Subjective questions of Solid State & Surface Chemistry

1. The density of mercury is 13.6 g/ml. Calculate approximately the diameter of an atom of mercury assuming that each atom is occupying a cube of edge length equal to the diameter of the mercury atom. (1983 - 3 Marks)

Ans : 2.91Å

Solution:

Avogadro's number = 6.023 × 1023

At. wt. of mercury(Hg) = 200

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

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

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

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

Q mass of 3.012×10^{21} atoms = 1g

∴ Mass of 3.012 × 1021 atoms = $\frac{1}{3.012 \times 10^{21}}$

Now volume of 1 atom of mercury (Hg)

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

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

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

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

Diameter of one Hg atom

$= (2.44 \times 10^{-23})^{\frac{1}{3}}$ cm

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

$= 2.905 \times 10^{-8}$ cm $\cong$ **2.91 Å**

2. Sodium metal crystallizes in body centred cubic lattice with the cell edge, a = 4.29Å. What is the radius of sodium atom? (1994 - 2 Marks)

Ans: 1.86 Å

TIPS/Formulae:

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

Solution:

$$\therefore r = \frac{\sqrt{3} \times 4.29Å}{4} = \frac{1.73 \times 4.29Å}{4} = \mathbf{1.86\ Å}$$

3. A metallic element crystallises into a lattice containing a sequence of layers of ABABAB..... Any packing of spheres leaves out voids in the lattice. What percentage by volume of this lattice is empty space? (1996 - 3 Marks)

Ans: 25.93%

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

∴ Volume of the unit cell

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

∴ Volume of the empty space of one unit cell = 33.94 r^3 – 25.08 r^3 = 8.86 r^3

∴ Percentage void = $\frac{8.816\, r^3}{33.94\, r^3} \times 100 = \mathbf{26.1\%}$

4. Chromium metal crystallizes with a body centred cubic lattice. The length of the unit cell edge is found to be 287 pm. Calculate the atomic radius. What would be the density of chromium in g/cm3? (1997 - 3 Marks)

Ans : 124.27 pm, 7.30 g/ml

Solution:

For bcc lattice , $r = \frac{\sqrt{3} \times a}{4} = \frac{\sqrt{3}}{4} \times 287 = \mathbf{124.27\,pm}$

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

$n = 2$ for bcc; $a = 287 \times 10^{-10}$ cm

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

5. A metal crystallises into two cubic phases, face centered cubic (FCC) and body centred cubic (BCC), whose unit cell lengths are 3.5 and 3.0 Å, respectively, Calculate the ratio of densities of FCC and BCC. (1999 - 3 Marks)

Ans : 1.259

Solution :

TIPS/Formulae : Density in fcc = $\frac{n_1 \times \text{atwt.}}{V_1 \times \text{No.}}$

Density in bcc = $\frac{n_2 \times \text{at.wt.}}{V_2 \times \text{No.}}$

fcc unit cell length = 3.5Å; bcc unit cell length = 3.0 Å

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

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

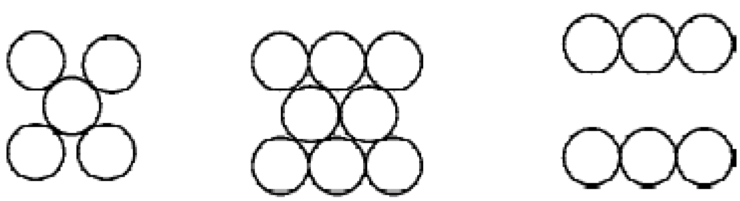
$$\therefore \frac{D_{fcc}}{D_{bcc}} = \frac{n_1}{n_2} \times \frac{V_2}{V_1}$$

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

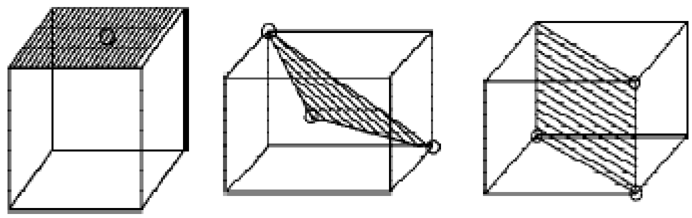
n_2 for fcc = 2; Also $V_2 = a^3 = (3.0 \times 10^{-8})^3$

$$\therefore \frac{D_{fcc}}{D_{bcc}} = \frac{4 \times (3.0 \times 10^{-8})^3}{2 \times (3.5 \times 10^{-8})^3} = \mathbf{1.259}$$

6. The figures given below show the location of atoms in three crystallographic planes in a FCC lattice. Draw the unit cell for the corresponding structure and identify these planes in your diagram. (2000 - 3 Marks)



Solution:



(I) (II) (III)

7. You are given marbles of diameter 10 mm. They are to be placed such that their centres are lying in a square bound by four lines each of length 40 mm. What will be the arrangements of marbles in a plane so that maximum number of marbles can be placed inside the area? Sketch the diagram and derive expression for the number of molecules per unit area. (2003 - 2 Marks)

Ans : (a) 25

Solution:

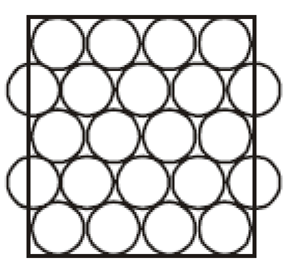
The area of square = 4 × 4 = 16 cm2

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

∴ Number of spheres per cm^2 = 18/16= 1.126

8. 1 gm of charcoal adsorbs 100 ml 0.5 M CH3COOH to form a monolayer, and thereby the molarity of CH_3COOH reduces to 0.49. Calculate the surface area of the charcoal adsorbed by each molecule of acetic acid. Surface area of charcoal = 3.01 × 102 m^2/gm. (2003 - 2 Marks)

Ans : 5 × 10^{-19} m^2

Solution :

Number of moles of acetic acid 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 m^2 (given)

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

9. A compound AB has rock salt type structure. The formula weight of AB is 6.023 Y amu, and the closest A – B distance is Y1/3 nm, where Y is an arbitrary number. (2004 - 2 Marks)
(a) Find the density of lattice
(b) If the density of lattice is found to be 20 kg m^{-3} , then predict the type of defect.

Ans :

(a) 5.0 kg/m3,

(b) metal excess defect

Solution:

(a) TIPS/Formulae : Density of AB = $\frac{Z \times M}{N_0 \times a^3}$

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

a = 2 $Y^{1/3}$ nm = 2 $Y^{1/3} \times 10^{-9}$ m

Thus,

$$\text{Density} = \frac{4 \times 6.023 Y}{6.023 \times 10^{23} \times (2Y^{1/3} \times 10^{-9})^3}$$

$= 5.0 kgm^{-3}$

(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.

10. In face centred cubic (fcc) crystal lattice, edge length is 400 pm. Find the diameter of greatest sphere which can be fit into the interstitial void without distortion of lattice. (2005 - 2 Marks)

Ans : 117.16 pm

Solution :

TIPS/Formulae : 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,

$$r = \frac{\sqrt{2} \times 400}{4} = 141.12 \text{ pm} \qquad (a = 400 \text{ pm})$$

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

∴ 2 R = a – 2r = 400 – 2 × 141. 12

∴ Diameter of greatest sphere = 117.16 pm

11. 20% of surface sites are occupied by N_2 molecules. The density of surface site is 6.023 × 1014 cm^{-2} and total surface area is 1000 cm^2. The catalyst is heated to 300 K while N_2 is completely desorbed into a pressure of 0.001 atm and volume of 2.46 cm^3. Find the number of active sites occupied by each N_2 molecule. (2005 - 4 Marks)

Ans: 2

Solution:

P_{N_2} = 0.001 atm, T = 300 K, V = 2.46 cm^2

∴ Number of N_2 molecules

$$= \frac{PV}{RT} \times N_{AV} = \frac{0.001 \times 2.46 \times 10^{-3}}{0.0821 \times 300} \times 6.023 \times 10^{23}$$

$= 6.016 \times 10^{16}$

Now total number of surface sites = Density × Total surface area

$= 6.023 \times 10^{14} \times 1000 = 6.023 \times 10^{17}$

Sites occupied by N_2 molecules

$$= \frac{20}{100} \times 6.023 \times 10^{17}$$

$$= 12.04 \times 10^{16}$$

∴ No. of sites occupied by each N_2 molecule $= \frac{12.04 \times 10^{16}}{6.016 \times 10^{16}} \approx \mathbf{2}$

12. The edge length of unit cell of a metal having molecular weight 75 g/mol is 5Å which crystallizes in cubic lattice. If the density is 2 g/cc then find the radius of metal atom (NA = 6 × 10^{23}). Give the answer in pm. (2006 - 6M)

Ans : 217 pm

Solution:

TIPS/Formulae: For bcc; $r = \frac{\sqrt{3}}{2} a;$

$$d = \frac{n \times M}{N_{Av} \times a^3} \quad \text{or} \quad n = \frac{d \times N_{Av} \times a^3}{M}$$

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

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

$$r = \frac{\sqrt{3}}{4}a = \frac{\sqrt{3} \times 5}{4} = 2.165 \mathring{A} = 216.5 \text{ pm}$$

So the required answer is 217 pm

Matching & Integer type Ques. of Solid State & Surface Chemistry

Direction : question contains statements given in two columns, which have to be matched. The statements in Column-I are labelled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column-I can have correct matching with ONE OR MORE statement(s) in Column-II

Match the crystal system/unit cells mentioned in Column I with their characteristic features mentioned in Column II. Indicate your answer by darkening the appropriate bubbles of the 4 × 4 matrix given in the ORS.

Column I	**Column II**
(A) Simple cubic and face-centered cubic parameters	**(p) have these parameters, a = b = c and $\alpha = \beta = \gamma$**
(B) cubic and rhombohedral	**(q) are two crystal systems**
(C) cubic and tetragonal	**(r) have only two crystallo-graphic angles of 90°**
(D) hexagonal and monoclinic	**(s) belong to same crystal system**

Ans:

(A - p, s); (B - p, q); (C - q); (D - q, r).

Solution:

A→ p, s; Parameters of a cubic system are a = b = c and $\alpha = \beta = \gamma = 90°$

There are three types of lattices in cubic system

These are simple, Face centred and body centred B→ p, q ; The parameters of a

Rhombohedral system are a = b = c; $\alpha = \beta = \gamma = 90°$

Cubic and Rhombohedral are two crystal systems. There are seven crystal systems in **all**

C→ q; These are two crystal systems.

D→ q, r; Hexagonal and monoclinic are two crystal systems.

The parameters of these are

Hexagonal; $a = b \neq c$ and $\alpha = \beta = 90°$, $r = 120°$

Monoclinic; $a \neq b \neq c$ and $\alpha = \gamma = 90°, \beta \neq 90°$

Integer Value Correct Type Question

Q. The number of hexagonal faces that are present in a truncated octahedron is (2011)

Ans: b