+ 2
CHEMISTRY

Volume
1 & 2

Gem

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UNIT-6: SOLID STATE

EVALUATE YOURSELF

1. **An element has a face centered cubic unit cell with a length of 352.4 pm along an edge. The density of the element is 8.9 gcm^{-3}. How many atoms are present in 100 g of an element?**

Solution:

a = 352.4 pm = 352.4×10^{-10} cm = 3.524×10^{-8} cm

$\rho = 8.9$ g cm^{-3}

$N_A = 6.023 \times 10^{23}$

for fcc, n = 4

w = 100g

M = ?

Density $\rho = \dfrac{nM}{a^3 N_A}$

Molar mass (M) $= \dfrac{\rho a^3 N_A}{n}$

$= \dfrac{8.9(3.524\times10^{-8})^3\times6.023\times10^{23}}{4}$

$= \dfrac{8.9\times43.7630\times6.023\times10^{-24}\times10^{23}}{4} = 5.865\times10^{2}\times10^{-1}$

$(3.524)^3 = 43.7630$

log	Value
8.9	0.9494 (+)
43.763	1.6411
6.023	0.7798
	3.3703(–)
log 4	0.6021
	2.7682

Antilog (2.7682) = 5.865×10^2

M = 58.65 g. mol^{-1}

Number of moles $n = \dfrac{w}{m} = \dfrac{100}{58.65} = 1.705$ moles

Number of atoms present in 'n' moles $= n \times N_A$

$= 1.705 \times 6.023 \times 10^{23} = 1.027 \times 10^{24}$ atoms

2. **Determine the density of CsCl which crystallizes in a bcc type structure with an edge length 412.1 pm.**

n = 2; a = 412.1 pm = 412.1×10^{-10} cm

$= 4.121 \times 10^{-8}$ cm

$N_A = 6.023\times10^{23}$

M = 132.9 + 35.5 = 168.4 g.mol^{-1}

ρ = ?

$\rho = \dfrac{nm}{a^3 N_A}$

log	Value
69.98	1.8450 (+)
6.023	0.7798
	2.6248
3368	3.5274 (–)
	2.6248
	0.9026

Antilog (0.9026) = 7.991

$$= \frac{2\times168.4}{(4.121\times10^{-8})^3\times6.023\times10^{23}}$$

$$= \frac{336.8}{69.98\times10^{-24}\times6.023\times10^{23}} = \frac{3368}{69.98\times6.023}$$

Density of CsCl (ρ) = 7.99 g. cm^{-3}

3. A face centered cubic solid of an element (atomic mass 60) has a cube edge of 4A°. Calculate its density.

for fcc n = 4

M = 60 a = 4 A° = 4 × 10^{-8} cm

N_A = 6.023 × 10^{23} ρ = ?

$$\text{Density } (\rho) = \frac{nm}{a^3.N_A}$$

log	Value
150	2.1761 (-)
24.092	1.3819
	0.7942

Anti log (0.7942) = 6.226

$$= \frac{4\times60}{(4\times10^{-8})^3\times6.023\times10^{23}} = \frac{\cancel{4}\times\cancel{60}^{15}}{\cancel{4}\times\cancel{4}\times4\times6.023\times10^{23}\times10^{-24}} = \frac{150}{24.092}$$

Density of cubic solid ρ = 6.226 g cm^{-3}

4. Barium has body centered cubic unit cell with a length of 508 pm along an edge. What is the density of barium in g. cm^{-3}?

n = 2; a =508 pm = 508 × 10^{-10} cm = 5.08 × 10^{-8} cm

N_A = 6.023×10^{23} M = 137.3 g mol^{-1} ρ = ?

$$\rho = \frac{nm}{a^3N_A} = \frac{2\times137.3}{(5.08\times10^{-8})^3\times6.023\times10^{23}}$$

$$= \frac{274.6\times10^1}{131.10\times6.023} = \frac{2746}{131.10\times6.023}$$

Density of Barium (ρ) = 3.5 g. cm^{-3}

log	Value
131.10	2.1176 (+)
6.023	0.7798
	2.8974
2746	3.4387 (−)
	2.8974
	0.5413

Antilog (0.5413) = 3.477

EVALUATION

Choose the Best Answer

1. Graphite and diamond are ***(JULY 22,23)***
   (a) covalent and molecular crystals (b) ionic and covalent crystals
   (c) both covalent crystals (d) both molecular crystals
   Ans: (c) both covalent crystals

2. An ionic compound A_x B_y crystallizes in fcc type crystal structure with B ions at the centre of each face and A ion occupying corner of the cube the correct formula of A_x B_y
   (a) AB (b) AB_3 (c) A_3B (d) A_8 B_6
   Ans: (b) AB_3

Solution: Number of A ions = $\left(\frac{N_c}{8}\right) = \left(\frac{8}{8}\right) = 1$

Number of B ions = $\left(\frac{N_f}{8}\right) = \left(\frac{6}{2}\right) = 3$

Simplest formula AB_3

3. The ratio of close packed atoms to tetrahedral hole in cubic packing is
   (a) 1:1 (b) 1:2 (c) 2:1 (d) 1:4

   Ans: (b) 1:2

   Solution: If number of close packed atoms = N; then,
   The number of Tetrahedral holes formed = 2N
   Number of Octahedral holes formed = N
   Therefore N: 2N = 1:2

4. Solid CO_2 is an example of
   (a) Covalent solid (b) metallic solid (c) molecular solid (d) ionic solid

   Ans: (c) molecular solid

   Solution: Lattice points are occupied by CO_2 molecules.

5. **Assertion :** Monoclinic sulphur is an example of monoclinic crystal system.
   Reason : For a monoclinic system, $a \neq b \neq c$ and $\alpha = \gamma = 90°$, $\beta \neq 90°$ ***(MAR 24)***
   (a) Both assertion and reason are true and reason is the correct explanation of assertion.
   (b) Both assertion and reason are true but reason is not the correct explanation of assertion.
   (c) Assertion is true but reason is false.
   (d) Both assertion and reason are false.

   Ans: (a) Both assertion and reason are true and reason is the correct explanation of assertion

6. In calcium fluoride, having the fluorite structure the coordination number of Ca^{2+} ion and F^- ion are ***(NEET)***
   (a) 4 and 2 (b) 6 and 6 (c) 8 and 4 (d) 4 and 8

   Ans: (c) 8 and 4

   Solution: CaF_2 has cubical close packed arrangement.
   Ca^{2+} Ions are in face centered cubic arrangement, each Ca^{2+} ions is surrounded by $8F^-$ ions and each F^- ion is surrounded by 4 Ca^{2+} ions.
   Therefore coordination number of Ca^{2+} is 8 and of F^- is 4.

7. The number of unit cells in 8gm of an element X (atomic mass 40) which crystallizes in bcc pattern is (N_A is the Avogadro number)
   (a) 6.023×10^{23} (b) 6.023×10^{22} (c) 60.23×10^{23} (d) $\left(\frac{6.023 \times 10^{23}}{8 \times 40}\right)$

   Ans: (b) 6.023×10^{22}

Solution:

In bcc unit cell,

2 atoms ≡ 1 unit cell

Number of atoms in 8 g of element is,

Number of moles = $\frac{8\text{ g}}{40\text{ g mol}^{-1}} = 0.2$ mol

1 mole contains 6.023×10^{23} atoms

0.2 mole contains $0.2 \times 6.023 \times 10^{23}$ atoms

0.2 mole contains $0.2 \times 6.023 \times 10^{23}$

$\left(\frac{1\text{ unit cell}}{2\text{ atoms}}\right) \times 0.2 \times 6.023 \times 10^{23}$

6.023×10^{22} unit cells

8. In a solid atom M occupies ccp lattice and $\left(\frac{1}{3}\right)$ of tetrahedral voids are occupied by atom N. Find the formula of solid formed by M and N.

(a) MN (b) M_3N (c) MN_3 (d) M_3N_2

Ans: (d) M_3N_2

Solution: If the total number of M atoms is n, then the number of tetrahedral voids = 2n given that $\left(\frac{1}{3}\right)^{rd}$ of tetrahedral voids are occupied i.e., $\left(\frac{1}{3}\right) \times 2n$ are occupied by N atoms.

$\therefore$ M: N $\Rightarrow$ n: $\left(\frac{2}{3}\right)$ n   1: $\left(\frac{2}{3}\right)$ 3:2 $\Rightarrow$ $M_3\ N_2$

9. The ionic radii of A^+ and B^- are 0.98×10^{-10} m and 1.81×10^{-10} m. The coordination number of each ion in AB is

(a) 8 (b) 2 (c) 6 (d) 4

Ans: (c) 6

Solution: $\frac{r_{c^+}}{r_{A^-}} = \frac{0.98 \times 10^{-10}}{1.81 \times 10^{-10}} = 0.54$

It is in the range of 0.414 - 0.732, hence the coordination number of each ion is 6.

10. CsCl has bcc arrangement, its unit cell edge length is 400pm, its inter atomic distance

(a) 400pm (b) 800pm (c) $\sqrt{3} \times 100$pm (d) $\left(\frac{\sqrt{3}}{2}\right) \times 400$pm

Ans: (d) $\left(\frac{\sqrt{3}}{2}\right) \times 400$pm

Solution: $\sqrt{3}a = r_{cs^+} + 2r_{cl^-} + r_{cs^+}$; $\left(\frac{\sqrt{3}}{2}\right)a = \left(r_{cs^+} + r_{cr^-}\right)$; $\left(\frac{\sqrt{3}}{2}\right)400 =$ inter ionic distance

11. A solid compound XY has NaCl structure. If the radius of the cation is 100 pm, the radius of the anion will be

(a) $\left(\frac{100}{0.414}\right)$ (b) $\left(\frac{0.732}{100}\right)$ (c) 100×0.414 (d) $\left(\frac{0.414}{100}\right)$

Ans: (a) $\left(\frac{100}{0.414}\right)$

Solution: for an fcc structure $\frac{r_{x^+}}{r_{y^-}} = 0.414$; given that $r_{x^+} = 100pm$; $r_{y^-} = \frac{100pm}{0.414}$

12. The vacant space in bcc lattice unit cell is ***(MAR 20)***
(a) 48% (b) 23% (c) 32% (d) 26%

Ans: (c) 32%

Solution: Packing efficiency = 68%
Therefore empty space percentage = (100-68) = 32%

13. The radius of an atom is 300 pm, if it crystallizes in a face centered cubic lattice, the length of the edge of the unit cell is
(a) 488.5pm (b) 848.5pm (c) 884.5pm (d) 484.5pm

Ans: (b) 848.5pm

Solution: Let edge length = a $\sqrt{2}a = 4r$ $a = \frac{4 \times 300}{\sqrt{2}} = 600 \times 1.414 = 848.4$ pm

14. The fraction of total volume occupied by the atoms in a simple cubic is
(a) $\left(\frac{\pi}{4\sqrt{2}}\right)$ (b) $\left(\frac{\pi}{6}\right)$ (c) $\left(\frac{\pi}{4}\right)$ (d) $\left(\frac{\pi}{3\sqrt{2}}\right)$

Ans: (b) $\left(\frac{\pi}{6}\right)$

Solution: $\left(\frac{\frac{4}{3}\pi r^3}{a^3}\right) = \left(\frac{\frac{4}{3}\pi\left(\frac{a}{2}\right)^3}{a^3}\right) = \left(\frac{\pi}{6}\right)$

15. The yellow colour in NaCl crystal is due to
(a) excitation of electrons in F centers (b) reflection of light from Cl ion on the surface
(c) refraction of light from Na^+ ion (d) all of the above

Ans: (a) excitation of electrons in F centers

16. If 'a' stands for the edge length of the cubic system; sc, bcc, and fcc. Then the ratio of radii of spheres in these systems will be respectively.
(a) $\left(\frac{1}{2}a : \frac{\sqrt{3}}{2}a : \frac{\sqrt{2}}{2}a\right)$ (b) $\left(\sqrt{1}a : \sqrt{3}a : \sqrt{2}a\right)$ (c) $\left(\frac{1}{2}a : \frac{\sqrt{3}}{4}a : \frac{1}{2\sqrt{2}}a\right)$ (d) $\left(\frac{1}{2}a : \sqrt{3}a : \frac{1}{\sqrt{2}}a\right)$

Ans: (c) $\left(\frac{1}{2}a : \frac{\sqrt{3}}{4}a : \frac{1}{2\sqrt{2}}a\right)$

Solution: $sc \Rightarrow 2r = a \Rightarrow r = \frac{a}{2}$; $bcc \Rightarrow 4r = \sqrt{3}a \Rightarrow r = \frac{\sqrt{3}a}{4}$

$fcc \Rightarrow 4r = \sqrt{2}a \Rightarrow r = \frac{\sqrt{2}a}{4} = \frac{a}{2\sqrt{2}}$; $\left(\frac{a}{2}\right) : \left(\frac{\sqrt{3}a}{4}\right) : \left(\frac{a}{2\sqrt{2}}\right)$

17. If 'a' is the length of the side of the cube, the distance between the body centered atom in one corner atom in the cube will be

(a) $\left(\frac{2}{\sqrt{3}}\right)a$ (b) $\left(\frac{4}{\sqrt{3}}\right)a$ (c) $\left(\frac{\sqrt{3}}{4}\right)a$ (d) $\left(\frac{\sqrt{3}}{2}\right)a$

Ans: (d) $\left(\frac{\sqrt{3}}{2}\right)a$

Solution: If a is the length of the side $\sqrt{3}a$, then the length of the leading diagonal passing through the body centered atom is $\frac{\sqrt{3}}{2}a$.

18. Potassium has a bcc structure with nearest neighbour distance 4.52A°. Its atomic weight is 39. Its density will be

(a) 915 kg m^{-3} (b) 2142 kg m^{-3} (c) 452 kg m^{-3} (d) 390 kg m^{-3}

Ans: (a) 915 kg m^{-3}

Solution: $\rho = \frac{n \times M}{a^3 N_A}$

for bcc

n = 2

M = 39

Nearest distance 2r = 4.52

$a = \frac{4r}{\sqrt{3}} = \frac{2 \times 4.52 \times 10^{-10}}{\sqrt{3}} = 5.21 \times 10^{-10}$

$\rho = \frac{2 \times 39}{(5.21 \times 10^{-10})^3 \times (6.023 \times 10^{23})}$

$\rho = 915 \text{ Kg m}^{-3}$

19. Schottky defect in a crystal is observed when

(a) unequal number of cations and anions are missing from the lattice

(b) equal number of cations and anions are missing from the lattice

(c) an ion leaves its normal site and occupies an interstitial site

(d) no ion is missing from its lattice

Ans: (b) equal number of cations and anions are missing from the lattice

20. The cation leaves its normal position in the crystal and moves to some interstitial position, the defect in the crystal is known as

(a) Schottky defect (b) F center (c) Frenkel defect (d) non-stoichiometric defect

Ans: (c) Frenkel defect

21. **Assertion :** Due to Frenkel defect, density of the crystalline solid decreases.

Reason : In Frenkel defect cation and anion leaves the crystal.

(a) Both assertion and reason are true and reason is the correct explanation of assertion

(b) Both assertion and reason are true but reason is not the correct explanation of assertion

(c) Assertion is true but reason is false (d) Both assertion and reason are false

Ans: (d) Both assertion and reason are false

22. The crystal with a metal deficiency defect is ***(JULY 21, PTA MQ, MAY 22)***
    (a) NaCl (b) FeO (c) ZnO (d) KCl
    Ans: (b) FeO

23. A two dimensional solid pattern formed by two different atoms X and Y is shown below. The black and white squares represent atoms X and Y respectively. The simplest formula for the compound based on the unit cell from the pattern is
    (a) XY_8 (b) X_4Y_9 (c) XY_2 (d) XY_4
    Ans: (a) XY_8

ADDITIONAL QUESTIONS

24. Which of the following statements is not correct?
    (a) The number of carbon atoms in an unit cell of diamond is 4
    (b) The number of Bravais lattices in which a crystal can be categorized is 14
    (c) The fraction of the total volume occupied by the atoms in a primitive cell is 0.48
    (d) Molecular solids are generally volatile
    Ans: (c) The fraction of the total volume occupied by the atoms in a primitive cell is 0.48

25. AB crystallizes in a body centred cubic lattice with edge length 'a' equal to 387 pm. The distance between two oppositively charged ions in the lattice is:
    (a) 300 pm (b) 335 pm (c) 250 pm (d) 200 pm
    Ans: (b) 335 pm

26. A metal crystallises within a face centred cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is:
    (a) 204 pm (b) 144 pm (c) 408 pm (d) 288 pm
    Ans: (d) 288 pm

27. The packing efficiency of a face centered cubic structure is ***(PTA MQ)***
    (a) 74% (b) 68% (c) 52.38% (d) 48%
    Ans: (a) 74%

28. In FCC unit cell of the edge length is $8\sqrt{2}$ pm. The radius of the metal atom is ..... A° ***(PTA MQ)***
    (a) 0.04 (b) 0.02 (c) 8×10^{-2} (d) $\frac{8}{\sqrt{2}}$
    Ans: (a) 0.04

29. The arrangement of crystallographic axes and angles respectively in hexagonal crystal systems is ***(PTA MQ)***
    (a) $a \neq b \neq c$ $\alpha = \beta = \gamma = 90°$ (b) $a = b \neq c$ $\alpha = \beta = \gamma = 90°$
    (c) $a = b \neq c$ $\alpha = \beta = 90°$ $\gamma = 120°$ (d) $a = b = c$ $\alpha \neq \beta \neq$ $\gamma = 90°$
    Ans: (c) $a = b \neq c$, $\alpha = \beta = 90°$ $\gamma = 120°$

30. The formula used to identify density of the unit cell: ***(Corona-20)***
    (a) $\rho = a^3N_A \times nM$ (b) $a^3N_A - nM$ (c) $\rho = \frac{nM}{a^3N_A}$ (d) $\rho = \frac{a^3N_A}{nM}$
    Ans: (c) $\rho = \frac{nM}{a^3N_A}$

31. Packing efficiency of Body Centred Cube (BCC): *(SEP 20)*
(a) 52.31% (b) 68% (c) 86% (d) 52.13%
Ans: (b) 68%

32. The crystal with metal excess defect is: *(MAR 23)*
(a)NaCl (b)AgBr (c)Agcl (d) FeO
Ans: (a)NaCl

EVALUATION (BOOK BACK)

2, 3 and 5 Mark Question and Answers

1. **Define unit cell.** *(AUG 21, JULY 22, PTA MQ)*
A basic repeating structural unit of a crystalline solid is called a unit cell.

2. **Give any three characteristics of ionic crystals.** *(PTA MQ)*
    1. Ionic solids have high melting points.
    2. They do not conduct electricity in solid state.
    3. They conduct electricity in molten state or dissolved in water.
    4. They are hard.

3. **Differentiate crystalline solids and amorphous solids.**
(PTA MQ) (Corona-20, MAY 22, JULY 23)

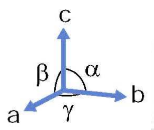
S. No.	Crystalline solids	Amorphous solids
1.	Long range orderly arrangement of constituents.	Short range, random arrangement of constituents.
2.	Definite shape	Irregular shape
3.	They are anisotropic	They are isotropic
4.	They are true solids	They are super cooled liquids
5.	Definite Heat of fusion	Heat of fusion is not definite
6.	They have sharp melting points	Gradually soften over a range of temperature.
7.	Examples: NaCl, diamond.	Examples: Rubber, plastics, glass.

4. **Classify the following solids** *(AUG 21)*
(a) P_4 (b) Brass (c) diamond (d) NaCl (e) Iodine

a) P_4	Molecular solid
b) Brass	Metallic solid
c) diamond	Covalent solid
d) NaCl	Ionic solid
e) Iodine	Molecular solid

5. Explain briefly seven types of unit cell.

Units	Crystallographic axes	Crystallographic angles
1. Cubic	a = b = c	$\alpha = \beta = \gamma = 90°$
2. Rhombohedral	a = b = c	$\alpha = \beta = \gamma \neq 90°$
3. Hexagonal	a = b ≠ c	$\alpha = \beta = 90°$ $\gamma = 120°$
4. Tetragonal	a = b ≠ c	$\alpha = \beta = \gamma = 90°$
5. Orthorhombic	a ≠ b ≠ c	$\alpha = \beta = \gamma = 90°$
6. Monoclinic	a ≠ b ≠ c	$\alpha = \gamma = 90°$, $\beta \neq 90°$
7. Triclinic	a ≠ b ≠ c	$\alpha \neq \beta \neq \gamma \neq 90°$



Crystallographic axes = a, b, c
Crystallographic angles = $\alpha = \beta = \gamma$

6. Distinguish between hexagonal close packing and cubic close packing.

S. No.	HCP	CCP
1.	Primitives are not same a = b ≠ c	Primitives are same a = b = c
2.	Crystallographic angle $\alpha = \beta = 90°$; $\gamma = 120°$	Crystallographic angles $\alpha = \beta = \gamma = 90$
3.	This type is found in metals like Mg, Zn	This type is found in metals like Cu, Ag
4.	The unit cell of hcp has 6 spheres	The unit cell of CCP is 4 spheres
5.	The repeating unit of hcp has two layers of spheres	The repeating unit of CCP has three layers of spheres

7. Distinguish tetrahedral and octahedral voids.

S. No.	Tetrahedral voids	Octahedral voids
1.	The sphere of second layer is above the void of first layer, a tetrahedral void is formed	The triangular voids in the second layer are above the triangular voids in the first layer and the triangular voids do not overlap
2.	The co-ordination number is 4.	The co-ordination number is 6.

8. What are point defects?

If the deviation occurs due to missing atoms, displaced atoms or extra atoms, the imperfection is named as point defect.

9. Explain Schottky defect. ***(PTA MQ, SEP 20, MAR 23)***

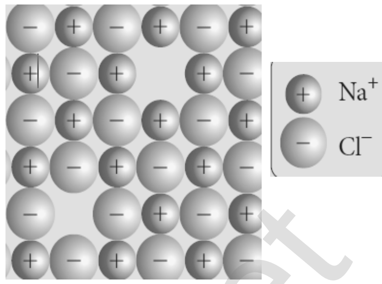
Schottky defect arises due to missing of equal number of cation and anion from the crystal lattice.

This defect does not change the stoichiometry of the crystal.

Ionic solids in which the cation and anion are almost of similar size shows this defect.

(E.g) NaCl

Presence of large number of this defect in the crystal, lower its density.

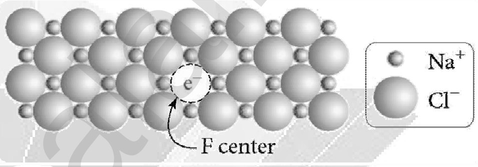


10. Write short note on metal excess ('f' centers) and metal deficiency defect with an example. ***(PTA MQ)***

metal excess defect ('f' centers)

This defect arises due to presence of more number of metal ions as compared to anions.

(E.g) Alkali metals, halides (NaCl, KCl).



The presence of anionic vacancies equal to excess metal ion or by the presence of extra cation and electron present in interstitial position make the crystal electrically neutral.

When NaCl is heated in sodium vapour, Na^+ ions are formed and deposited on the surface of crystal.

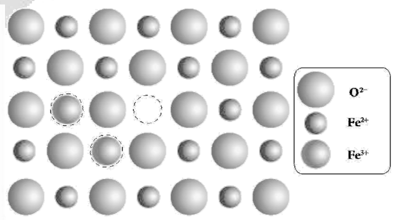
Chloride ion diffuse to the surface from the lattice point and combines with Na^+ ion.

The anionic vacancies which are occupied by unpaired electrons are called 'F' Centers.

Metal deficiency defect

This defect arises due to the presence of less number of cations than the anions.

This defect observed in a crystal having the cations with variable oxidation states.



(E.g) FeO

Some of the Fe^{2+} ions are missing from crystal lattice.

To maintain the electrical neutrality, twice the number of other Fe^{2+} ions in the crystal is oxidised to Fe^{3+} ions.

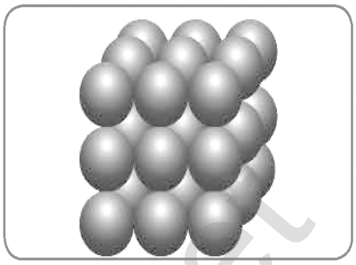
In such cases overall number of Fe^{2+} and Fe^{3+} ions is less than O^{2-} ions.

11. Calculate the number of atoms in a fcc unit cell. ***(PTA MQ, MAR 23)***

The number of atoms in a fcc unit cell in FCC = $\frac{N_C}{8} + \frac{N_f}{2} = \frac{8}{8} + \frac{6}{2} = 1+3 = 4$

12. Explain AAAA and ABABA and ABCABC type of three dimensional packing with the help of neat diagram. (Any one heading may be asked in Board Exam)

(i) AAA type

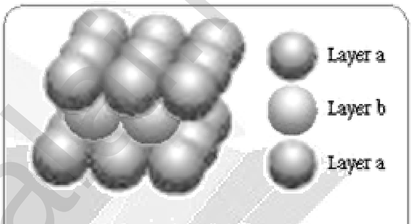


This type of three dimensional packing arrangements can be obtained by repeating the AAAA type two dimensional arrangements in three dimensions.

Spheres in one layer sitting directly on the top of those in the previous layer so that all layers are identical.

In simple cubic packing, each sphere is in contact with 6 neighbouring spheres – Four in its own layer, one above and one below and hence the coordination number of the sphere in simple cubic arrangement is 6.

(ii) ABABAB type



Body Centered Cubic (BCC)

The spheres in the first layer (A type) are slightly separated and the second layer is formed by arranging the spheres in the depressions between the spheres in layer A as shown in figure. The third layer is a repeat of the first. Each sphere has a coordination number of 8.

(iii) ABCABC type

Wherever a sphere of second layer (b) is above the void (x) of the first layer (a), a tetrahedral void is formed. This constitutes four spheres – three in the lower (a) and one in the upper layer (b). When the centres of these four spheres are joined, a tetrahedron is formed.

At the same time, the voids (y) in the first layer (a) are partially covered by the spheres of layer (b), now such a void in (a) is called a octahedral void. This constitutes six spheres – three in the lower layer (a) three in the upper layer (b). When the centres of these six spheres are joined, an octahedron is formed. Simultaneously new tetrahedral voids (or holes) are also created by three spheres in second year (b) and one sphere of first layer (a).

Formation of third layer

The third layer of spheres can be formed in two ways to achieve closest packing

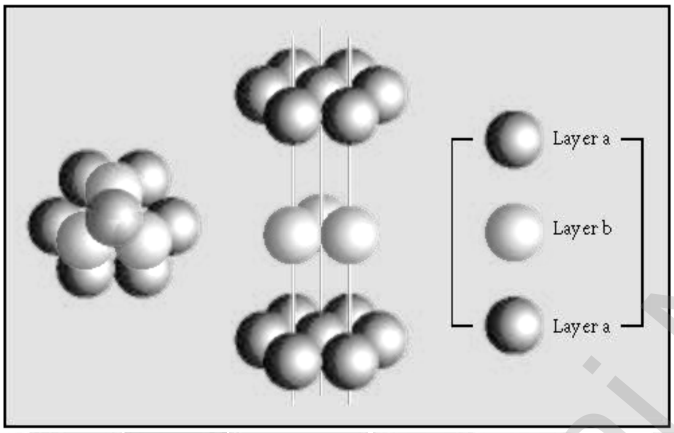
(i) aba arrangement - hcp structure

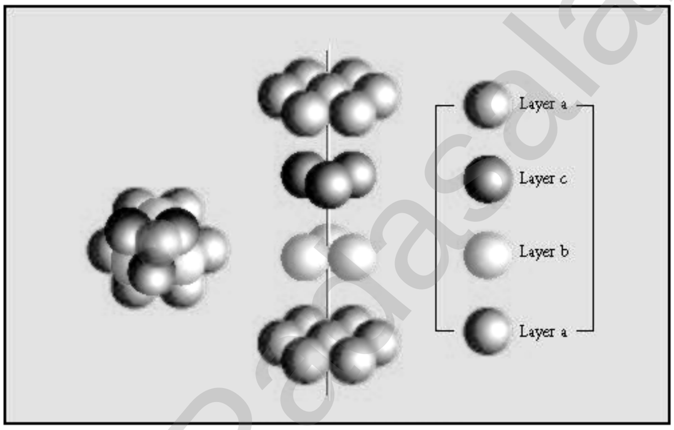
(ii) abc arrangement - ccp structure

The spheres can be arranged so as to fit into the depression in such a way that the third layer is directly over a first layer. This "aba" arrangement is known as the hexagonal close packed (hcp) arrangement. In this arrangement the tetrahedral voids of the second layer as covered by the spheres of the third year.

In this type the third layer is placed over the second layer in such a way that all the sphere of the third layer fit to octahedral voids.

This arrangement of third layer is different from other two layer 'A' and 'B'.
This type of arrangement is called CCP structure.
The co-ordination number of each sphere is 12.





13. Why ionic crystals are hard and brittle?

Ionic crystals are formed by three dimensional arrangements of cations and anions bound by strong electrostatic force of attraction. So Ionic crystals are hard and brittle.

14. Calculate the percentage efficiency of packing in case of body centered cubic crystal.

Number of Spheres in bcc arrangement = 2

$\therefore$ Total volume of spheres $= 2 \times \frac{\sqrt{3}\pi}{16} a^3 = \frac{\sqrt{3}\pi a^3}{8}$

Packing fraction or efficiency =

$$\frac{\text{Total Volume occupied by spheres in unit cell}}{\text{Volume of unit cell}}$$

log	Value
1.732	0.2385 (+)
3.14	0.4969
12.5	1.0969
	1.8323

Antilog(1.8323) = 6.797×10^1
= 67.97

$$= \frac{\frac{\sqrt{3}\pi a^3}{8}}{a^3} \times 100 = \frac{\sqrt{3}\pi}{8} \times 100 = 1.732 \times 3.14 \times 12.5 = 68\%$$

68% of available volume is occupied.

15. What is the two dimensional co-ordination number of molecule in square close packed layer?

The two dimensional co-ordination number of a molecule in square close packed layer is 4.

16. What is meant by the term "Coordination number"? What is the coordination number of atoms in a bcc structure? ***(AUG 21, MAY 22)***

The number of spheres directly surrounding a single sphere in a crystal is called co-ordination number. Sphere may be molecule, atoms or ions.

The co-ordination number of atoms in bcc structure is 8.

17. An element has bcc structure with a cell edge of 288 pm. The density of the element is 7.2 gcm^{-3}. How many atoms are present in 208 g of the element?

Total atoms present in bcc = 2

Cell edge of bcc = 288 pm = 2.88×10^{-8} cm

Density = 7.2 g cm^{-3}

Mass of the atoms = 208 g

Total atoms = ?

log	Value
3.6	0.5563 (+)
23.89	1.3783
6.023	0.7798
	2.7144

Antilog (2.7144) = 5.1795×10^2

Density ρ $= \frac{nM}{a^3 N_A}$

Molecular mass (M) $= \frac{\rho a^3 N_A}{n}$

$$= \frac{7.2 \times (2.88 \times 10^{-8})^3 \times 6.023 \times 10^{23}}{2}$$

$$= \frac{\overset{3.6}{\cancel{7.2}} \times 23.89 \times 6.023 \times 10^{23} \times 10^{-24}}{\cancel{2}} = 5.1795 \times 10^2 \times 10^{-1}$$

M = 51.795 g mol^{-1}

Number of moles (n) $= \frac{W}{M} = \frac{208}{51.795} = 4.015$

Total number of atoms = Number of moles (n) × N_A

$= 4.015 \times 6.023 \times 10^{23} = 24.19 \times 10^{23} = 2.419 \times 10^{24}$ atoms

18. Aluminium crystallizes in a cubic close packed structure. Its metallic radius is 125 pm. calculate the edge length of unit cell. ***(MAR 24)***

r = 125 pm a = 354 pm

Radius r = 125 pm

$$r = \frac{a\sqrt{2}}{4}$$

Edge length (a) = $\frac{4r}{\sqrt{2}} = \frac{4\times125}{\sqrt{2}} = 2\sqrt{2}\times125 = 2\times1.414\times125 = 353.55$ pm

19. If NaCl is doped with 10^{-2} mol percentage of strontium chloride, what is the concentration of cation vacancy?

Concentration of $SrCl_2$ = 10^{-2} mol %

Concentration is in percentage so that total 100 mole of solution can be taken.

Number of moles of NaCl = 100 – moles of $SrCl_2$

Number of moles of $SrCl_2$ is very negligible as compared to total moles.

Number of moles of NaCl = 100

1 mole of NaCl is dopped with = $10^{-2}/100$ mole of $SrCl_2$

= 10^{-4} moles of $SrCl_2$

Cation vacancies per mole of NaCl = 10^{-4} mole

$\therefore$ 1 mole = 6.022×10^{23} particles

So cation vacancies per mole of NaCl = $10^{-4} \times 6.022 \times 10^{23} = 6.022 \times 10^{19}$

So, the concentration of cation vacancies created by $SrCl_2$ is 6.022×10^{19} per mole of NaCl.

20. KF crystallizes in fcc structure like sodium chloride. Calculate the distance between K^+ and F^- in KF. (Given: density of KF is 2.48 g cm^{-3}) ***(PTA MQ)***

Total number of atoms in fcc = 4

Density = 2.48 g cm^{-3}

Volume of unit cell $a^3 = \frac{n\times m}{\text{density}\times N_A}$

$$= \frac{4\times58}{2.48\text{gcm}^{-3}\times6.023\times10^{23}} = \frac{58}{0.62\times6.023\times10^{23}}$$

$a^3 = 15.41 \times 10^{-23}$ cm^3

Edge length (a) = 5.375×10^{-8} cm

The distance between the K^+ and F^- ions

$$(2r) = \frac{a\sqrt{2}}{2} = \frac{5.375\times10^{-8}\times1.414}{2} = 3.796 \times 10^{-8}\text{ cm}$$

log	Value
0.62	$\bar{1}.7924$ (+)
6.023	0.7798
	0.5722
58	1.7634 (–)
	0.5722
	1.1912

Antilog (1.1912) = 1.553×10^1
= 15.53

21. An atom crystallizes in fcc crystal lattice and has a density of 10 g cm^{-3} with unit cell edge length of 100 pm. Calculate the number of atoms present in 1 g of crystal. ***(PTA MQ)***

Total number of atoms in fcc (n) = 4

ρ = 10 g cm^{-3} W = 1 g $N_A = 6.023 \times 10^{23}$ M = ?

$$\rho = \frac{nM}{a^3N_A}$$

$$M = \frac{\rho a^3 N_A}{n} = \frac{10\times(1.0\times10^{-8})^3(6.023\times10^{23})}{4} = \frac{6.023}{4} = 1.506 \text{ g mol}^{-1}$$

Number of moles (n) $= \frac{W}{M} = \frac{1}{1.506} = 0.664$

Total number of atoms $=$ Number of moles $\times N_A$

$= 0.664 \times 6.023 \times 10^{23} = 3.999 \times 10^{23}$ atoms

22. Atoms X and Y form bcc crystalline structure. Atom X is present at the corners of the cube and Y is at the center of the cube. What is the formula of the compound? ***(PTA MQ)***

Atom present in corners = X
Atom present in center = Y
Crystal structure = bcc
Formula of the compound = XY

23. Sodium metal crystallizes in bcc structure with the edge length of the unit cell 4.3×10^{-8} cm. Calculate the radius of sodium atom.

Edge length of sodium unit cell $= 4.3 \times 10^{-8}$ cm

The radius of sodium $= \frac{\sqrt{3}a}{4}$

$$= \frac{\overset{0.433}{\cancel{1.732}} \times 4.3\times10^{-8}}{\cancel{4}} \text{ cm} = 1.86 \times 10^{-8} \text{ cm}$$

log	Value
0.433	$\bar{1}.6365(+)$
4.3	0.6335
	0.2700

Antilog (0.27) = 1.862

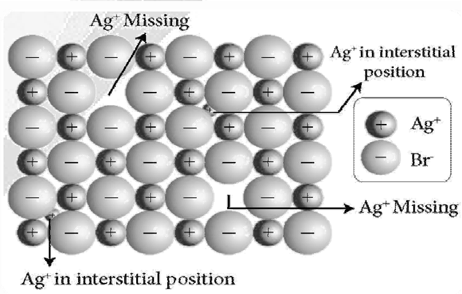
24. Write a note on Frenkel defect. ***(PTA MQ, MAR 20, MAR 23)***

This defect arises due to dislocation of ion from it crystal lattice.

The ions missing from lattice points occupies an interstitial position.

This defect is shown by ionic solids in which cation and anion differ in size.

This defect does not affect the density of crystal.



(Eg.) Ag Br

Small Ag^+ ion leaves its normal site and occupies an interstitial position.

ADDITIONAL QUESTIONS

2 and 3 Mark Question and Answers

25. Define: Isotrophy, anisotrophy.

In solid state, isotropy means having identical values of physical properties such as refractive index, electrical conductance in all direction. Amorphous solids are isotropic.

In solid state, anisotropy means having different values of physical properties such as refractive index, electrical conductance in different direction. Crystalline solids are anisotropic.

26. Write the classification of crystal defects.

1) Point defects; 2) Line defects; 3) Interstitial defects; 4) Volume defects

27. What are covalent solids? ***(MAY 22)***

In covalent solids, the atoms are bound together in a three dimensional network entity by covalent bonds. (Eg.) Diamond

28. What are Non-polar molecular solids?

In this solids, constituent molecule are held together by weak dispersion forces or London forces. (Eg.) naphthalene

29. What are polar molecular solids?

In this solids, constituent molecules are held together by polar covalent bonds. (Eg.) Solid CO_2

30. What is primitive unit cell?

A unit cell that contain only one lattice point is called primitive unit cell.

31. What is non-primitive unit cell?

In this type, there are additional lattice points, either on a face of the unit cell or within the cell.

32. Write the co-ordination number of sc, bcc, and fcc.

The co-ordination number in sc unit cell = 6

The co-ordination number in bcc unit cell = 8

The co-ordination number in fcc unit cell = 12

33. Find out the total number atoms in bcc unit cell?

Total number atoms in bcc unit cell = $\frac{N_c}{8} + \frac{N_b}{1} = \frac{8}{8} + \frac{1}{1} = 1 + 1 = 2$

34. Write Bragg equation and explain the term. ***(PTA MQ)***

$n\lambda = 2d \sin\theta$

n $\Rightarrow$ Order of reflection $\lambda \Rightarrow$ Wave length of X-ray

d $\Rightarrow$ Inter planar distance $\theta \Rightarrow$ angle of reflection

35. Write the formula for density of unit cell.

Density of unit cell (ρ) = $\frac{nm}{a^3 N_A}$

n = Number of atom in a unit cell; m = mass of a atom

a = edge length; N_A = Avagadro number

36. Define packing fraction or packing efficiency. ***(JULY 22)***

Packing fraction (or)efficiency = $\left\{\frac{\text{Total volume occupied by spheres in a unit cell}}{\text{volume of unit cell}}\right\} \times 100$

37. Define crystal lattice. ***(PTA MQ)***

Crystalline solid is characterised by a definite orientation of atoms, ions or molecules, relative to one another in a three dimensional pattern. The regular arrangement of these species through out the crystal is called a crystal lattice.

38. If the no. of close packed sphere is 6, calculate the number of Octahedral voids and Tetrahedral voids generated. ***(MAR 20)***

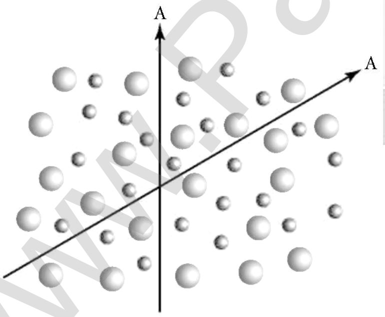
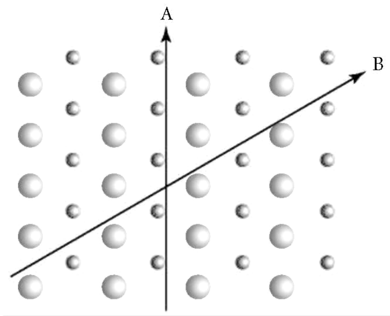
Number of close packed sphere = 6

Octahedral void (n) = 6 Tetrahedral void (2n) = 12

39. If the radius ratio of the compound is between 0.155-0.225, find out the co-ordination number and structure of the compound. ***(Corona-20)***

$\left(\frac{R_{c^+}}{r_{A^-}}\right)$	**Coordination number**	**Structure**	**Example**
0.155-0.225	3	Trigonal planar	$B_2 O_3$
0.225-0.414	4	Terahedral	ZnS
0.414-0.732	6	Octahedral	NaCl
0.732-1.0	8	Cubic	CsCl

40. Distinguish between Isotropy and Anisotropy in solids. ***(SEP 20)***

S. No.	**Isotropy**	**Anisotropy**
1.	In solids, identical values of physical properties in all directions	Shows different values of physical properties in different direction
2.	Eg. Glass	Eg. NaCl
3.	 Isotropy in Amorphous solids	 Anisotropy in Crystals

41. Why ZnO changes to yellow colour during heating?

On heating ZnO loses oxygen and forms free Zn^{2+} ions.

The excess Zn^{2+} ions move to interstitial sites and the electrons also occupy interstial positions.

42. What are metallic solids? Give e.g.

In metallic solids, the lattice points are occupied by positive metal ions and a cloud of electrons pervades the space. (Eg) Ag, Au, Fe

43. Calculate the percentage efficiency of packing in SC and FCC. ***(MAR 24)***

Packing efficiency in SC:

Radius of sphere (r) = a/2

Volume of sphere = $\frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{a}{2}\right)^3 = \frac{4}{3}\pi\frac{a^3}{8} = \frac{\pi a^3}{6}$

Number of spheres in Sc arrangement = 1

Total volume occupied by the spheres in SC unit cell = $1\times\left(\frac{\pi a^3}{6}\right)$

Packing fraction (or) efficiency = $\frac{\left\{\begin{matrix}\text{Total Volume Occupied by}\\ \text{spheres in a unit cell}\end{matrix}\right\}}{\text{Volume of unit cell}} \times 100$

$= \frac{\left(\frac{\pi a^3}{6}\right)}{a^3} \times 100 = \frac{100\pi}{6} = 52.38\%$

Packing efficiency in FCC:

Radius of sphere $r = \frac{a\sqrt{2}}{4}$

Volume of sphere = $\frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{\sqrt{2}a}{4}\right)^3 = \frac{4}{3}\pi\frac{2\sqrt{2}a^3}{64} = \frac{\sqrt{2}\pi a^3}{24}$

Number of spheres in FCC arrangement = 4

Total volume of spheres occupied in Fcc = $4\times\left(\frac{\sqrt{2}\pi a^3}{24}\right) = \frac{\sqrt{2}\pi a^3}{6}$

Packing fraction (or) efficiency = $\frac{\left\{\begin{matrix}\text{Total Volume Occupied by}\\ \text{spheres in a unit cell}\end{matrix}\right\}}{\text{Volume of unit cell}} \times 100$

Packing fraction or efficiency = $\frac{\frac{\sqrt{2}\pi a^3}{6}}{a^3} \times 100 = \frac{\sqrt{2}\pi}{6} \times 100 = \frac{1.414\times3.14\times100}{6} = 74\%$

44. What is radius ratio in ionic solid? Tabulate the relation between radius ratio and structural arrangement in ionic solids. ***(PTA MQ)***

r_{C^+}/r_{A^-}	Coordination Number	Structure	Example
0.155-0.225	3	Trigonal Planar	B_2O_3
0.225-0.414	4	Tetrahedral	ZnS
0.414-0.732	6	Octahedral	NaCl
0.732-1.0	8	Cubic	CsCl

Five Mark Question and Answers

45. Write the characteristics of solids.

i) Solids have definite volume and shape.

ii) Solids are rigid and incompressible.

iii) Solids have strong cohesive forces.

iv) Solids have short inter atomic, ionic or molecular distances.

v) Their constituents have fixed positions and can only oscillate about their mean positions.

46. Write the classification of solids.

Solids

- Crystalline solids
  - Ionic Crystal (NaCl, KCl)
  - Covalent Crystals (Diamond)
  - Molecular crystals (Naphthalene)
  - Metallic crystals (Na, Mg)
  - Atomic solids (frozen elements of group 18)
- Amorphous solids (E.g) Glass, rubber

47. Explain the classification of point defect with example. ***(PTA MQ)***

Point defect

- Stoichiometric defects
  - Schottky defect (NaCl)
  - Frenkel defect (AgBr)
- Non-stoichiometric defects
  - Metal excess defect (NaCl)
  - Metal deficiency defect (FeO)
- Impurity defects

48. Explain the impurity defects in crystals.

This defect arises when impurity ions are added to ionic solids.

If the impurity ions are in different valency from that of host, vacancies are created in the crystal lattice of the host.

(E.g) Addition of $CdCl_2$ to silver chloride yields solid solutions. When the Cd^{2+} occupies the position of Ag^+, disturb the electrical neutrality.

In order to maintain the same, proportional number of Ag^+ ions leave the lattice.

This produce a cation vacancy in the lattice such kind of crystal defects are called impurity defects.