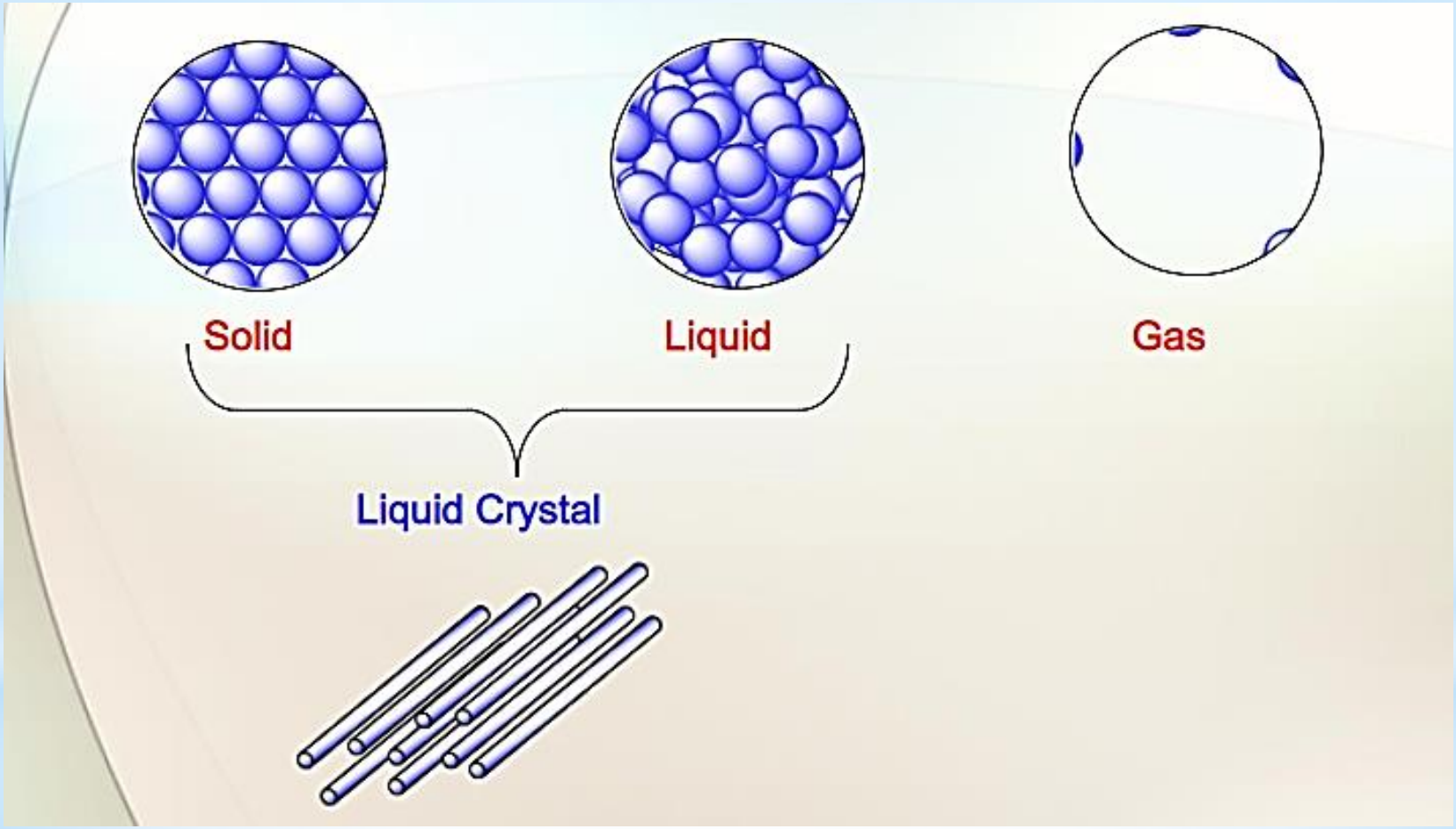
*Liquid Crystals

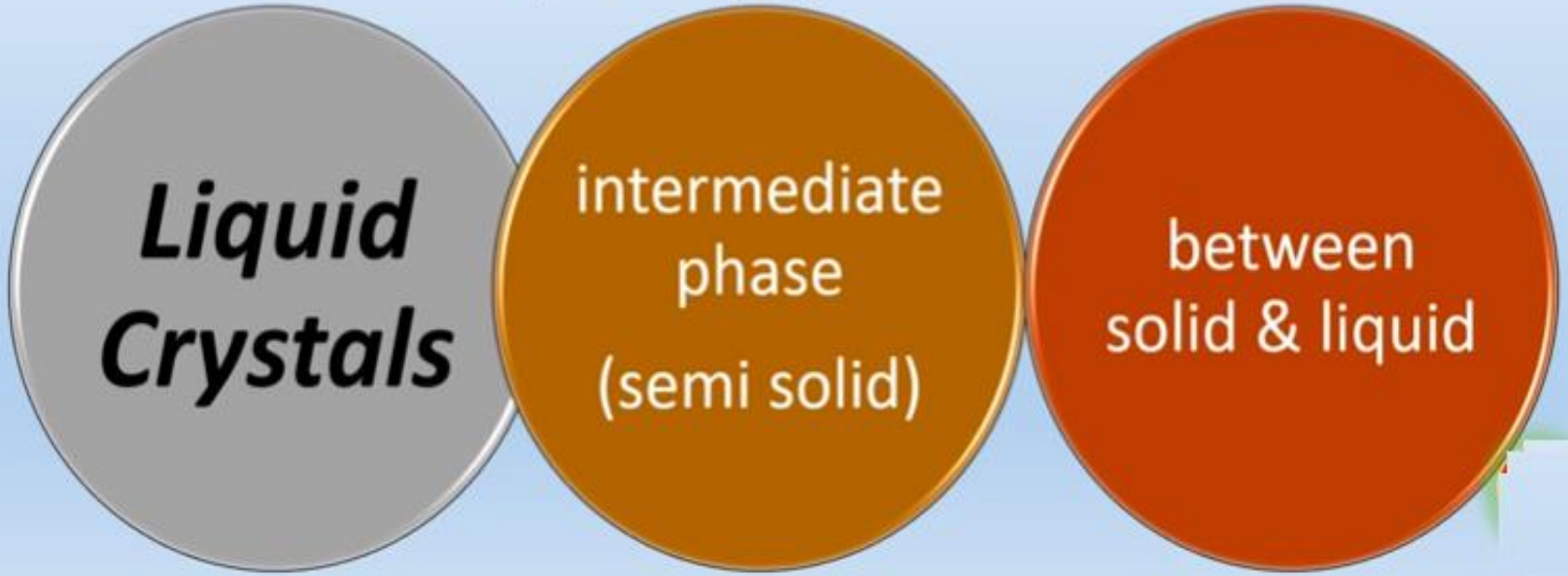
By DR. SUNITA GOYAL

*States of Matter



Liquid Crystals

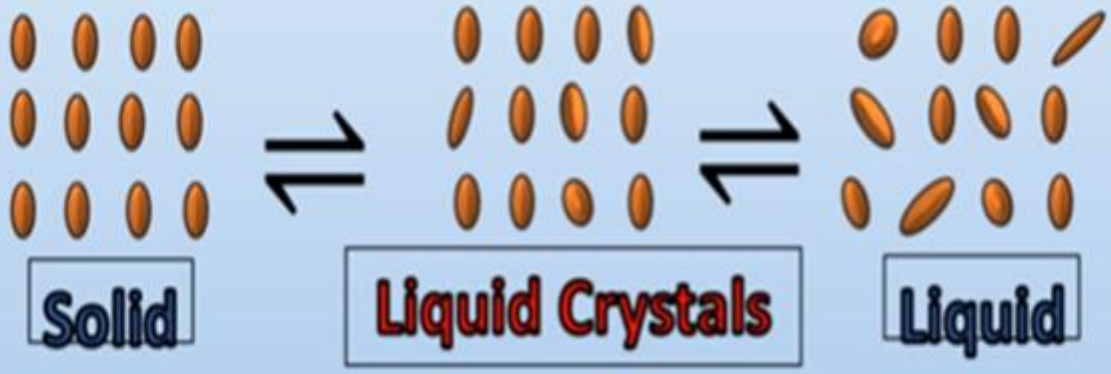
Solid $\overset{\text{on heating}}{\rightleftharpoons}$ Liquid Crystals (turbid liquid) $\overset{\text{on heating}}{\rightleftharpoons}$ Liquid



*What is Liquid Crystal?

Definition:

"The phase which is intermediate of solid and liquid and which has properties in between *true crystalline solid* and *true liquid* (clear liquid) is called liquid crystal."



Properties of Liquid Crystals like solids:

- orderly arrangement of particles.
- optical activity

Properties of Liquid Crystals like liquids:

- fluidly
- viscosity
- surface tension

* In some substance the tendency towards ordered arrangement is so high that on heating they pass through an intermediate state before forming clear liquid.

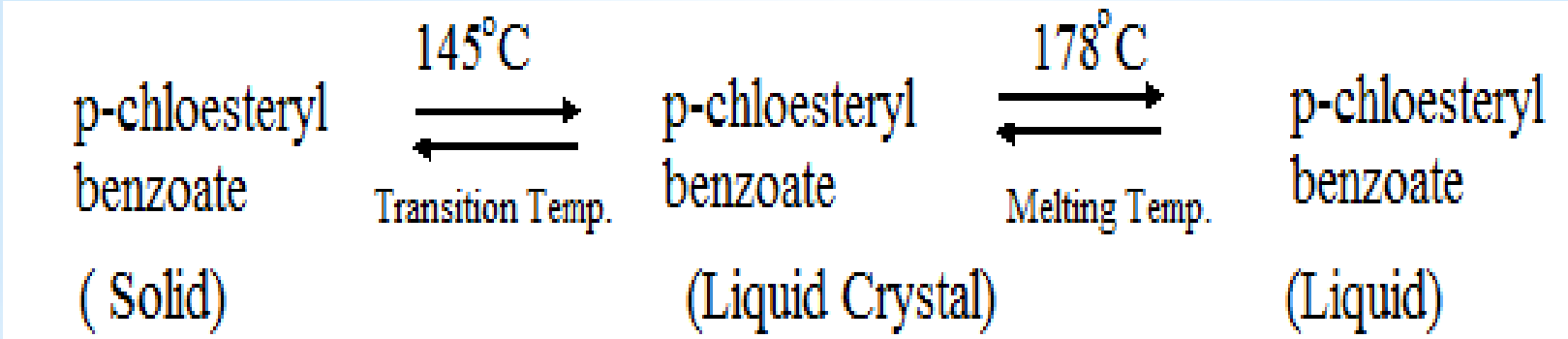
* This intermediate state known as liquid crystal state.

* It is also known as mesophase or middle phase.

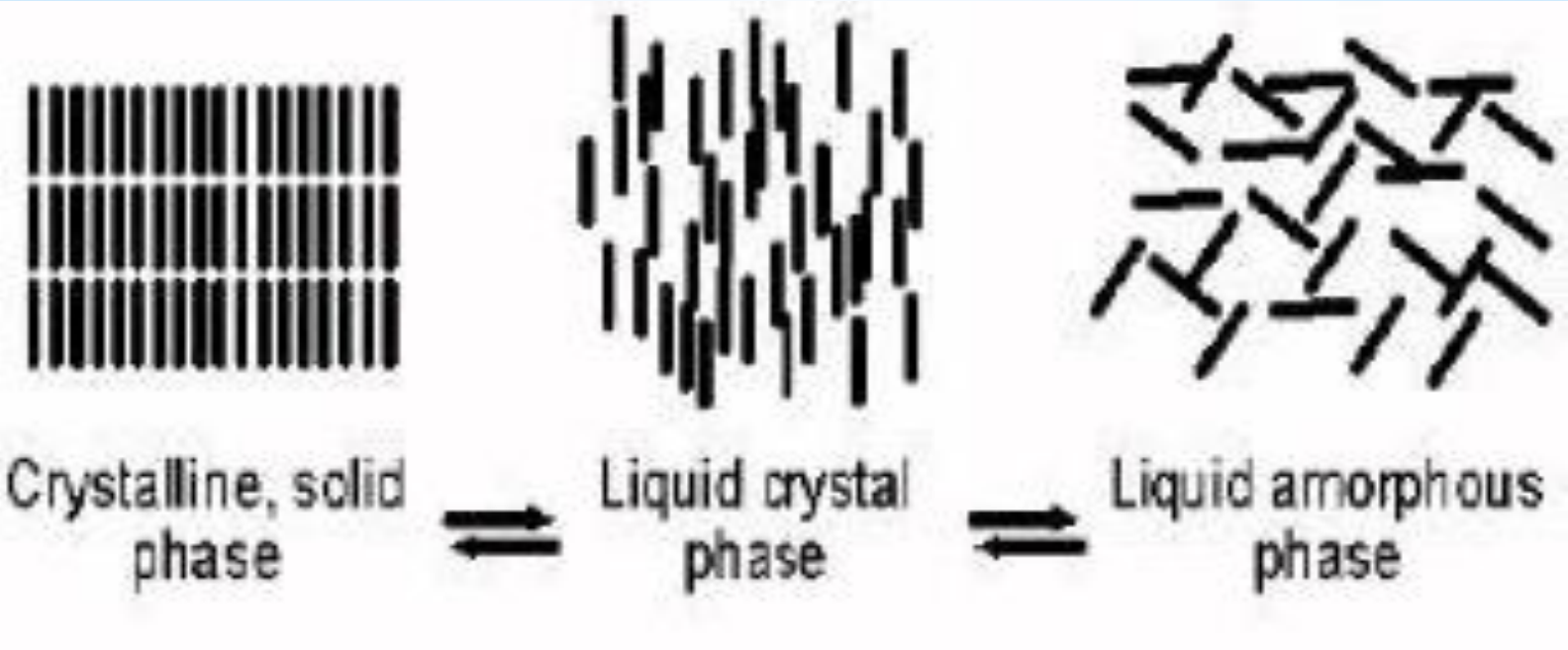
* It will play an important role in modern technology.

* A phase that exists between solid and liquid

* 1888, Austrian Botanist Freidrich Reinitzer discovers liquid crystals

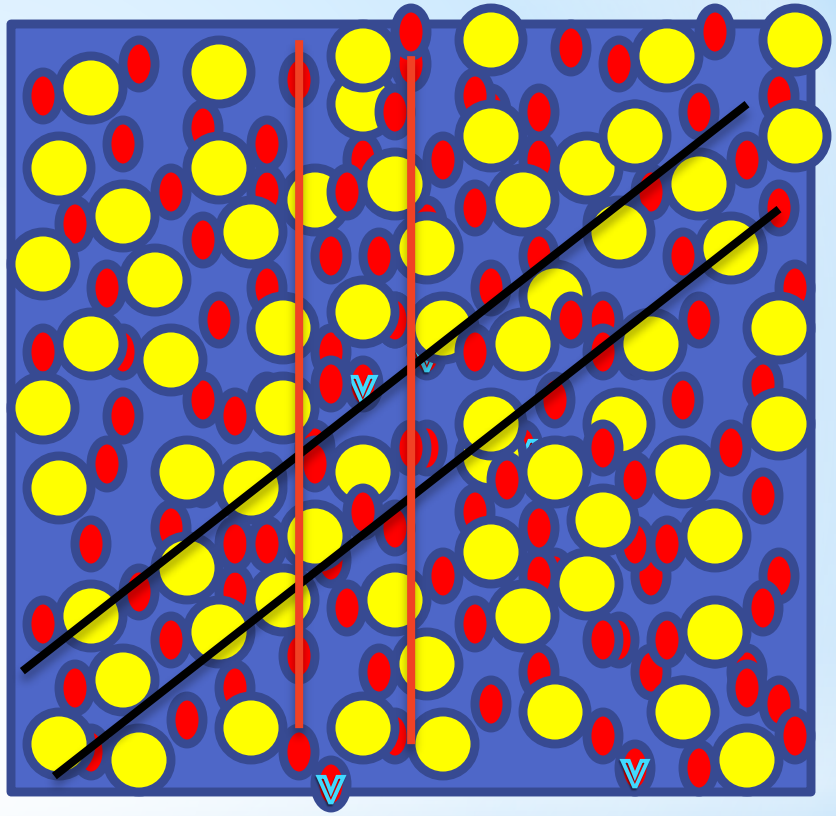


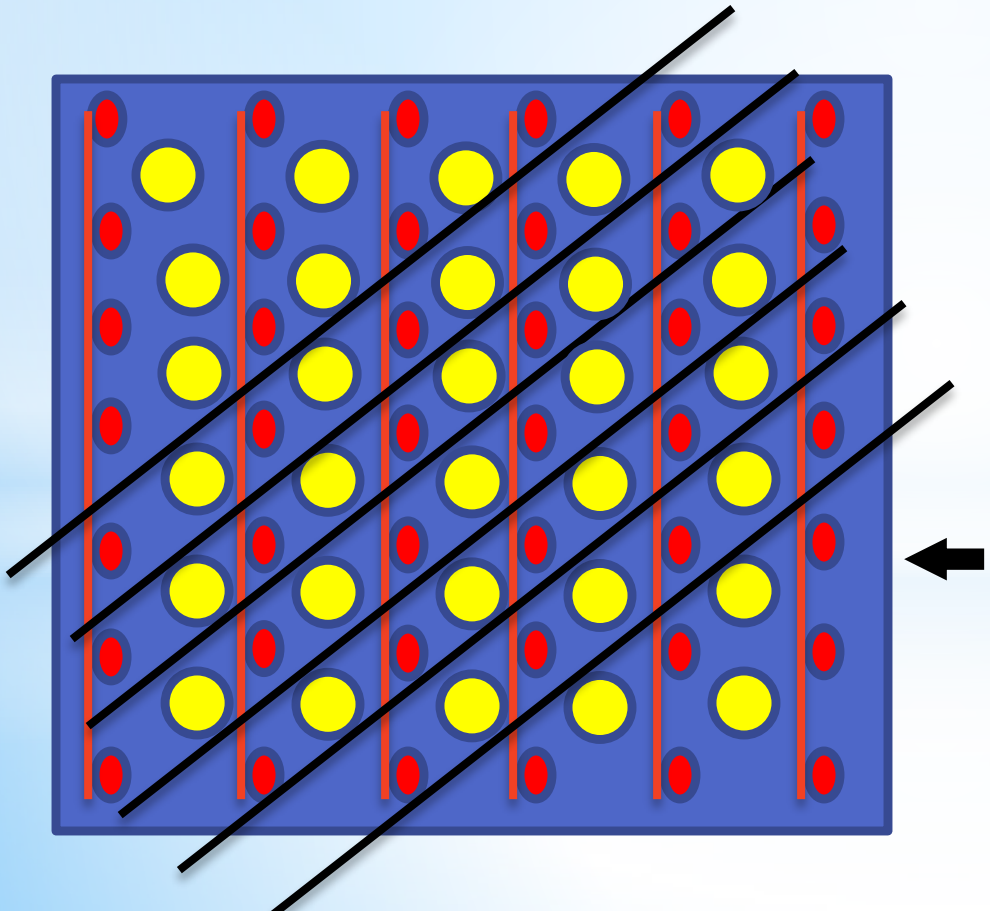
*Liquid Crystal Phase



* Isotropic

Liquids and gases (uniform physical properties in all directions).





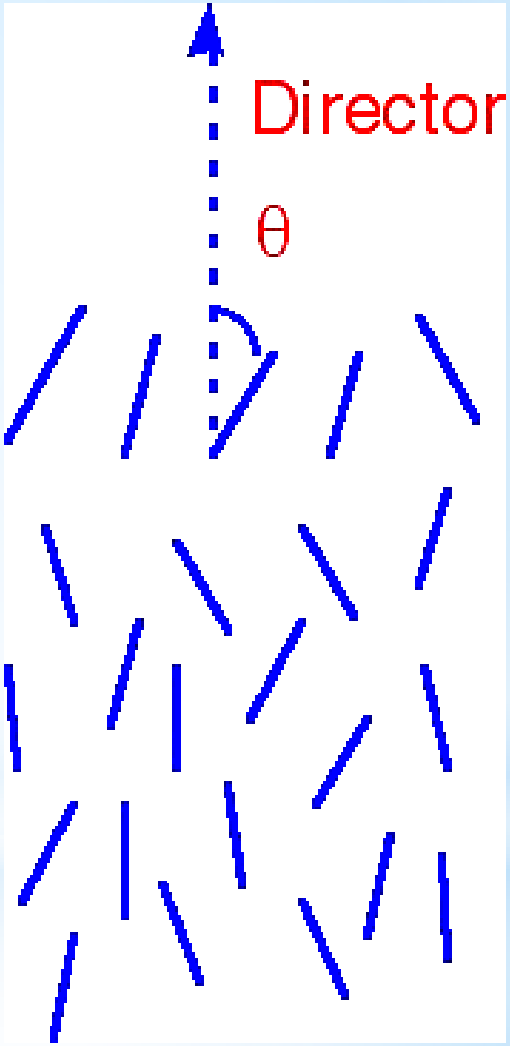
Crystals

have orientational order

Anisotropic

(Different physical properties (esp. optical properties like double refraction & interference patterns) in different directions)

- The molecules in a LC tend to remain oriented in a particular direction. The direction of preferred orientation in a liquid crystal is called the Director.
- Each molecule is orientated at some angle to the director.
- Orientational order: The tendency of a molecule to point along the common axis.



Comparison of Liquid Crystalline Phase with solid and liquid phases

Characteristics	Solid Phase	Liquid Crystalline Phase	Liquid Phase
Positional Order	Present	Absent	Absent
Orientational Order	Present	Present	Absent
Mobility	Immobile	Mobile	Mobile

*Molecular structure

*The most common liquid crystal molecules are long chain organic molecules.

*A side chain R, two or more aromatic rings A and A', connected by linkage groups X and Y, and at the other end connected to a terminal group R'. (R & R' may be –R,-OR, -COOR,& X may be –CH=N-, -N=N-, -N=N-O, -CH=CH-, -COO etc.

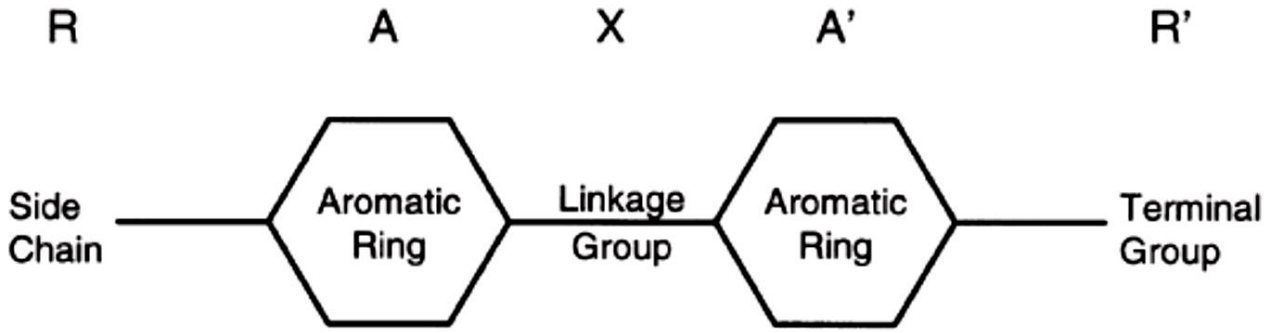


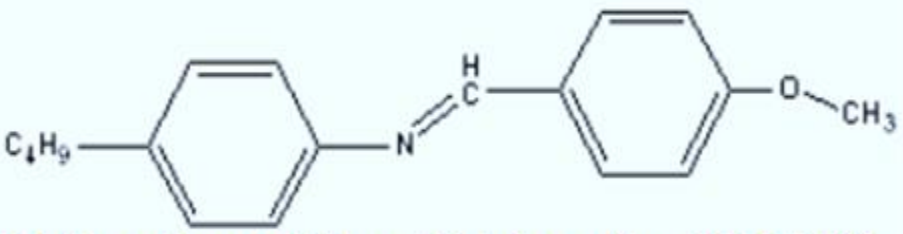
Figure 1.1. Molecular structure of a typical liquid crystal.

*Fundamental units of liquid crystals are known as mesogens.

Characteristics of molecules capable of forming liquid crystals:

- Rod-like molecular structure
- Rigidness of the long axis
- Strong dipoles and/or easily polarizable susbtituents

Examples:



Methoxybenzylidene Butylanaline ("MBBA")

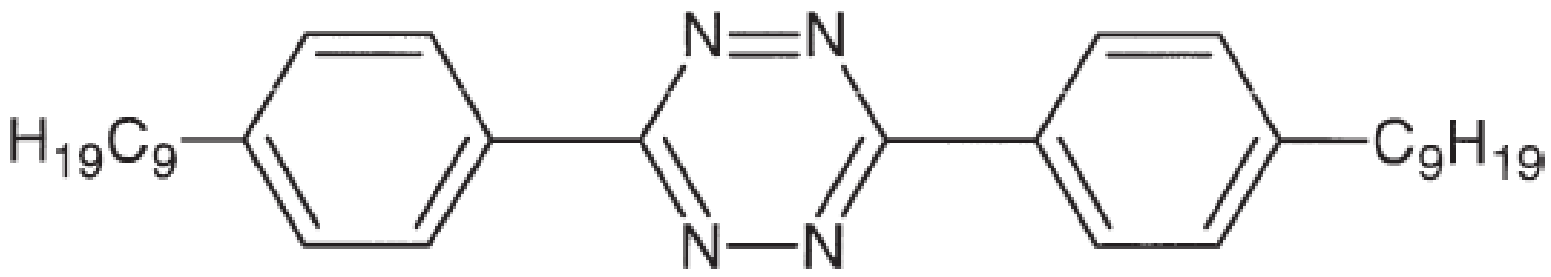


Figure 1.2. Molecular structure of a heterocyclic liquid crystal.

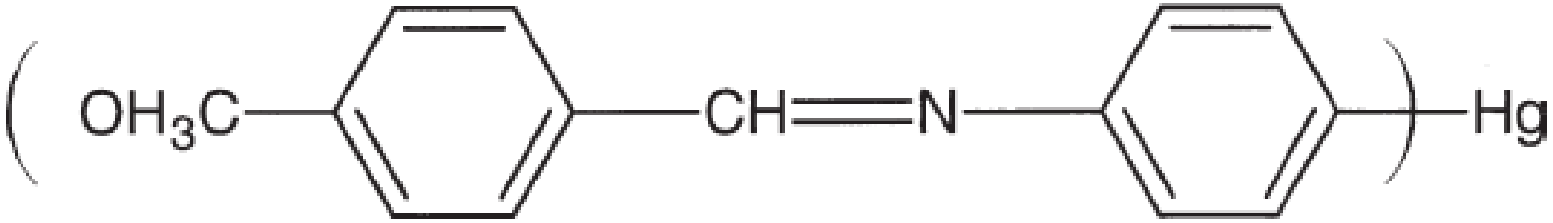
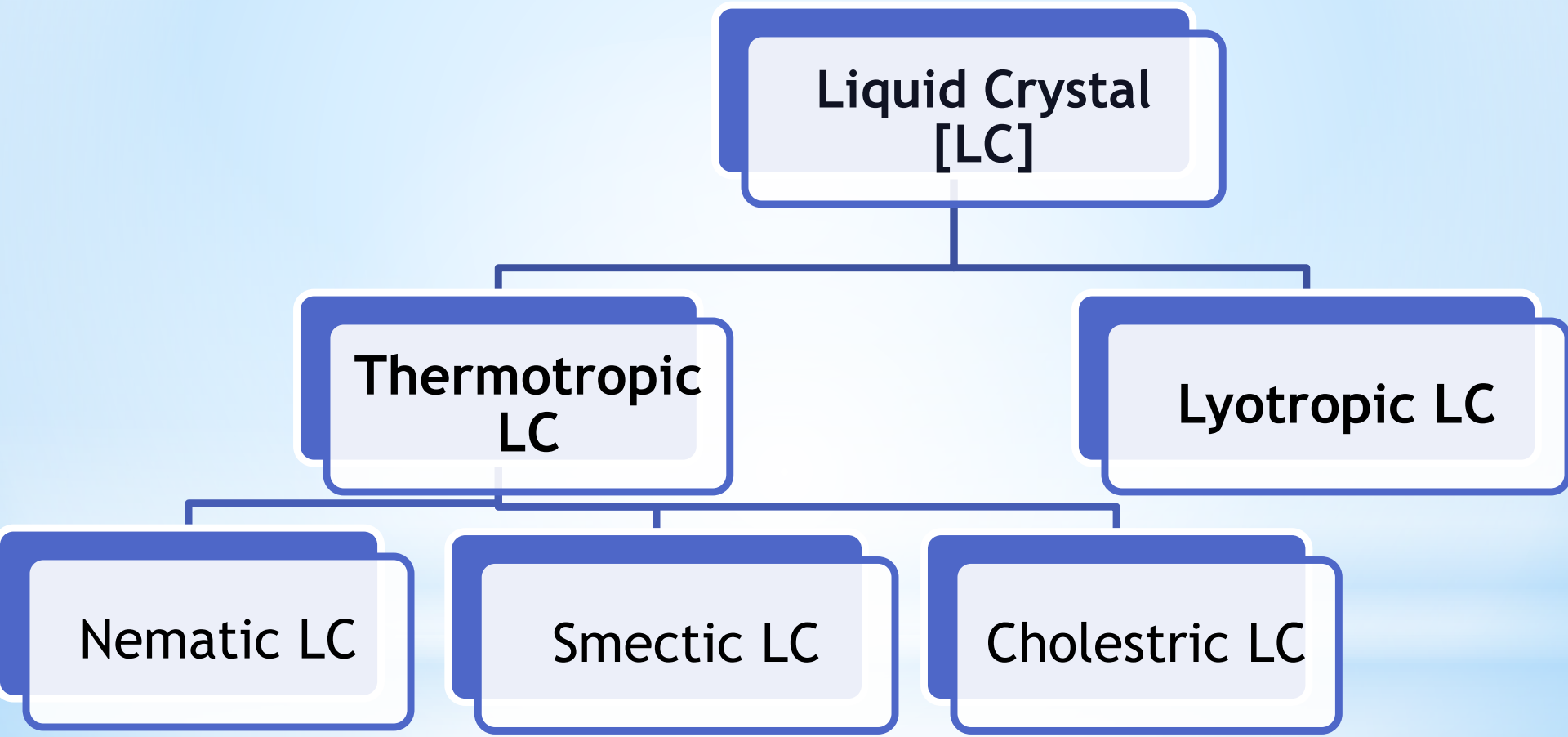


Figure 1.3. Molecular structure of an organometallic liquid crystal.

*Classifications



*Thermotropic Liquid crystals :

*Liquid crystals are said to be thermotropic if the liquid crystalline properties depend on the temperature.

*E.g. p-Cholsteryl benzoate (Temp. range: 145.5-178.5 ^{0}C)

*Lyotropic Liquid Crystals

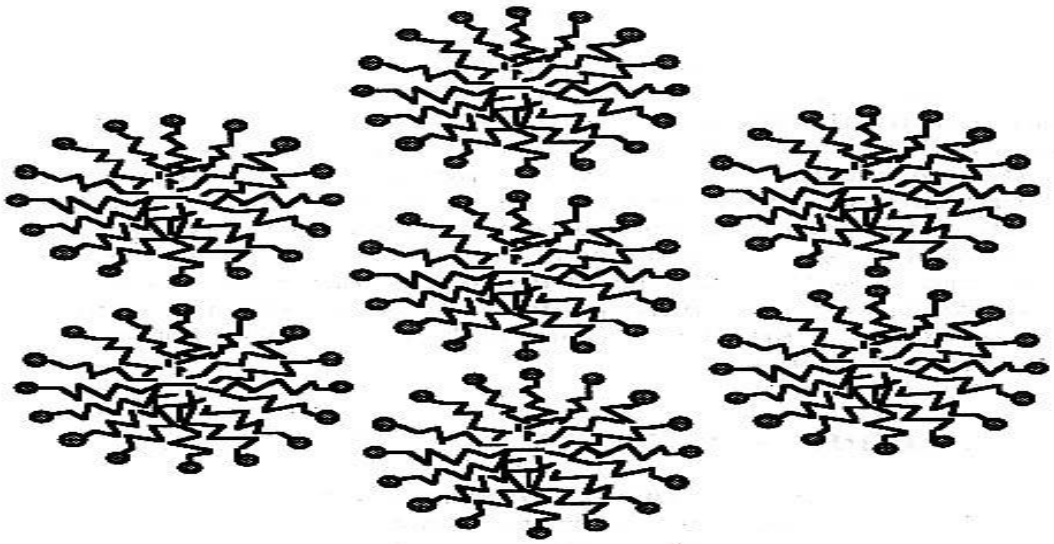
*Lyotropic LC phase is formed when a molecule is dissolved in a suitable solvent with specific concentration (Critical Micellization Concentration (cmc) at a particular temperature.

*Such compound are typically amphiphilic as they have both lyophilic (sovent attracting) and lyophobic (solvent repelling) parts in the same molecule.

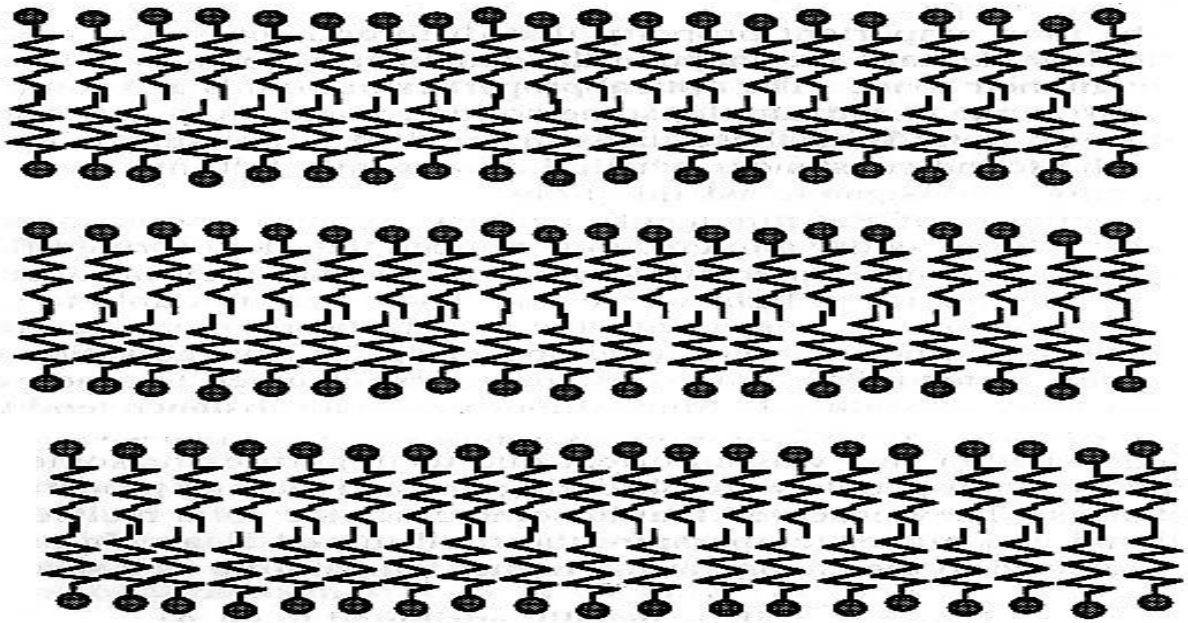
*Lyotropic Liquid Crystals

* In the presence of a solvent, the lyophobic ends come closer while the lyophilic ends are directed away. They form Micelle only beyond a particular concentration of solution called the Critical Micelle Concentration (cmc).

* Beyond cmc., when such solution is heated or cooled to a particular temp., the size of the micelle increases, eventually collapses out as Liquid crystal. Thus solvent–solute interactions play a vital role in such systems.



Cross-section of the hexagonal lyotropic liquid crystal phase.



Cross-section of the lamellar lyotropic liquid crystal phase.

*Molecular Ordering in Different Mesophases

* Nematic Liquid Crystals :

i. In Greek ‘nematic’ means thread and in polarized light they appear to have mobile thread like structure.

ii. In nematic liquid crystal, the molecules (mesogens) have no positional order, but they have long-range orientational order.

iii. The molecules are aggregate together in groups with their axis parallel to one another .

iv. Nematics have fluidity similar to that of ordinary liquids .

v. They can be easily aligned by an external magnetic or electric field.

*Nematic Liquid Crystals

Ex: p-azoxy anisole (PAA) ,
p-azoxy phenetole,
p-methoxy cinnamic acid.

*Smectic Liquid Crystals :

i. Smectic liquid crystal are found at lower temperature than the nematic crystals.

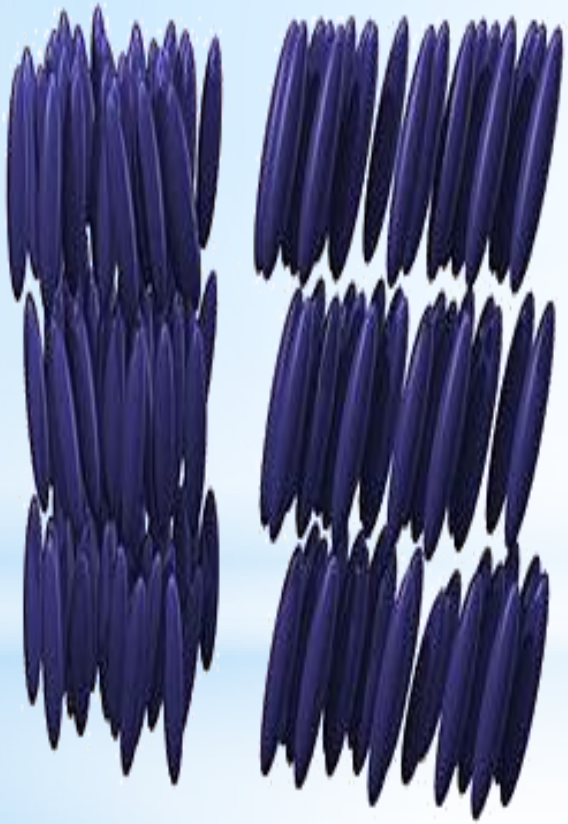
ii. These crystals are arranged in layers and slide over one another like soap.

iii. They do not flow as normal liquid.

iv. These crystal flows in layers and the layers are held together by weak inter layer forces.

v. They are characterized by small orientation and positional order.

*Smectic Liquid Crystals



Ex: ethyl p-azoxybenzoate

ethyl p-azoxycinnamate

*Cholestric Liquid Crystals :

i. They named as cholestric liquid crystal because the basic structure similar to cholesterol.

ii. They s how strong colour effect under polarized light. (Note: The change in temp. generates the changes of distances between individual layers and change in pitch length, resulting in change in wavelength, therefore the color changes accordingly)

iii. These crystal possess a very high optical rotatory power.

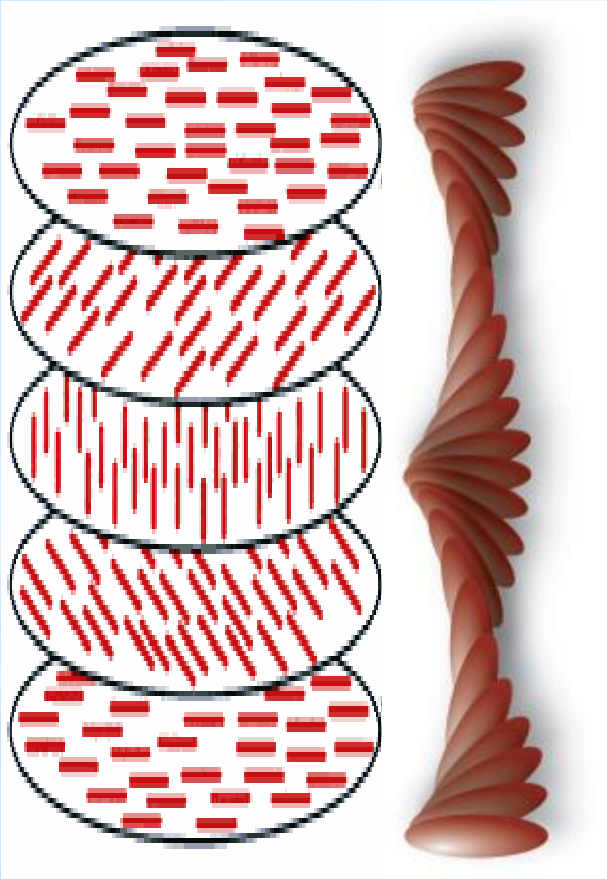
iv. In this crystal molecules are arranged in layers.

v. The crystal structure described as twisted nematic structure.

*Cholestric Liquid Crystals

- The cholestric phase can be defined as a special type of nematic liquid crystal.
- In this phase, the thin layers of the parallel mesogens have their longitudinal axes rotated in adjacent layers at certain angle.
- Addition of a chiral dopant to a nematic liquid crystal induces a helical twist to create a chiral nematic phase.
- Due to this helical structure the cholesteric phase exhibits some unique optical properties.

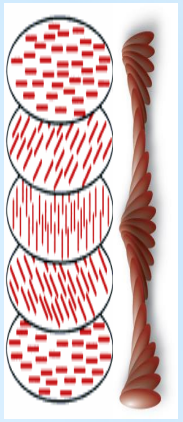
*Cholestric Liquid Crystals

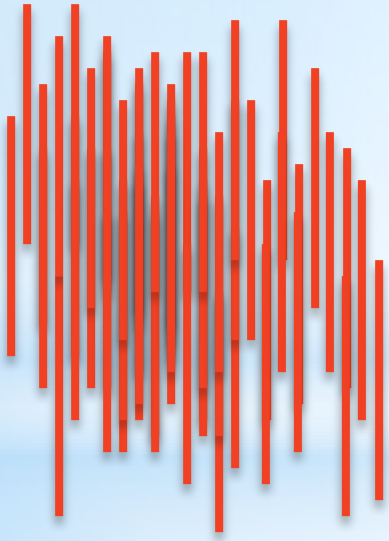


Ex: poly benzyl L- glutamate (PBLG)

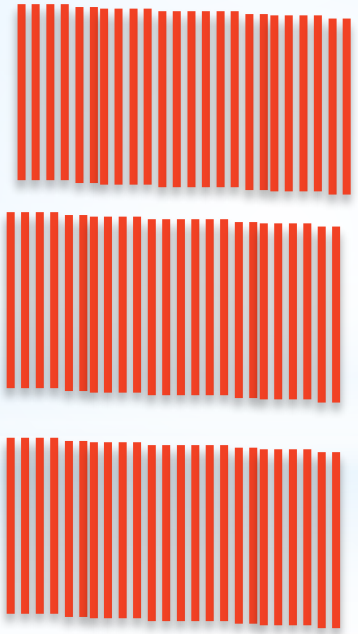
poly benzyl D- glutamate (PBDG)

Note: The director rotates about a horizontal axis. The distance for one full rotation is called a pitch.

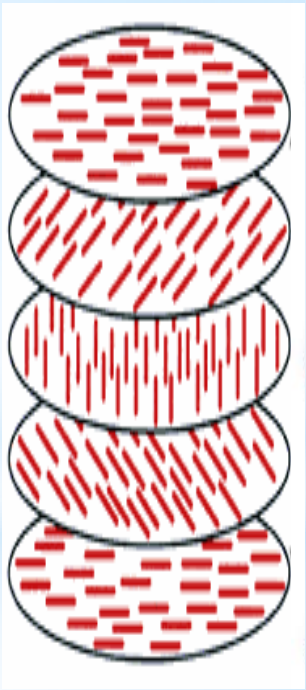




Nematic Liquid Crystals



Smectic Liquid Crystals

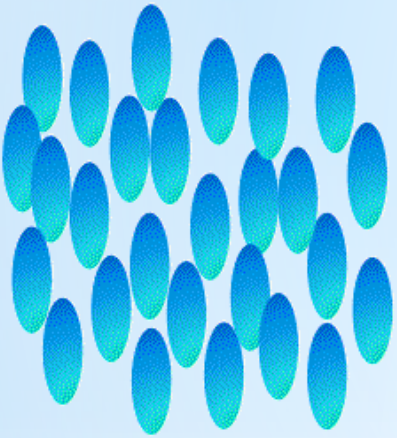


* Cholestric Liquid Crystals

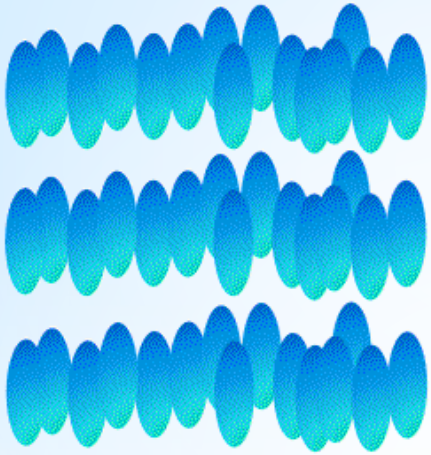
*Columnar Liquid Crystals

* The mesophases formed from the molecules having disc-like or plate like structures are known as Discotic or columnar liquid crystals. They are of two types:

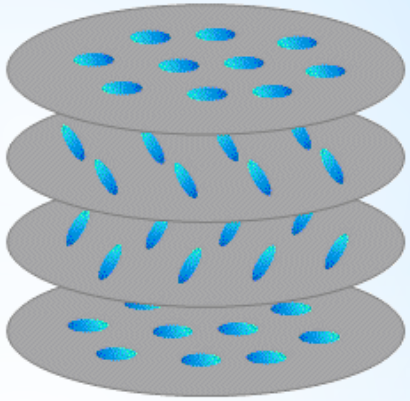
* **Smectic Discotic or Columnar Discotic phase:** Most of the molecules in such phases have both orientational as well as positional order. The majority of molecules tend to position themselves in columns. The columns are arranged in a hexagonal lattice.
* **Nematic Discotic Phase: It has orientational order but no positional order. The molecules are free to move.**



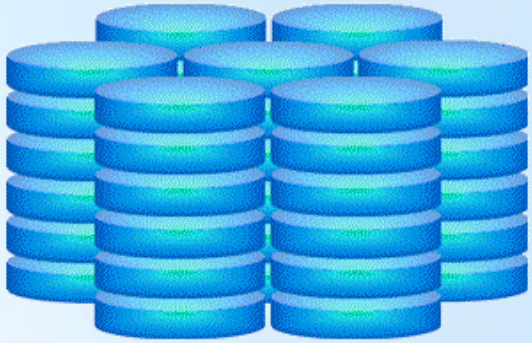
Nematic Phase



Smectic Phase



Cholesteric Phase
(Chiral Nematic Phase)



Discotic Phase
(Columnar Phase)

Phase changes of an ordinary solid into liquid & gaseous state is as:

Solid ⇌ **Liquid** ⇌ **Vapour**

Phase changes of a solid showing meso-morphic behavior is as:

Solid ⇌ **Liquid Crystal** ⇌ **Liquid** ⇌ **Vapour**

(mesomorphic state)

P-T Curve for both type of solids are:

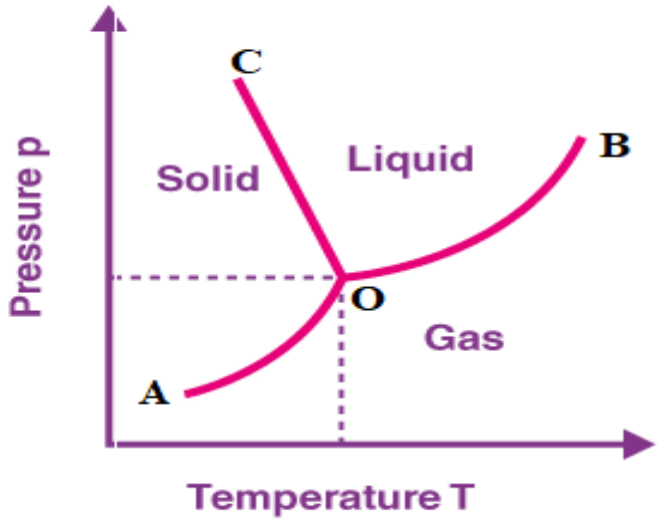


Fig. Vapour pressure & Temperature curve for Ordinary Solid

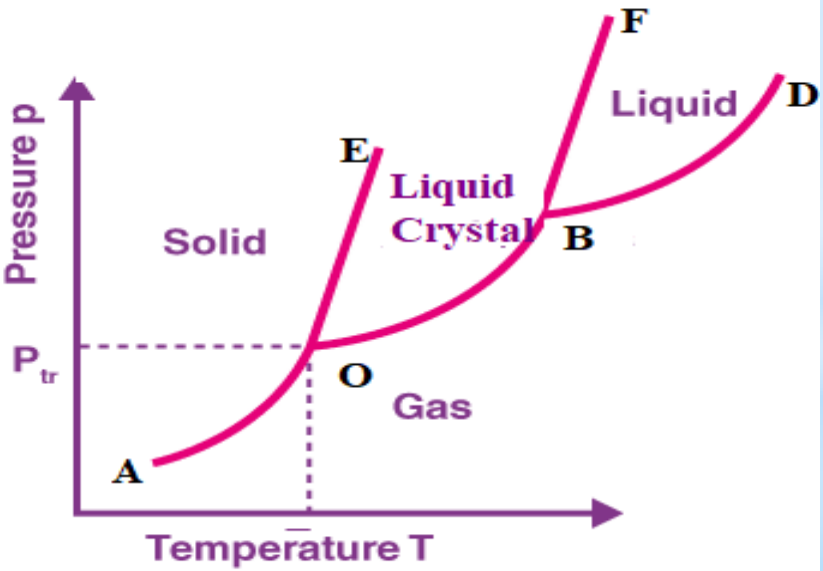


Fig. Vapour pressure & Temperature curve for a substance undergoing mesomorphic change

ThankYou