

SOLID STATE

Single correct :

1. Diamond has face-centred cubic lattice. There are two atoms per lattice point, with the atoms at (000) and $\left(\frac{1}{4} \frac{1}{4} \frac{1}{4}\right)$ coordinates. The ratio of the carbon-carbon bond distance to the edge of the unit cell is

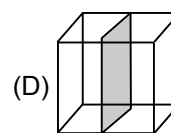
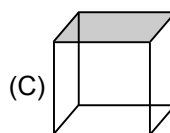
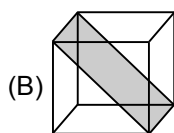
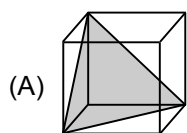
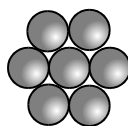
(A) $\sqrt{\frac{3}{16}}$ (B) $\sqrt{\frac{1}{4}}$ (C) $\frac{1}{4}$ (D) $\frac{1}{\sqrt{2}}$

2. The maximum radius of an atom which can occupy empty spaces (voids) in a body centred structure, of an element having atomic radius R, without causing any distortion, can be :

(A) $\left(\frac{2-\sqrt{3}}{\sqrt{3}}\right)R$ (B) $\left(\sqrt{\frac{5}{3}}-1\right)R$ (C) $\left(\sqrt{\frac{4}{3}}-1\right)R$ (D) $(\sqrt{2}-1)R$

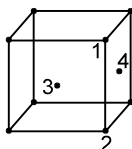
3. In hcp (ABAB...) and ccp (ABCABC...) structures made up of spheres of equal size, the volume occupied per sphere (including the empty spaces) is (a = radius of sphere) :
- (A) $5.66 a^3$ (B) $1.33 a^3$ (C) $2.66 a^3$ (D) $7.40 a^3$

4. In an f.c.c. crystal, which of the following shaded planes contains the following type of arrangement of atoms?



5. A crystal of formula AB_3 has A ions at the cube corners and B ions at the edge centres. The coordination numbers of A and B are respectively
- (A) 6 and 6 (B) 2 and 6 (C) 6 and 2 (D) 8 and 8

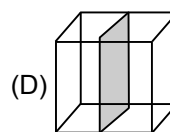
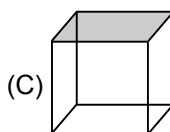
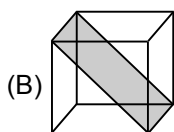
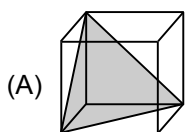
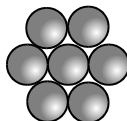
6. In an f.c.c. unit cell, atoms are numbered as shown below. The atoms not touching each other are (Atom numbered 3 is face centre of front face).



(A) 3 & 4 (B) 1 & 3 (C) 1 & 2 (D) 2 & 4

7. The face diagonal length of f.c.c. cubic cell is $660\sqrt{2}$ pm. If the radius of the cation is 110 pm, the radius of the anion is
- (A) 249 pm (B) 220 pm (C) 608 pm (D) 176 pm

8. A mineral having the formula AB_2 , crystallises in the cubic close - packed lattice, with the A atoms occupying the lattice points. The co-ordination number of the A atoms, that of B atoms and the fraction of the tetrahedral sites occupied by B atoms are
 (A) 3, 1, 25% (B) 2, 6, 75% (C) 8, 4, 100% (D) 6, 6, 50%
9. Barium titanate has a pyrolusite structure (a cubic lattice), with barium ions occupying the corners of the unit cell, oxide ions the face centres and titanium ions the body centres. Assuming that Ti^{4+} ions occupy the holes of the BaO lattice, what type of hole and what fraction of such holes do these ions occupy?
 (A) 25% of octahedral voids (B) 75% of tetrahedral voids
 (C) 50% of tetrahedral voids (D) 100% of octahedral voids
10. Given that interionic distance in $Na^+ F^-$ crystal is 2.31 \AA , which of the following predictions will be wrong
 (A) $r_{Na^+} / r_{F^-} \approx 0.7$
 (B) coordination number of Na^+ = coordination number of $F^- = 6$
 (C) $Na^+ F^-$ must have rock salt type crystal structure
 (D) effective nuclear charge for Na^+ and F^- are equal
11. The density of steam at $27^\circ C$ and 8.314×10^4 pascal is 0.8 Kg m^{-3} . The compressibility factor would be
 (A) 0.75 (B) 1 (C) 0.88 (D) 1.1
12. The number of atoms in 100 g of an FCC crystal with density $d = 10 \text{ gcm}^{-3}$ and cell edge of 200 pm is equal to
 (A) 3×10^{25} (B) 5×10^{24} (C) 1×10^{25} (D) 2×10^{25}
13. The ionic radii for Na^+ and Br^- ions are 1.012 \AA and 1.973 \AA respectively. What the coordination number of Na^+ is predicted on the basis of the radii ratio. $\frac{r_+}{r_-}$?
 (A) 6 (B) 8 (C) 4 (D) 2
14. In hexagonal close packing of sphere in three dimensions.
 (A) In one unit cell there are 12 octahedral voids and all are completely inside the unit cell
 (B) In one unit cell there are six octahedral voids and all are completely inside the unit cell.
 (C) In one unit cell there are six octahedral void and of which three are completely inside the unit cell and other three are from contributions of octahedral voids which are partially inside the unit cell
 (D) In one unit cell there are 12 tetrahedral voids, all are completely inside the unit cell.
15. Suppose you had a face-centered arrangement of A and B atoms when A atoms were at the corners of the unit cell and B atoms were at face-centers. Suppose in each unit cell one of the A atoms was missing from one corner. What then would be the simplest formula of the compound?
 (A) A_7B_8 (B) $A_{15}B_{16}$ (C) AB_3 (D) A_7B_{24}
16. The size of Cl^- ion is 1.8 \AA . The size of a cation for which a change in coordination just becomes possible from 6 to 8 in an ideal ionic crystal would be :
 (A) 0.7452 \AA (B) 1.3176 \AA (C) 0.405 \AA (D) 1.8 \AA
17. The number of nearest neighbours and next near neighbours of a Na^+ ion in a crystal of NaCl are respectively
 (A) $6Na^+$, $12Cl^-$ (B) $6Cl^-$, $6Na^+$ (C) $12Cl^-$, $6Na^+$ (D) $6Cl^-$, $12Na^+$
18. In an f.c.c. crystal, which of the following shaded planes contains the following type of arrangement of atoms?



19. In the CaF_2 type structure if the radius ratio is $\left(\sqrt{\frac{3}{2}} - 1\right)$, then which of the options are correct?
- (A) Each cation will be touching 4 anions but will not be in contact with any cation
 (B) Each cation will be touching 4 anions and 12 cations simultaneously.
 (C) Each cation will be touching 8 anions and will not be in contact with cations
 (D) Each cation will be touching 8 anions and 12 cations simultaneously.
20. What is the maximum number of layers of atoms in close packed planes that will lie within two imaginary parallel planes having a distance between them of $13\sqrt{\frac{2}{3}}R$ in the copper crystal (FCC)? Consider the atoms to be within the parallel planes if their centres are on or within the two parallel planes.
- (A) 5 (B) 6 (C) 7 (D) 8
21. In an ionic solid $r_{(+)} = 1.6 \text{ \AA}$ and $r_{(-)} = 1.864 \text{ \AA}$. Use the radius ratio rule to determine the edge length of the cubic unit cell in \AA .
- (A) 4 (B) $2\sqrt{3}$ (C) $3\sqrt{3}$ (D) $\frac{4}{\sqrt{3}}$

Paragraph for Question Nos. 22 to 23

In HCP or CCP, constituent particles occupy 74% of the available space. The remaining space (26%) in between the spheres, remains unoccupied and is called interstitial voids or holes. Considering the close packing arrangement, each sphere in the second layer rests on the hollow space of the first layer, touching each other. The void created is called tetrahedral void. If R is the radius of the sphere in the close packed arrangement, then

$$r (\text{radius of tetrahedral void}) = 0.225 R$$

In a close packing arrangement, the interstitial void formed by the combination of two triangular voids of the first and second layer is called octahedral void. Thus, double triangular void is surrounded by six spheres. The centre of these sphere on joining, forms octahedron. If R is the radius of the sphere in a close packed arrangement, then

$$r (\text{radius of octahedral void}) = 0.414 R.$$

22. If the anions (A) form hexagonal close packing and cations (B) occupy only $\frac{2}{3}$ rd octahedral voids in it, then the general formula of the compound is
- (A) AB (B) A_3B_2 (C) A_2B (D) AB_2
23. If the spinel structure, oxide ions are cubic close whereas $\frac{1}{8}$ th of tetrahedral voids are occupied by A^{2+} cations and $\frac{1}{2}$ of octahedral voids are occupied by B^{3+} cations. The general formula of the compound having spinel structure is :
- (A) $A_2B_2O_4$ (B) AB_2O_4 (C) $A_2B_4O_2$ (D) $A_4B_2O_2$

ANSWER AND SOLUTION

1. (A)

Sol. Carbon atoms are at corners and are at alternate corners. So from geometry.

$$\sqrt{3} \left(\frac{a}{2} \right) \cdot \frac{1}{2} = 2r$$

$$\text{So required ratio} = \frac{2r}{a} = \frac{\sqrt{3}}{4} = \sqrt{\frac{3}{16}}$$

2. (B)

Sol. In a body centred lattice this position where the atom of maximum size can be fitted should not be lying on the edge centre as the distance between surfaces of two atoms which are at corners of a cube is very small

so will be off the edge so will be at distance of $\left(\frac{a}{4} \right)$ from edge centre on \perp bisector of edge of cube. Hence

$$\text{we get } R + r = \sqrt{\frac{a^2}{4} + \frac{a^2}{16}} = \sqrt{\frac{5a^2}{16}} = \sqrt{\frac{5}{16} \times \frac{16R^2}{3}} \text{ so } r = \left(\sqrt{\frac{5}{3}} - 1 \right) R$$

$$[4R = \sqrt{3} a]$$

3. (A)

Sol. so, volume of unitcell in ccp = $\left(\frac{4a}{\sqrt{2}} \right)^3$

$$\text{so volume per spheric/atom} = \frac{1}{4} \times \frac{64a^3}{2\sqrt{2}} = 0.566a^3.$$

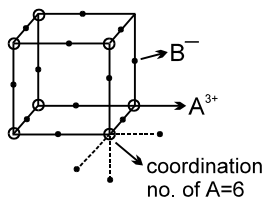
4. (A)

Sol. Shown arrangement is hexagonally closed pack plane & these type of planes are arranged perpendicular to body diagonal of fcc unit cell as shown.

5. (C)

Sol. $\frac{\text{Co-ordination of cation}}{\text{Co-ordination no. of anion}} = \frac{\text{charge of cation}}{\text{charge of anion}} = \frac{3}{1} = 3$

Now Co-ordination no. of A is as shown so of B is 2.



6. (C)

Sol. Atoms along one edge or at corners do not touch each other in fcc cell.

7. (B)

$$\text{Sol. } \sqrt{2} a = 660 \sqrt{2} \text{ pm}$$

$$\text{so } a = 660 \text{ pm}$$

Now if tetrahedral void is occupied by cations than

$$\frac{\sqrt{3}}{4} a = (r_+ + r_-)$$

$$r_- = \left(\frac{\sqrt{3} \times 600}{4} - 110 \right) = 110 \left[\frac{3}{2} \sqrt{3} - 1 \right] = 1.598 \times 110$$

so $\frac{r_+}{r_-} = \frac{1}{1.598} \approx \frac{1}{1.6} = \frac{10}{16} = 0.625$

but $\frac{r_+}{r_-} > 0.414$ so it must not be occupying tetrahedral void then

$$\begin{aligned} a &= 2(r_+ + r_-) \\ \Rightarrow 330 &= r_+ + r_- \\ r_- &= 220 \text{ pm} \end{aligned}$$

$$\left\{ \frac{r_+}{r_-} = 0.5 \text{ it can occupy octahedral void} \right\}$$

8. (C)

Sol. This will be CaF_2 type of structure so required answers are 8, 4, 100%.

9. (A)

Sol. In BaO - lattice body centre will be an octahedral void in the BaO fcc lattice, so only $(1/4)^{\text{th}}$ of voids are occupied.

10. (D)

Sol. Na^+ & F^- are isoelectronic hence they will have same screening const (s) but not the effective nuclear charge.

$$'s' \text{ for } 1s^2, 2s^2p^6 = 7 \times 0.35 + 2 \times 0.85 = 4.15$$

$$\therefore r_{\text{Na}^+} = \frac{c(\text{const.})}{11 - 4.15} \quad \text{and} \quad r_{\text{F}^-} = \frac{c(\text{const.})}{9 - 4.15}$$

$$\text{and } r_{\text{Na}^+} + r_{\text{F}^-} = 2.31 \text{ \AA}$$

$$\therefore r_{\text{Na}^+} / r_{\text{F}^-} \approx 0.7 \quad (\text{coordination} = 6, \text{rock salt structure})$$

11. (A)

$$\text{Sol. } Z = \frac{PV}{nRT} = \frac{w}{M} \frac{PV}{RT} = \frac{PM}{dRT} = \frac{8.314 \times 10^4 \times 18 \times 10^{-3}}{0.8 \times 8.314 \times 300} = \frac{18 \times 10}{300 \times 0.8} = \frac{3}{4} = 0.75$$

12. (B)

Sol. $a = 200 \text{ pm} = 200 \times 10^{-10} \text{ cm} = 2 \times 10^{-8} \text{ cm}$
volume = $(2 \times 10^{-8})^3$

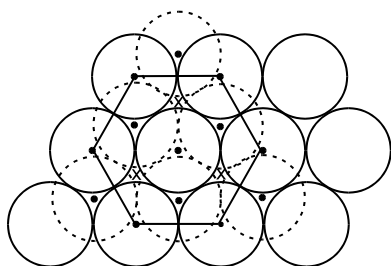
$$\text{No. of atoms} = \frac{Z \times A}{d \times a^3} = \frac{4 \times 100}{10 \times (2 \times 10^{-8})^3} = 5 \times 10^{24}$$

13. (A)

$$\text{Sol. } \frac{r_+}{r_-} = \frac{1.012}{1.973} = 0.513$$

14. (B)

Sol.



hcp = AB AB ABpattern repeat
 For calculating voids between two layers A and B.
 The dots are representing tetrahedral voids.

$$\text{no. of tetrahedral voids} = 3 + 1 + \frac{1}{3} \times 6 = 6$$

so in one complete unit cell total tetrahedral voids = 12, out of which 8 are completely inside but rest are shared by other unit cells.

Octahedral voids = 3 = represented by (x).

So total octahedral voids = 6 = All are completely inside.

15. (D)

Sol. Initial formula $\equiv A_1B_3$
 later the formula becomes $A_{1-1/8} B_3$
 i.e. $A_{7/8} B_3$ i.e. A_7B_{24}

16. (B)

Sol. RRR CN

$$0.414 \leq \frac{r_+}{r_-} < 0.732 \qquad \qquad \qquad 6$$

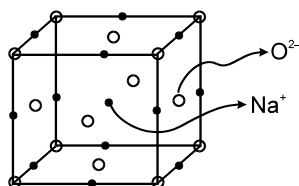
$$0.732 \leq \frac{r_+}{r_-} < 1.00 \qquad \qquad \qquad 8$$

Hence use the RR of 0.732 corresponding to the said changeover from CN of 6 to CN of 8.

$$\begin{aligned} \text{Hence cation size is } & 0.732 \times 1.8 \\ & = 1.3176 \text{ \AA} \end{aligned}$$

17. (D)

Sol.



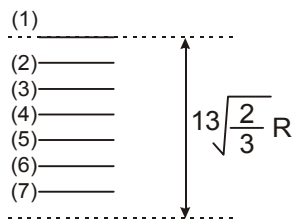
18. (A)

Sol. Shown arrangement is hexagonally closed pack plane & these type of planes are arranged perpendicular to body diagonal of fcc unit cell as shown.

19. (D)

20. (C)

Sol. Parallel layer are at a distance of $2\sqrt{\frac{2}{3}} R$



21. (A)

Sol. $\frac{r_+}{r_-} = \frac{1.6}{1.864} = 0.858$

So, it is CsCl type of unit cell

So $\sqrt{3} a = 2(r_+ + r_-)$

So $a = \frac{2(1.864 + 1.6)}{\sqrt{3}} \text{ \AA} = 2 \times 2 \text{ \AA} = 4 \text{ \AA}$

22. (B)

Sol. No. of octahedral voids in hcp = 6

so formula $A_6B_4 = A_3B_2$

23. (B)

Sol. no. of tetrahedral voids = 8

no of octahedral voids = 4

so formula = AB_2O_4