

Volume of the effluent sample = 25 ml

Volume of the $\text{K}_2\text{Cr}_2\text{O}_7$ consumed by the effluent = 8.3 ml

(i) 1000 ml of 1M $\text{K}_2\text{Cr}_2\text{O}_7$ = 294 g

8.3 ml of 0.001M $\text{K}_2\text{Cr}_2\text{O}_7$ = $(294 \times 8.3 \times 0.001) / 1000$

Amount of $\text{K}_2\text{Cr}_2\text{O}_7$ present = 2.4402 mg

(ii) 1 mol of $\text{K}_2\text{Cr}_2\text{O}_7$ \equiv 6 equivalents of oxygen

i.e., 294 mg of $\text{K}_2\text{Cr}_2\text{O}_7$ \equiv 6 \times 8 mg of oxygen

$$\therefore 2.4402 \text{ mg of } \text{K}_2\text{Cr}_2\text{O}_7 \equiv \frac{6 \times 8 \times 2.4402}{294} = 0.3984 \text{ mg}$$

(iii) COD in 25 ml of water = 0.3984 mg

1000 ml of water = $398.4 / 25 = 15.92$ mg

\therefore COD of water = 15.92 mg/dm³

2. What would be BOD value for a sample containing 200 mg/dm³ of glucose assuming that it was completely oxidized in the BOD test? (Atomic wt. of C=12; H=1; O=16).



Molecular mass of glucose = 180 g

From the above equation, 180 g of glucose requires 192 g of oxygen

$$\therefore 200 \text{ mg of glucose} \equiv \frac{192 \times 200}{180} = 213.33 \text{ mg}$$

UNIT III

CRYSTAL STRUCTURE

Types of Solids

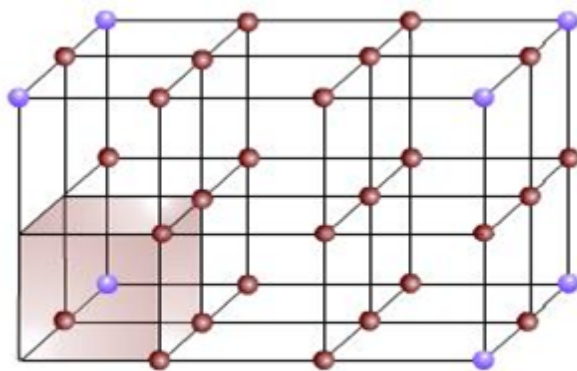
a) **Crystalline solids:** atoms self-organize in a periodic array

b) **Amorphous solids:** disordered – lack of a systematic atomic arrangement

In mineralogy and crystallography, **crystal structure** is a unique arrangement of atoms or molecules in a crystalline liquid or solid. A crystal structure is composed of a pattern, a set of atoms arranged in a particular way, and a lattice exhibiting long-range order and symmetry. Patterns are located upon the points of a lattice, which is an array of points repeating periodically in three dimensions. The points can be thought of as forming identical tiny boxes, called unit cells, that fill the space of the lattice.. The symmetry properties of the crystal are embodied in its space group

A Crystal is a solid composed of atoms or other microscopic particles arranged in an orderly repetitive array. The study of Crystal aims to interpret the macroscopic properties in terms of properties of the microscopic particles of which the solid is composed. The arrangement of atoms in a Crystal is called Crystal Structure.

Space Lattice and Unit Cell



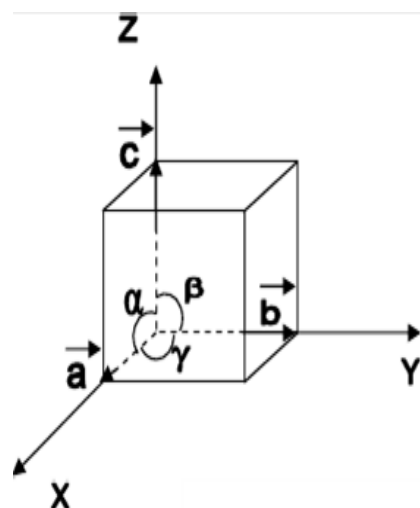
Representation of space
lattice and unit cell

Points can be imagined in space about which atoms or molecules are located. Such points are called Lattice Points. The totality of such points is called Space Lattice or Crystal Lattice. The Three-Dimensional space lattice (3-D space lattice) may be defined as a finite array of lattice points in three-dimension in which each and every lattice point has identical surrounding in an array OR regular arrangement of the constituent particles of a crystal in a three dimensional space is called **crystal lattice** or **space lattice**.

The constituent particles of a crystalline solid are arranged in a definite fashion in the three dimensional space. One such arrangement by representing the particles with points is shown below

From the complete space lattice, it is possible to select a smallest three dimensional portion which repeats itself in different directions to generate the complete space lattice. This is called a **Unit Cell**.

Unit cell



The smallest three-dimensional portion of a complete space lattice, which when repeated over and again in different directions produces the complete space lattice. OR The unit cell is a structural unit or building block that can describe the crystal structure. Repetition of the unit cell generates the entire crystal. The size and shape of a unit cell is determined by the lengths of the edges of the unit cell (a , b and c) and by the angles α , β and γ between the edges b and c , c and a , and a and b respectively.

If we take into consideration, the symmetry of the axial distances (a , b , c) and also the axial angles between the edges α , β and γ , the various crystals can be divided into seven systems. These are also called crystal habits.

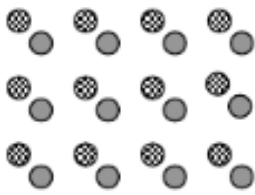
Basis:

Every lattice point can be associated with one or unit assembly of atoms or molecules identical in composition called Basis or Pattern. The regular periodic three-dimensional arrangement of Basis is called Crystal Structure. Space lattice is imaginary. Crystal structure is real.

Lattice parameters:

In every crystal some fundamental grouping of particles is repeated. Such fundamental grouping particles is called unit cell. A unit cell is chosen to represent the symmetry of the crystal. Hence the unit cell with maximum symmetry is chosen. They are the basic building blocks of the crystal. When these unit cells are translated in three dimensions that will generate the crystal. Each crystal lattice is described by type of unit cell. But each unit cell is described three vectors a , b and c when the length of the vectors and the angles (α, β, γ) between them are specified. They are nothing but the intercepts of the faces and the interfacial angles. All together they constitute lattice parameters

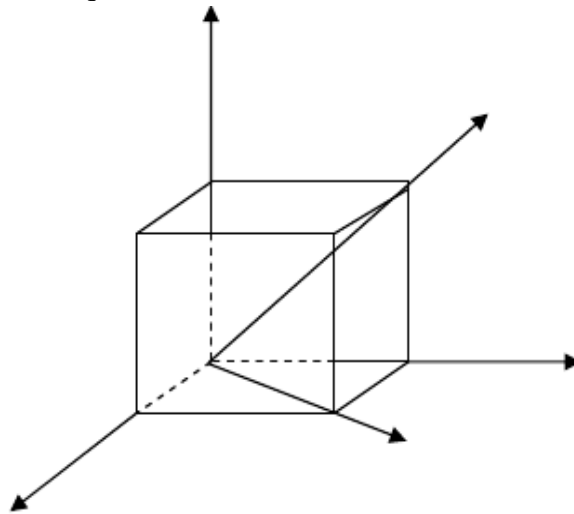
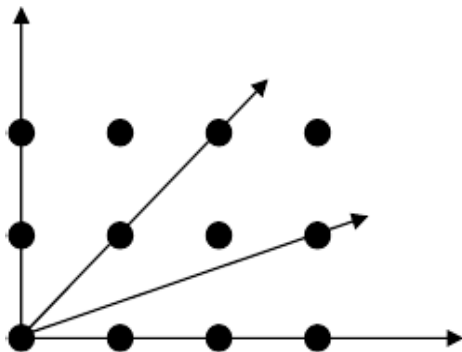
Bravais and Non-Bravais lattice: - A **Bravais** lattice is one in which all lattice points are identical in composition. If the lattice points are not identical then lattice is called *Non -Bravais* lattice.



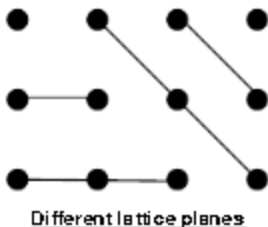
The set of lattice points \bullet 's together constitutes a Bravais lattice. Similarly the set of lattice points \bullet 's together constitutes a Bravais lattice. But set of all lattice points \bullet 's and \bullet 's together constitute a Non – Bravais lattice. Hence a Non-Bravais lattice could be considered as the superposed pattern of two or more interpenetrating Bravais lattices.

Directions and Planes:

In crystals there exists directions and planes in which contain concentration of atoms. It is necessary to locate these directions and planes for crystal analysis. Arrows in two dimensions show directions. “The directions are described by giving the coordinates of the first whole numbered point ((x , y) in two dimension, (x, y, z) in three dimension) through which each of the direction passes”. Directions are enclosed within square brackets



Planes: -



The crystal may be regarded as made up of an aggregate of a set of parallel equidistant planes, passing through the lattice points, which are known as lattice planes. These lattice planes can be chosen in different ways in a crystal. The problem in designating these planes was solved by Miller who evolved a method to designate a set of parallel planes in a crystal by Miller indices hkl

Crystal systems

Based on lattice parameters crystals are classified into seven basic systems. If atoms are placed only at corners seven crystal systems yield seven lattices. But few more lattices could be constructed by placing atoms at face center, body center etc., Bravais showed that there are 14 such lattices exist in nature. Hence the name Bravais space lattices. Each crystal system differs from the other in lattice parameters.

BRAVAIS LATTICE:

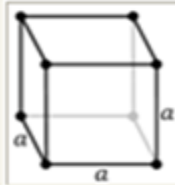
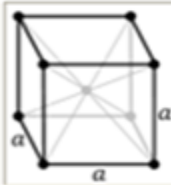


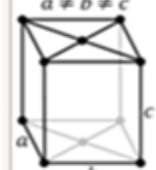


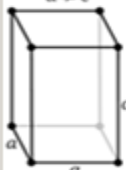
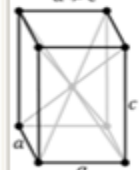
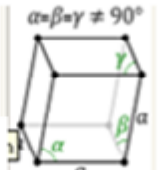
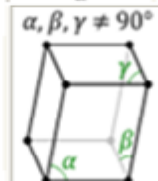
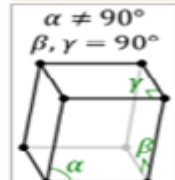
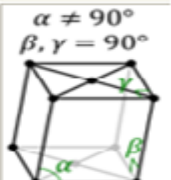
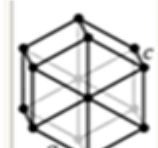
When the crystal systems are combined with the various possible lattice centerings, They describe the geometric arrangement of the lattice points, and thereby the translational symmetry of the crystal. In three dimensions, there are 14 unique Bravais lattices which are distinct from one another in the translational symmetry they contain. The fourteen three-dimensional lattices, classified by crystal system, are shown above. The Bravais lattices are sometimes referred to as *space lattice*

| Name of the system | Relation between length of edges | Angle between axes | Examples |
|--------------------|----------------------------------|---|------------|
| Cubic | $a=b=c$ | $\alpha = \beta = \gamma = 90^\circ$ | NaCl , KCl |
| Orthorhombic | $a \neq b \neq c$ | $\alpha = \beta = \gamma = 90^\circ$ | KnO3 |
| Tetragonal | $a=b \neq c$ | $\alpha = \beta = \gamma = 90^\circ$ | TiO2 |
| Monoclinic | $a \neq b \neq c$ | $\alpha = \gamma = 90^\circ \neq \beta$ | CaSO4 |
| Triclinic | $a \neq b \neq c$ | $\alpha \neq \beta \neq \gamma \neq 90^\circ$ | CuSO4 |
| Rhombohedral | $a=b=c$ | $\alpha = \beta = \gamma \neq 90^\circ$ | Quartz |

| | | | |
|-----------|--------------|--|----------|
| Hexagonal | $a=b \neq c$ | $\alpha = \beta = 90^\circ \quad \gamma = 120^\circ$ | graphite |
|-----------|--------------|--|----------|

The 7 lattice systems (From least to most symmetric)

The 14 Bravais Lattices

| | | | | |
|---|---|---|--|---|
| cubic (4 triads) | simple (SC) | body-centered (bcc) | face-centered (fcc) | |
| |  |  |  | |
| | a | a | a | |
| orthorhombic (3 perpendicular diads) | simple | base-centered | body-centered | face-centered |
| | $a \neq b \neq c$ | $a \neq b \neq c$ | $a \neq b \neq c$ | $a \neq b \neq c$ |
| |  |  |  |  |
| | a | a | b | b |
| tetragonal (1 tetrad) | simple | body-centered | | |
| | $a \neq c$ | $a \neq c$ | | |
| |  |  | | |
| rhombohedral (1 triad) | $\alpha = \beta = \gamma \neq 90^\circ$ | | | |
| |  | | | |
| triclinic (none) | $\alpha, \beta, \gamma \neq 90^\circ$ | | | |
| |  | | | |
| monoclinic (1 diad) | simple | base-centered | | |
| | $\alpha \neq 90^\circ$ $\beta, \gamma = 90^\circ$ | $\alpha \neq 90^\circ$ $\beta, \gamma = 90^\circ$ | | |
| |  |  | | |
| | a | a | | |
| hexagonal (1 hexad) |  | | | |
| | a | | | |

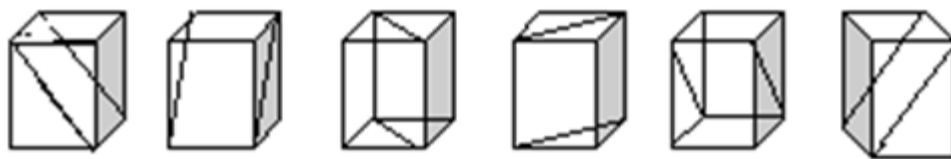
Elements of Symmetry:

Symmetry in an object arises because of uniformity in shape and arrangement in a balanced proportion some object or more symmetrical than others. For ex: a sphere is most symmetrical because it looks exactly the same in whatever way the sphere is turned about any axis passing through its centre.

However, a cube looks identical only when rotated through angles of 90, 180 or 270 degree. About the axis passing through its centre. A crystal which is made up of unit cells is associated with symmetry because of the arrangement of its constituent units in an ordered way. The unit cells themselves being ordered, exhibits certain elements of symmetry in crystals are plane of symmetry, axis of symmetry and centre of symmetry.

Plane of Symmetry:

A plane of symmetry is an imaginary plane passing through the centre of a crystal dividing the crystal into two exactly equivalent halves such that one is the mirror image of the other. For Ex: a cube as 9 planes of symmetry 3 of which are horizontal and rest are diagonal..



Diagonal plane of symmetry



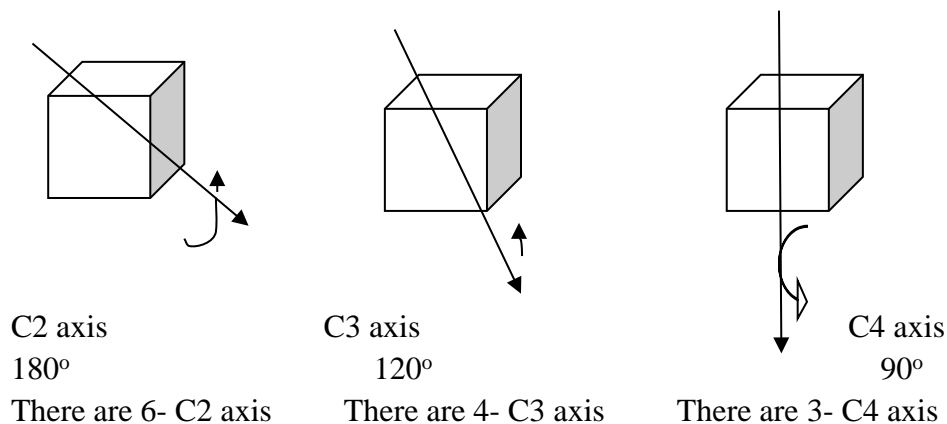
Axis of Symmetry:

An axis of symmetry is an imaginary line passing through the crystal about which the crystal is rotated through 360 degree presents the same appearance more than once. If during the rotation it looks axis n times, the crystal is said to have an n fold of symmetry(denoted by C_n).

There are 3 types of Axis of Symmetry based on the no of appearance

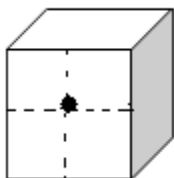
- **C₂ axis** - when a cube is rotated about an axis passing through the centres diagonally opp edges (sides), it appears identical two times – at 180 and again at 360 degree. Thus the cube there are six C₂-axis emerging from the opposite edges of the unit cell
- **C₃ axis** - when a cube is rotated about an axis passing through the diagonally opp vertices, it appears identical three times – at 120, 240 and again at 360 degree. Thus the cube has four C₃-axis passing through the opposite corner.
- **C₄ axis** - when a cube is rotated about an axis passing through the centres of opposite sides, it appears identical four times – at 90, 180, 270 and again at 360 degree. Thus a cube has a four-fold axis of symmetry (C₄ axis) along a line passing through the centres of opposite sides. Three such C₄-axis exist in a cube

Thus a cube has thirteen axes of symmetry



Centre of symmetry:

A crystal is said to have a centre of symmetry if every face has another identical face at an equal distance from the centre. There can be several axes and planes of symmetry for a crystal but only one centre of symmetry for a cube, the centre of symmetry is the point at which any two axes meet.



Planes of symmetry, axes of symmetry and centre of symmetry are collectively known as elements of symmetry. A cubic system has 23 elements of symmetry comprising of nine planes of symmetry, thirteen axes of symmetry (three C₄, four C₃ and six C₂) and one centre of symmetry.

Law of Rational indices: proposed by A.R Haüy in 1784 “The intercepts of the planes on various faces of a crystal are small integral multiples of the std plane “

Weiss Indices: The coefficients of the intercepts of a plane on a crystal is called **weiss indices**

Weiss Indices and Miller Indices: The coefficients intercepts of the planes on the faces of a crystal is called Weiss Indices

Calculation of Miller Indices from Weiss Indices. In the above fig:

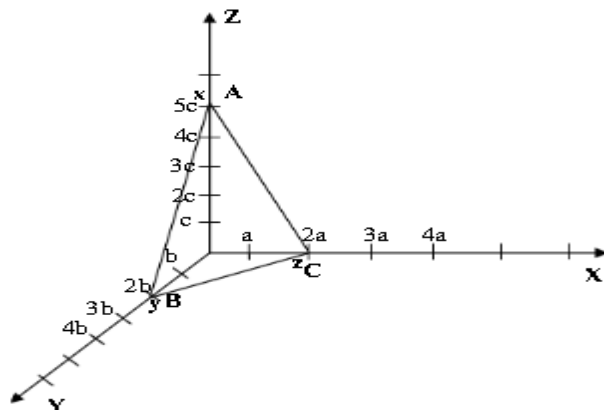
| | |
|---|-----------------------|
| The intercepts of a new plane wrt std plane | 3a:2b:4c |
| Weiss indices | 3: 2: 4 |
| Reciprocal | $1/3 : 1/2 : 1/4$ |
| LCM | <u>4: 6 : 3</u> |
| 12 | |
| Miller indices are | 4:6:3 (only whole no) |

Steps to determine miller Indices of given set of parallel planes: -

“Miller indices may be defined as the reciprocals of the intercepts made by the plane on the Crystallographic axes when reduced to smallest numbers. Consider a plane ABC which is one of the planes belonging to the set of parallel planes with miller indices (h k l). Let x, y and z be the intercepts made by the plane along the Three crystallographic axes X, Y and Z respectively.

1. Determine the coordinates of the intercepts made by the plane along the three crystallographic axes.
2. Express the intercepts as multiples of the unit cell dimensions, or lattice parameters along the axes
3. Determine the reciprocals of these numbers
4. Reduce them into the smallest set of integral numbers and enclose them in simple brackets. (No commas to be placed between indices)

The intercepts $x=2a$, $y=2b$ & $z=5c$ Generally $x=pa$, $y=qb$, $z=rc$.



The multiples of lattice parameters are

$$\frac{x}{a} = \frac{2a}{a} = 2, \frac{y}{b} = 2, \text{ \& } \frac{z}{c} = 5$$

Taking the reciprocals

$$\frac{a}{x} = \frac{1}{2}, \frac{b}{y} = \frac{1}{2}, \text{ \& } \frac{c}{z} = \frac{1}{5}$$

Reducing the reciprocals to smallest set of integral numbers by taking LCM.

$$\begin{array}{ccc} 10 \times \frac{1}{2} & 10 \times \frac{1}{2} & 10 \times \frac{1}{5} \\ \hline 5 & 5 & 2 \end{array}$$

Miller indices of plane ABC = (h k l) = (5 5 2).

Note: - a) All parallel equidistant planes have the same Miller indices.

b) If the Miller indices have the same ratio, then the planes are parallel.

c) If the plane is parallel to any of the axes, then the corresponding Intercept is taken to be ∞ .

Definitions

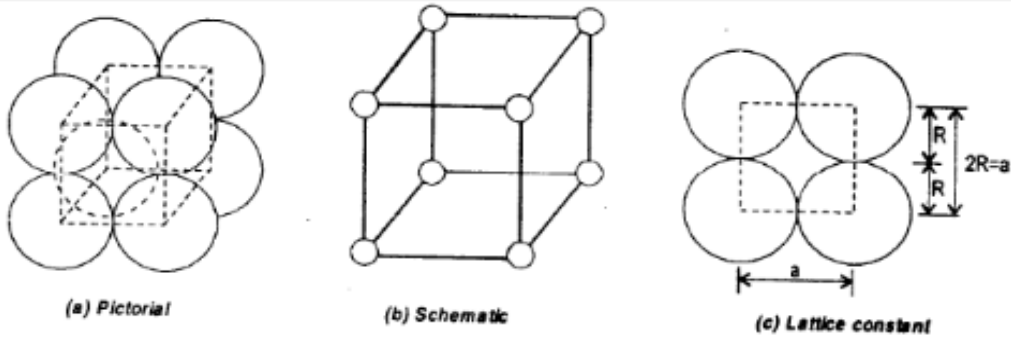
1. **Coordination number:** - It is the number of equidistant nearest neighbors that an atom has in a crystal structure.
2. **Nearest neighbor distance:** - It is the distance between two nearest neighbors in a crystal structure.

3. **Atomic packing factor (APF) or Packing fraction:** - It is the fraction of space occupied by atoms in a unit cell. It is defined as the ratio of volume occupied by atoms in unit cell to the volume of the unit cell. If the number of atoms per unit cell are 'n' and if V_a is the volume of atoms in the unit cell and V is the volume of the unit cell

$$\text{APF} = \frac{\text{Total Volume occupied by atoms in a unit cell.}}{\text{Volume occupied by atoms}}$$

4. **Lattice Constant:** - In a cubic lattice the distance between atoms remains constant along crystallographic axes and is called Lattice Constant

Simple Cubic Structure:



In simple cubic structure each atom consists of 6 equidistant nearest neighbors. Hence its co-ordination number is 6.

Eight unit cells share each atom at the corner. Hence only $1/8^{\text{th}}$ of the volume of the atom lies in each cell. Since the atoms are present only at corners, the No. of atoms per unit cell is given by

$$n = \frac{1}{8} \times 8 = 1 \text{ atom}$$

We know that the APF is given by

$$\text{APF} = \frac{n \times V_a}{V}$$

$$\text{APF} = \frac{1 \times \frac{4\pi R^3}{3}}{a^3}$$

In this structure the atoms touch each other along the sides of the cube. There fore **$a = 2R$** , Where R is the radius of each atom.

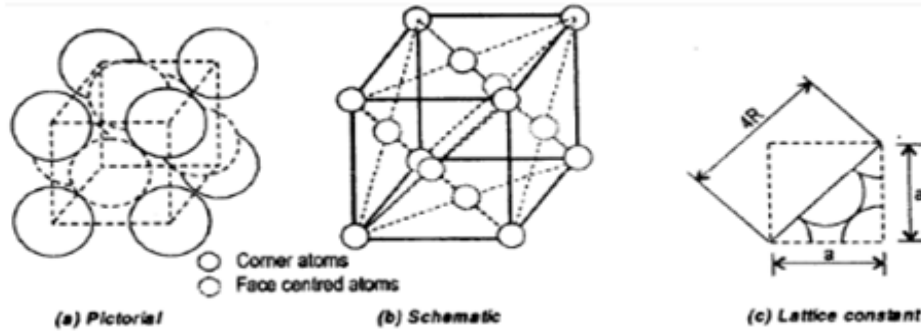
$$\text{APF} = \frac{4\pi R^3}{3(2R)^3}$$

$$\text{APF} = \frac{4\pi R^3}{3(8R^3)}$$

$$\text{APF} = 0.5235$$

Hence atoms occupy 52.35% off the volume of the unit cell.

Face Centered Cubic (FCC) Structure:



In FCC structure in addition to atoms at corners, atoms are present at face centers. Each atom consists of 12 equidistant nearest neighbors. Hence the coordination number is 12.

The number of atoms per unit cell is

$$n = \frac{1}{2} \times 6 + \frac{1}{8} \times 8 = 4 \text{ atoms}$$

In this structure atoms touch each other along the face diagonal. There fore

$$(4R)^2 = a^2 + a^2$$

$$16R^2 = a^2 + a^2 = 2a^2$$

Where **R** is the atomic radius.

$$a^2 = \frac{16R^2}{2}$$

$$a = \frac{4R}{\sqrt{2}} = 2\sqrt{2}R$$

$$APF = \frac{1 \times \frac{4\pi R^3}{3}}{a^3}$$

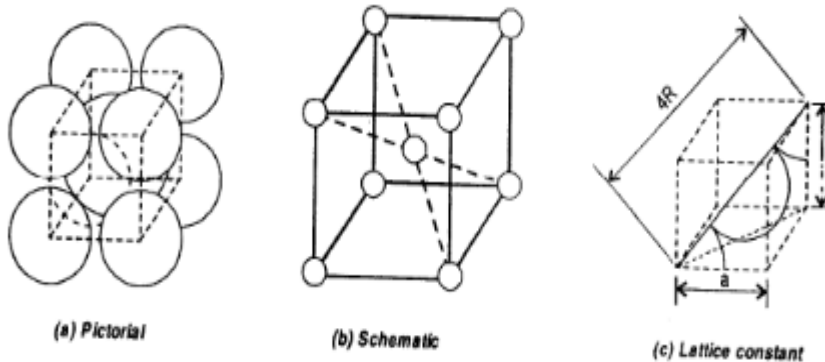
$$APF = \frac{1 \times \frac{4\pi R^3}{3}}{(2\sqrt{2}R)^3}$$

$$APF = \frac{\sqrt{2}\pi}{6}$$

$$APF = 0.7405$$

Hence atoms occupy 74.05% of the volume of the unit cell.

Body Centered Cubic (BCC) Structure:



Each atom has 8 equidistant nearest neighbors. Hence the **co-ordination number** is 8.

Since there are eight atoms at corners and 1 atom at the body center, the no. of atoms per unit cell is given by

$$n = 1 + \frac{1}{8} \times 8 = 2 \text{ atoms}$$

Also in this structure the atoms touch each other along the body diagonal. Therefore

$$(4R)^2 = (\sqrt{2} a)^2 + a^2$$

$$16R^2 = 2a^2 + a^2 = 3a^2$$

Where **R** is the radius of the atom

$$a^2 = \frac{16R^2}{3}$$

$$a = \frac{4R}{\sqrt{3}}$$

Now the APF is given by

$$APF = \frac{n \times V_a}{V}$$

$$APF = \frac{1 \times \frac{4\pi R^3}{3}}{a^3}$$

$$APF = \frac{1 \times \frac{4\pi R^3}{3}}{\left(\frac{4R}{\sqrt{3}}\right)^3}$$

$$APF = \frac{\sqrt{3}\pi}{8}$$

$$APF = 0.6802$$

Hence atoms occupy 68.02% of the volume of the unit

Expression for Interplanar spacing in terms of Miller Indices:

Consider a Lattice plane ABC, which is one of the planes belonging to the set of planes with Miller indices (h k l). Let x, y and z be the intercepts made by the plane along the Three crystallographic axes X, Y and Z respectively.

Let OP be the perpendicular drawn from the origin to the plane. Let α , β and γ be the angles made by OP with the crystallographic axes X, Y and Z respectively. Let another consecutive plane parallel to ABC pass through the origin. Let a, b and c be the lattice parameters. OP is called interplanar spacing and is denoted by d hkl.

From right angled triangle OCP

$$\cos \alpha^l = \frac{OP}{OC} = \frac{d_{hkl}}{x}$$

$$\cos \beta^l = \frac{OP}{OB} = \frac{d_{hkl}}{y}$$

$$\cos \gamma^l = \frac{OP}{OA} = \frac{d_{hkl}}{z}$$

but we know that

$$h = \frac{a}{x}, k = \frac{b}{y} \text{ \& } l = \frac{c}{z}$$

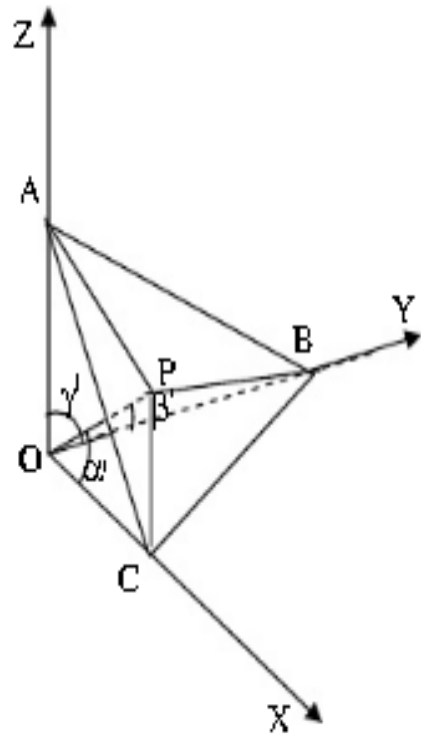
$$\Rightarrow x = \frac{a}{h}, y = \frac{b}{k} \text{ \& } z = \frac{c}{l}$$

There fore

$$\cos \alpha^l = \frac{h}{a} d_{hkl}$$

$$\cos \beta^l = \frac{k}{b} d_{hkl}$$

$$\cos \gamma^l = \frac{l}{c} d_{hkl}$$



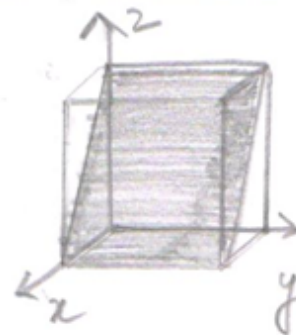
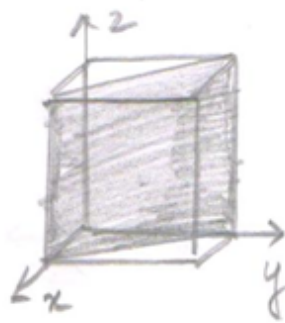
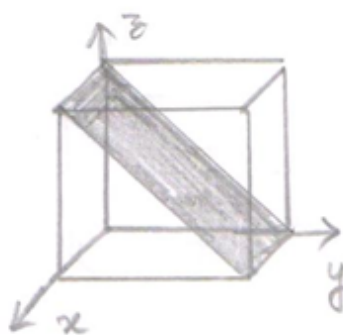
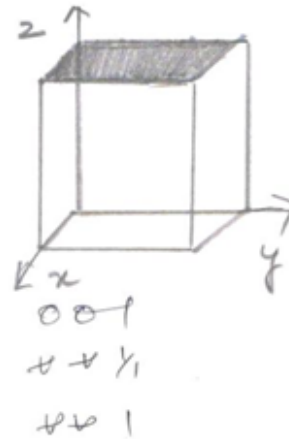
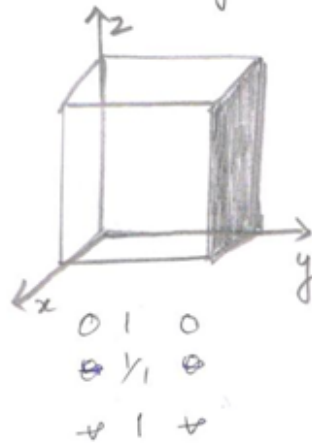
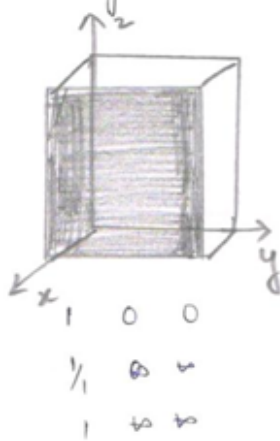
$$d_{hkl} = \frac{1}{\sqrt{\left(\frac{h^2}{a^2}\right) + \left(\frac{k^2}{b^2}\right) + \left(\frac{l^2}{c^2}\right)}}$$

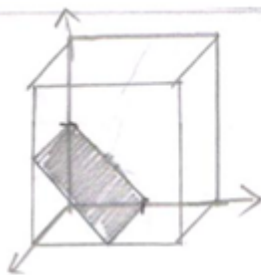
is the expression for Interplanar spacing. For a cubic lattice $a=b=c$, There fore

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

PROBLEMS:

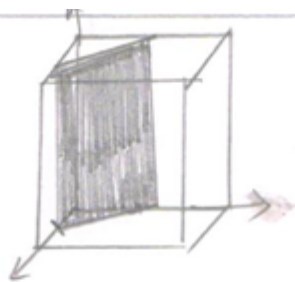
Drawing Planes in a cubic crystal given Miller are :-





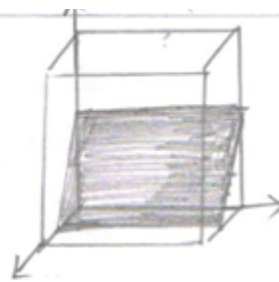
0 2 2

$\frac{1}{2} \frac{1}{2} \frac{1}{2}$



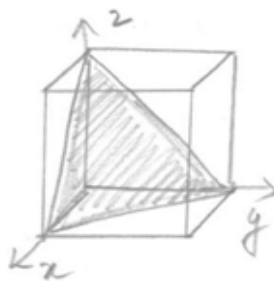
2 2 0

$\frac{1}{2} \frac{1}{2} \frac{1}{2}$

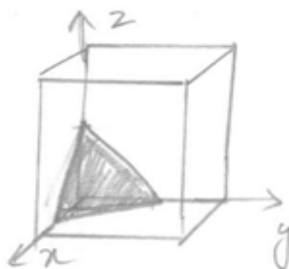


2 0 2

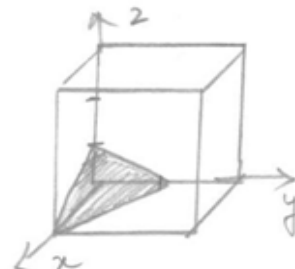
$\frac{1}{2} \frac{1}{2} \frac{1}{2}$



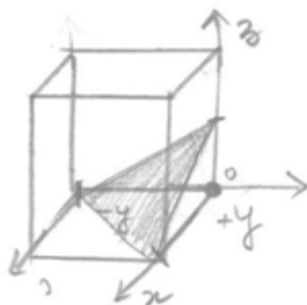
1 1 1
 $\frac{1}{1} \frac{1}{1} \frac{1}{1}$
1 1 1



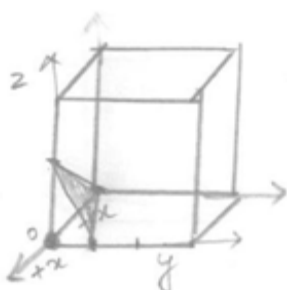
2 2 2
 $\frac{1}{2} \frac{1}{2} \frac{1}{2}$



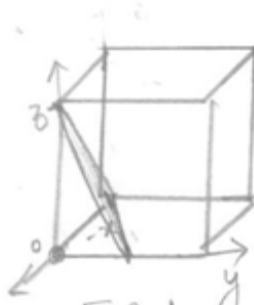
1 2 3
 $\frac{1}{1} \frac{1}{2} \frac{1}{3}$



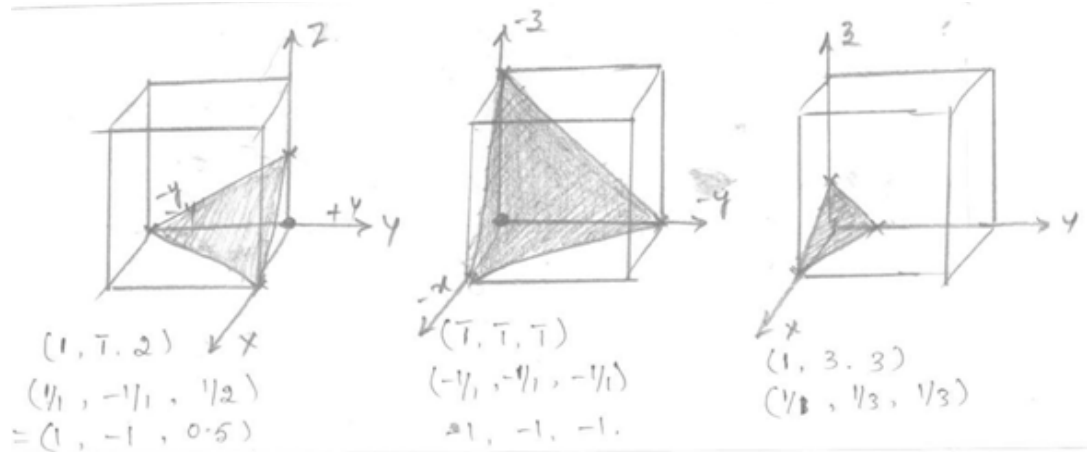
1 T 2
 $\frac{1}{1} -\frac{1}{1} \frac{1}{2}$



T 3 2
 $-\frac{1}{1} \frac{1}{3} \frac{1}{2}$



T 2 1
 $-\frac{1}{1} +\frac{1}{2} \frac{1}{1}$



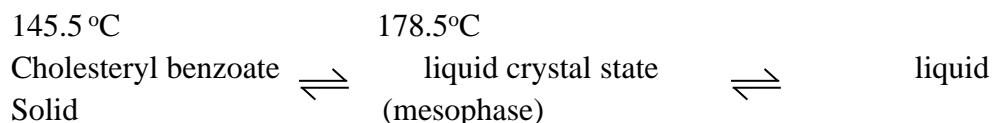
Problems

1. Ni has FCC structure with lattice constant 3.52\AA . Calculate the d_{hkl} for (101) ; (123) ; (320) planes.
2. Cu has FCC structure with atomic radius 0.1278 nm . Calculate the d_{hkl} for (3211) ; (123) ; (320) planes.
3. The d_{hkl} of 110 plane is 2\AA for FCC crystal. Find the atomic radius r .

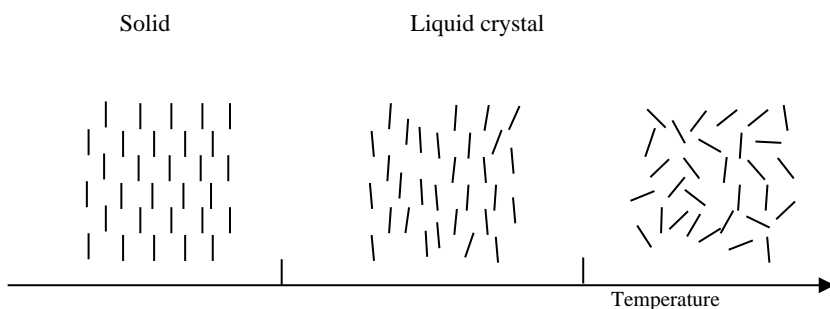
LIQUID CRYSTALS

DEFINITION:

It was observed by an Austrian botanist; Freidrich Reinitzer that solid cholesteryl benzoate on heating becomes a hazy liquid at 145.5°C and on further heating turns into a clear, transparent liquid at 178.5°C. Cholesteryl benzoate is said to exist as a *liquid crystal* between 145.5°C and 178.5°C.). On cooling, the change from liquid crystal state to solid took place exactly at the same temperature.



- Thus *liquid crystal* is a state of matter between highly ordered crystalline and disordered liquid states.
- In crystalline state, not only do the molecules occupy specific positions but also tend to orient in a preferred direction. Thus the molecules have both positional and orientational order.
- In liquid state, the molecules neither occupy specific positions nor are oriented in any particular manner. The molecules are free to move at random and collide with one another abruptly changing their positions thus losing both positional and orientational order.
- Intermediate between the solid and the liquid state exists the liquid crystal phase, wherein *the molecules are free to move but are oriented in a particular manner*. The molecules have no positional order but retain some orientational order.



- Liquid crystal phase is also called mesophase and the molecules, which can exist in mesophase, are called mesogens.

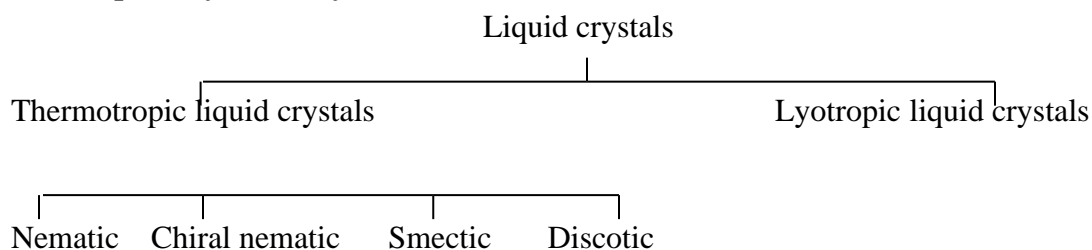
- **Director** : in liquid crystal state the molecules have no positional order but are oriented in a particular direction. The preferred orientation of the molecules of a liquid crystal is called the *Director*.

Classification of liquid crystals

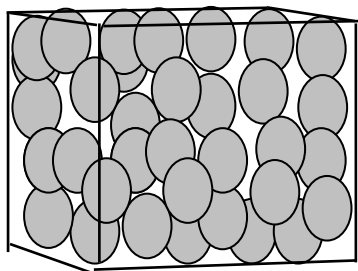
Liquid crystals may be broadly classified into two

- Thermotropic liquid crystals: are those that exhibit liquid crystalline state on change of temperature alone. Example: para azoxy anisole.
- Lyotropic liquid crystals: these exhibit liquid crystalline state in mixture and when the concentration of one of the constituents is varied. Example: soap.

Thus liquid crystals may be classified as follows



Nematic liquid crystals:



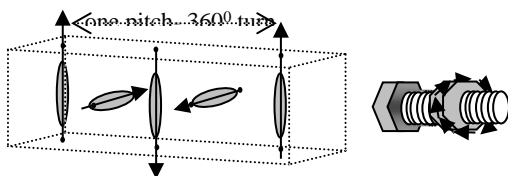
- These have thread like texture. (Greek nematos = thread).
- These are formed from optically inactive compounds.
- The molecules do not have positional order but the molecules are arranged parallel to one another and hence have orientational order.
- Less Viscous as they are less closely arranged
- Fluidity is more
- p- azoxy anisole is an example for nematic liquid crystals.

Chiral nematic or twisted nematic or cholesteric liquid crystals.

- Cholesteric liquid crystals exhibit finger print texture.

- These are formed from optically active compounds.
- A group of molecules is oriented at an angle to the adjacent group of molecules such that the director takes a helical path as it travels through the liquid crystal just as a nut is moved on to a screw.
- The distance through which a director travels as it completes one full rotation is called the pitch of the liquid crystal.
- Less Viscous as they are less closely arranged
- Fluidity is more

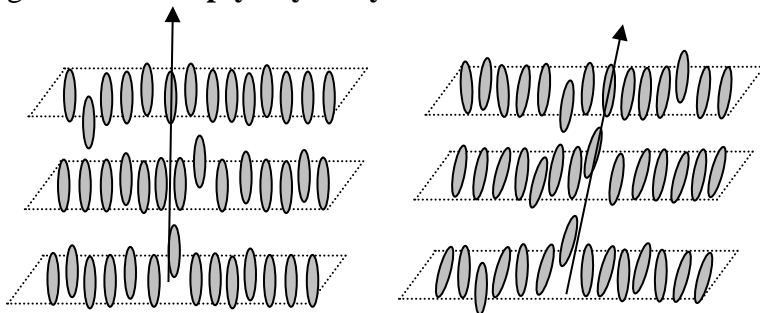
Eg for chiral nematic liquid crystal is cholesteryl benzoate.



Smectic liquid crystals:

- Greek smectos = soap
- Smectic liquid crystals exhibit focal conic (broken fan) texture
- Molecules are arranged in layers. At any instant of time the number of molecules within a layer is much more than the number of molecules between the layers.
- Highly Viscous as they are closely arranged
- Fluidity is less
- Depending of the orientation of the molecules(inclination to the director) smectic liquid crystals are called smectic A,.B,C etc.

Eg: 44' - **di-n-Heptyloxyazoxybenzene**



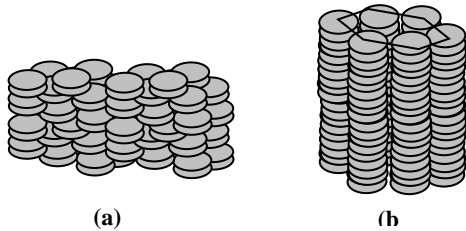
Discotic liquid crystals:

- Here the molecules are disk like.
- These may be columnar liquid crystals or discotic nematic liquid crystals

In columnar liquid crystals, the molecules are stacked one above the other forming a column. **In discotic nematic liquid crystals** the molecules have coin like shape and have no positional order but possess orientational order. The columns form definite shape such as hexagon.

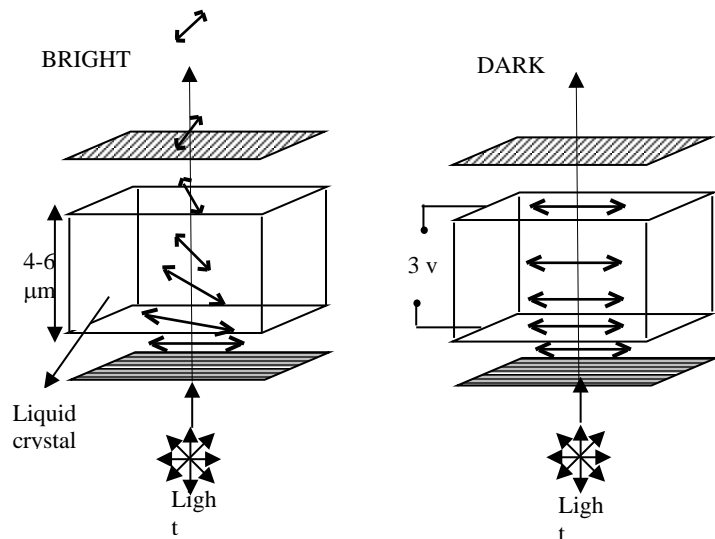
- Highly Viscous as they are closely arranged
- Fluidity is less

Eg: Benzene-hexa -n- alkanates



Applications of liquid crystals in LCD'S

Working of LCD



It has been observed that when a liquid crystal film is placed between two polarizer using a cell as shown in the diagram. When a light incident on it a part of light is absorbed and emerges out giving a bright appearance and to view this phenomena normally twisted Nematic liquid crystal is used. This is because it has the ability to rotate plane of polarization of light by 90.

However when voltage of 3volts is applied to the cell, under the influence of electric field liquid crystal molecule align parallel to each other as shown in the diagram, hence liquid crystal molecule loses its 90 shift, giving dark appearance. This mechanism of bright and dark appearance are manipulated in liquid crystal display, to give respective image in the back ground to bright appearance.

- When light passes through two crossed polarisers, light coming out of one polariser is absorbed by the other and hence darkness is observed.
- However, when a film of liquid crystals placed between specially treated glass plates is placed in between the crossed polarisers and an electric field is applied, the director acts as a wave guide, and light emerges in the orthogonal direction and brightness is observed.
- Electrooptic effect is utilized in LCDs.

The conditions necessary are:

- Light should be incident either parallel or perpendicular to the glass surface.
- The wavelength of the light incident should be $\lambda = P \times \Delta n$ where P is the pitch of the liquid crystal and Δn is the difference in the refractive indices perpendicular and parallel to the director.

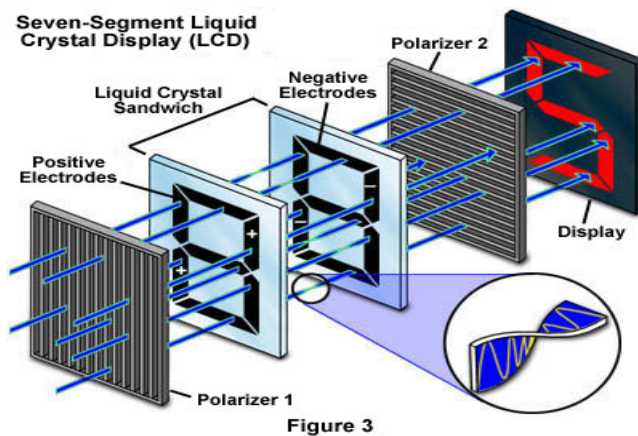


Figure 3

Here, the liquid crystalline phase is sandwiched between two glass plates that have seven electrodes, which can be individually charged, attached to them. Although the electrodes appear black in this example, they are transparent to light in real devices. As demonstrated in Figure, light passing through Polarizer 1 is polarized in the vertical direction and, when no current is applied to the electrodes, the liquid crystalline phase induces a 90 degree twist of the light and it can pass through Polarizer 2, which is polarized horizontally. This light can then form one of the seven segments on the display.

When current is applied to the electrodes, however, the liquid crystalline phase aligns with the current and loses the cholesteric spiral pattern. Therefore, light passing through a charged electrode is not twisted and is blocked by Polarizer 2. By coordinating the voltage on the seven positive and negative electrodes, the display is capable of rendering the numbers 0 through 9. In this example, the upper right and lower left electrodes are charged and, consequently, block light from passing through them, which results in the formation of the number "5"

Other applications of liquid crystals in thermography:

- In medicine: Tumour cells are at an elevated temperature than normal cells. Liquid crystals show a different colour when in contact with tumour cells than when in contact with normal cells. Hence liquid crystals can be used to detect subcutaneous tumours.
- In electronic industry: whenever there is a break in circuit, there will be slight rise in temperature and this can be detected from the variation in the colour of liquid crystal.
- Liquid crystals can be used in themostrips (to read body temperature) and disposable thermometers.
- Liquid crystals can be used to detect radiations.
- Liquid crystals can be used to detect pollutants in atmosphere. Temperature sensitive liquid crystals are also used in detecting air pollution and aerodynamics
- **Liquid crystal displays** are used in watches, calculators, laptop computers, sign boards etc.

Difference between Thermotropic and Lyotropic liquid crystals.

| Thermotropic liquid crystals | Lyotropic liquid crystals |
|--|--|
| 1. This type of liquid crystals depends on temperature | This type of liquid crystals depends on concentration |
| 2. There are optically active. Therefore used in electronic display. | These are optically inactive so that these are not used in electronic display. |
| 3. This type of L C possess definite texture. | There are not possess definite texture. |
| 4. It is single component system. | It is double component system ie., substance +water system |
| 5. Eg: Cholesteryl Benzoate | Eg: Phospholipids |
| 6. It must contain at least one benzene ring. | It may or may not benzene ring |