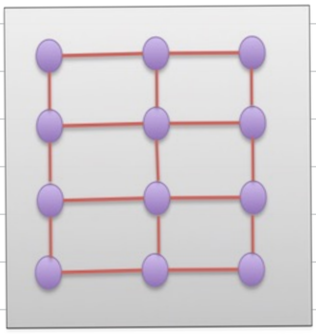
Solid State

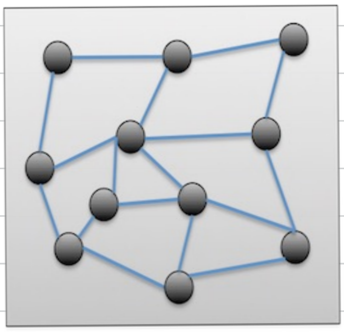
Crystals (True Solids)

→ Strong forces which work in long ranges.
→ Regular and fixed arrangement of particles.
→ Sharp m.p.
→ Definite value of enthalpy of fusion.
→ Anisotropic in nature.

eg: Ice, Diamond, Graphite, NaCl etc



Crystalline Solid

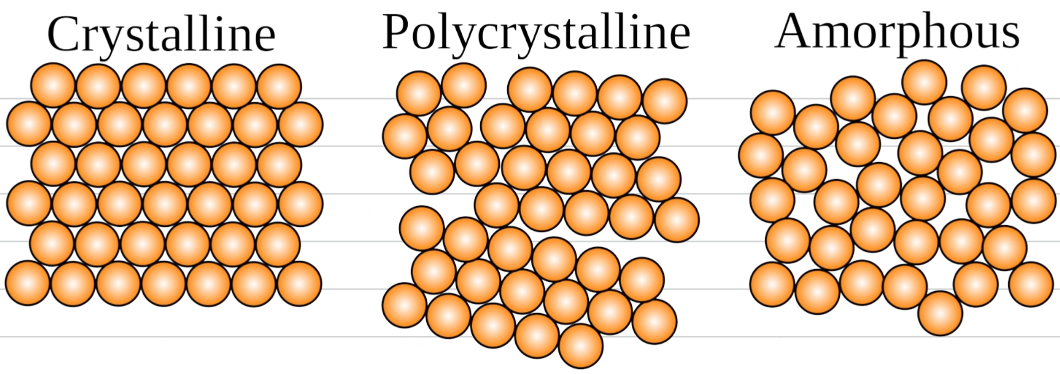


Amorphous Solid

Amorphous Solids

→ Weak forces which work in short ranges.
→ Random arrangement of particles.
→ Melt over a range of temp.
→ Enthalpy of fusion is not fixed.
→ Isotropic in nature.

eg: glass, rubber, polymers etc



Crystalline Solids	Amorphous solids
They have a definite shape and geometrical form.	They do not have a definite geometrical shape.
They have a sharp (definite) melting point.	They melt over a wide range of temperatures.
They are rigid and incompressible.	They too are usually rigid and cannot be compressed to any appreciable extent. However graphite is soft because of its unusual structure.
They give a clean clevage, i.e, break into pieces with plane surfaces.	They give irregular clevage.
They have a definite heat of fusion.	They do not have a definite heat of fusion.
Anisotropic, i.e. their mechanical properties and electrical properties depend on the direction along which they are measured.	Isotropic, i.e. they have similar physical properties in all directions because the constituents are arranged in random manner.

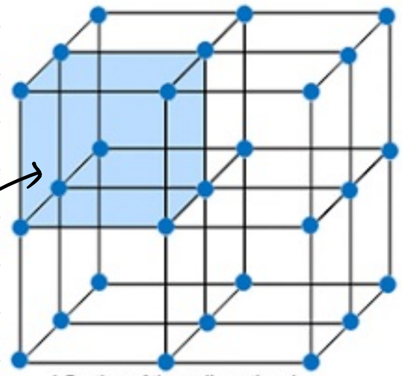
Type of crystals

Type	Structural Particles	Intermolecular Forces	Typical Properties	Examples
1 Metallic	Cations and delocalized electrons	Metallic bonds	Hardness varies from soft to very hard; melting point varies from low to very high; lustrous; ductile; malleable; very good conductors of heat and electricity	Na, Mg, Al, Fe, Sn, Cu, Ag, W
2 Ionic	Cations and anions	Electrostatic attractions	Hard; moderate to very high melting points; nonconductors as solids, but good electric conductors as liquids; many are soluble in polar solvents like water	$NaCl$, MgO, $NaNO_3$
3 Covalent Crystal or Network covalent	Atoms or molecules	Covalent bonds	Most are very hard and either sublime or melt at very high temperatures; most are nonconductors of electricity	C (diamond), C (graphite), SiC, AlN, SiO_2
4 Molecular *Nonpolar*	Atoms or nonpolar molecules	Dispersion forces	Soft; extremely low to moderate melting points (depending on molar mass); sublime in some cases; soluble in some nonpolar solvents	He, Ar, H_2, CO_2, CCl_4, CH_4, I_2
Polar	Polar molecules	Dispersion forces and dipole–dipole attractions	Low to moderate melting points; soluble in some polar and some nonpolar solvents	$(CH_3)_2O$, $CHCl_3$, HCl
Hydrogen-Bonded	Molecules with H bonded to N, O, or F	Hydrogen bonds	Low to moderate melting points; soluble in some hydrogen-bonded solvents and some polar solvents	H_2O, NH_3

Terms used in crystals:

Crystal lattice

3-D arrangement of particle in Crystal is called as Crystal lattice.

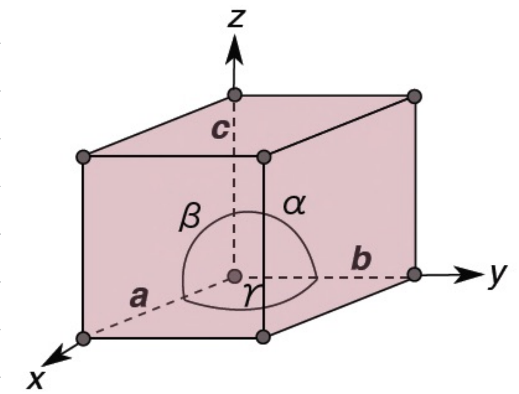


A Portion of three dimentional cubic lattice and its unit cell

Unit Cell

Crystal Lattice.

Unit cell



Where x, y, z = Crystallographic axis

a, b, c = Dimension of Unit Cell

α, β, γ = Crystallographic angle.

On the basis of position of particle Unit cell is divided in to —

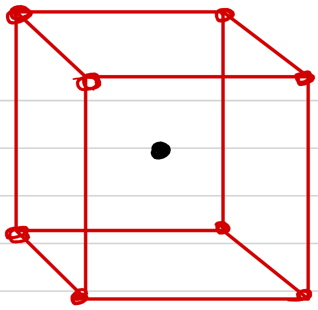
① <u>Primitive</u> :- Particles are present only at the corners.

② Centered

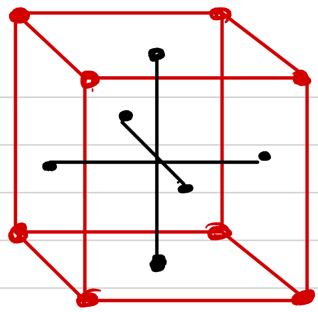
→ ① <u>Body centered</u> : Particles are at the corners and at the body Center.

→ ② <u>Face Centered</u> : Particles are at the corners and at the Center of each Face.

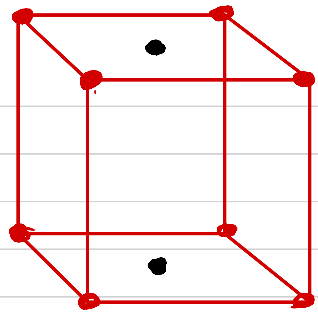
→ ③ <u>End centered</u> : Particles are at the corners and at the Center of two opposite faces only.



Body Centered



Face Centered



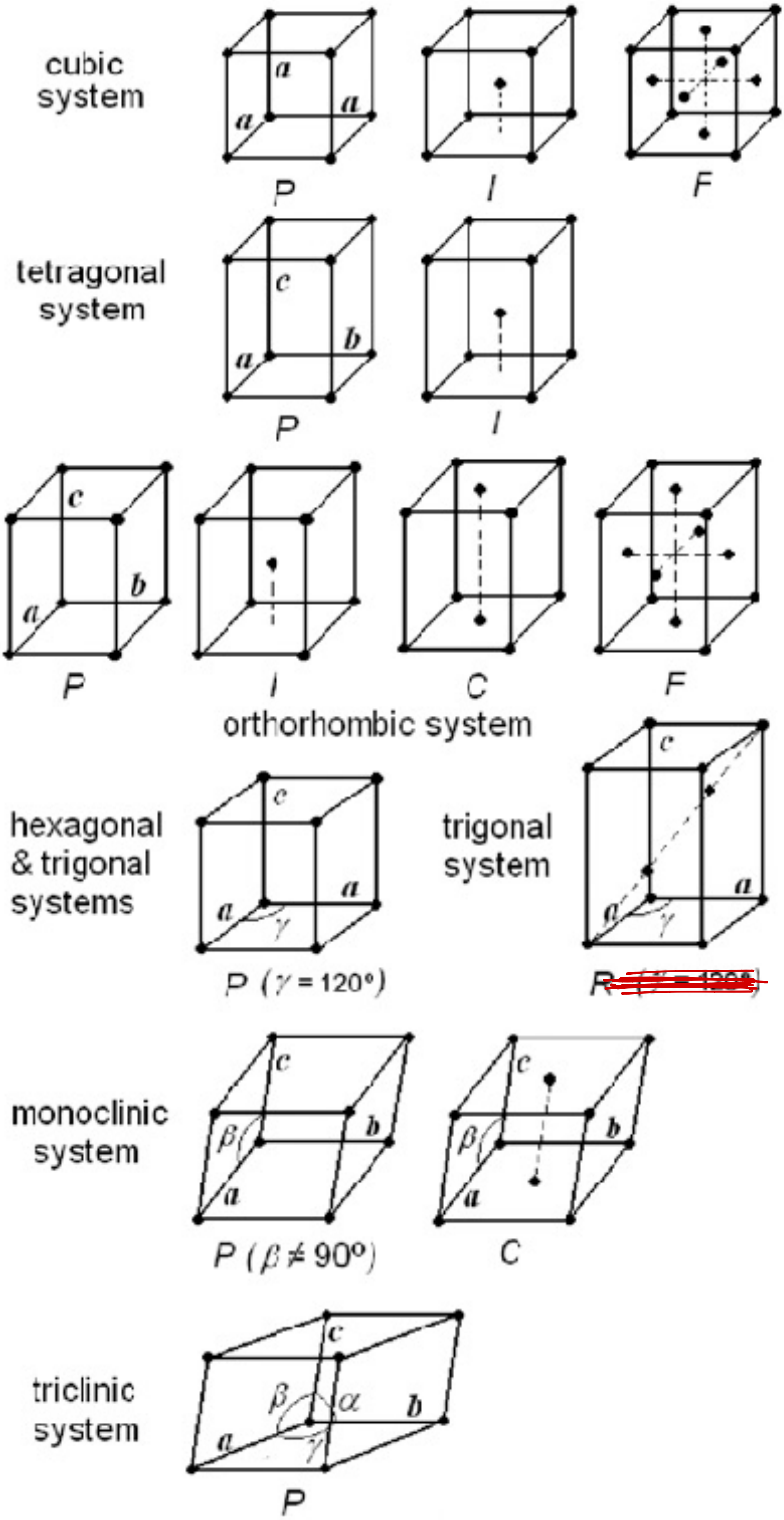
End Centered

On the basis of dimension and Crystallographic angle

Unit Cell	Dimension	Angle	Lattice
① Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	P + B + F
② Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	P + B
③ Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	P + B + F + E
④ Monoclinic	$a \neq b \neq c$	$\alpha = \beta = 90^\circ \neq \gamma$	P + E
⑤ Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	P
⑥ Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ, \gamma = 120^\circ$	P
⑦ Trigonal or Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	P

Total = 14

$\Rightarrow$ Bravais Lattice = 14


cubic system
a
a
a
P
I
F
tetragonal system
c
a
b
P
I
c
a
b
P
I
C
F
orthorhombic system
hexagonal & trigonal systems
c
a
a
γ
P (γ = 120°)
trigonal system
c
a
a
γ
R
monoclinic system
c
β
b
a
P (β ≠ 90°)
c
β
b
a
C
triclinic system
c
β
α
b
a
γ
P

Coordination No (CN) :-

No of closest particles to a given particle is Called as coordination No. (CN)

Packing Fraction (PF) :-

Fraction of space occupied by the particle is Called its packing fraction (or packing efficiency).

$$PF = \frac{Z \times \frac{4}{3}\pi r^3}{V}$$

Where

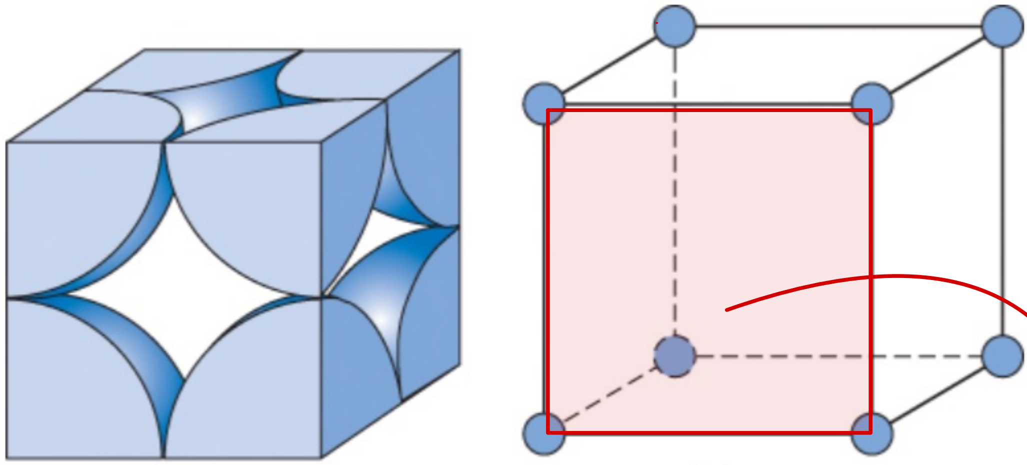
Z = Effective No of particle in Unit cell

r = Radius of particle

V = Volume of unit cell

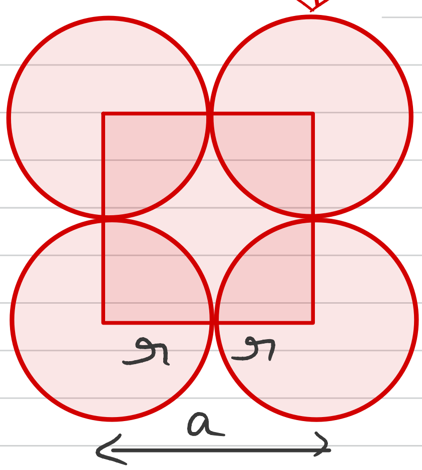
Cubic crystal system:

Simple cubic:- (Primitive)



(a) (b)

$\longleftrightarrow$ a



① $a = 2r$

② Effective Particle $= 8 \times \frac{1}{8}$

$= 1$

③ CN $= 6$

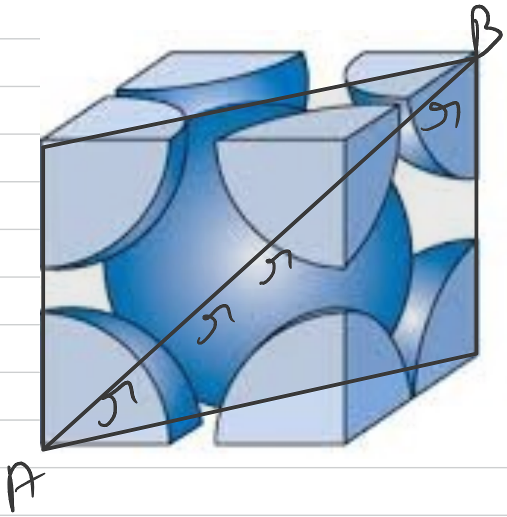
④ $PF = \dfrac{1 \times \frac{4}{3}\pi r^3}{a^3} = \dfrac{\frac{4}{3}\pi r^3}{(8r^3)} = \dfrac{\pi}{6} = 0.524$

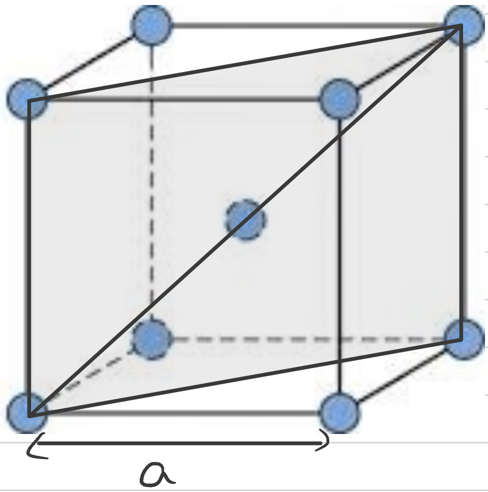
No of nearest particle = , distance =

No of next nearest Particle = , distance =

No of next to next nearest particle = , distance =

Body entered cubic(BCC):-





① $4r = a\sqrt{3} = AB$

② Effective particle $= 8 \times \frac{1}{8} + 1 = 2$

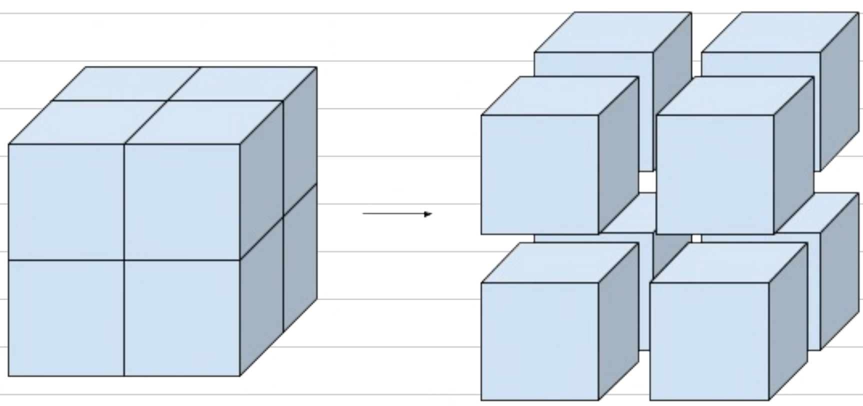
③ CN $= 8$

④ $PF = \dfrac{2 \times \frac{4}{3}\pi r^3}{a^3} = \underline{0.68}$

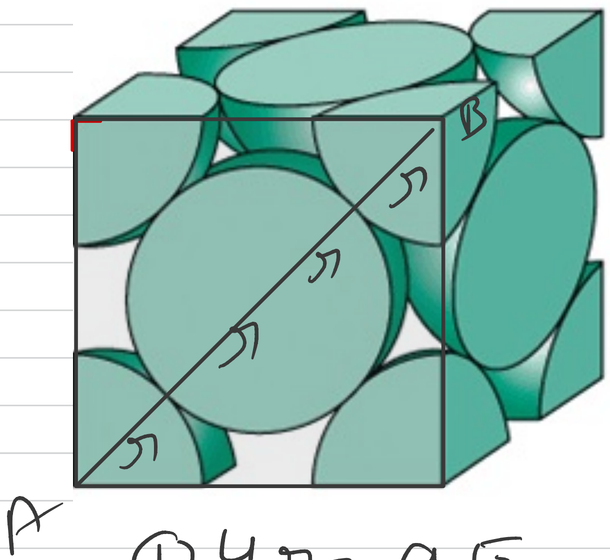
No of nearest particle = , distance =

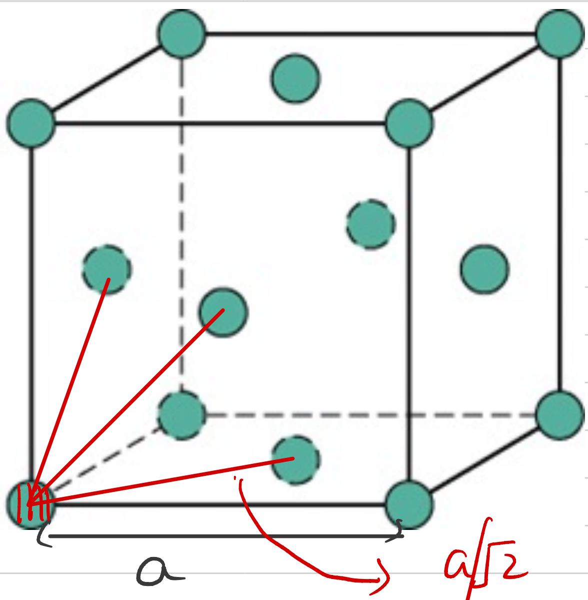
No of next nearest Particle = , distance =

No of next to next nearest particle = , distance =



Face cantered cubic (FCC):-





① $4r = a\sqrt{2}$

② Effective Particle $= 8\times\frac{1}{8} + 6\times\frac{1}{2} = 4$

③ CN $= 12 = 8\times 3/2$

④ $PF = \dfrac{4\times\frac{4}{3}\pi r^3}{a^3} = 0.74$

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No of nearest particle = , distance =

No of next nearest Particle = , distance =

No of next to next nearest particle = , distance =

Density of Crystals :

M = Molar mass
= mass of 1 mole

① $$d = \frac{Z \times m}{V}$$

$$m = \left(\frac{M}{N_A}\right) = \text{mass of 1 particle}$$

$$\boxed{d = \frac{Z \times \left(\frac{M}{N_A}\right)}{V}} \quad \frac{gm}{cm^3}$$

② $$d = \frac{Z_1 \times \left(\frac{M_1}{N_A}\right) + Z_2 \times \left(\frac{M_2}{N_A}\right)}{V}$$

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$$\frac{4}{3}\pi r^3 \times \quad d = \frac{Z \times \frac{M}{N_A}}{V} \quad \times \frac{4}{3}\pi r^3$$

$$Pf = \frac{d \times \frac{4}{3}\pi r^3}{(M/N_A)}$$

$$\boxed{Pf \propto d}$$