Chapter
The Solid State

Topic-1: Different Types, Crystal Structure and Properties of Solids

7 Match the Following

1. 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. **[2007]**

Column-I	Column-II
(A) Simple cubic and face-centered cubic	(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 crystallographic angles of 90°
(D) hexagonal and monoclinic	(s) belong to same crystal system

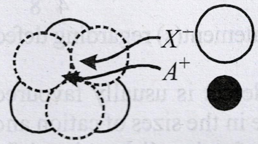
Topic-2: Cubic Systems, Bragg's Equation and Imperfection in Solids

1 MCQs with One Correct Answer

1. Atom X occupies the fcc lattice sites as well as alternate tetrahedral voids of the same lattice. The packing efficiency (in %) of the resultant solid is closest to **[Adv. 2022 (II)]**

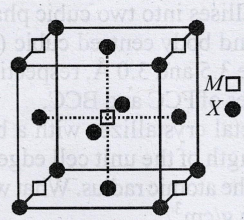
(a) 25 (b) 35
(c) 55 (d) 75

2. The arrangement of X^- ions around A^+ ion in solid AX is given in the figure (not drawn to scale). If the radius of X^- is 250 pm, the radius of A^+ is **[Adv. 2013]**



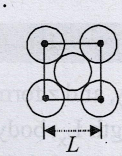
(a) 104 pm (c) 183 pm
(b) 125 pm (d) 57 pm

3. A compound M_pX_q has cubic close packing (ccp) arrangement of X. Its unit cell structure is shown below. The empirical formula of the compound is **[2012 - I]**



(a) MX (b) MX_2 (c) M_2X (d) M_5X_{14}

4. The packing efficiency of the two-dimensional square unit cell shown below is : **[2010]**



(a) 39.27% (b) 68.02% (c) 74.05% (d) 78.54%

5. A substance A_xB_y crystallizes in a face centred cubic (FCC) lattice in which atoms 'A' occupy each corner of the cube and atoms 'B' occupy the centres of each face of the cube. Identify the correct composition of the substance A_xB_y **[2002S]**

(a) AB_3
(b) A_4B_3
(c) A_3B
(d) Compostion cannot be specified

6. In a solid 'AB' having the NaCl structure, 'A' atoms occupy the corners of the cubic unit cell. If all the face-centered atoms along one of the axes are removed, then the resultant stoichiometry of the solid is **[2001S]**
(a) AB_2 (b) A_2B (c) A_4B_3 (d) A_3B_4

7. The coordination number of a metal crystallizing in a hexagonal close-packed structure is **[1999 - 2 Marks]**
(a) 12 (b) 4 (c) 8 (d) 6

8. CsBr has *bcc* structure with edge length 4.3. The shortest inter ionic distance between Cs^+ and Br^- is : **[1995S]**
(a) 3.72 (b) 1.86 (c) 7.44 (d) 4.3

2 Integer Value Answer

9. Consider an ionic solid MX with NaCl structure. Construct a new structure (Z) whose unit cell is constructed from the unit cell of MX following the sequential instructions given below. Neglect the charge balance. **[Adv. 2018]**
(i) Remove all the anions (X) except the central one
(ii) Replace all the face centered cations (M) by anions (X)
(iii) Remove all the corner cations (M)
(iv) Replace the central anion (X) with cation (M)
The value of $\left(\frac{\text{number of anions}}{\text{number of cations}}\right)$ in Z is ______.

10. A crystalline solid of a pure substance has a face-centred cubic structure with a cell edge of 400 pm. If the density of the substance in the crystal is 8 g cm^{-3}, then the number of atoms present in 256 g of the crystal is $N \times 10^{24}$. The value of N is **[Adv. 2017]**

11. The number of hexagonal faces that are present in a truncated octahedron is **[2011]**

3 Numeric / New Stem Based Questions

12. 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]**

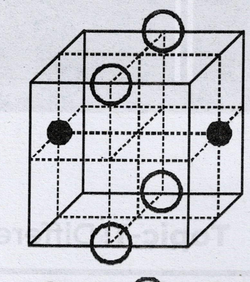
13. Chromium metal crystallizes with a body centred cubic lattice. The length of the unit cell edge is found to be 287 pm. Calculate the atomic radius. What would be the density of chromium in g/cm^3? **[1997 - 3 Marks]**

14. 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]**

6 MCQs with One or More than One Correct Answer

15. Atoms of metals x, y, and z form face-centred cubic (fcc) unit cell of edge length L_x, body-centred cubic (bcc) unit cell of edge length L_y, and simple cubic unit cell of edge length L_z, respectively. **[Adv. 2023]**
If $r_z = \frac{\sqrt{3}}{2} r_y$; $r_y = \frac{8}{\sqrt{3}} r_x$; $M_z = \frac{3}{2} M_y$ and $M_z = 3M_x$, then the correct statement(s) is (are)
[Given: M_x, M_y, and M_z are molar masses of metals x, y, and z, respectively. r_x, r_y, and r_z are atomic radii of metals x, y, and z, respectively.]
(a) Packing efficiency of unit cell of x > Packing efficiency of unit cell of y > Packing efficiency of unit cell of z
(b) $L_y > L_z$
(c) $L_x > L_y$
(d) Density of x > Density of y

16. The cubic unit cell structure of a compound containing cation M and anion X is shown below. When compared to the anion, the cation has smaller ionic radius. Choose the correct statement(s). **[Adv. 2020]**



(a) The empirical formula of the compound is MX.
(b) The cation M and anion X have different coordination geometries.
(c) The ratio of M-X bond length to the cubic unit cell edge length is 0.866.
(d) The ratio of the ionic radii of cation M to anion X is 0.414.

17. The CORRECT statement(s) for cubic close packed (ccp) three dimensional structure is (are) **[Adv. 2016]**
(a) The number of the nearest neighbours of an atom present in the topmost layer is 12
(b) The efficiency of atom packing is 74%
(c) The number of octahedral and tetrahedral voids per atom are 1 and 2, respectively
(d) The unit cell edge length is $2\sqrt{2}$ times the radius of the atom

18. If the unit cell of a mineral has cubic close packed (*ccp*) array of oxygen atoms with *m* fraction of octahedral holes occupied by aluminium ions and *n* fraction of tetrahedral holes occupied by magnesium ions, *m* and *n*, respectively, are **[Adv. 2015]**
(a) $\frac{1}{2}, \frac{1}{8}$ (b) $1, \frac{1}{4}$
(c) $\frac{1}{2}, \frac{1}{2}$ (d) $\frac{1}{4}, \frac{1}{8}$

19. The correct statement(s) regarding defects in solids is (are) **[2009S]**
(a) Frenkel defect is usually favoured by a very small difference in the sizes of cation and anion
(b) Frenkel defect is a dislocation defect
(c) Trapping of an electron in the lattice leads to the formation of F-centre
(d) Schottky defects have no effect on the physical properties of solids

20. Which of the following statement(s) is (are) correct? **[1998 - 2 Marks]**

(a) The coordination number of each type of ion in CsCl crystal is 8.
(b) A metal that crystallizes in *bcc* structure has a coordination number of 12.
(c) A unit cell of an ionic crystal shares some of its ions with other unit cells.
(d) The length of the unit cell in NaCl is 552 pm. (r_{Na^+} = 95 pm; r_{Cl^-}=181 pm).

8 Comprehension/Passage Based Questions

Passage

In hexagonal systems of crystals, a frequently encountered arrangement of atoms is described as a hexagonal prism. Here, the top and bottom of the cell are regular hexagons and three atoms are sandwiched in between them. A space-filling model of this structure, called hexagonal close-packed (HCP), is constituted of a sphere on a flat surface surrounded in the same plane by six identical spheres as closely as possible. Three spheres are then placed over the first layer so that they touch each other and represent the second layer. Each one of these three spheres touches three spheres of the bottom layer. Finally, the second layer is covered with third layer that is identical to the bottom layer in relative position. Assume radius of every sphere to be 'r'.

21. The number of atoms in the HCP unit cell is **[2008]**
(a) 4 (b) 6
(c) 12 (d) 17

22. The volume of this *hcp* unit cell is – **[2008]**
(a) $24\sqrt{2}r^3$ (b) $16\sqrt{2}r^3$
(c) $12\sqrt{2}r^3$ (d) $\frac{64}{3\sqrt{3}}r^3$

23. The empty space in this *hcp* unit cell is **[2008]**
(a) 74% (b) 47.6%
(c) 32% (d) 26%

9 Assertion and Reason /Statement Type Questions

Each question contains **STATEMENT-1 (Assertion)** and **STATEMENT-2 (Reason)**. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct. Mark your answer as
(a) If both Statement -1 and Statement -2 are correct, and Statement -2 is the correct explanation of the Statement -2.
(b) If both Statement -1 and Statement -2 are correct, but Statement -2 is not the correct explanation of the Statement -1.
(c) If Statement -1 is correct but Statement -2 is incorrect.
(d) If Statement -1 is incorrect but Statement -2 is correct.

24. Assertion : In any ionic solid [*MX*] with Schottky defects, the number of positive and negative ions are same.
Reason : Equal number of cation and anion vacancies are present. **[2001S]**

10 Subjective Problems

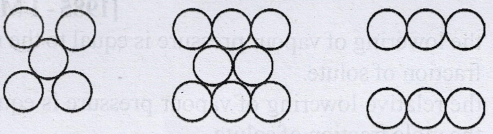
25. The edge length of unit cell of a metal having molecular weight 75 g/mol is 5Å which crystallizes in cubic lattice. If the density is 2 g/cc then find the radius of metal atom ($N_A = 6 \times 10^{23}$). Give the answer in pm. **[2006 - 6M]**

26. 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]**

27. 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 $Y^{1/3}$ 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.

28. 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]**

29. The figures given below show the location of atoms in three crystallographic planes in an FCC lattice. Draw the unit cell for the corresponding structure and identify these planes in your diagram. **[2000 - 3 Marks]**



30. 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]**

31. 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]**

Answer Key

Topic-1 : Different Types, Crystal Structure and Properties of Solids

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

Topic-2 : Cubic Systems, Bragg's Equation and Imperfection in Solids

1. (b)	**2.** (a)	**3.** (b)	**4.** (d)	**5.** (a)	**6.** (d)	**7.** (a)	**8.** (a)	**9.** (3)	**10.** (2)
11. (8)	**12.** (1.259)	**13.** (124.27)	**14.** (1.86)	**15.** (a, b, d)	**16.** (a, c)	**17.** (b, c, d)	**18.** (a)	**19.** (b, c)	
20. (a, c, d)		**21.** (b)	**22.** (a)	**23.** (d)	**24.** (a)				

Hints & Solutions

Topic-1: Different Types, Crystal Structure and Properties of Solids

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

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

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 $\alpha = \beta = 90°, \gamma = 120°$

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

Topic-2: Cubic Systems, Bragg's Equation and Imperfection in Solids

1. **(b)** Atom X in fcc lattice sites $= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

Atom X in alternate tetrahedral voids $= \frac{1}{2} \times 8 = 4$

Total number of atom X in one unit cell $= 4 + 4 = 8$

T.V. forms at 1/4th of body diagonal, thus,

$$\frac{1}{4} \times \sqrt{3}a = 2r \Rightarrow a = \frac{8r}{\sqrt{3}}$$

$$\text{Packing efficiency} = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}}$$

$$= \frac{8 \times \frac{4}{3}\pi r^3}{a^3} \times 100 = \frac{8 \times \frac{4}{3}\pi r^3}{\left(\frac{8r}{\sqrt{3}}\right)^3} \times 100 \approx 35\%$$

2. **(a)** The arrangement given, shows octahedral void arrangement; limiting radius ratio for octahedral void is

$$\frac{r_{A^+}}{r_{X^-}} = 0.414$$

$r_{A^+} = 0.414 \times r_{X^-} = 0.414 \times 250 = 103.5 \approx 104$ pm.

3. **(b)** No. of M atoms $= \frac{1}{4} \times 4 + 1 = 1 + 1 = 2$

No. of X atoms $= \frac{1}{2} \times 6 + \frac{1}{8} \times 8 = 3 + 1 = 4$

So, formula $= M_2X_4 = MX_2$

4. **(d)** Packing effieincy

$$= \frac{\text{Area occupied by effective circles}}{\text{Area of square}}$$

Effective no. of atoms in 2D $= \frac{1}{4} \times 4 + 1 = 2$

∴ Area occupied by effective circles $= 2\pi r^2$

$$= \frac{2\pi r^2}{L^2} \times 100 = \frac{2\pi r^2}{(2\sqrt{2}r)^2} \times 100$$

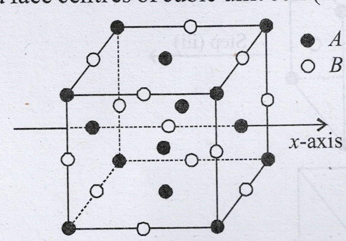
$$= \frac{\pi}{4} \times 100 = 78.54\%$$

5. **(a)** Effective number of atoms at corners, $A = 8 \times \frac{1}{8} = 1$

Effective number of atoms at centre, $B = \frac{1}{2} \times 6 = 3$

Thus, the composition will be AB_3.

6. **(d)** In the given solid AB, A atoms occupy the corners and face centres of cubic unit cell (NaCl structure).



NaCl type AB solid

B atoms occupy the body and edge-centres.

If all the face-centred atoms along x-axis are removed *i.e.* removal of two A atoms then effective number of A atoms in a unit cell

$$= \left(8 \times \frac{1}{8}\right) + \left(4 \times \frac{1}{2}\right) = 3$$

Effective number of B atoms

$$= (1) + \left(12 \times \frac{1}{4}\right) = 4$$

Hence, the resultant stoichiometry of solid $= A_3B_4$

7. **(a)** In an *hcp* structure, atoms are located at the corners and at centres of two hexagons placed parallel to each other; three more atoms are placed in a parallel plane midway between these two planes. Here, each atom is surrounded by 12 others and is said to have co-ordination number of 12.

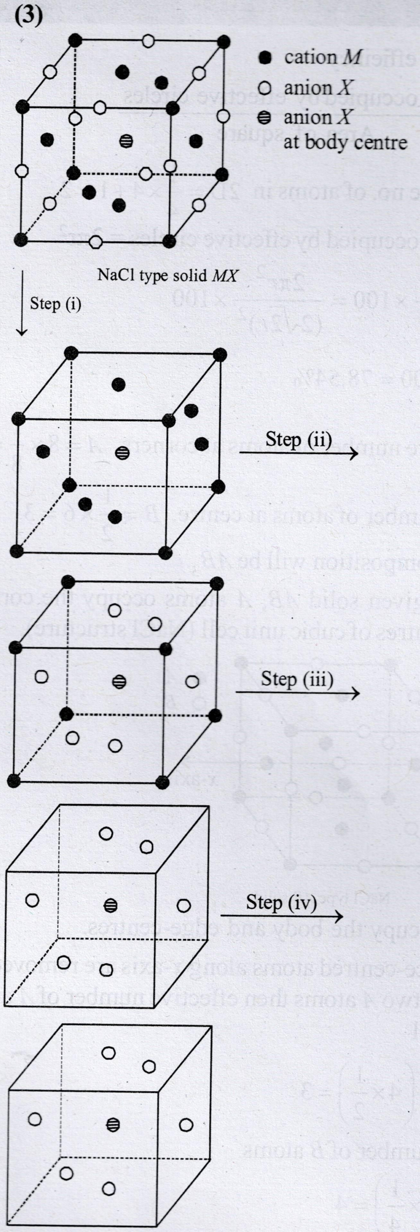
8. **(a)** For *bcc* structure, atomic radius, $r = \frac{\sqrt{3}}{4}a$

$= \frac{\sqrt{3}}{4} \times 4.3 = 1.86$

Since, r = half the distance between two nearest neighbouring atoms.

$\therefore$ Shortest inter ionic distance $= 2 \times 1.86 = 3.72$

9. **(3)**



(Z)

Number of cation = 1

Number of anions $= 6 \times \frac{1}{2} = 3$

$\frac{\text{Number of anions}}{\text{Number of cations}} = \frac{3}{1} = 3$

10. **(2)** Density $(d) = \frac{Z \times M}{a^3 \times N_A}$

For *fcc*, $Z = 4$

Given $a = 4 \times 10^{-8}$ cm

$$8 = \frac{4 \times M}{(4 \times 10^{-8})^3 \times N_A}$$

$$M = \frac{8 \times (4 \times 10^{-8})^3 \times N_A}{4}$$

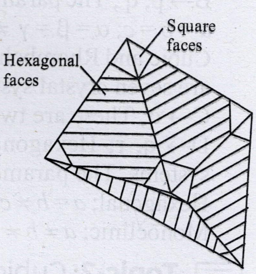
$= 2 \times (4 \times 10^{-8})^3 \times \text{NA} = 128 \times 10^{-24} N_A$

$$\text{No. of atoms} = \frac{\text{Given mass}}{\text{Molar mass}} \times N_A$$

$$= \frac{256 \times N_A}{128 \times 10^{-24} \times N_A} = 2 \times 10^{24}$$

$\therefore$ Value of $N = 2$

11. **(8)** A truncated octahedron is constructed by removing 6 square pyramids from its 6 vertices.



In the remaining structure there are 6 square faces and 8 hexagonal faces.

12. **(1.259)**

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

$$\text{Density in } fcc = \frac{z_1 \times \text{at.wt.}}{V_1 \times N_A}$$

$$\text{Density in } bcc = \frac{z_2 \times \text{at.wt.}}{V_2 \times N_A}$$

$$\therefore \frac{d_{fcc}}{d_{bcc}} = \frac{z_1}{z_2} \times \frac{V_2}{V_1}$$

z_1 for $fcc = 4$; Also $V_1 = a^3 = (3.5 \times 10^{-8})^3$ cm^3

z_2 for $bcc = 2$; Also $V_2 = a^3 = (3.0 \times 10^{-8})^3$ cm^3

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

13. **(124.27)**

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

$$\text{Now, Density} = \frac{z \times \text{at.wt.}}{V \times N_A} = \frac{z \times \text{at. wt.}}{a^3 \times N_A}$$

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

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

14. (1.86)

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

Solution

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

15. (a, b, d)

Element	X	Y	Z
Packing	FCC	BCC	Primitive
Edge	L_x	L_y	L_z
Relation between edge length and radius	$L_x = 2\sqrt{2}r_x$	$L_y = \frac{4}{\sqrt{3}}r_y$	$L_z = 2r_z$
Packing fraction	$\frac{\pi}{3\sqrt{2}}$	$\frac{\sqrt{3}\pi}{8}$	$\frac{\pi}{6}$

Now, $r_y = \frac{8}{\sqrt{3}}r_x$ & $r_z = \frac{\sqrt{3}}{2}r_y = \frac{\sqrt{3}}{2} \times \frac{8}{\sqrt{3}}r_x \Rightarrow r_z = 4r_x$

So, $L_x = 2\sqrt{2}r_x$, $L_y = \frac{4}{\sqrt{3}} \times \frac{8}{\sqrt{3}}r_x$, $L_z = 8r_x$

$L_x = 2\sqrt{2}r_x$, $L_y = \frac{32}{3}r_x$, $L_z = 8r_x$

So, $L_y > L_z > L_x$

Density $= \frac{4M_x}{L_x^3}, \frac{2xM_y}{L_y^3}$]

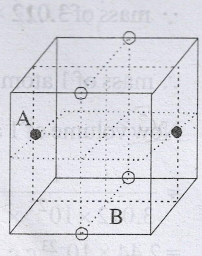
[density of X and Y $= \frac{\text{Mass}}{\text{Volume}}$, n (per atom) = 4 and 2 for FCC and BCC respectively]

Now, $3M_x = \frac{3M_y}{2}$ or $M_x \times 2 = M_y$ (Given)

$$\frac{\text{density }(x)}{\text{density }(y)} = \frac{4M_x}{2M_y} \times \frac{L_y^3}{L_x^3} = \frac{4M_x}{4M_x} \times \frac{\left(\frac{32}{3}\right)^3}{(2\sqrt{2})^3}$$

Hence d(x) > d(y)

16. (a, c)



(a) Contribution of M $= 2 \times \frac{1}{2} = 1$

Contribution of X $= 4 \times \frac{1}{4} = 1$

$\therefore$ Empirical formula is MX

(b) Coordination numbers of both M and X is 8.

(c) Bond length of M – X bond

$= AB = \sqrt{3}.\frac{a}{2} = 0.866a$

(d) Assuming anions are in contact, the ratio of ionic radii of cation to anion is 0.732 which is the radius ratio of cubical void.

17. (b, c, d)

ccp is ABC ABC ...... type packing

(a) In topmost layer, each atom is in contact with 6 atoms in same layer and 3 atoms below this layer. Thus, the number, of nearest neighbours is 9.

(b) Packing fraction $= \frac{4 \times \frac{4}{3}\pi r^3}{\left(\frac{4r}{\sqrt{2}}\right)^3} = (0.74)$

(c) Each fcc unit has effective no. of atoms = 4

Octahedral void = 4

Tetrahedral void = 8

(d) $4r = a\sqrt{2} \Rightarrow a = 2\sqrt{2}r$

18. (a) In *ccp*, number of O^{2-} ions are 4.

Hence, total negative charge = –8

Let number of Al^{3+} ions be x, and Mg^{2+} ions be y.

Total positive charge = $3x + 2y$

$\Rightarrow 3x + 2y = 8$

This relation is satisfied only by $x = 2$ and $y = 1$.

Hence, number of $Al^{3+} = 2$.

and number of $Mg^{2+} = 1$.

$\Rightarrow n$ = fraction of octahedral holes occupied by Al^{3+}

$= \frac{2}{4} = \frac{1}{2}$

and m = fraction of tetrahedral holes occupied by $Mg^{2+} = \frac{1}{8}$

19. (b, c) Frenkel defect is a dislocation effect, observed when the size of the cation and anion differ largely. F-center is created when an anion is lost from the lattice and vacancy is filled by trapping of an electron. Schottky defect changes the density of a crystalline solid.

20. (a, c, d) The crystals of CsCl has body - centred cubic unit cell. Hence, each ion in this structure has coordination number of eight.

In case of crystals of NaCl, each Na^+ ion is located half way between two Cl^- ions and vice versa. A unit cell of NaCl crystal has Cl^- ions at the corners as well as at the face centres and Na^+ ions are located at body and edge-centers. On each edge of cubic unit cell, there are two Cl^- ions and one Na^+ ions. Hence, $a = 2\left(r_{Na^+} + r_{Cl^-}\right) = 2$ (95 pm + 181 pm) = 552 pm.

21. (b) In 1 unit cell of *hcp*, the number of atoms can be calculated as follows

Number of atoms in a unit cell of *hcp*

$= 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 = 6$

i.e. the correct answer is option (b).

22. (a) The volume of hcp unit cell is given by the formula:-

Volume of hexagon = Area of base × height

$$= 6 \times \frac{\sqrt{3}}{4}(2r)^2 \times 4r\sqrt{\frac{2}{3}} = 24\sqrt{2}\,r^3$$

i.e. the correct answer is option (a).

23. **(d)** In an *hcp* unit cell, the space occupied is 74%, as calculated below:

$$\text{Packing fraction} = \frac{\text{Volume of the atoms in a unit cell}}{\text{Volume of a unit cell}}$$

$$= \frac{6 \times \frac{4}{3}\pi r^3}{24\sqrt{2}\, r^3} = \frac{\pi}{3\sqrt{2}} = \frac{22}{7} \times \frac{1}{3\sqrt{2}} = 0.74 \text{ or } 74\,\%$$

$\therefore$ Empty space is HCP unit cell = (100–74)% = 26%

i.e. the correct answer is option (d).

24. **(a)** Schottky defect is defined as a vacancy developed for anion and cation site, so cation and anion vacancy will be same in number. Therefore, an ionic solid *MX* with Schottky defects will still have the same number of anions and cations.

25. $d = \frac{n \times M}{N_A \times a^3}$ or $n = \frac{d \times N_A \times a^3}{M}$

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

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

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

So, the required answer is **217** pm.

26. For an octhedral 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, $r = \frac{\sqrt{2} \times 400}{4} = 141.12$ pm ($a = 400$ pm)

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

$\therefore 2R = a - 2r = 400 - (2 \times 141.12) = 117.16$ pm

$\therefore$ Diameter of greatest sphere = **117.16 pm**

27. (a) Density of $AB = \frac{Z \times M}{N_A \times a^3}$

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

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

Thus,

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

$= \mathbf{5.0\ kgm^{-3}}$

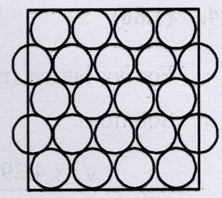
(b) Since the observed density (20 kg m^{-3}) of AB is higher than the calculated (5 kg m^{-3}), the compound must have **metal excess defect.** (non-stoichiometric defect).

28. The area of square = 4 × 4 = 16 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

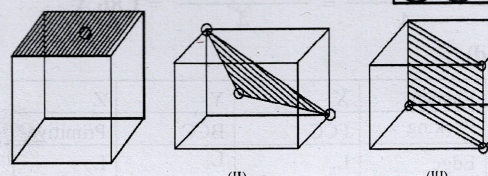


Area = 16 cm^2

$\therefore$ Number of spheres per cm^2

$= \frac{18}{16} = 1.126$

29.



(I) (II) (III)

30. For an *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

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

$\therefore$ Volume of the unit cell

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

$\therefore$ Volume of the empty space of one unit cell

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

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

31. Avogadro's number = 6.023 × 10^{23}

At. wt. of mercury(Hg) = 200 g/mol

$\because$ 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.

$\because$ mass of 3.012×10^{21} atoms = 1 g

$$\therefore \text{mass of 1 atom} = \frac{1}{3.012 \times 10^{21}} \text{ g}$$

Now volume of 1 atom of mercury (Hg)

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

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

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

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

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

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