

The solid state & surface chemistry-solutions

SUBJECTIVE PROBLEMS:

Sol 1.

$$\text{Avogadro's number} = 6.023 \times 10^{23}$$

$$\text{At. wt. of mercury(Hg)} = 200$$

∴ In 1 g of Hg, the total number of atom

$$= 6.023 \times 10^{23} / 200 = 6.023 \times 10^{23} / 2 \times 10^2$$

$$= 3.0115 \times 10^{21} = 3.012 \times 10^{21}$$

∴ Density of Mercury (Hg) = 13.6 g/c.c.

$$\therefore \text{mass of } 3.012 \times 10^{21} \text{ atoms} = 1/3.012 \times 10^{21}$$

Now volume of 1 atom of mercury (Hg)

$$= 1/3.012 \times 10^{21} \times 13.6 \text{ c.c.} = 10^3 \times 10/3012 \times 10^{21} \times 136 \text{ c.c.}$$

$$= 10^{-17}/3012 \times 136 \text{ c.c.} = 10^{-17}/409632 \text{ c.c.} = 1000000 \times 10^{-23}/409632 \text{ c.c.}$$

$$= 2.44 \times 10^{-23} \text{ c.c.}$$

Since each mercury atom occupies a cube of edge length equal to its diameter, therefore,

$$\text{Diameter of one Hg atom} = (2.44 \times 10^{-23})^{1/3} \text{ cm}$$

$$= (24.4 \times 10^{-24})^{1/3} \text{ cm.}$$

$$= 2.905 \times 10^{-8} \text{ cm} \equiv \mathbf{2.91 \text{ \AA}}$$

Sol 2.

For bcc lattice, (radius), $r = \sqrt{3}a/4$

Solution

$$\therefore r = \sqrt{3} \times 4.29 \text{ \AA} / 4 = 1.73 \times 4.29 \text{ \AA} / 4 = \mathbf{1.86 \text{ \AA}}$$

Sol 3.

For a hcp unit cell, there are 6 atoms per unit cell. If r is the radius of the metal atoms, volume occupied by the metallic

$$\text{Atoms } 6 \times \frac{4}{3} \times \pi \times r^3 = 6 \times 1.33 \times \frac{22}{7} \times r^3 = 25.08 \times r^3$$

Geometrically it has been shown that the base area of hcp unit cell

$$= 6 \times \sqrt{3}/4 \times 4r^2 \text{ and the height} = 4r \times \sqrt{2}/3$$

∴ Volume of the unit cell

$$= \text{Area} \times \text{height} = 6 \times \sqrt{3}/4 \times 4r^2 \times 4r \times \sqrt{\frac{2}{3}} = 33.94 r^3$$

∴ Volume of the empty space of one unit cell

$$= 33.94 r^3 - 25.08 r^3 = 8.86 r^3$$

$$\therefore \text{Percentage void} = 8.816 r^3 / 33.94 r^3 \times 100 = \mathbf{26.1\%}$$

Sol 4.

Density of NaCl

$$= n * \text{at. wt.}/\text{Av. No.} * a^3 = 4 * 58.5/6.023 * 10^{23} * (5.64 * 10^{-8})^3$$
$$= 2.16 \text{ g/cm}^3$$

Sol 5.

For bcc lattice, $r = \sqrt{3} * a/4 = \sqrt{3}/4 * 287 = 124.27 \text{ pm}$

Now Density = $n * \text{at. wt.}/V * \text{Av. No.} = n * \text{at. wt.}/a^3 * \text{Av. No.}$

$N = 2$ for bcc; $a = 287 * 10^{-10} \text{ cm}$

$$\therefore \text{Density} = 2 * 51.99/(287 * 10^{-10})^3 * 6.023 * 10^{23} = 7.30 \text{ g/ml}$$

Sol 6.

Density in fcc = $n_1 * \text{at. wt.}/V_1 * \text{No.}$

Density in bcc = $n_2 * \text{at. wt.}/V_2 * \text{No.}$

fcc unit cell length = 3.5 \AA

bcc unit cell length = 3.0 \AA

Density in fcc = $n_1 * \text{at. wt.}/V_1 * \text{Av. No.}$

Density in bcc = $n_2 * \text{at. wt.}/V_2 * \text{Av. No.}$

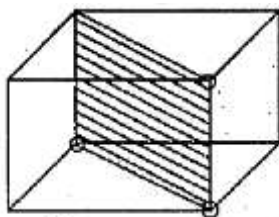
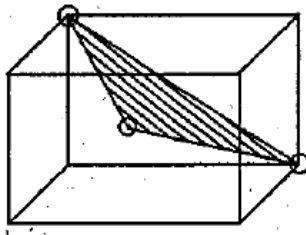
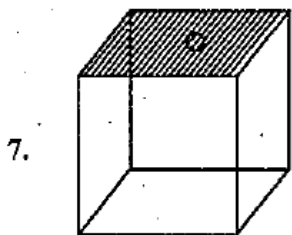
$$\therefore D_{\text{fcc}}/D_{\text{bcc}} = n_1/n_2 * V_2/V_1$$

n_1 for fcc = 4; Also $V_1 = a^3 = (3.5 * 10^{-8})^3$

n_2 for bcc = 2; Also $V_2 = a^3 = (3.0 * 10^{-8})^3$

$$\therefore D_{\text{fcc}}/D_{\text{bcc}} = 4 * (3.0 * 10^{-8})^3/2 * (3.5 * 10^{-8})^3 = 1.259$$

Sol 7.

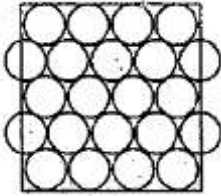


Sol 8.

The area of square = $4 * 4 = 16 \text{ cm}^2$

Again to have the maximum number of spheres the packing must be hcp.

Maximum number of spheres = $14 + 8 = 14 + 4 = 18$
full half



Area = 16 cm^2

\therefore Number of spheres $\text{cm}^2 = 18/16$
 $= 1.126$

Sol 9.

Number of moles of acetic in 100 ml before adding charcoal = 0.05

Number of moles of acetic acid in 100 ml after adding charcoal = 0.049

Number of moles of acetic acid adsorbed on the surface of charcoal = 0.001

Number of molecules of acetic acid adsorbed on the surface of charcoal = $0.001 * 6.02 * 10^{23} = 6.02 * 10^{20}$

Surface area of charcoal = $3.01 * 10^2 \text{ m}^2$ (given)

Area occupied by single acetic acid molecule on the surface of charcoal $3.01 * 10^2 / 6.02 * 10^{20} = 5 * 10^{-19} \text{ m}^2$

Sol 10.

(a) Density of AB = $Z * M / N_0 * a^3$

Here, Z = 4 (for fcc), M = 6.023 Y,

$A = 2 Y^{1/3} \text{ nm} = 2 Y^{1/3} * 10^{-9} \text{ m}$

Thus,

Density = $4 * 6.023 / 6.023 * 10^{23} * (2 Y^{1/3} * 10^{-9})^3$
 $= 5.0 \text{ kg m}^{-3}$

(b) Since the observed density (20 kg m^{-3}) of AB is higher than the calculated (5 kg m^{-3}), the compound must have metal excess **defect**. Non-stocheometric defect.

Sol 11.

For an octahedral void $a = 2 (r + R)$ In fcc lattice the largest void present is octahedral void. If the radius of void sphere is R and of lattice sphere is r. Then,

$r = \sqrt{2} * 400 / 5 = 141.12 \text{ pm}$ (a = 400 pm)

applying condition for octahedral void, $2 (r + R) = a$

$\therefore 2 R = a - 2r = 400 - 2 * 141.12 \therefore$ Diameter of greatest sphere = **117.16 pm**

Sol 12.

$$P_{N_2} = 0.001 \text{ atm}, T = 300 \text{ K}, V = 2.46 \text{ cm}^3$$

∴ Number of N_2 molecules

$$\begin{aligned} &= PV/RT * N_{AV} = 0.001 * 2.46 * 10^{-3} / 0.0821 * 300 * 6.023 * 10^{23} \\ &= 6.016 * 10^{16} \end{aligned}$$

Now total number of surface sites

= Density * Total surface area

$$= 6.023 * 10^{14} * 1000 = 6.023 * 10^{17}$$

$$\text{Sites occupied by } N_2 \text{ molecules} = 20/100 * 6.023 * 10^{17} = 12.04 * 10^{16}$$

∴ No. of sites occupied by each N_2 molecule

$$= 12.04 * 10^{16} / 6.016 * 10^{16} = 2$$

Sol 13.

For bcc ; $r = \sqrt{3}/2 a$;

$$d = n * M/N_{AV} * a^3 \text{ or } n = d * N_{AV} * a^3 / M$$

$$\Rightarrow n = 2 * 6 * 10^{23} (5 * 10^{-8})^3 / 75 = 2$$

Therefore Metal crystallizes in BCC structure and for a BCC lattice $\sqrt{3}a = 4r$

$$r = \sqrt{3}/4 a = \sqrt{3} * 5/4 = 2.165 \text{ \AA} = 216.5 \text{ pm}$$

so the required answer is **217 pm**.