Unit-III

Solids:- Solids consists of atoms, ions or molecules packed closely together. Solids are of two types i.e. crystalline solids and amorphous solids.

(i) **Crystalline solids:-** The solids which have regular, repeated arrangement of atoms, or ions or molecules, are known as crystalline solids. Example - calcite, quartz, tourmaline etc.

(ii) **Amorphous solids:-** The solids which do not have regular, repeated arrangement of atoms, or ions or molecules, are known as amorphous solids. Such solids have short-range order in their structure.

Example - Glass, concrete, paper etc.

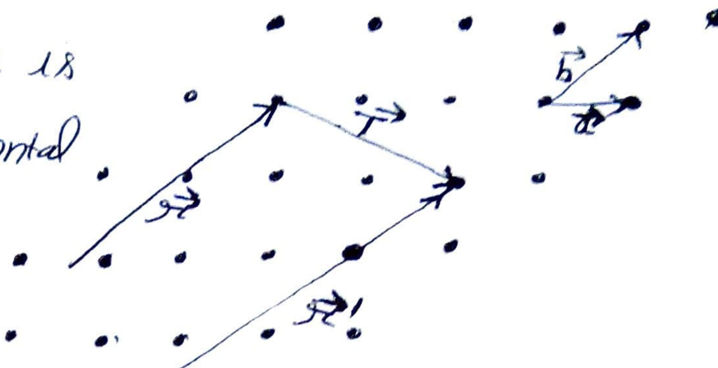
Space lattice or Bravais Lattice in crystal Structures

Bravais assumed that a crystal consists of a three-dimensional arrangement of points such that each point is surrounded by the neighbouring points in an identical way. Such an arrangement of points is known as space or Bravais Lattice. The space lattice is a regular periodic arrangement of points extended repeatedly in space.

space lattice
OR
Bravais lattice.

Translation vectors:→

mathematically a lattice is defined by three fundamental translation vectors $\vec{a}, \vec{b}, \vec{c}$ such that the atomic arrange-ment looks exactly identical when viewed from any two points $\vec{r}$ and $\vec{r}'$,



where $$\vec{r}' = \vec{r} + u\vec{a} + v\vec{b} + w\vec{c}$$
$$\vec{r}' = \vec{r} + \vec{T}$$

$\vec{a}, \vec{b}, \vec{c}$ are fundamental translation vectors,
u, v, w are arbitrary integers.

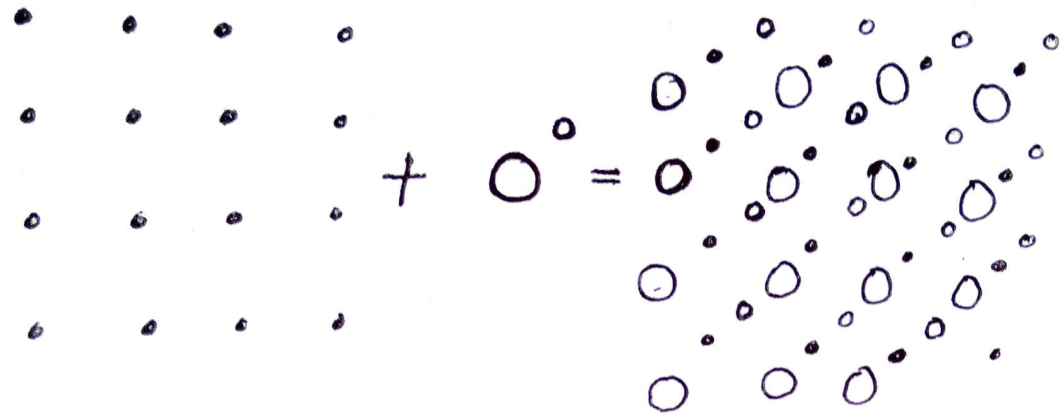
Basis→ In the simplest crystals (such as copper, silver, sodium etc), there is single atom or ion associated with each lattice point. But generally there is a group of several atoms or ions associated with each lattice point. This group is called the 'basis'. Each basis is idental in composition, arrangement and orientation with any other basis. Exp- In crystals NaCl and CsCl the basis has two atoms, while in crystals like CaF_2 the basis has three atoms.

or

Basis   Basis

Crystal structure:→ The actual crystal structure is formed when a basis of atoms (or ions) is attached identically to each lattice point.

space lattice + basis = crystal structure



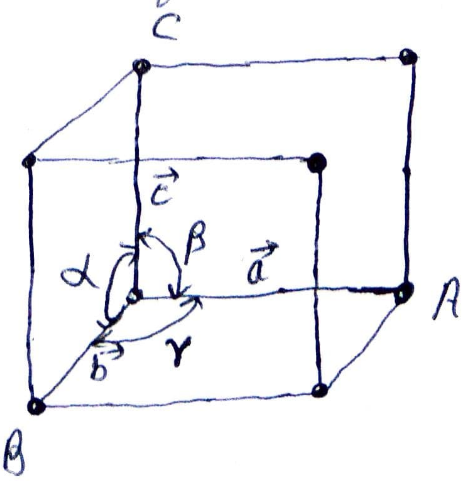
crystal structure

Unit cell:→ In space lattice, a parallelopaid formed by the translation vectors $\vec{a}, \vec{b}, \vec{c}$ as edges is called a unit cell of the space lattice. The space lattice is made up of the repetition of unit cells in all the three directions. The unit cell is the basic structural unit or building block of the crystal structure.

α - Angle between $\vec{b}$ and $\vec{c}$.

β - Angle between $\vec{c}$ and $\vec{a}$.

γ - Angle between $\vec{a}$ and $\vec{b}$.



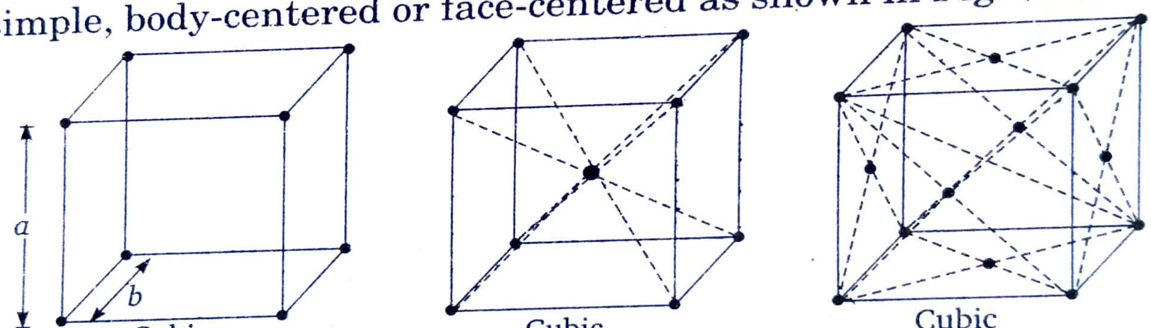
Types of crystals:→ In Practice, there are seven crystal systems, which are distinguished from one another by there axial ratios ($\vec{a}:\vec{b}:\vec{c}$) and angle between them (α,

The basic crystal systems are:- (1) cubic, (2) tetragonal, (3) orthorhombic (4) monoclinic, (5) triclinic (6) trigonal (7) hexagonal.

These seven crystal systems give rise to fourteen types of space lattices. The characteristics features of these crystal systems and their Bravais lattices are as —

(1) Cubic Crystals:-

1. Cubic Crystals : In cubic crystals, the crystal axes are perpendicular to one another ($\alpha = \beta = \gamma = 90°$) and the repetitive interval is the same along the three axes ($a = b = c$). Cubic lattice may be simple, body-centered or face-centered as shown in Fig. (12).



Cubic
(Simple)
(a)

Cubic
(BODY-CENTERED)
(b)

Cubic
(FACE-CENTERED)
(c)

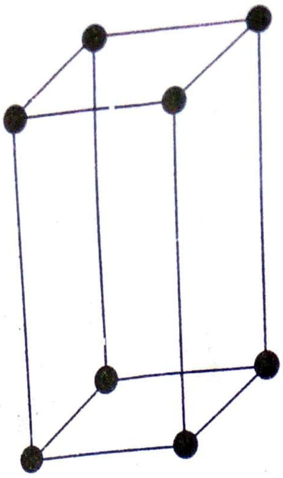
Fig. 12

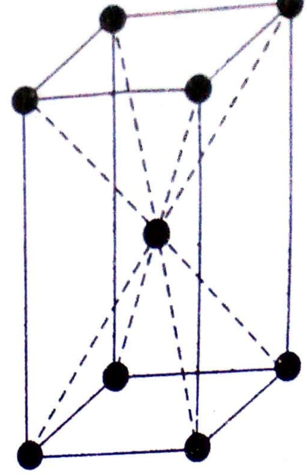
In the simple cubic lattice, the lattice points are situated only at the corners of the unit cell (Fig. 12a). In the body-centered lattice, the lattice points are situated at the corners and also at the intersection of *body* diagonals of the unit cell (Fig. 12b). In the face-centered lattice, the lattice points lie at the corners as well as at the centers of all the six *faces* of the unit cell (Fig. 12c).

Au, Ag, Cu, NaCl are examples of cubic crystals.

2. Tetragonal Crystals : The crystal axes are perpendicular to one another ($\alpha = \beta = \gamma = 90°$). The repetitive intervals along two axes are the same, but the interval along the third axis is different ($a = b \neq c$). Tetragonal lattices may be simple or body-centered (Fig. 13)

TiO_2, SnO_2 are examples of tetragonal crystals.



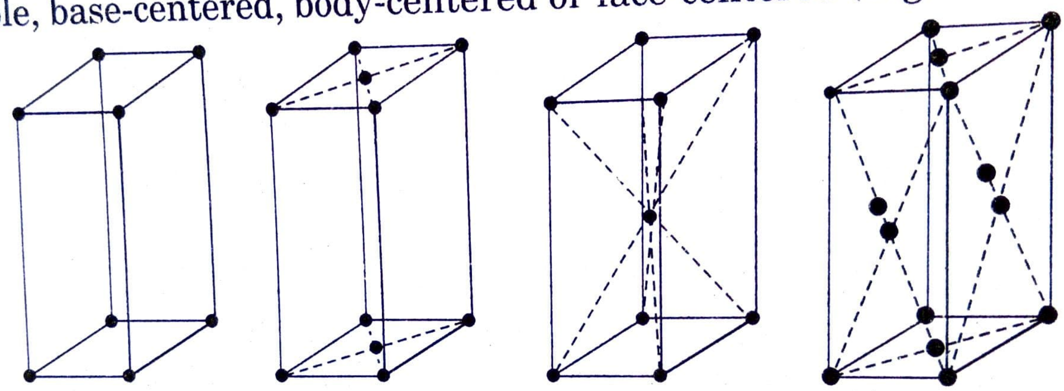


Simple

Body-Centered

Fig. 13

3. Orthorhombic Crystals : The crystals axes are perpendicular to one another ($\alpha = \beta = \gamma = 90°$), but the repetitive intervals are different along all three axes ($a \neq b \neq c$). Orthorhombic crystals may be simple, base-centered, body-centered or face-centered (Fig. 14).



Simple

Base-Centered

Body-centered

Face-Centered

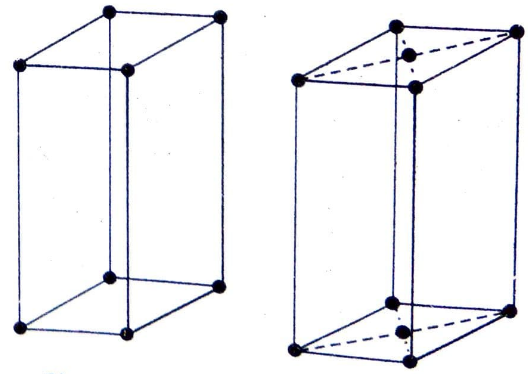
Orthorhombic

Fig. 14

Ga, KNO_3, $PbCO_3$ are examples of orthorhombic crystals.

4. Monoclinic Crystals : Two of the crystal axes are not perpendicular to each other, but the third is perpendicular to both of them ($\alpha = \gamma = 90° \neq \beta$). The repetitive intervals are different along all three axes ($a \neq b \neq c$). Monoclinic lattices may be simple or base-centered (Fig. 15).

$CaSO_4 \cdot 2H_2O$ (gypsum) and borax are examples of monoclinic crystals.



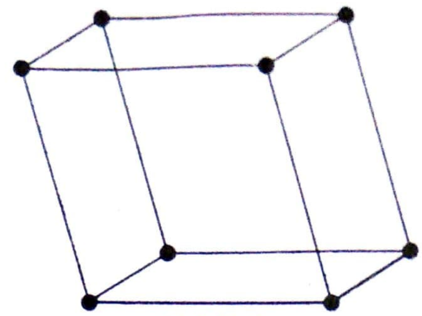
Simple

Base-Centered

Monoclinic

Fig. 15

5. Triclinic Crystals : None of the crystal axes is perpendicular to any of the others ($\alpha \neq \beta \neq \gamma$), and the repetitive intervals are different along all three axes ($a \neq b \neq c$). The triclinic lattice is only simple (Fig. 16)

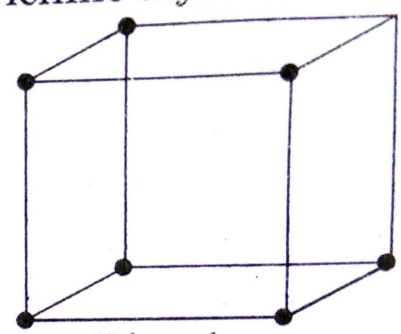


Triclinic

Fig. 16

$CuSO_4.5H_2O$ and $K_2Cr_2O_7$ are examples of triclinic crystals.

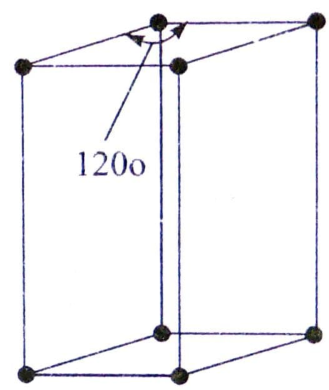
6. Trigonal (or Rhombohedral) Crystals : The angles between each pair of crystal axes are the same but different from 90° ($\alpha = \beta = \gamma \neq 90°$). The repetitive interval is the same along all three axes ($a = b = c$). The trigonal lattice is only simple (Fig. 17). As, Sb, Bi, $CaCO_3$ (calcite) are examples of trigonal crystals.



Trigonal

Fig. 17

7. Hexagonal Crystals : Two of the crystal axes are 60° apart while the third is perpendicular to both of them ($\alpha = \beta = 90°, \gamma = 120°$). The repetitive intervals are the same along the two 60°-apart axes, but the interval along the third is different ($a = b \neq c$). The hexagonal lattice is only simple (Fig. 18).



Hexagonal

Fig. 18

SiO_2, Zn, Cd and Mg are examples of hexagonal crystals.

The above description can be tabulated as below :

No.	**Crystal class**	**Intercepts on Axes**	**Angles between Axes**	**Types of Bravais space lattices (14)**
1.	Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$	simple, body-centered, face-centered } 3
2.	Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$	simple, body-centered } 2

3.	Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	simple, base-centered, body-centered, face-centered $\}$ 4
4.	Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90° \neq \beta$	simple, base-centered $\}$ 2
5.	Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma$	simple 1
6.	Trigonal	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$	simple 1
7.	Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$	simple 1