization:

PMMA :

Date: 11/Nov/2024

PMMA: Polymethyl methacrylate (PMMA)

also known as acrylic or plexiglass or lucite.

Preparation: It is synthesis by addition polymerization of methyl methaacrylate in presence of benzoyl peroxide as catalyst.

$$n\,CH_2=\overset{CH_3}{\overset{|}{C}}-COOCH_3 \xrightarrow[\text{peroxide}]{\text{Benzoyl}} \left(CH_2-\underset{\underset{COOCH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}- \right)_n$$

(methyl methaacrylate) (393K) (Polymethylmethaacrylate)

USES OF PMMA:
- ☆ furniture
- ☆ Scooter toy
- ☆ Acrylic trophy
- ☆ Display case
- ☆ motor lamp
- ☆ head lamp
- ☆ acrylic roof
- ☆ cosmetic box

(1) Display Technology

- **Transparent Substrates:** It is lightweight & shatter resistant so, alternative to glass in screen & displays.

- **Optical Coatings:** Such as anti scratch treatments or anti reflective coatings.

② Light Guide Applications

- LED lightings: light transmission properties

③ It can be used as a protective layer for touch sensitive displays.

④ Sensor housing: to encapsulate sensors

⑤ 3D printing and prototyping

- Rapid prototyping: 3D printing for creating prototypes

⑥ Smart home applications

- Smart ~~Applications~~ Appliances: housings and interfaces of smart appliances.

Advantages of PMMA in Smart devices

- ★ Lightnings
- ★ Shatter resistance
- ★ Chemical Resistance
- ★ Optical Clarity

Sustainable Polymers: are materials designed to minimize environmental impact throughout their lifecycle, from production to disposal.

Types:

1. **Biodegradable Polymers**: Polylactic acid (PLA)
   Polyhydroxyalkanoates (PHA)

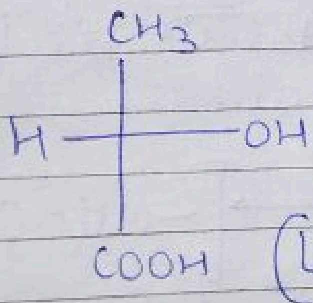
2. **Bio-based polymers**: Bio-polyethylene (bio-PE)
   Bio-polyethylene terephthalate (bio-PET)

3. **Recycled Polymers**: Recycled high density polyethylene (HDPE)

PLA

PLA: polylactic Acid (polymer of lactic acid)

- ☆ PLA is a biodegradable
- ☆ bio-based polymer primarily derived from renewable resources like cornstarch, Sugarcane and other plant materials.



(Lactic Acid)

Synthesis of PLA: (1) Via lactide

There are 2 main steps:

- ☆ production of lactic acid (or lactide)
- ☆ its polymerization into PLA

S-1: fermentation: production of Lactic Acid: it occurs by microbial fermentation of carbohydrates like glucose using bacteria, Lactobacillus.

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} \longrightarrow \underset{\text{(lactic Acid)}}{2\,CH_3CH(OH)COOH}$$

S-2: Formation of Lactide: (Cyclic dimer of lactic Acid) dimer lactide is formed by condensation Rxn

$$2\,CH_3CH(OH)COOH \xrightarrow{\text{dehydration}} \underset{\text{(lactide)}}{(CH_3CH(COO)_2} + 2H_2O$$

★ Lactide is easier to polymerize.

S-3: Ring opening polymerization: of dimer occurs in presence of catalysts tin (II) Octoate & an initiator like alcohol.

$$n\,(CH_3CH(COO)_2 \xrightarrow{\text{catalyst}} \underset{\text{(polylactic acid)}}{\left[-CH(CH_3)COO-\right]_n}$$

★ This rxn can be controlled to produce low molecular weight & high molecular weight PLA.

2nd Method: Direct Polycondensation: it gives low molecular weight PLA & sometimes incomplete polymerization may result into low quality PLA.

$$n\,CH_3CH(OH)COOH \xrightarrow{\text{dehydration}} [CH(CH_3)COO]_n + nH_2O$$

(Lactic Acid) (PLA)

Properties of PLA

1. Biodegradable (only under high temperature & humidity) (industrial composting conditions).

2. Renewability : it is derived from Renewable plant resource

3. Mechanical Properties: it has high tensile strength but it is brittle & prone to cracking under stress. that's why copolymers like (PCL-polycaprolactone) is mixed.

4. Thermal Properties : Glass transition temperature (55-60°C) melting point (150-180°C)

5. Transparent, clear, glass like material

6. Barrier properties: oxygen barrier properties useful in food packaging

7. Biocompatibility: used in biodegradable implants.

Applications :
1. Packaging
2. 3D Printing
3. Medical devices
4. Textiles

Applications of PLA

* **Packaging:** PLA is commonly used in food containers, bottles and packaging films.

* **3D printing:** PLA is one of the most popular filaments for 3D printing due to its ease of use and low toxicity.

* **Medical devices:** PLA is used in biodegradable sutures, stents and scanffolds for tissue engineering.

* **Textiles:** PLA can be used to make fibres for clothing and biodegradable bags.

PGA

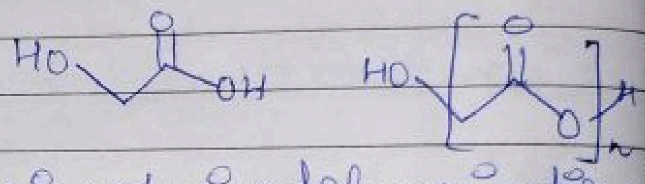
PGA (PolyGlycolic Acid)

- ☆ a biodegradable polymer
- ☆ part of polyesters family

CH_2OH
|
$COOH$ $-H_2O$

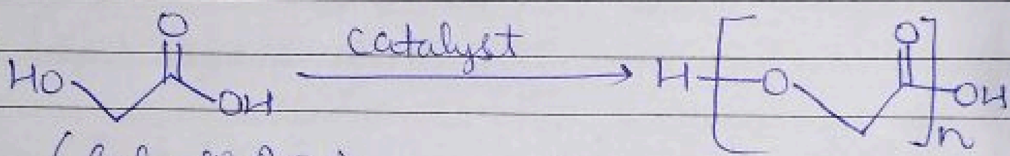
(Glycolic Acid)

Glycolic Acid | Polyglycolic Acid



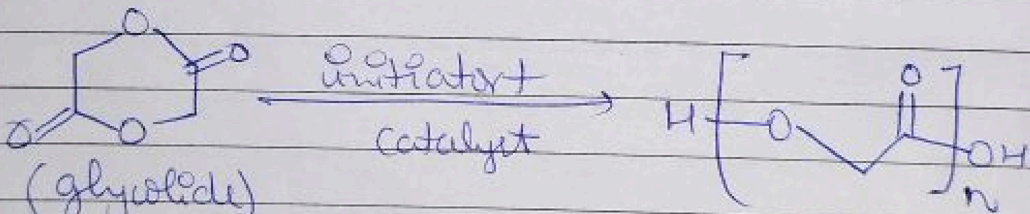
Synthesis: PGA is formed by ring opening polymerization of glyolic Acid (in its cyclic dimer form)

(a)



(Glycolic Acid) poly (glycolic acid)

(b)



(glycolide) poly (glycolic acid)

Properties:
- ☆ Biodegradability – through hydrolysis
- ☆ Mechanical properties – high tensile strength
- ☆ Thermal properties – melting temp – 225°C

Applications: ① Medical Applications
- → Sutures (biodegradable & biocompatible)
- → Drug delivery Systems (as microspheres for controlled drug release)
- → Tissue engineering (as scaffolding material).

HW: # What do you know about microplastics?
Study about microplastics

(2) Environmental Applications

→ In Biodegradable packaging
→ Agricultural films

(3) Biomedical devices

→ Implants
→ Wound dressings

PHBV :

(PHBV): Poly(3 hydroxybutyrate-co-3-hydroxyvalerate)

- is a biopolymer
- belonging to the family of polyhydroxyalkanoates
- it is a thermoplast

Synthesis: It is obtained by the copolymerization of 3 hydroxybutanoic acid and 3 hydroxy pentanoic acid

$$n\,(HO-\overset{\beta}{\underset{\underset{CH_3}{|}}{C}H}-\overset{\alpha}{C}H_2-COOH) + n\,(HO-\overset{\beta}{\underset{\underset{CH_2-CH_3}{|}}{C}H}-\overset{\alpha}{C}H_2-COOH)$$

$$\xrightarrow{-H_2O} \left[-O-\underset{\underset{CH_3}{|}}{CH}-CH_2-\underset{\underset{O}{\|}}{C}-O-\underset{\underset{CH_2-CH_3}{|}}{CH}-CH_2-\overset{\overset{O}{\|}}{C}-\right]_n$$

Properties: (1) Mechanical properties: high tensile strength and elasticity which depends upon the ratio of monomers

(2) Biodegradability: easy to biodegrade

T_g: 5°C and T_m: 170°C

KITTU

Date ______
Page ______

③ Thermal properties: Thermal Stability So it can be easily processing.

④ Barrier properties: good gas barrier propertres, used for packaging.

Applications: ① Packaging

② Sutures and Scaffolds

③ Drug delivery Systems

④ Agriculture

⑤ 3D printing

⑥ Textiles