Chemistry Study Materials for Class 12
(NCERT Based Notes of Chapter- 01)

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The Solid State

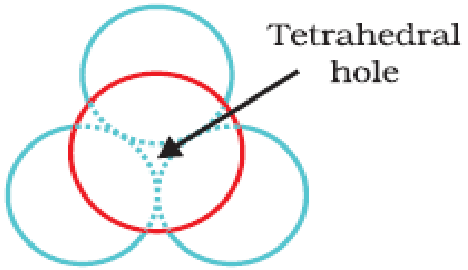
Interstitial voids

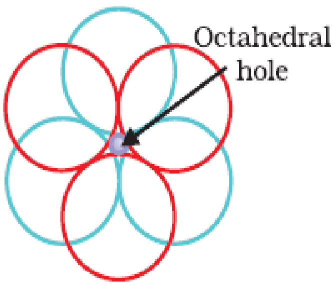
The vacant space in close packed arrangement is called *voids*. These are of two types- tetrahedral voids and octahedral voids.

Tetrahedral void: A void surrounded by *four* spheres in tetrahedral position is called tetrahedral void. In a close packed arrangement the number of tetrahedral voids is double the number of spheres, i.e. there are two tetrahedral voids per sphere.

Octahedral voids: A void surrounded by *six* spheres in octahedral position is called octahedral void. In a close packed arrangement the number of octahedral voids is equal to the number of spheres, i.e. there is only one octahedral void per sphere.

If there are N close packed spheres, The number of tetrahedral voids = 2N and The number of octahedral voids = N





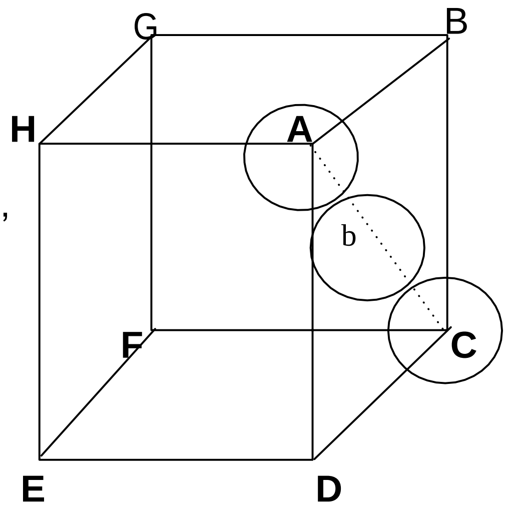
Packing Efficiency

The percentage of the total space occupied by spheres (particles) is called packing efficiency.

$$\text{Packing Efficiency} = \frac{\text{Volume occupied by all the spheres in the unit cell} \times 100}{\text{Total volume of the unit cell}}\%$$

<u>**Calculation of Packing Efficiency**</u>

1) In hcp and ccp structures



Consider a cube with edge length ‘a’ and face diagonal ‘b’

In ΔABC, $AC^2 = AB^2 + BC^2$

i.e. $b^2 = a^2 + a^2$

or, $b^2 = 2a^2$

or, $b = \sqrt{2}a$

If ‘r’ is the radius of the sphere, then b = 4r

∴ $4r = \sqrt{2}a$

Or, $a = 4r/\sqrt{2} = 2\sqrt{2}r$

We know that, volume of a sphere = (4/3) π r3

In ccp (fcc) or hcp, there four spheres per unit cell

∴ Volume of four spheres = $4 \times (4/3)\pi r^3$

Volume of the cube = a^3

$= (2\sqrt{2}r)^3$

$$\text{Packing Efficiency} = \frac{\text{Volume occupied by all the spheres in the unit cell} \times 100}{\text{Total volume of the unit cell}} \%$$

$$= \frac{4 \times (4/3)\pi r3 \times 100}{(2\sqrt{2}r)\ 3} \%$$

$$= \frac{(16/3)\ \pi r3 \times 100}{16\sqrt{2}r^3} \%$$

$= 74\%$

2) In Body-centred cubic (bcc) structures:

Consider a cube with edge length ‘a’, face diagonal ‘b’ and body diagonal ‘c’

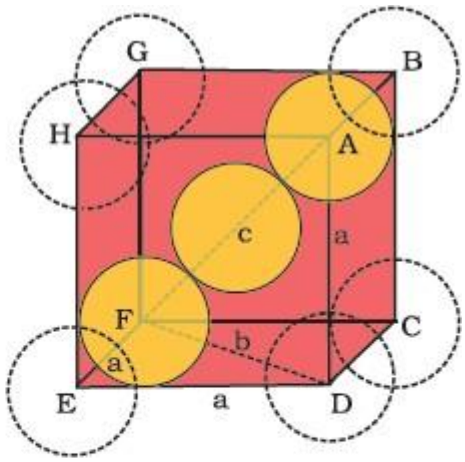
From the figure it is clear that the atom at the centre is in cont with the other two atoms diagonally placed.

In ΔEFD,

$FD^2 = EF^2 + ED^2$

i.e. $b^2 = a^2 + a^2 = 2a^2$

or, $b = \sqrt{2}a$



In ΔAFD,

$AF^2 = AD^2 + FD^2$

i.e. $c^2 = a^2 + b^2$

$= a^2 + 2a^2 = 3a^2$

Or, $c = \sqrt{3}a$

But, c = 4r (where r is **the radius of the particle)**

$\therefore$ $4r = \sqrt{3}a$

Or, $a = 4r/\sqrt{3}$ (also $r = \sqrt{3}a/4$)

In a bcc, the no. of atoms present per unit cell = 2

Volume of 2 spheres = $2 \times (4/3)\ \pi r^3$

Volume of the cube = $a^3 = (4r/\sqrt{3})^3$

Packing Efficiency = $\dfrac{\text{Volume occupied by two spheres in the unit cell} \times 100}{\text{Total volume of the unit cell}}$ %

$= \dfrac{2\times (4/3)\pi r3 \times 100}{(4r/\sqrt{3})\ 3}$ %

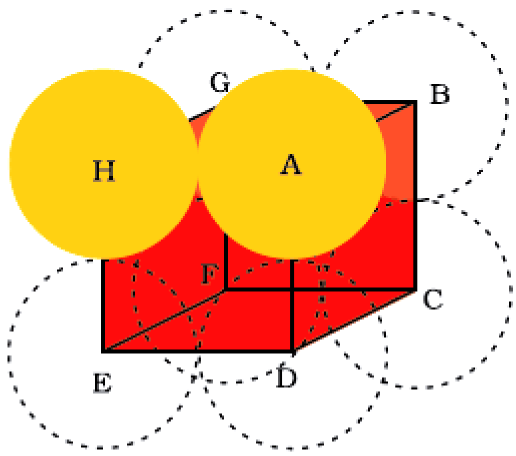
$= \dfrac{(8/3)\ \pi r3 \times 100}{64/(3\sqrt{3})r3}$

$=$ 68%

3) In simple cubic structures:

Consider a cube with edge length ‘a’ and the radius of the particle ‘r’. Here the edge length is related to the radius of the particle as a = 2r

The volume of the cubic unit cell = a = (2r) =8r



A simple cubic unit cell contains only one particle.

Volume of one sphere = $(4/3)\ \pi r^3$

$$\text{Packing Efficiency} = \frac{\text{Volume occupied by the spheres in the unit cell} \times 100}{\text{Total volume of the unit cell}}\ \%$$

$$= \frac{(4/3)\ \pi r^3 \times 100\ \%}{8r^3}$$

$$= \pi/6 \times 100\ \%$$

$$= 52.4\%$$

Calculation of Density of the unit cell (Solid)

Consider a cubic unit cell with edge length 'a'. Then volume of the unit cell = a^3.

Let 'M' be the atomic mass of the element in the unit cell

(i.e. mass of Avogadro number (N_A) of atoms).

Then mass of one atom = M/ N_A.

Let the number of particles present per unit cell = z

Then mass of the unit cell = $z \times M/ N_A$

$$\text{Density of the unit cell} = \frac{\text{Mass of the unit cell}}{\text{Volume of the unit cell}}$$

$$\text{i.e. density (d)} = \frac{z \times M/ N_A}{a^3}$$

$$\text{Or, } d = \frac{z.\ M}{N_A.a^3}$$

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