Solid state

$C = \partial Q$

State of matter depends on.
(i) Tendency of relative motion at a particular temperature.
(ii) Intermolecular forces.

Properties	Solid	Liquid	Gases
(i) Motion of partical.	No free motion only vibration allow.	Random motion to a limited extent is allowed.	Totally random.
(ii) Inter molecular forces	Very strong	Intermediate strength	Very weak (~ zero)
(iii) Average separation (volume)	Average separation is fixed so volume is fix.	Average separation is almost constant so almost fixed volume.	No fixed volume.
(iv) Shape	Definate shape as location of partical are fixed.	Average separation is fixed but location of partical is not fixed so no definate shape..	No fixed shape.
(v) Effect of change in pressure & temperature.	Are incompressible.	Liquid are also almost incompressible.	Highly compressible.
(vi) Heat capacities (C)	Heat capacity is almost independent of process.	Same as solid.	Heat capacity is dependent on process.

Types of Solid of the basis of Force of interaction

Type of solid	Constituent partical	Force of interaction	Example	Physical state	Melting point
(i) Molecular solid (non conducting) "Non conducting"	Molecules	(i) Non polar → dispersion force. (ii) Polar → dipole-dipole. (iii) Polar & H-bonding.	I_2, Xe(s), C_6H_6, CCl_4, H_2 HCl, SO_2, SF_4 H_2O (s), H_3BO_3(s)	Very soft Soft Hard	Very low Low Low
(ii) Ionic solid. solid → insulator Molten & aqueous → conducting.	Ions	Coulombic non directional long range.	NaCl, ZnS, CaF_4, CsCl	Very hard brittle	Very high
(iii) Metallic solid good conductor in solid & molten state.	Metal ion at fixed locations in sea of delocalised electrons.	Metallic bond.	Cu, Al, Zn, Ag, etc.	Soft → Hard depending on metallic bond	Low → High
(iv) Covalent or network, Insulator except C (graphite).	Atoms	Covalent bond.	C(diamond), SiC, SiO_2, AlN, graphite.	Very hard Graphite → Soft only conducting.	Very high

Cubic cell angles and edges

Thus, a unit cell is characterised by six parameters, a, b, c, α, β, and γ. These parameters of a typical unit cell are shown in figure.

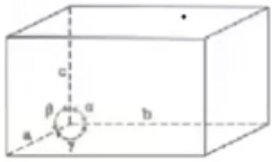


Illustration of parameters of a unit cell

A unti cell may also be defined as a1D, 2D, 3D three dimensional group of lattice points that generates the whole lattice by repetation or stacking.

Note : (1) Which particular type of unit cell will be found in a particular crystal class is decided on the basis of "the surroundings of each & every lattice point in a particular lattice which is exactly identical.

(2) In 3-d to specify any unit cell 6 parameter are required.

→ 3-egde length (a,b,c) and 3-angle between these. (α, β, γ), [a–b→γ], b–c→α], [c–a–β].

Types of Solid of the basis of arrangement of atom

	Crystalline solid		Amorphous solids
	True solid		Pseudo solids, super cooled liquid [In between solid & liquid]
1	The constituent partical (atoms, molecule, ion) follow a definite repetiting arrangement.	1	No particular pattern is followed partical are random arranged.
2	These have long range order.	2	They have short range order no long range order are found.
3	These are produced by slow cooling under controlled condition of liquid. The crystalline structure is also dependent on conditions. Same substance can have different crystalline structure in different condition. Different crystalline structure of the same substance are called its polymorphic forms & this is known as polymorphism.	3	Rapid or suddenly cooling of the liquid generate the amorphous solid.

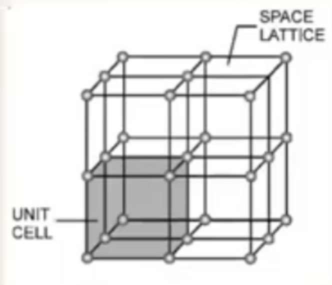
Internal arrangement of atom is solid crystal

Solid

Each constituent partical (Molecule of any shape, atom, ions) will be represented by a dot (.) and this dot is called a lattice point.

Lattice : The 3-D regular and repeating arrangement of constituent partical represent by dots in solid is called lattice.

Unit Cell :
The group of the lattice point (generally the smallest one) which on repetition parallel to its edges & equal to its edge length generates whole of the lattice is called unit cell of the lattice.



Characteristices of a Unit Cell :

(i) Its dimensional along the three edges, a, b and c. These edges may or may not be mutually perpendicular.
(ii) Angles between the edges, α (between b and c) β (between a and c) and γ (between a and b).
(iii) Each unit cell has characteristic relation between a, b and c or α, β, and γ to give rise different types of unit cell.

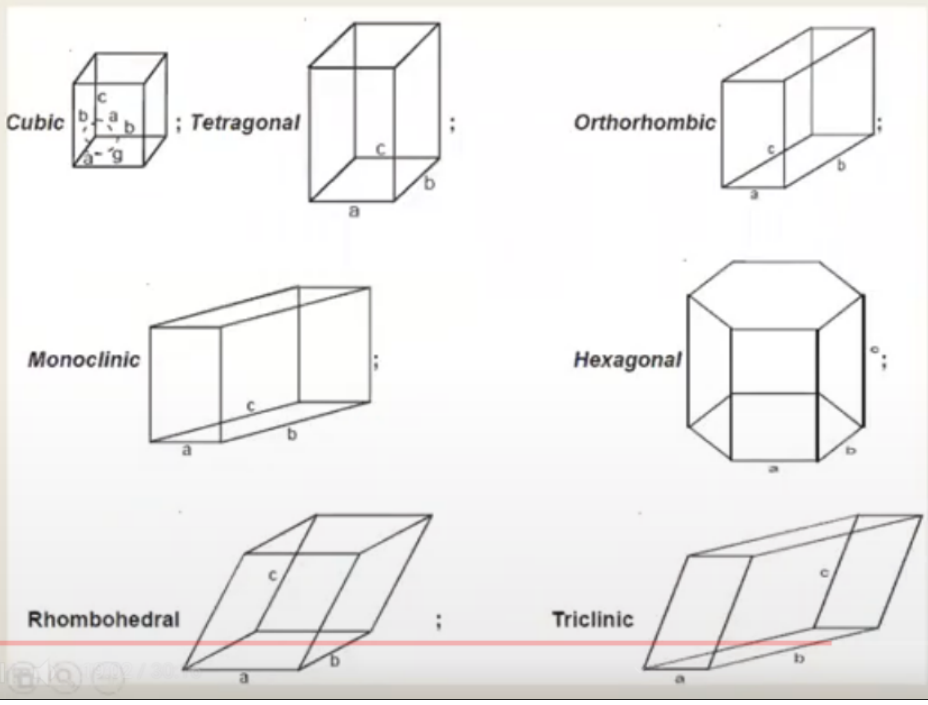
Seven crystal system

Crystal System	Features	Unit cell found	Examples
1 Cubic C	$a = b = c$ $\alpha = \beta = \gamma = 90°$	SC, BCC, FCC	NaCl, ZnS, Fe, Al, Cu, C (diamond), CsCl, CaF_2, Na_2O, KCl, Pb, Alum.
2 Tetragonal T	$a = b \neq c$ $\alpha = \beta = \gamma = 90°$	S, BC	Sn (white tin), SnO_2, TiO_2, ZnO_2, $NiSO_4$, urea.
3 Orthorhombic O	$a \neq b \neq c$ $\alpha = \beta = \gamma = 90°$	S, BC, FC, EC	Rhombic sulphur, $BaSO_4$, KNO_3, $PbCO_3$, $CaCO_3$ (aragonite)
6 Rhombohedral or Trigonal R	$a = b = c$ $\alpha = \beta = \gamma \neq 90°$	S	$CaCO_3$(Calcite), HgS(Cinnabar), $NaNO_3$, ICl.
4 Monoclinic M	$a \neq b \neq c$ $\alpha = \gamma = 90°$; $\beta \neq 120°, \neq 90°, \neq 60°$	S, EC	Monoclinic sulphur, $PbCrO_4$, $Na_2SO_4.10H_2O$, $Na_2B_4O_7.10H_2O$.
5 Hexagonal H	$a = b \neq c$ $\alpha = \beta = 90°, \gamma = 120°$	S	Graphite, ZnO, CdS, Mg, PbI_2, SiC.
7 Triclinic T	$a \neq b \neq c$ $\alpha \neq \beta \neq \gamma \neq 90°$	S	$K_2Cr_2O_7$, $CuSO_4.5H_2O$, H_3BO_3.

Note : In 3-D 14 different types of unit cell are found and these are also known as 14 **Bravais lattice**.

INTERNAL ARRANGEMENT OF ATOMS IN SOLID STATE

3-D lattice



Important Points

Contribution of different Lattice point in one Cubical unit cell :

(i) Contribution from one corner lattice point = $\frac{1}{8}$th.

(ii) Contribution from one face centered lattice point = $\frac{1}{2}$.

(iii) Contribution from edge centered lattice point = $\frac{1}{4}$th.

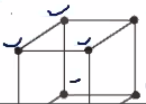
(iv) Contribution from body centered lattice point = 1.

3-D crystal Cubic System

The type of unit cells found in different types of crystals.

1. **Primitive /simple unit cell :**

SCC, SC, S



SC → Simple cubic.

all atoms are present only at corner, (Total '8' atom)

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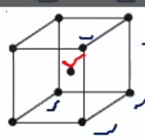
2. **Non primitive :**

(a) **Body centered (B.C.) :**

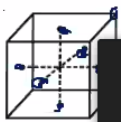


B.C.C → Body centered cubic.

Total 9

as well as at body centre

(b) **Face centered (F.C.) :**



8 corner as well as all faces.

Laser Pointer
Pen
Highlighter
Eraser
Erase All Ink on Slide

amit kumar

Important definition

Coordination number : *The number of nearest neighbours sphere in a packing is called coordination number.*
Density of unit cell : *It is the ratio of mass of the spheres present in unit cell and total volume of unit cell.*

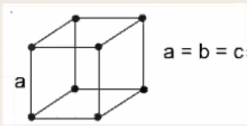
Density of the unit cell= $\dfrac{z \times M}{a^3 \times N_A \times 10^{-30}}$ gcm^{-3}

Z = effective no. of atoms
M = molecular mass of ".

Packing efficiency : *The perecentage of total space filled by the particles is called packing efficiency. Different types of packing arrangements have different packing efficiency.*

$$\text{Packing efficiency} = \frac{\text{Volume of atoms in a unit cell}}{\text{Total volume of a unit cell}} \times 100$$

Simple Cubic Crystal (SCC)



(i) Relation between a & R.

corner atoms are touching each other so, a = 2R.

(ii) Effective no. of atom (Z) (per unit cell).

$$Z = 8\ [\text{corner}] \times \frac{1}{8} = 1 \text{ atom.}$$

(iii) Packing efficiency : $\dfrac{1 \times \frac{4}{3}\pi R^3}{(2R)^3} = \dfrac{\pi}{6}$ = 52.33%.

(iv) Density = $\dfrac{\text{Mass of unit cell}}{\text{volume of unit cell}} = \left(\dfrac{Z \times M}{N_A \times a^3}\right)$.

(v) Co-ordination number :
Number of nearest neighbors's or (no. of sphere which are touching any particular sphere). **CN = 6.**