SOLVED EXAMPLES

Ex. 1 Titanium metal has a density of 4.54 g/cm^3 and an edge length of 412.6 pm. In what cubic unit cell does titanium crystallise? (Ti = 48)

Sol. $$\text{Density } d = \frac{zM}{a^3 N_0}$$

$d = 4.54\ g/cm^3$, $M = 48 g\ mol^{-1}$, $Z = ?$ $\quad N_0 = 6.023 \times 10^{23}\ mol^{-1}$

If value of z is known, structure can be decided

$$z = \frac{dN_0a^3}{M} = \frac{4.54 \times 6.023 \times 10^{23} \times (412.6 \times 10^{-10})^3}{48} = 4$$

Thus, titanium has **face-centred cubic** structure.

Ex. 2 MgO has a structure of NaCl and TiCl has the structure of CsCl. What are the coordination numbers of ions in each (MgO and TiCl).

Sol. C.N. of Na^+ in NaCl = 6

C.N. of Cl^- in NaCl = 6

hence C.N. of Mg^{2+} is also = **6**

and that of O^{--} or O^{2-} = **6 in MgO**

We know in CsCl

C.N. of Cs^+ = 8

C.N. of Cl^- = 8

Hence, **Ti+ and Cl^-, in TiCl, have also C.N. 8 each.**

Ex. 3 A solid AB has the NaCl structure, If radius of cation A^+ is 120 pm, calculate the maximum possible value of the radius of the anion B^-.

Sol. We know for the NaCl structure, for maximum of radius of B^-, the ratio r^+ / r^- should be minimum for octahedral void i.e. 0.414.

radius of cation/radius of anion = 0.414

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

$$r_{B^-} = \frac{r_{A^+}}{0.414} = \frac{120}{0.414} = \textbf{290 pm.}$$

Ex. 4 Calculate the number of formula units in each of the following types of unit cells :

(a) MgO in a rock salt type unit cell

(b) ZnS in zinc blende structure

(c) platinum in a face-centred cubic unit cell.

Sol. **(a)** 4 (the same as in NaCl)

(b) 4

(c) 4 (1 at the corner, 3 at the face-centres)

Ex. 5 A mineral having the formula AB_2 crystallises in the cubic close-packed lattice, with the A atoms occupying the lattice points. What is the coordination number of the A atoms and B atoms ? What percentage fraction of the tetrahedral sites is occupied by B atoms ?

Sol. C.N. of A atom = 8

C.N. of B atom = 4

tetrahedral sites occupied by atoms B = 100% (all tetrahedral voids are occupied).

Ex. 6 **(a)** What is the C.N. of Cr atom in bcc structure ?

(b) Cobalt metal crystallises in a hexagonal closest packed structure. What is the C.N. of cobalt atom ?

(c) Describe the crystal structure of Pt, which crystallises with four equivalent atoms in a cubic unit cell.

Sol. **(a)** 8, **(b)** 12, **(c)** fcc or cubic close packed.

Ex. 7 The C.N. of the barium ion Ba^{2+}, in BaF_2 is 8. What must be the C.N. of F^- ion ?

Sol. C.N. of barium ion tells us that it is surrounded by eight fluoride ions (charge $8 \times (-1) = -8$). In order to balance out the eight negative charges, we need four barium ion (charge $4 \times (+2) = +8$). Hence, the C.N. of F^- ions must be **4.**

Ex. 8 The radius of calcium ion is 94 pm and of oxide ion is 146 pm. Predict the crystal structure of calcium oxide.

Sol. The ratio $\frac{r_+}{r_-} = \frac{94}{146} = 0.644$

The prediction is an octahedral arrangement of the oxide ions around the calcium. Because the ions have equal but opposite charges, there must also be an octahedral arrangement of calcium ions around oxide ions. Thus CaO structure is similar to Rock Salt(NaCI) structure.

Ex. 9 Sodium metal crystallises in body centred cubic lattice with cell edge = 4.29 Å. What is radius of sodium atom?

Sol. In 'BCC' structure

$$\text{body diagonal} = 4 \times r_{Na} = \sqrt{3} \times a$$

$$\therefore \quad 4 \times r_{Na} = \sqrt{3} \times 4.29$$

$$r_{Na} = \frac{\sqrt{3}}{4} \times 4.29 = \mathbf{1.86\ Å}$$

Ex. 10 The effective radius of an iron atom is 1.42 Å. It has a rock-salt structure. Calculate its density (Fe = 56).

Sol. Due to rock-salt (fcc) structure, number of atoms in a unit cell (z) = 4.

Thus, $\quad d\ (\text{density}) = \frac{zM}{a^3 N_0} \qquad a = 2\sqrt{2}\ r = 2\sqrt{2} \times 1.42 \times 10^{-8}\ \text{cm}$

$$\therefore \quad d = \frac{4 \times 56}{6.02 \times 10^{23} \times (2\sqrt{2} \times 1.42 \times 10^{-8})^3} = \mathbf{5.743\ g/cm3}$$

Ex. 11 In a CPS (close packed structure) of mixed oxides, it is found that lattice has O^{2-} (oxide ions), and one-half of octahedral voids are occupied by trivalent cations (A^{3+}) and one-eighth of tetrahedral voids are occupied by divalent cations (B^{2+}). Derive formula of the mixed oxide.

Sol. Number of octahedral voids per ion in lattice = 1

Hence, $\quad$ number of trivalent cations $(A^{3+}) = 1 \times \frac{1}{2} = \frac{1}{2}$

number of tetrahedral voids per ion in lattice = 2

Hence, $\quad$ number of divalent cations $(B^{2+}) = 2 \times \frac{1}{8} = \frac{1}{4}$

Thus, formula is $A_{1/2}B_{1/4}O$ or A_2BO_4.

Ex. 12 An element crystallises as face-centred cubic lattice with density as 5.20 g/cm^3 and edge length of the side of unit cell as 300 pm. Calculate mass of the element which contains 3.01×10^{24} atoms.

Sol. $z = 4$ in fcc lattice $M = ?$, $d = 5.20$ g/cm^3

$a = 300 \text{ pm} = 3 \times 10^{-8}$ cm

$\therefore \quad a^3 = 27 \times 10^{-24}$ cm^3

$N_0 = 6.02 \times 10^{23}$

$$\therefore \quad M = \frac{dN_0 a^3}{z} = \frac{5.20 \text{ g/cm}^3 \times 6.02 \times 10^{23} \text{ mol}^{-1} \times 27 \times 10^{-24} \text{ cm}^3}{4} = 21.13 \text{ g mol}^{-1}$$

Thus, 6.02×10^{23} atoms have $= 21.13$ g

$$\therefore \quad 3.01 \times 10^{24} \text{ atoms have} = \frac{21.13}{6.02 \times 10^{23}} \times 3.01 \times 10^{24} \text{ g} = \mathbf{105.65 \text{ g}}$$

Ex. 13 CsCI crystallises in a cubic that has a CI^- at each corner and Cs^+ at the centre of the unit cell. If $(r_{Cs^+}) = 1.69$ Å and $r_{CI^-} = 1.81$ Å, what is value of edge length a of the cube?

Sol. We assume that the closest Cs^+ to CI^- distance is the sum of the ionic radii of $Cs^{\oplus}$ and $Cl^{\ominus}$.

$= 1.69 + 1.81 = 3.50$ Å

This distance is one-half of the cubic diagonal $= \frac{a\sqrt{3}}{2}$

$$\therefore \quad \frac{a\sqrt{3}}{2} = 3.50 \text{ Å} \qquad \therefore \quad a = \mathbf{4.04 \text{ Å}}$$

Ex. 14 Platinum (atomic radius = 1.38 Å) crystallises in a cubic closest packed structure. Calculate the edge length of the face-centred cubic unit cell and the density of the platinum (Pt = 195).

Sol. $r = \frac{a}{2\sqrt{2}}$ (for fcc), $a = 2\sqrt{2}\, r = 3.9$ Å

$$\text{density} = \frac{ZM}{a^3 N_0} = \frac{4 \times 195}{(3.9 \times 10^{-8})^3 \times 6.023 \times 10^{23}} = 21.83 \text{ g/cm}^3.$$

Ex. 15 Calculate the edge length of the unit cell of sodium chloride given density of NaCI is 2.17×10^3 kg m^{-3} and molecular weight 58.5×10^{-3} kg mol^{-1}.

Sol. NaCI is face-centred cubic lattice so that number of NaCI molecules in a unit cell $(z) = 4$.

We know density $d = \frac{zM}{a^3 N_0}$

where a = length of the unit cell

$$\text{Volume} = a^3 = \frac{Mz}{dN_0} = \frac{4 \times 58.8 \times 10^{-3}}{2.17 \times 10^3 \times 6.02 \times 10^{23}} = 1.79 \times 10^{-28} \text{ m}^3$$

$a = 5.64 \times 10^{-10}$ m

$a = 5.64$ Å $= \mathbf{564 \text{ pm.}}$

Ex. 16 Calcium crystallises in a face-centred cubic unit cell with $a = 0.556$ nm. Calculate the density if it contained 0.1% Vacancy defects.

Sol. Thus, density can be determined using $d = \frac{zM}{a^3 N_0}$

Exercise # 1 [Single Correct Choice Type Questions]

1. The smallest repeating pattern which when repeated in three dimensions results in the crystal of the substance is called

(A) Space lattice **(B)** Crystal lattice **(C)** Unit cell **(D)** coordination number

2. The crystal system for which $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^0$ is said to be :

(A) triclinic **(B)** tetragonal **(C)** cubic **(D)** orthorhombic

3. Which of the following is/are pseudo solids ?

I. KCI II. Barium chloride dihydrate

III. Rubber IV. Solid cake left after distillation of coal tar

(A) I, III **(B)** II, III **(C)** III, IV **(D)** only III

4. Choose the correct statements

(A) equivalent points in unit cells of a periodic lattice lie on a Bravais lattice

(B) equivalent points in unit cells of a periodic lattice do not lie on a Bravais lattice

(C) There are four Bravais lattices in two dimensions

(D) There are five Bravais lattices in three dimensions

5. Which of the following are the correct axial distance and axial angles for rhombohedral system?

(A) $a = b = c, \alpha = \beta = \gamma \neq 90^0$ **(B)** $a = b \neq c, \alpha = \beta = \gamma = 90^0$

(C) $a \neq b \neq c, \alpha = \beta = \gamma = 90^0$ **(D)** $a \neq b \neq c, \alpha \neq \beta \neq \gamma \neq 90^0$

6. A metal crystallizes in a body centered cubic lattice (bcc) with the edge of the unit cell 5.2Å. The distance between the two nearest neighbour is

(A) 10.4 Å **(B)** 4.5 Å **(C)** 5.2Å **(D)** 9.0Å

7. Body centred cubic lattice has co–ordination number of :

(A) 8 **(B)** 12 **(C)** 6 **(D)** 4

8. Consider a Body Centered Cubic(bcc) arrangement, let d_e, d_{fd}, d_{bd} be the distances between successive atoms located along the edge, the face-diagonal, the body diagonal respectively in a unit cell.Their order is given by:

(A) $d_e < d_{fd} < d_{bd}$ **(B)** $d_{fd} > d_{bd} > d_e$ **(C)** $d_{fd} > d_e > d_{bd}$ **(D)** $d_{bd} > d_e > d_{fd}$,

9. Lithium crystallizes in a body centered cubic lattice. How many next–nearest neighbors does each Li have?

(A) 6 **(B)** 8 **(C)** 12 **(D)** 4

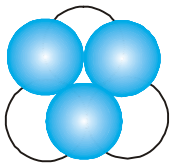
10. The empty space between the shaded balls and hollow balls as shown in the diagram is called

(A) hexagonal void

(B) octahedral void

(C) tetrahedral void

(D) double triangular void



11. You are given 4 identical balls. What is the maximum number of square voids and triangular voids (in separate arrangements) that can be created ?

(A) 1, 2 **(B)** 2, 1 **(C)** 3, 1 **(D)** 1, 3

12. Which one of the following schemes of ordering closed packed sheets of equal sized spheres does not generate close packed lattice.

(A) ABCABC **(B)** ABACABAC **(C)** ABBAABBA **(D)** ABCBCABCBC

13. Copper crystallises in a structure of face centerd cubic unit cell. The atomic radius of copper is 1.28 Å. What is axial length on an edge of copper.

(A) 2.16 Å **(B)** 3.62 Å **(C)** 3.94 Å **(D)** 4.15 Å

14. The maximum percentage of available volume that can be filled in a face centred cubic system by atoms is-

(A) 74% **(B)** 68% **(C)** 34% **(D)** 26%

15. In a face centred cubic lattice the number of nearest neighbours for a given lattice point are :

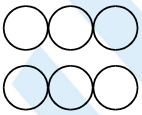
(A) 6 **(B)** 8 **(C)** 12 **(D)** 14

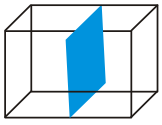
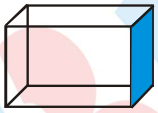
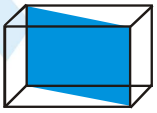
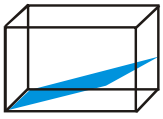
16. In a ccp structure, the (according to cubic 3D arrangement) :

(A) first and third layers are repeated **(B)** first and fourth layers are repeated

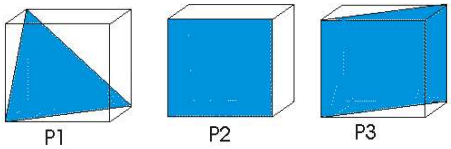
(C) second and fourth layers are repeated **(D)** first, third and sixth layers are repeated.

17. Which of the following shaded plane in fcc lattice contains arrangement of atoms as shown by circles :



(A)  **(B)**  **(C)**  **(D)** 

18. Following three planes(P_1, P_2, P_3) in an FCC unit cell are shown:



Consider the following statements and choose the correct option that follow:

(i) P_1 contains no voids of three dimensions.

(ii) P_2 contains only Octahedral voids.

(iii) P_3 contains both Octahedral and Tetrahedral voids.

(A) All are true **(B)** Only (i) & (ii) are true

(C) (i) & (iii) are true **(D)** Only (iii) is true.

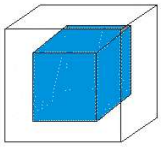
19. In an FCC unit cell a cube is formed by joining the centers of all the tetrahedral voids to generate a new cube.Then the new cube would contain voids as :

(A) 1 full Tetrahedral void, 1 full Octahedral void

(B) 1 full Tetrahedral void only

(C) 8 full Tetrahedral voids and 1 full Octahedral void

(D) 1 full Octahedral void only



20. Volume of HCP unit cell is :

(A) $24\sqrt{2}\ r^3$ **(B)** $8\sqrt{2}\ r^3$ **(C)** $16\sqrt{2}\ r^3$ **(D)** $24\sqrt{3}\ r^3$

21. Fraction of empty space in ABAB type arrangement in 3D :

(A) 0.74 **(B)** 0.26 **(C)** 0.68 **(D)** 0.32

22. If the anions **(A)** form hexagonal closest packing and cations **(C)** occupy only 2/3 octahedral voids in it, then the general formula of the compound is

(A) CA **(B)** CA_2 **(C)** C_2A_3 **(D)** C_3A_2

23. The crystal system of a compound with unit cell dimensions, $a = 0.387$ and $b = 0.387$ and $c = 0.504nm$ and $\alpha = \beta = 90^o$ and $\gamma = 120^o$ is :

(A) Cubic **(B)** Hexagonal **(C)** Orthorhombic **(D)** Rhombohedral

24. The shortest distance between I^{st} and V^{th} layer of HCP arrangement is :

(A) $8\sqrt{\frac{2}{3}}\ r$ **(B)** $4\sqrt{\frac{3}{2}}\ r$ **(C)** $16\frac{\sqrt{2}}{3}\ r$ **(D)** $8\sqrt{\frac{3}{2}}\ r$

25. In zinc blende structure the coordination number of Zn^{2+} ion is

(A) 2 **(B)** 4 **(C)** 6 **(D)** 8

26. Strontium chloride has a fluorite structure, which of the following statement is true for the structure of strontium chloride ?

(A) the strontium ions are in a body–centered cubic arrangement

(B) the strontium ions are in a face–centered cubic arrangement

(C) each chloride ion is at the center of a cube of 8 strontium ions

(D) each strontium ion is at the center of a tetrahedron of 4 chloride ions

27. The spinal structure (AB_2O_4) consists of an fcc array of O^{2-} ions in which the :

(A) A cation occupies one-eighth of the tetrahedral holes and B cation occupies one-half of octahedral holes

(B) A cation occupies one-fourth of the tetrahedral holes and the B cations the octahedral holes

(C) A cation occupies one-eighth of the octahedral hole and the B cation the tetrahedral holes

(D) A cation occupies one-fourth of the octahedral holes and the B cations the tetrahedral holes

28. The radius of Ag^+ ion is 126 pm and that of I^- ion is 216 pm. The co-ordination number of Ag^+ ion is.

(A) 2 **(B)** 4 **(C)** 6 **(D)** 8

29. The tetrahedral voids formed by ccp arrangement of Cl^- ions in rock salt structure are

(A) Occupied by Na^+ ions **(B)** Occupied by Cl^- ions

(C) Occupied by either Na^+ or CI^- ions **(D)** Vacant

30. Antifluorite structure is derived from fluorite structure by :

(A) heating fluorite crystal lattice

(B) subjecting fluorite structure to high pressure

(C) Inter changing the positions of positive and negative ions in the lattice

(D) none of these

31. In the crystal lattice of diamond, carbon atoms adopt :

(A) fcc arrangement along with occupancy of 50% tetrahedral holes

(B) fcc arrangement along with occupancy of 25% tetrahedral holes

(C) fcc arrangement along with occupancy of 25% octahedral hole

(D) bcc arrangement

32. Cesium chloride on heating to 760 K changes into

(A) CsCI(g) **(B)** NaCI structure **(C)** antifluorite structure **(D)** ZnS structure

33. Which of the following statements are correct in context of point defects in a crystal ?

(A) AgCl has anion Frenkel defect and CaF_2 has Schottky defects

(B) AgCl has cation Frenkel defects and CaF_2 has anion Frenkel defects

(C) AgCl as well as CaF_2 have anion Frenkel defects

(D) AgCl as well as CaF_2 has Schottky defects

34. In a solid lattice the cation has left a lattice site and is located at an interstitial position, the lattice defect is :

(A) Interstitial defect **(B)** Valency defect **(C)** Frenkel defect **(D)** Schottky defect

35. Which of the following is true about the charge acquired by p-type semiconductors?

(A) positive **(B)** neutral

(C) negative **(D)** depends on concentration of p impurity

36. F–centers are

(A) the electrons trapped in anionic vacancies

(B) the electrons trapped in cation vacancies

(C) non-equivalent sites of stoichiometric compound

(D) all of the above

37. In a CCP lattice of X and Y, X atoms are present at the corners while Y atoms are at face centers. Then the formula of the compound would be if one of the X atoms from a corner is replaced by Z atoms (also monovalent)?

(A) $X_7Y_{24}Z_2$ **(B)** $X_7Y_{24}Z$ **(C)** $X_{24}Y_7Z$ **(D)** $XY_{24}Z$

38. Consider a cube 1 of Body Centered Cubic unit cell of edge length a now atom at the body center can be viewed to be lying on the corner of another cube 2. Find the volume common to cube 1 and cube 2.

(A) $\frac{a^3}{27}$ **(B)** $\frac{a^3}{64}$ **(C)** $\frac{a^3}{2\sqrt{2}}$ **(D)** $\frac{a^3}{8}$

39. An element (atomic mass = 100 g/mole) having bcc structure has unit cell edge 400 pm. The density of the element is (no. of atoms in bcc(Z) = 2).

(A) 2.144 g/cm^3 **(B)** 5.2 g/cm^3 **(C)** 7.289 g/cm^3 **(D)** 10.376 g/cm^3

40. Which of the following solids are not correctly matched with the bonds found between the constituent particles:

(A) Solid CO_2 : Vanderwaal's **(B)** Graphite : Covalent and Vanderwaal

(C) Grey Cast Iron : Ionic **(D)** Metal alloys : Ions-delocalised electrons

41. You are given 6 identical balls. What is the maximum number of square voids and triangular voids(in separate arrangements) that can be created?

(A) 2 , 4 **(B)** 4 , 2 **(C)** 4 , 3 **(D)** 3 , 4

42. Square packed sheets are arranged on the top of other such that a sphere in the next layer rests on the center of a square in the previous layer. Identify the type of arrangement and find the coordination number.

(A) Simple Cubic, 6 **(B)** Face Centered Cubic, 8

(C) Face Centered Cubic, 12 **(D)** Body Centered Cubic, 8

43. In a simple cubic lattice of anions, the side length of the unit cell is 2.88 Å. The diameter of the void in the body centre is

(A) 1.934 Å **(B)** 0.461 Å **(C)** 2.108 Å **(D)** 4.988 Å

44. In a compound, oxide ions are arranged in cubic close packing arrangement. Cations A occupy one-sixth of the tetrahedral voids and cations B occupy one-third of the octahedral voids. The formula of the compound is

(A) A_2BO_3 **(B)** AB_2O_3 **(C)** $A_2B_2O_2$ **(D)** ABO_3

45. Three lines are drawn from a single corner of an FCC unit cell to meet the other corner such that they are found to pass through exactly only 1 octahedral void, no voids of any type and exactly 2 tetrahedral voids with 1 octahedral void. Identify the line in the same order.

(A) Edge, Face diagonal, Body diagonal **(B)** Face diagonal, Edge, Body diagonal

(C) Body diagonal, Face diagonal, Edge **(D)** Edge, Body diagonal, Face diagonal

46. Metallic gold crystallises in face centered cubic. Lattice with edge-length 4.070 Å. Closest distance between gold atoms is :

(A) 2.035 Å **(B)** 8.140 Å **(C)** 2.878 Å **(D)** 1.357 Å

47. Given an alloy of Cu, Ag and Au in which Cu atoms constitute the CCP arrangement. If the hypothetical formula of the alloy is Cu_4Ag_3Au. What are the probable locations of Ag and Au atoms.

(A) Ag - all Tetrahedral voids; Au - all Octahedral voids

(B) Ag - 3/8th Tetrahedral voids; Au - 1/4th Octahedral voids

(C) Ag - 1/2 Octahedral voids; Au - 1/2 Tetrahedral voids

(D) Ag - all Octahedral voids; Au - all tetrahedral voids

48. In an arrangement of type ABABA... identical atoms of I layer A and III layer A are joined by a line passing through their centers. Suggest the correct statement.

(A) No void is found on the line

(B) Only Tetrahedral voids are found on the line

(C) Only octahedral voids are found on the line

(D) Equal number of tetrahedral and octahedral voids are found on the line

49. In a multi layered close-packed structure

(A) there are twice as many tetrahedral holes as many close-packed atoms

(B) there are as many tetrahedral holes as many closed packed atoms

(C) there are twice as many octahedral holes as many close-packed atoms

(D) there are as many tetrahedral holes as many octahedral holes

50. Platinum crystallizes in a face-centered cubic crystal with a unit cell length 'a'. The distance between nearest neighbors is

(A) a **(B)** a $\frac{\sqrt{3}}{2}$ **(C)** a $\frac{\sqrt{2}}{2}$ **(D)** a $\frac{\sqrt{2}}{4}$

51. Platinum crystallises in a face centered cube crystal with a unit cell length of 3.9231 Å. The density and atomic radius of platinum are respectively. [Atomic mass of Pt = 195]

(A) 45.25 g. cm^{-3}, 2.516 Å **(B)** 21.86 g. cm^{-3}, 1.387 Å

(C) 29.46 g. cm^{-3}, 1.48 Å **(D)** None of these

52. The co-ordinatation number of a metal crystallizing in a hexagonal closed packed structure is :

(A) 12 **(B)** 4 **(C)** 8 **(D)** 0

53. The number of nearest neighbours to each sphere in hexagonal close packing pattern in its own layer will be:

(A) 4 **(B)** 6 **(C)** 12 **(D)** 8

54. Which of the following statements is correct in the rock-salt structure of ionic compounds?

(A) co-ordination number of cation is four whereas that of anion is six.

(B) co-ordination number of cation is six whereas that of anion is four.

(C) co-ordination number of each cation and anion is four.

(D) co-ordination number of each cation and anion is six.

55. Zinc sulphide exists in two different forms-zinc blende and wurtzite. Both occur as 4:4 co-ordination compounds. Choose the correct option from among the following :

(A) zinc blende has a bcc structure and wurtzite an fcc structure

(B) zinc blende has an fcc structure and wurtzite an hcp structure

(C) zinc blende as well as wurtzite have a hcp structure

(D) zinc blende as well as wurtzite have a cpp structure

56. 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) 8, 4, 100% **(B)** 2, 6, 75% **(C)** 3, 1, 25% **(D)** 6, 6, 50%

57. BaO has a rock-salt type structure. When subjected to high pressure, the ratio of the coordination number of Ba^{+2} ion to O^{-2} changes to

(A) 4 : 8 **(B)** 8 : 4 **(C)** 8 : 8 **(D)** 4 : 4

58. The coordination number of cation and anion in Fluorite CaF_2 and Rutile TiO_2 are respectively :

(A) 8 : 4 and 6 : 3 **(B)** 6 : 3 and 4 : 4 **(C)** 6 : 6 and 8 : 8 **(D)** 4 : 2 and 2 : 4

59. The compound AB crystallizes in a cubic lattice in which both A and B atoms have coordination numbers of 8. To what crystal class does the unit cell belong ?

(A) CsCI structure **(B)** NaCI structure **(C)** ZnS structure **(D)** AI_2O_3 structure

60. The distance between adjacent, oppositely charged ions in rubidium chloride is 3.285 Å; in potassium chloride is 3.139Å; in sodium bromide is 2.981 Å and in potassium bromide is 3.293 Å. The distance between adjacent oppositely charged ions in rubidium bromide is

(A) 3.147 Å **(B)** 3.385 Å **(C)** 3.393 Å **(D)** 3.439 Å

61. A crystal of NaCl, which has sodium ions and chloride ions missing from the lattice point, is said to exhibit
(A) Surface defect **(B)** Lattice defect **(C)** Frenkel defect **(D)** Schottky defect

62. In the Schoottky defect :
(A) cations are missing from the lattice sites and occupy the interstitial sites
(B) equal number of cations and anions are missing
(C) anion are missing and electrons are present in their place
(D) equal number of extra cations and electrons are present in the interstitial sites

63. Zinc Oxide, white in colour at room temperature, acquires yellow colour on heating due to:
(A) Zn being a transition element
(B) paramagnetic nature of the compound
(C) trapping of electrons at the site vacated by Oxide ions
(D) Both (A) & (B)

64. NaCl shows Schottky defects and AgCl Frenkel defects. Their electrical conductivity is due to :
(A) motion of ions and not the motion of electrons
(B) motion of electrons and not the motion of ions
(C) lower co-ordination number of NaCl
(D) higher co-ordination number of AgCl

65. A solid has a structure in which W atoms are located at the corners of a cubic lattice. O atom at the center of the edges and Na atom at center of the cube. The formula for the compound is
(A) $NaWO_2$ **(B)** $NaWO_3$ **(C)** Na_2WO_3 **(D)** $NaWO_4$

66. A certain metal fluoride crystallises in such a way that F atoms occupy simple cubic lattice corner sites, while metal atoms occupy the body centre of the cubes. The formula of metal fluoride is :
(A) M_2F **(B)** MF **(C)** MF_2 **(D)** MF_8

67. CsBr has b.c.c. structure with edge length 4.3 A. The shortest inter ionic distance in between Cs^+ and Br^- is:
(A) 3.72 **(B)** 1.86 **(C)** 7.44 **(D)** 4.3

68. In a square close packing pattern, one atom is in contact with how many atoms in the 2-D plane base?
(A) 2 **(B)** 4 **(C)** 6 **(D)** 8

69. In a cubic structure of compound which is made from X and Y, where X atoms are at the corners of the cube and Y at the face centers of the cube. The molecular formula of compound is
(A) X_2Y **(B)** X_3Y **(C)** XY_2 **(D)** XY_3.

70. In a face centerd lattice of X and Y, X atoms are present at the corners while Y atoms are at face centers. Then the formula of the compound would be if one of the X atoms is missing from a corner in each unit cell
(A) X_7Y_{24} **(B)** $X_{24}Y_7$ **(C)** XY_{24} **(D)** $X_{24}Y$

71. Space lattice of CsCl is :
(A) Face centered cubic **(B)** Body centered cubic **(C)** Simple cubic **(D)** Hexagonal close packing

72. The density of crystalline CsCl is 3.988 g/cc. The volume effectively occupied by a single CsCl ion pair in the crystal is :
(A) 7.014×10^{-23}cc **(C)** 2.81×10^{-22}cc **(C)** 6.022×10^{23}cc **(D)** 3.004×10^{-23}cc

73. Match list-I with list-II and select the correct answer by using the codes given below:

	List I (Shapes)	List II (Radius ratio)
(A)	Planar triangle	1. 0.732
(B)	Square planar	2. 0.225
(C)	Body centered cubic	3. 0.155
(D)	Tetrahedral	4. 0.414

Code

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

74. If the radius of a metal atom is 2.00 Å and its crystal structure in cubic close packed (fcc lattice), what is the volume (in cm^3) of one unit cell ?

(A) 8.00×10^{-24} **(B)** 1.60×10^{-23} **(C)** 1.80×10^{-22} **(D)** 2.26×10^{-23}

75. A crystal is made of particle X, Y & Z. X forms FCC packing, Y occupies all octahedral voids of X and Z occupies all tetrahedral voids of X, if all the particles along one body diagonal are removed then the formula of the crystal would be -

(A) XYZ_2 **(B)** X_2YZ_2 **(C)** $X_8Y_4Z_5$ **(D)** $X_5Y_4Z_8$

76. A crystal is made of particles A and B. A forms FCC packing and B occupies all the octahedral voids. If all the particles along the plane as shown in figure are removed, then, the formula of the crystal would be :

(A) AB **(B)** A_5B_7 **(C)** A_7B_5 **(D)** None of these.

77. In the closest packing of atoms,

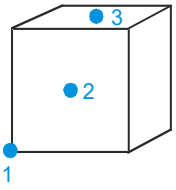
(A) the size of tetrahedral void is greater than that of octahedral void

(B) the size of tetrahedral void is smaller than that of octahedral void

(C) the size of tetrahedral void is equal to that of octahedral void

(D) the size of tetrahedral void may be greater or smaller or equal to that of octahedral void depending upon the size of atoms.

78. Figure shows a cube of unit cell of CCP arrangement with face centered atoms marked 1, 2, 3. Which of the following statements is true.



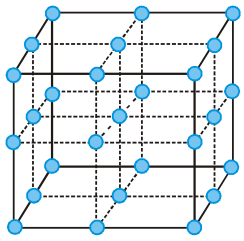
(A) Atom 3 is twice as far from 1 as from 2

(B) Atom 2 is equidistant from atoms 1 & 3.

(C) Atom 2 is nearer to 1 than to 3.

(D) All atoms lie on a right angled triangle.

79. The following diagram shows arrangement of lattice point with $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$.



Choose the correct options.

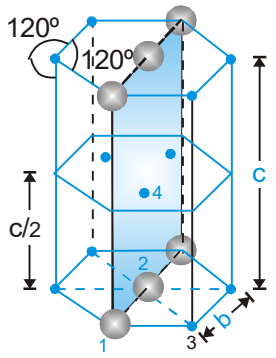
(A) The arrangement is SC with each lattice point surrounded by 6 nearest neighbours.

(B) The arrangement is SC with each lattice point surrounded by 8 nearest neighbours.

(C) The arrangement is FCC with each lattice point surrounded by 12 nearest neighbours.

(D) The arrangement in BCC with each lattice point surrounded by 8 nearest neighbours

80. Calculate the perimeter of given plane in HCP unit cell (Given that radius of atoms = R Å).



(A) 6.437 R **(B)** 15.32 R **(C)** 16 R **(D)** 8 R

81. For an Ionic solid of the general formula AB and coordination number 6, the value of the radius ratio will be

(A) less than 0.225

(B) in between 0.225 and 0.414

(C) between 0.414 and 0.732

(D) greater than 0.732

82. In the zinc blende structure, zinc ions occupy alternate tetrahedral voids and S^{2-} ions exist as ccp. The radii of Zn^{2+} and S^{2-} ions are 0.83 Å and 1.74 Å respectively. The edge length of the ZnS unit cell is

(A) 2.57 Å **(B)** 5.14 Å **(C)** 5.93 Å **(D)** 4.86 Å

83. Which of the following statements is not true?

(A) Paramagnetic substances are weakly attracted by magnetic field.

(B) Ferromagnetic substances cannot be magnetised permanently.

(C) The domains in antiferromagnetic substances are oppositely oriented with respect to each other.

(D) Pairing of electrons cancels their magnetic moment in the diamagnetic substances.

84. An ionic solid of XY type having anions in CCP lattice and cations in the octahedral voids. Let a be the edge length of an FCC cube.The radius ratio of cation(R_+) to that of anion(R_-)is greater than 0.415.Then which of the following is false:

(A) $R_+ = \frac{a}{2\sqrt{2}}$ **(B)** $R_+ + R_- = \frac{a}{2}$

(C) Anions will not be in contact with each other. **(D)** Cations will not be in contact with each other.

85. How many units cells are there in 1.00 g cube shaped ideal crystal of AB (Mw = 60) which has a NaCl type lattice

(A) 6.02×10^{23} **(B)** 1.00×20^{22}

(C) 2.50×10^{21} **(D)** 6.02×10^{24}

86. $MgAl_2O_4$, is found in the Spinal structure in which O^{2-} ions constitute CCP lattice, Mg^{2+} ions occupy 1/8th of the Tetrahedral voids and Al^{3+} ions occupy 1/2 of the Octahedral voids.

Find the total +ve charge contained in one unit cell.

(A) +7/4 electronic charge **(B)** +6 electronic charge

(C) +2 electronic charge **(D)** +8 electronic charge

Exercise # 2 Part # I [Multiple Correct Choice Type Questions]

1. Which of the following statements is/are false.
(A) It is the isotropic nature of amorphous solids that all the bonds are of equal strength.
(B) Entropy of a crystalline solid is higher than that of an amorphous solid.
(C) Amorphous solids have definite volume but not definite shape.
(D) Amorphous solids can become crystalline on slow heating(annealing).

2. Which statements is/are true about HCP and CCP lattice
(A) Number of tetrahedral voids are twice of octahedral holes
(B) 12 tetrahedral and 6 octahedral voids are present in one HCP unit cell
(C) C.N. of HCP unit cell is 12
(D) If atom of tetrahedral voids displace into octahedral voids then it is Schootky defect.

3. The co-ordination number of FCC structure for metals is 12, since
(A) each atom touches 4 others in same layer, 3 in layer above and 3 in layer below.
(B) each atom touches 4 others in same layer, 4 in layer above and 4 in layer below.
(C) each atom touches 6 others in same layer, 3 in layer above and 3 in layer below.
(D) each atom touches 3 others in same layer, 6 in layer above and 6 in layer below.

4. Which of the following is/are correct ?
(A) Schottky defect lowers the density
(B) Frenkel defect increases the dielectric constant of the crystals
(C) Stoichiometric defects make the crystals electrical conductors
(D) In the Schoottky defect, equal number of extra cations and electrons are present in the interstitial sites

5. A perfect crystal of silicon (Fig). is doped with some elements as given in the options. Which of these options show n-type semiconductors?

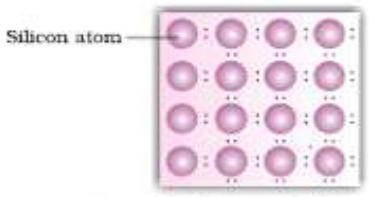
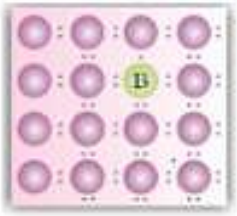
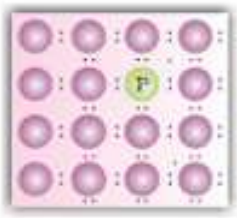
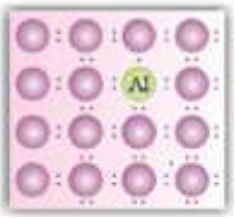


Fig. 1.1 Pure crystal

(A) 

(B) 

(C) 

(D) 

6. Lead metal has a density of 11.34 g/cm^3 and crystallizes in a face–centered lattice. Choose the correct alternatives
(A) the volume of one unit cell is 1.214×10^{-22} cm^3
(B) the volume of one unit cell is 1.214×10^{-19} cm^3
(C) the atomic radius of lead is 175 pm
(D) the atomic radius of lead is 155.1 pm

7. Given that interionic distance in $Na^+ F^-$ crystal is 2.31Å and r_{F^-} = 1.36Å, which of the following predictions will be right

(A) $r_{Na^+}/r_{F^-} \approx 0.7$

(B) coordination number of Na^+ = coordination number of F^- = 6

(C) $Na^+ F^-$ will have rock salt type crystal structure

(D) effective nuclear charge for Na^+ and F^- are equal

8. Which of the following statement(s) for crystal having schottky defect is/are correct.

(A) Schottky defect arises due to absence of cations & anion from positions which they are expected to occupy.

(B) The density of crystal having schottky defect is smaller than that of perfect crystal.

(C) Schottky defect are more common in co-valent compound with higher co-ordination number.

(D) The crystal having schottky defect is electrically neutral as a whole.

9. Which of the following statements are correct?

(A) Ferrimagnetic substances lose ferrimagnetism on heating and become paramagnetic.

(B) Ferrimagnetic substances do not lose ferrimagnetism on heating and remain ferrimagnetic.

(C) Antiferromagnetic substances have domain structures similar to ferromagnetic substances and their magnetic moments are not cancelled by each other.

(D) In ferromagnetic substances all the domains get oriented in the direction of magnetic field and remain as such even after removing magnetic field.

Part # II [Assertion & Reason Type Questions]

Each question has 5 choices (A), (B), (C), (D) and (E) out of which only one is correct.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.

(C) Statement-1 is True, Statement-2 is False.

(D) Statement-1 is False, Statement-2 is True.

(E) Statement-1 and Statement-2 both are False.

1. **Statement-1 :** In HCP structure the contribution of hexagonal face corner per atom is 1/12.
Statement-2 : It is shared by 6 different unit cell.

2. **Statement-1 :** An ionic structure is composed of oppositely charged ions.
Statement-2 : If the larger ions are close packed, then he smaller ions may occupy either the octahedral holes or the tetrahedral holes depending on their size.

3. **Statement-1 :** ZnO becomes yellow when it is heated.

Statement-2 : NaCl becomes yellow when heated in the presence of Na vapours due to anion vacancy.

4. **Statement-I :** Crystalline solids can cause X-rays to diffract.

Statement-II : Interatomic distance in crystalline solids is of the order of 0.1 nm.

5. **Statement-I :** Graphite is an example of tetragonal crystal system.

Statement-II : For a tetragonal system $a = b \neq c$, $\alpha = \beta = 90^{\circ}$, $\gamma = 120^{\circ}$

6. **Statement-1 :** The apparent ionic radius increases 3% if the co-ordination number is changed from 6 to 8 and decreases 6% when the co-ordination number is decreased from 6 to 4.

Statement-2 : Ionic radii can not be measured absolutely, but are estimated, and since they vary with the co-ordination number , conclusions based on them are not very rigorous.

7. **Statement-1 :** In Frenkel defect in an ionic crystal, an ion is displaced from its normal site to an interstitial site.

Statement-2 : There is both a vacancy and an interstitial ion.

8. **Statement-1 :** Stoichiometric compounds obey the law of constant composition.

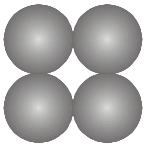
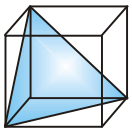
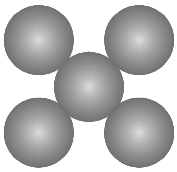
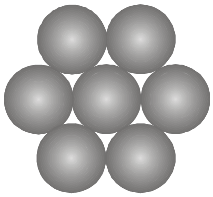
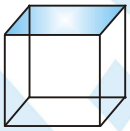
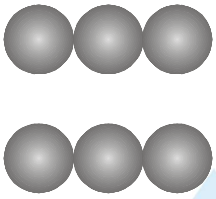
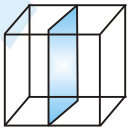
Statement-2 : Schottky and Frenkel defects are observed in stoichiometric compounds

9. **Statement-1 :** In point defect density of solid may decrease and increase

Statement-2 : Formation $Fe_{0.93}$ O is called non–stoichiometric defects.

Exercise # 3 Part # I [Matrix Match Type Questions]

1.

Column I (Arrangement of the atoms/ions)		Column II (Planes in fcc lattice)	
(A)		(p)	
(B)		(q)	
(C)		(r)	
(D)		(s)	

2.

Column I	Column II
(A) ZnS crystal	(p) fcc
(B) CaF_2 crystal	(q) hcp
(C) NaCl crystal	(r) Distance between closest particles is $\frac{\sqrt{3}}{4}$ a.
(D) Diamond crystal	(s) Only one type of voids are occupied

3.

Column-I		Column-II
(A)	68% occupy of space	(p) Simple cubic lattice
(B)	CsCl	(q) Diamond
(C)	Hexagonal close packing in three dimensions	(r) Na_2O
(D)	Antifluorite structure	(s) AB AB type of close packing
(E)	Covalent crystal	(t) Body centred cubic lattice.

4.

Column-I	Column-II
(A) Spinel structure	**(p)** Framework silicate
(B) Glass	**(q)** $ZnFe_2O_4$
(C) Quartz	**(r)** NaCl crystal
(D) Metallic crystal	**(s)** Pseudo solid
(E) Co-ordination number 6	**(t)** Melleable and ductile

Part # II [Comprehension Type Questions]

Comprehension # 1

When an atom or an ion is missing from its normal lattice site, a lattice vacancy **(Schottky defect)** is created. In stoichiometric ionic crystals, a vacancy of one ion has to be accompanied by the vacancy of the oppositely charged ion in order to maintain electrical neutrality.

In a **Frenkel defect** an ion leaves its position in the lattice and occupies an interstitial void. This is the Frenkel defect commonly found along with the Schottky defects and interstitials. In pure alkali halides, Frenkel defects are not found since the ions cannot get into the interstitial sites. Frenkel defects are found in silver halides because of the small size of the Ag^+ ion. Unlike Schottky defects, Frenkel defects do not change the density of the solids. In certain ionic solids (e.g. AgBr) both Schottky and Frenkel defects occur.

The defects discussed above do not disturb the stoichiometry of the crystalline material. There is large variety of non-stoichiometric inorganic solids which contain an excess or deficiency of one of the elements. Such solids showing deviations from the ideal stoichiometric composition form an important group of solids. For example in the **vanadium oxide, VO_x**, x can be anywhere between 0.6 and 1.3. There are solids which are difficult to prepare in the stoichiometric composition. Thus, the ideal composition in compounds such as FeO is difficult to obtain (normally we get a composition of $Fe_{0.95}O$ but it may range from $Fe_{0.93}O$ to $Fe_{0.96}O$). Non-stoichiometric behaviour is most commonly found for transition metal compounds though is also known for some lanthanoids and actinoids.

Zinc oxide loses oxygen reversibly at high temperatures and turns yellow in colour. The excess metal is accommodated interstitially, giving rise to electrons trapped in the neighbourhood. the enhanced electrical conductivity of the non-stoichiometric ZnO arises from these electrons.

Anion vacancies in alkali halides are produced by heating the alkali halide crystals in an atmosphere of the alkali metal vapour. When the metal atoms deposit on the surface they diffuse into the crystal and after ionisation the alkali metal ion occupies cationic vacancy whereas electron occupies anionic vacancy. Electrons trapped in anion vacancies are referred to as F-centers (from Farbe the German word for colour) that gives rise to interesting colour in alkali halides. Thus, the excess of potassium in KCl makes the crystal appear violet and the excess of lithium in LiCl makes it pink.

1. When LiCI is heated into the vapour of lithium, the crystal acquires pink colour. This is due to

(A) Schottkty defects **(B)** Frenkel defects

(C) Metal excess defect leading to F-centers **(D)** Electronic defect

2. Strongly heated ZnO crystal can conduct electricity. This is due to

(A) Movement of extra Zn^{2+} ions present in the interstitial sites

(B) Movement of electrons in the anion vacancies

(C) Movement of both Zn^{2+} ions and electrons

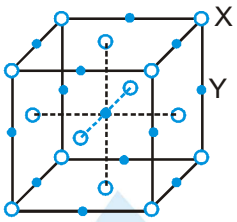
(D) None of these

3. AgCl is crystallized from molten AgCl containing a little $CdCl_2$. The solid obtained will have
(A) cationic vacancies equal to number of Cd^{2+} ions incorporated
(B) cationic vacancies equal to double the number of Cd^{2+} ions
(C) anionic vacancies
(D) neither cationic nor anionic vacancies

4. Which of the following is most appropriate crystal to show Frenkel defect.
(A) CsCl (B) NaCl (C) AgBr (D) $CaCl_2$

Comprehension # 2

Consider the figure given for solid XY. Answer the following questions

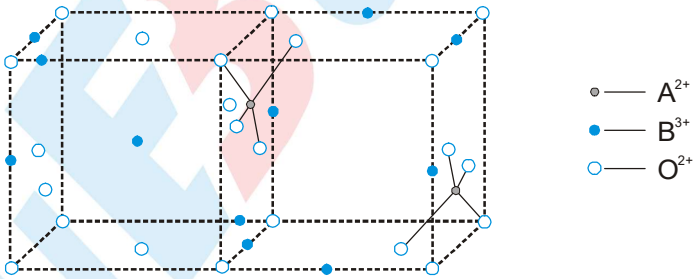


1. The site Y represents
(A) tetrahedral void (B) Octahedral void (C) triangular void (D) cubical void.

2. The number of XY units per unit cell is
(A) 4 (B) 3 (C) 3 (D) 8

3. Co-ordination number of Y is
(A) 3 (B) 4 (C) 6 (D) 8

Comprehension # 3



Answer the following questions :

1. The space lattice given in the figure refers to :
(A) fluoride structure (B) rock salt structure
(C) spinel structure (D) inverse spinel structure

2. O^{2-} ions are present in :
(A) bcc arrangement (B) fcc arrangement
(C) simple cubic arrangement (D) hcp arrangement

3. The formula of the compound is :
(A) ABO_2 (B) A_2BO_3 (C) AB_2O_4 (D) A_2BO_4

4. Fraction of the total octahedral voids occupied will be :

(A) $\frac{1}{2}$ (B) $\frac{1}{4}$ (C) $\frac{1}{8}$ (D) $\frac{1}{6}$

5. B^{3+} and A^{2+} ions are present in :

(A) tetrahedral voids (B) octahedral, tetrahedral voids

(C) tetrahedral, octahedral voids (D) octahedral cubic voids

Comprehension # 4

Packing refers to the arrangement of constituent units in such a way that the forces of attraction among the constituent particles is maximum and the constituents occupy the maximum available space. In two dimensions, there are square close packing and hexagonal close packing. In three dimensions, however, there are hexagonal close packing, cubic close packing and body-centred cubic packing.

(i) hcp : AB AB AB AB . . . arrangement
Coordination no. = 12
% occupied space = 74

(ii) ccp : ABC ABC . . . arrangement
Coordiantion no. = 12
% occupied space = 74

(iii) bcc : 68% space is occupied
Coordination no. = 8

Answer the following questions :

1. The empty space left in hcp in three dimensions is :

(A) 26% (B) 74% (C) 52.4% (D) 80%

2. In closed packed lattice containing 'n' particles, the numbers of tetrahedral and octahedral voids are :

(A) n, 2n (B) n, n (C) 2n, n (D) 2n, n/2

3. The pattern of successive layers of ccp arrangement can be designated as :

(A) AB AB AB . . . (B) AB ABC AB ABC . . .

(C) ABC ABC ABC . . . (D) AB BA AB BA . . .

4. The space occupied by spheres in bcc arrangement is :

(A) 74% (B) 70% (C) 68% (D) 60.4%

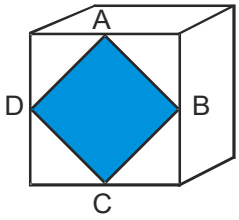
5. A certain oxide of metal M crystallises in such a way that O^{2-} ions occupy hcp arrangement following AB AB . . . pattern. The metal ions, however, occupy $\frac{2}{3}$ rd of the octahedral voids. The formula of the compound is

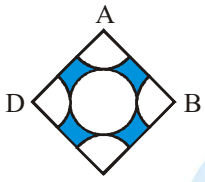
(A) M_2O_3 (B) M_3O (C) $M_{8/3}O_3$ (D) MO_2

Exercise # 4 [Subjective Type Questions]

1. How many number of atom effectively present in a cubic unit formed by arrangement of eight B.C.C unit cell.

2. Consider a cube containing n unit cells of a cubic system.





Arrangement of atoms

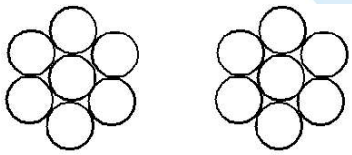
A plane ABCD obtained by joining the mid points of the edges on one of its identical faces had atoms arranged as shown. Let p be the packing fraction. What is the value of n and p ?

3. An element has body centered cubic structure with a cell edge of 3.0Å. The density of the metal is 2 amu/Å^3. How many atoms are present in 243×10^{24} amu of the element.

4. Classify each of the following solids as ionic, metallic, molecular network (covalent) or amorphous.

(a) S_8 **(b)** Diamond **(c)** Bronze **(d)** $ZnSO_4$
(e) SiO_2 **(f)** Fe **(g)** I_2 **(h)** NaCl
(i) Glass **(j)** Si **(k)** Rubber.

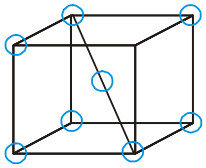
5. The 2D unit cell of an element is shown. The two layers are placed one over the other and touching each other. Calculate :



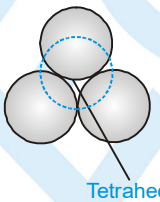
(a) effective number of atoms in the unit cell **(b)** packing efficiency

6. Four identical spheres of radius r are arranged such that centers of three of them form an equilateral triangle and the fourth one rests symmetrically above the triangle touching all of them. Find :
(i) The area of the triangle thus formed.
(ii) Perpendicular distance between the triangle and the center of the fourth atom.
(iii) Are all the balls identical in the arrangement ?

7. Potassium crystallises in a body-centered cubic lattice (Fig.), with a unit cell length a = 5.20Å.



(a) What is the distance between nearest neighbors?
(b) What is the distance between next-nearest neighbors?
(c) How many nearest neighbors does each K atom have?
(d) How many next-nearest neighbors does each K atom have?
(e) What is the calculated density of crystalline K?

8. 

The interstitial hole is called tetrahedral because :

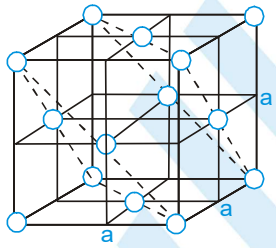
9. **(i)** What is the number of octahedral voids in case of H.C.P and F.C.C ?
(ii) True or False
Number of octahedralvoids is a whole number multiple of the number of tetrahedral void where n is any integer.

10. Distance between 2 layers in HCP unit cell or ABAB type arrangement in 3D lattice (distance between A & B layers).

11. Titanium has hexagonal close packing with cell edge length a = b = 295.5 pm, height = c = 472.9 pm. Calculate its density (At. mass of Ti = 47.8).

12. **(a)** Ferric oxide crystallizes in a hexagonal close - packed array of oxide (O^{2-}) ions with two out of every three octahedral holes occupied by iron ions. What is the formula of ferric oxide?
(b) In cadmium iodide every alternate octahedral hole in an HCP array of iodide I^- ions is occupied by a cadmium ion. What is the formula of cadmium iodine.

13. Metallic gold crystallizes in the face-centered cubic lattice. The length of the cubic unit cell (a = 4.070 Å.)
(a) What is the closest distance between gold atoms?
(b) How many "nearest neighbours" does each gold atom have at the distance calculated in **(a)**?
(c) What is the density of gold?
(d) Prove that the packing factor for gold, the fraction of the total volume occupied by the atoms themselves, is 0.74.



14. An element of atomic mass 98.5 g mol^{-1} occur in fcc structure. If its unit cell edge length is 500 pm and its density is 5.22 g cm^{-3}. What is the value of Avogadro constant?

15. In a face centered lattice of X and Y, X atoms are present at the corners while Y atoms are at face centers,
(a) What is the formula of the compound ?
(b) What would be the formula of the compound if
(i) one of the X atoms is missing from a corner in each unit cell
(ii) two atoms of X are missing from the corners,
(iii) one of the X atoms from a corner is replaced by Z atoms (also monovalent) ?

16. Calculate the value of Avogadro's number from the internuclear distance of adjacent ions in NaCI, 0.282 nm, and the density of solid NaCI, 2.17×10^3 kg/m^3.

17. In a crystalline solid having molecular formula A_2B anion **(B)** are arranged in cubic close packed lattice and cations **(A)** are equally distributed between octahedral and tetrahedral voids.
(i) What percentage of octahedral voids is occupied?
(ii) What percentage of tetrahedral voids is occupied?

18. FeO crystalizes into a cubic structure and has edge length 5.0 Å . The density is 4.0 g cm^{-3}, calculate the number of Fe^{2+} & O^{-2} ions present in each unit cell .

19. What is the difference between ferro magnetic and ferrimagnetic substances?

20. Why does pure silicon, which is an insulator, behave as a semiconductor on heating?

21. Let $MgTiO_3$ exists in pervoskite structure. In this lattice, all the atoms of one of the face diagonals are removed. Calculate the density of unit cell if the radius of Mg^{2+} is 0.7 Å and the corner ions are touching each other. [given atomic mass of Mg = 24, Ti = 48]

22. What is meant by 'Point Defects' in crystals?

23. It is believed that non stoichiometric compound $Fe_{0.93}O$ forms by doping of Fe^{3+} ions in FeO crystal by replacement of Fe^{2+}. Calculate total no. of cationic vacancies in 0.1 mole of $Fe_{0.93}O$ and also calculate the total no. of cationic vacancies if now all the Fe^{2+} ions are replaced by Si^{4+} ions in 0.1 mole of $Fe_{0.93}O$.

24. **(a)** If the density of crystalline CsCI is 3.988 g/cm^3, calculate the volume occupied by a single unit cell in the crystal.
(b) Calculate the smallest Cs-to-Cs internuclear distance which is equal to the length of the side of a cube corresponding to the volume of one CsCI ion pair.
(c) Calculate the smallest Cs-to-Cl internuclear distance in the crystal, assuming each Cs^+ ion to be located in the center of a cube with Cl^- ions at each corner of the cube.

25. A small sphere of radius 10Å was found to fit perfectly in the largest void of Simple Cubic arrangement. Find the location of the sphere and the volume of the unit cell.

26. An element has a body centered cubic structure with a cell edge of 288 pm. The density of the element is 7.2 g/cc. How many atoms are present in 208 gms of the element ?

27. In the orthorhombic lattice of sulphur a = 10.46 Å, b = 12.87 Å, c = 24.49 Å. This unit cell contains 128 atoms of sulphur (atomic weight = 32). Calculate the theoretical density.

28. For each of the following substances, identify the intermolecular force or forces that predominate. Using your knowledge of the relative strengths of the various forces, rank the substances in order of their normal boiling points.
A●$_2O_3$, F_2, H_2O, Br_2, IC●, NaC●

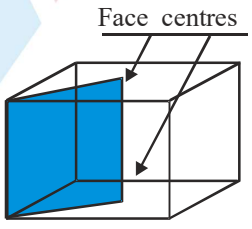
29. An organic compound crystallizes in an orthorhombic pattern with two molecules per unit cell. The unit cell dimensions are 12.05, 15.05 and 2.69 Å. If the density of the crystal is 1.419 gm cm^{-3}, calculate the molecular weight of the organic compound.

30. A metal crystallises with a b.c.c. structure with a density of 19.3 g.cm^{-3}. Calculate the length of the body diagonal of the unit cell. (Atomic weight of metal = 183.9)

31. The density of solid argon is 2/3 (amu/ Å ^{3}) at 40K.If the Argon atom is assumed to be sphere of radius $\frac{3}{\pi^{1/3}}$ Å, what percentage of solid Argon is apparently without anything.

32. A mineral of iron contains an oxide containing 72.36% iron by mass and has a density of 5.2 g/cc. Its unit cell is cubic with edge length of 839 pm. What is the total number of atoms (ions) present in each unit cell ?
(Fe - 56, O-16)

33. In Rock Salt type structure cations(radius r) occupy Octahedral holes in the FCC of anions(radius R) such that there is no distortion in the FCC lattice. Find the perimeter of the shaded region.



Rock salt type

34. An alloy of gold and cadmium crystallises with a cubic structure in which gold atoms occupy the corners and cadmium atoms fit into face centres. What formula would you assign to the alloy?

35. Iron crystallizes in several modifications. At about 910°C, the body-centered cubic 'α' form undergoes a transition to the face-centered cubic 'γ' form. Assuming that the distance between nearest neighbours is the same in the two forms at the transition temperature, calculate the ratio of the density of γ iron to that of α iron at the transition temperature.

36. Illustrate an octahedral void in the close packing of spheres. Why is it so called ?

37. Consider the arrangement of circles of equal radii with their centers arranged as per the 2-dimensional lattice defined by $a = b$, $\theta = 60°$ such that each circle is touching all its nearest neighbours. If all the void areas present are additionally occupied by smaller circles of relevant size so that the void circles are just contacting their neighbours find the packing efficiency of the configuration in percent.

38. Titanium crystallizes in a face-centered cubic lattice. It reacts with carbon or hydrogen interstitially, by allowing atoms of these elements to occupy holes in the host lattice. Hydrogen occupies tetrahedral holes, but carbon occupies octahedral holes.

(a) Predict the formulas of titanium hydride and titanium carbide formed by saturating the titanium lattice with either "foreign" element.

(b) What is the maximum ratio of "foreign" atom radius to host atom radius that can be tolerated in a tetrahedral hole without causing a strain in the host lattice?

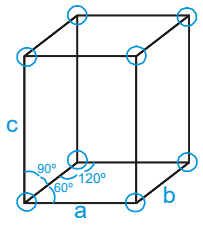
(c) What is the maximum allowable radius ratio in an octahedral hole?

(d) Account for the fact that hydrogen occupies tetrahedral holes while carbon occupies octahedral holes.

39. Volatile compound **(A)** crystallizes in fcc manner. It's density in solid state is 2.3 g/cc. 25.45 g of compound **(A)** along with 39.6g of CO_2 at 100ºC and 3.2 atmospheric pressure occupied 9.56 L volume. Calculate the value of Vander Walls constant 'b' for compound **(A)**. Compound **(A)** exists in gaseous state at 100ºC.

40. A metal (M), shows ABAB arrangement of atoms in solid state, then what is the relation between radius of atom (r) and edge length **(a)** and height **(c)** of HCP unit cell.

41. Ice crystallizes in a hexagonal lattice. At the low temperature at which the structure was determined, the lattice constants were a = 4.53 Å and c = 7.41 Å (as shown in fig.). How many H_2O molecules are contained in a unit cell? (Density of ice = 0.92 gm/cc)



42. NH_4Cl crystallizes in a body-centered cubic lattice with a unit cell distance of 387 pm. Calculate

(a) the distance between the oppositely charged ions in the lattice and

(b) the radius for the NH_4^+ ion, if the radius for the Cl^- ion being 181 pm.

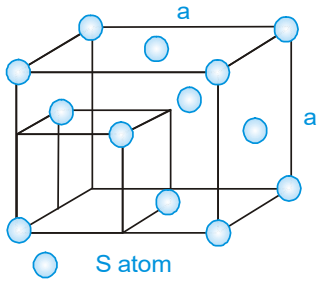
43. The edge length of the unit cube of diamond is 356.7 pm and this cube contains 8 carbon atoms. Calculate:

(a) the distance d_{C-C} between carbon atoms, assuming them to be spheres in contact;

(b) the fraction of the total volume that is occupied by carbon atoms.

44. A spinal is an important class of oxides consisting of two types of metal ions with the oxides ions arranged in CCP layers. The normal spinal has one-eighth of the tetrahedral holes occupied by one type of metal ion and one-half of the octahedral holes occupied by another type of metal ion. Such a spinal is formed by Zn^{2+}, Al^{3+} and O^{2-} with Zn^{2+} in the tetrahedral holes. Give formula of the spinal.

45. The ZnS zinc blende structure is cubic. The unit cell may be described as a face-centered sulfide ion sublattice with zinc ions in the centers of alternating minicubes made by partitioning the main cube into 8 equal parts (as shown in fig.)



(a) How many nearest neighbors does each Zn^{2+} have?
(b) How many nearest neighbors does each S^{2-} have?
(c) What angle is made by the lines connecting any Zn^{2+} to any two of its nearest neighbors?
(d) What minimum r_+/r_- ratio is needed to avoid anion-anion contact, if closest cation-anion pairs are assumed to touch ?

46. Percentage of void space in AB solid having rock salt structure if $\frac{r_+}{r_-} = \frac{1}{2}$ having cation anion contact.

Given $\pi = 3.15$.

47. In an ionic solid $r_{(+)} = 1.6$ Å and $r_{(-)} = 1.864$ Å. Use the radius ratio rule to determine the edge length of the cubic unit cell in Å.

48. Strontium titanate, $SrTiO_3$, has a cubic unit cell with a titanium at the cube center, and oxygen at each face center, and a strontium at each corner. The length of the edge of the unit cell is 391 pm at 25°C. **(a)** What is the coordination number of the titanium atom ? **(b)** what is the coordination number of the strontium atom ? **(c)** what is the density of $SrTiO_3$ at 25°C? **(d)** How far is each Sr atom from its nearest neighbours?

49. Given that η is the ratio of the observed to the theoretical densities of a solid. Can one give the idea about the value of η for the following.

(i) Schottky defects are present in the solid. Find fraction of the missing units.

(ii) Interstitial defects are present in the solid.

(iii) Frenkel defects are present.

50. A transition metal M can exist in two oxidation states +2 and +3. It forms an oxide whose experimental formula is given by M_xO where $x < 1$. Then the ratio of metal ions in +3 state to those in +2 state is (in terms of x).

Exercise # 5 Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

1. What type of crystal defect is indicated in the diagram below? **[AIEEE-2004]**

Na^+	Cl^-	Na^+	Cl^-	Na^+	Cl^-
Cl^-	□	Cl^-	Na^+	□	Na^+
Na^+	Cl^-	□	Cl^-	Na^+	Cl^-
Cl^-	Na^+	Cl^-	Na^+	□	Na^+

(1) Frenkel defect **(2)** Schottky defect
(3) interstitial defect **(4)** Frenkel and Schottky defects

2. An ionic compound has a unit cell consisting of A ions at the corners of a cube and B ions on the centers of the faces of the cube. The empirical formula for this compound would be **[AIEEE-2005]**

(1) AB **(2)** A_2B **(3)** AB_3 **(4)** A_3B

3. Total volume of atoms present in a face-center cubic unit cell of a metals (r is atomic radius) **[AIEEE-2006]**

(1) $\frac{20}{3}\pi r^3$ **(2)** $\frac{24}{3}\pi r^3$ **(3)** $\frac{12}{3}\pi r^3$ **(4)** $\frac{16}{3}\pi r^3$

4. In a compound, atoms of element Y form ccp lattice and those of element X occupy $2/3^{rd}$ of tetrahedral voids. The formula of the compound will be **[AIEEE - 2008]**

(1) X_2Y_3 **(2)** X_2Y **(3)** X_3Y_4 **(4)** X_4Y_3

5. Copper crystallises in fcc with a unit cell length of 361 pm. What is the radius of copper atom ? **[AIEEE - 2009]**

(1) 127 pm **(2)** 157 pm **(3)** 181 pm **(4)** 108 pm

6. The edge length of a face centred cubic cell of an ionic substance is 508 pm. If the radius of the cation is 110 pm, the radius of the anion is **[AIEEE - 2010]**

(1) 288 pm **(2)** 398 pm **(3)** 618 pm **(4)** 144 pm

7. Percentages of free space in cubic close packed structure and in body centered packed structure are respectively. **[AIEEE - 2010]**

(1) 30% and 26% **(2)** 26% and 32% **(3)** 32% and 48% **(4)** 48% and 26%

8. In a face centred cubic lattice, atom A occupies the corner positions and atom B occupies the face centre positions. If one atom of B is missing from one of the face centred points, the formula of the compound is: **[AIEEE-2011]**

(1) A_2B **(2)** AB_2 **(3)** A_2B_3 **(4)** A_2B_5

9. Copper crystallises in fcc lattice with a unit cell edge of 361 pm. The radius of copper atom is: **[AIEEE-2011]**

(1) 108 pm **(2)** 128 pm **(3)** 157 pm **(4)** 181 pm

10. Lithium forms body centred cubic structure. The length of the side of its unit cell is 351 pm. Atomic radius of the lithium will be : **[AIEEE-2012]**

(1) 75 pm **(2)** 300 pm **(3)** 240 pm **(4)** 152 pm

11. A metal crystallises in a face centred cubic structure. If the edge length of its unit cell is 'a', the closest approach between two atoms in metallic crystal will be : **[JEE MAIN-2017]**

(1) 2a **(2)** $2\sqrt{2}\,a$ **(3)** $\sqrt{2}\,a$ **(4)** $\frac{a}{\sqrt{2}}$

12. Which type of 'defect' has the presence of cations in the interstitial sites ? **[JEE MAIN-2018]**

(1) Vacancy defect **(2)** Frenkel defect

(3) Metal deficiency defect **(4)** Schottky defect

Part # II [Previous Year Questions][IIT-JEE ADVANCED]

1. A binary salt AB (formula weight = 6.023 Y amu, where Y is an arbitrary number) has rock salt structure with 1 : 1 ratio of A to B. The shortest A-B distance in the unit cell is $Y^{1/3}$ nm. **[JEE-2004]**

(A) Calculate the density of the salt in kg m^{-3}.

(B) Given that the measured density of the salt is 20 kg m^{-3}, specify the type of point defect present in the crystal.

2. In which of the following compounds the cations are present in alternate tetrahedral voids: **[JEE-2005]**

(A) NaCl **(B)** ZnS **(C)** CaF_2 **(D)** Na_2O

3. In a FCC lattice of a metal edge length is 400 pm. Find the maximum diameter of an atom which can be accommodated in an interstitial gap in this lattice without causing any distortion. **[JEE-2005]**

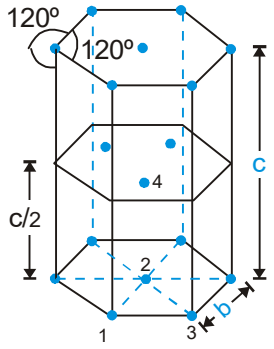
4. For a unit cell edge length = 5Å, the element is of atomic mass 75, has density of 2gm/cc. Calculate atomic radius of the element. **[JEE-2006]**

5. Match the crystal system/unit cells mentioned in **Column I** with their characteristic features mentioned in **Column II**. **[JEE-2007]**

Column I	Column II
(A) simple cubic and face-centerd cubic	**(p)** have these cell 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

Comprehension : (6-8)

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. There 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'.



6. The number of atoms in the HCP unit cell is **[JEE-2008]**

(A) 4 **(B)** 6 **(C)** 12 **(D)** 17

7. The volume of this HCP unit cell is **[JEE-2008]**

(A) $24\sqrt{2}\ r^3$ **(B)** $16\sqrt{2}\ r^3$ **(C)** $12\sqrt{2}\ r^3$ **(D)** $\frac{64}{3\sqrt{3}} r^3$

8. The empty space in this HCP unit cell is **[JEE-2008]**

(A) 74% **(B)** 47.6% **(C)** 32% **(D)** 26%

9. The correct statement(s) regarding defects in solids is(are) : **[JEE-2009]**

(A) Frenkel defect is usually favoured by a very small difference in the sizes of cation and anion.

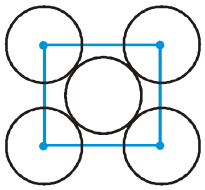
(B) Frenkel defect is a dislocation defect.

(C) Trapping of an electron in the lattice leads to the formation of F-center.

(D) Schottky defects have no effect on the physical properties of solids.

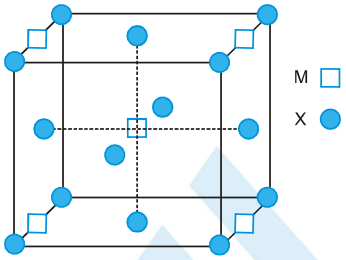
10. The packing efficiency of the two dimensional square unit cell shown below is : **[JEE-2010]**

(A) 39.27%
(B) 68.02%
(C) 74.05%
(D) 78.54%



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

12. A compound $M_p X_q$ has cubic close packing (ccp) arrangement of X. Its unit cell structure is shown below. The empirical formula of the compound is : **[JEE - 2012]**



(A) MX **(B)** MX_2 **(C)** M_2X **(D)** M_5X_{14}

13. 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 **[JEE - 2017]**

14. Among the species given below, the total number of diamagnetic species is __. **[JEE(ADVANCED) 2018]**

H atom, NO_2 monomer, O_2^- (superoxide), dimeric sulphur in vapour phase,

Mn_3O_4, $(NH_4)_2[FeCl_4]$, $(NH_4)_2[NiCl_4]$, K_2MnO_4, $K_2Cr_2O_4$

15. 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.

[JEE(ADVANCED) 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 cation (M)

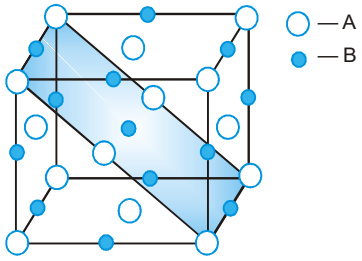
(iv) Replace the central anion (X) with cation (M)

The value of $\left(\frac{\text{number of anions}}{\text{number of cations}}\right)$ in Z is_____.

MOCK TEST

SECTION - I : STRAIGHT OBJECTIVE TYPE

1. A crystal is made of particles A and B. A forms FCC packing and B occupies all the octahedral voids. If all the particles along the plane as shown in figure are removed. Then, the formula of the crystal would be :

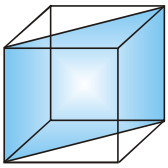


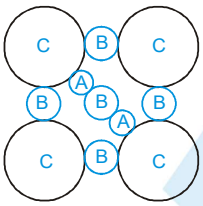
(A) AB **(B)** A_5B_7 **(C)** A_7B_5 **(D)** None of these

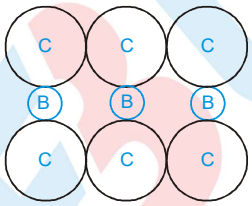
2. A crystal is made of particle X, Y & Z. X forms FCC packing, Y occupies all octahedral voids of X and Z occupies all tetrahedral voids of X, if all the particles along one body diagonal are removed then the formula of the crystal would be –

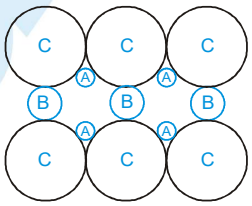
(A) XYZ_2 **(B)** X_2YZ_2 **(C)** $X_8Y_4Z_5$ **(D)** $X_5Y_4Z_8$

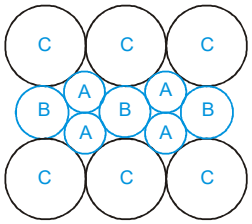
3. In a hypothetical solid C atoms are found to from cubical close packed lattice. A atoms occupy all tetrahedral voids & B atoms occupy all octahedral voids. A and B atoms are of appropriate size, so that there is no distortion in CCP lattice of C atoms. Now if a plane as shown in the following figure is cut. Then the cross section of this plane will look like.



(A)


(B)


(C)


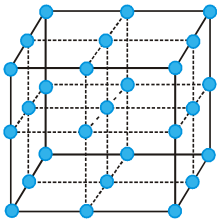
(D)


4. Diamond has face-centred cubic lattice. There are two atoms at (0, 0, 0) and $\left(\frac{1}{4},\frac{1}{4},\frac{1}{4}\right)$ coordinates. The ratio other carbon-carbon bond distance to the edge of the unit cell is

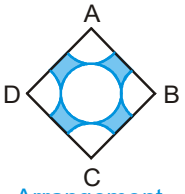
(A) $\sqrt{\frac{3}{16}}$ **(B)** $\sqrt{\frac{1}{4}}$ **(C)** $\frac{1}{4}$ **(D)** $\frac{1}{\sqrt{2}}$

5 The following diagram shows arrangement of lattice point with $a = b = c$ and $\alpha = \beta = \gamma = 90°$. Choose the correct options.

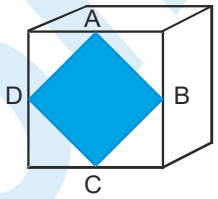
(A) The arrangement is SCwith each lattice point surrounded by 6 nearest neighbours.
(B) the arrangement is SC with each
(C) The arrangement is FCC with each lattice point surrounded by 12 nearest neighbours.
(D) The arrangement in BCC with each lattice point surrounded by 8 nearest neighbours.



6. Consider a cube containing n unit cells of a cubic system. A plane ABCD obtained by joining the mid point of the edges on one of its identical faces had atoms arranged as shown. Let p be the packing fraction. Choose the correct option :



Arrangement of atoms



(A) $n = 1, p = \frac{22}{21\sqrt{2}}$ **(B)** $n = 8, p = \frac{11}{21}$

(C) $n = 8, p = \frac{11}{14}$ **(D)** $n = 1, p = \frac{11\sqrt{3}}{28}$

7. Spinel is an important class of oxides consisting of two types of metal ions with the oxide ions arranged in CCP pattern. The normal spinel has 1/8 of the tetrahedral holes occupied by one type of metal ion and 1/2 of the octahedral holes occupied by another type of metal ion. Such a spinel is formed by Zn^{2+}, Al^{3+} and O^{2-} with Zn^{2+} in the tetrahedral holes. If CCP arrangement of oxide ions remains undistorted in the presence of all the cations, formula of spinel and fraction of the packing fraction of crystal are respectively :

(A) $ZnAl_2O_4$, 77% **(B)** $ZnAl_2O_4$, 74% **(C)** Zn_2AlO_4, 74% **(D)** $Zn_3Al_2O_6$, 74%

8. A transition metal M can exist in two oxidation states +2 and +3. It forms an oxide whose experimental formula is given by M_xO where $x < 1$. Then the ratio of metal ions in +3 state to those in +2 state in oxide is given by :

(A) $\frac{1-x}{1+x}$ **(B)** $1+2x$ **(C)** $1+\frac{x}{2}$ **(D)** $\frac{2(x-1)}{3x-2}$

SECTION - II : MULTIPLE CORRECT ANSWER TYPE

9. The co-ordination number of FCC structure for metals is 12, since

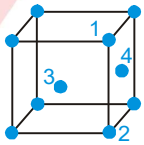
(A) each atom touches 4 others in same layer, 3 in layer above and 3 in layer below.

(B) each atom touches 4 others in same layer, 4 in layer above and 4 in layer below.

(C) each atom touches 6 others in same layer, 3 in layer above and 3 in layer below.

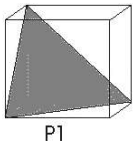
(D) each atom touches 3 others in same layer, 6 in layer above and 6 in layer below.

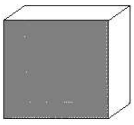
10. In an FCC unit cell, atoms are numbered as shown below. The atoms not touching each other are (Atom numbered 3 is face centre of front face).

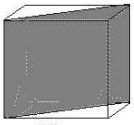


(A) 3 & 4 **(B)** 1 & 3 **(C)** 1 & 2 **(D)** 2 & 4

11. Following three planes (P_1, P_2, P_3) in an FCC unit cell are shown. Consider the following statements and choose the correct option that follow :


P1


P2


P3

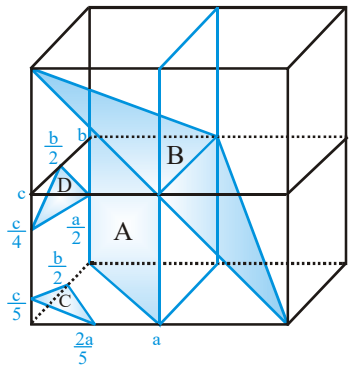
(A) P_1 contains no three dimensional voids.

(B) P_2 contains only octahedral voids.

(C) P_3 contains both octahedral and tertahedral voids.

(D) All are true

12. The Miller indicate of the four planes shown in the figure below:



(A) A – [1 1 0] : B – [1 2 1] ; C – [5 4 10] ; D – [2 2 4]
(B) A – [1 2 1] : B – [1 1 0] ; C – [2 2 4] ; D – [5 4 10]
(C) A – [1 2 1] : B – [0 1 1] ; C – [4 4 2] ; D – [5 4 10]
(D) A – [0 0 1] : B – [1 2 1] ; C – [4 4 2] ; D – [10 2 5]

SECTION - III : ASSERTION AND REASON TYPE

Each question has 5 choices (A), (B), (C), (D) and (E) out of which only one is correct.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.
(E) Statement-1 and Statement-2 both are False.

13. **Statement-1 :** ZnO becomes yellow when it is heated.
Statement-2 : NaCl becomes yellow when heated in the presence of Na vapours due to anion vacancy.

SECTION - IV : COMPREHENSION TYPE

Comprehension # 1

Read the following comprehension carefully and answer the questions

When an atom or an ion is missing from its normal lattice site, a lattice vacancy (Schottky defect) is created. In stoichiometric ionic crystals, a vacancy of one ion has to be accompanied by the vacancy of the oppositely charged ion in order to maintain electrical neutrality.

If a Frankel defect an ion leaves its position in the lattice and occupies an interstitial void. This is the Frenkel defect commonly found along with the Schottky defects and interstitials. In pure alkali halides, Frenkel defects are not found since the ions cannot get into the interstitial sites. Frenkel defects are found in silver halides because of the small size of the Ag+ ion. Unlike Schottky defects, Frenkel defects do not change the density of the solids. In certain ionic solids (e.g. AgBr) both Schottky and Frenkel defects occur.

The defects discusses above do not disturb the stoichiometry of the crystalline material. There is large variety of non-stoichiometric inorganic solids which contain an excess or deficiency of one of the elements. Such solids showing deviations from the ideal stoichiometric composition form an important group of solids. For example in the vanadium oxide, VO_x, x can be anywhere between 0.6 and 1.3. There are solids which are difficult to prepare in the stoichiometric composition. Thus, the ideal composition in compounds such as FeO is difficult to obtain (normally we get a composition of $Fe_{0.95}$ O but it may range from $Fe_{0.93}$ O to $Fe_{0.96}$O). NOn-stoichiometric behaviour is most commonly found for transition metal compounds though is also known for some lanthanoids and actinoids

Zinc oxide loses oxygen reversibly at high temperatures and turns yellow in colour. The excess metal is accommodated interstitially, giving rise to electrons trapped in the neighbourhood. The enhanced electrical conductivity of the non-stoichiometric ZnO arises from these electrons.

Anion vacancies in alkali halides are produced by heating the alkali halide crystals in an atmosphere of the alkali metal vapour. Then the metal atoms deposit on the surface they diffuse into the crystal and after ionisation the alkali metal ion occupies cationic vacancy whereas electron occupies anionic vacancy. Electrons trapped in anion vacancies are referred to as F-centres (from Farbe the German word for colour) that gives rise to interesting colour in alkali halides. Thus, the excess of potassium in KCl makes the crystal appear violet and the excess of lithium in Licl makes it pink.

14. The type of semiconduction shown by crystal capable of showing Schottky defect, will be.

(A) p - type **(B)** n - type **(C)** both **(D)** None

15. Which of the following is most appropriate crystal to show Frenkel defect.

(A) CsCl **(B)** NaCl **(C)** AgBr **(D)** $CaCl_2$

16. In the crystal of $Fe_{0.93}O$, the percentage of Fe(III) will be

(A) 15% **(B)** 85% **(C)** 30% **(D)** 78%

Comprehension # 2

Read the following comprehension carefully and answer the questions.

Only those atoms which form four covalent bonds produce a repetitive three dimensional structure using only covalent bonds, e.g., diamond structure. The latter is bases on a FCC lattice where lattice points are occupied by carbon atoms. Every atom in this structure is surrounded tetrahedrally by four others. Germanium, silicon and grey tin also crystallize in the same way as diamond. (Given : $N_A = 6 \times 10^{23}$, $\sin 54°44' = 0.8164$).

17. If edge length of the cube is 3.60Å, then radius of carbon atom is

(A) 0.78Å **(B)** 0.92Å **(C)** 0.64Å **(D)** 0.35Å

18. If the edge length is 3.60Å, density of diamond crystal is

(A) 3.92 gm/cc **(B)** 2.40 gm/cc **(C)** 3.37 gm/cc **(D)** 2.58 gm/cc

19. Total number of diamond unit cells in 1.2 g of diamond sample is

(A) 6.0×10^{21} **(B)** 6.0×10^{22} **(C)** 7.5×10^{21} **(D)** 5.0×10^{22}

SECTION - V : MATRIX - MATCH TYPE

20.

Column - I (Arrangement in unit cell, radius ratio in higher limit)	Column - II (Coordination number of cation : Anion)
(A) Cations in CCP and anions in alternate tetrahedral voids	**(p)** ratio of number of cation to anion in one unit cell is 1 : 1
(B) Cations in simple cubic and anions in the body centre	**(q)** ratio coordination number of cation to anion is 1: 1
(C) Anions in CCP and cations in all tetrahedral other voids.	**(r)** ratio of number of cation to anion just touching each is not 1.
(D) Cations in CCP and anions in all octahedral voids.	**(s)** number of next neighbours of ion is greater than 10.

21. **Match - Matrix :**

(A) ZnS crystal	**(p)** FCC
(B) CaF_2 crystal	**(q)** HCP
(C) NaCl crystal	**(r)** Distance between closest particles is $\frac{\sqrt{3}}{4}$ a.
(D) Diamond crystal	**(s)** Only one type of voids are occupied

SECTION - VI : SUBJECTIVE TYPE

22. An ionic solid AB_2 isomorphous to the rutile structure (a **tetragonal** system with **effective number of formula units = 2**) has edge lengths of the unit cell of 4Å, 4Å and 5Å. Calculate the density of the substance if its formula weight is 81. Take $N_A = 6 \times 10^{23}$ and express your answer in mg/cc using four significant digits.

23. How many units cells are there in a
(a) 1.0 g cubic crystal of NaCl?
(b) Along each edge of the crystal?
The unit cell content of NaCl is 4 and molar mass of NaCl is 58.5?

24. A group 3A metal has a density of 2.7 g/cm^3 and a cubic unit cell with an edge length of 405.5 pm. Reaction of a 1cm^3 chunk of the metal with an excess of hydrochloric acid gives a colourless gas that occupies 4 L at 27°C and a pressure of 701.1 mm Hg. (R = 0.082 It-atm/ mol-K, NA = 6×10^{23}, $\sqrt[3]{66.67}$ = 405.5 pm)
(a) Identify the metal ?
(b) Is the unit cell primitive, body-centered, or face-centered?
(c) What is the atomic radius of the metal atom in picometers?

25. A cube-shaped crystal of an alkali metal, 1.62 mm on an dege, was vaporized in a 500.0 mL evacuated flask. The pressure of the resulting vapour was 12.5 mm of Hg at 802°C. The structure of the solid metal is known to be body-centered cubic. (R = 0.082 It-atm/mol-K)
(a) What is the atomic radius of the metal atom in picometers?
(b) Use following data to identify the metal
(c) What are the densities of the solid metal and the vapour of metal (in gm/cm^3)?

26. Ionic solid B^+A^- crystallizes in rock salt type of structure. 1.296 gm ionic solid salt B^+A^- is dissolved in water to make one litre solution. The pH of the solution is measured to be 6.0. If the value of face diagonal in the unit cell of B^+A^- be $600\sqrt{2}$ pm. Calculate the density of ionic solid in gm/cc. [T = 298 k, K_b for BOH is 10^{-5}, (Avogadro Number = 6.0×10^{23})]

ANSWER KEY

EXERCISE - 1

1.	C	**2.**	D	**3.**	C	**4.**	A	**5.**	A	**6.**	B	**7.**	A	**8.**	C	**9.**	A	**10.**	B
11.	A	**12.**	C	**13.**	B	**14.**	A	**15.**	C	**16.**	B	**17.**	C	**18.**	A	**19.**	A	**20.**	A
21.	B	**22.**	C	**23.**	B	**24.**	A	**25.**	B	**26.**	B	**27.**	A	**28.**	C	**29.**	D	**30.**	C
31.	A	**32.**	B	**33.**	B	**34.**	C	**35.**	A	**36.**	A	**37.**	B	**38.**	D	**39.**	B	**40.**	C
41.	A	**42.**	C	**43.**	C	**44.**	D	**45.**	A	**46.**	C	**47.**	B	**48.**	B	**49.**	A	**50.**	C
51.	B	**52.**	A	**53.**	B	**54.**	D	**55.**	B	**56.**	A	**57.**	C	**58.**	A	**59.**	A	**60.**	D
61.	D	**62.**	B	**63.**	C	**64.**	A	**65.**	B	**66.**	B	**67.**	A	**68.**	B	**69.**	D	**70.**	A
71.	B	**72.**	A	**73.**	A	**74.**	C	**75.**	D	**76.**	A	**77.**	B	**78.**	B	**79.**	A	**80.**	A
81.	C	**82.**	C	**83.**	B	**84.**	A	**85.**	C	**86.**	D								

EXERCISE - 2 : PART # I

1. A, B, C **2.** A, B, C **3.** B, C **4.** A, B, C **5.** A, C **6.** A, C **7.** A, B, C

8. A, B, D **9.** A, D

PART # II

1. D **2.** B **3.** B **4.** C **5.** D **6.** B **7.** A **8.** B **9.** B

EXERCISE - 3 : PART # I

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

2. A → r, s, B → r, s, C → p, D-q

3. A → q, B → s, C → p, D → t, E → r

4. A → t, B → p, C → s, D → r, E → r

PART # II

Comprehension # 1 : **1.** C **2.** B **3.** A **4.** C

Comprehension # 2 : **1.** B **2.** A **3.** C

Comprehension # 3 : **1.** C **2.** B **3.** C **4.** A **5.** B

Comprehension # 4 : **1.** A **2.** C **3.** C **4.** C **5.** A

EXERCISE - 5 : PART # I

1. 2 **2.** 3 **3.** 4 **4.** 4 **5.** 1 **6.** 4 **7.** 2 **8.** 4 **9.** 3 **10.** 4 **11.** 4 **12.** 2

PART # II

1. **(a)** $5\ kg\ m^{-3}$ **(b)** Cancelled Full marks given in part a) **2.** B **3.** 117.08 pm

4. $d = \frac{ZM}{N_A a^3} \Rightarrow Z = 20 \times 10^{-1} = 2$ So its is a bcc unit cell. Hence $\sqrt{3}\,a = 4R$ so $R = \frac{\sqrt{3}}{4} \times 5\text{Å} = 216.5$ pm.

5. $A \to p, s, B \to q, p, C \to q, D \to q, r$ **6.** B **7.** A **8.** D **9.** B,C **10.** D **11.** 8 **12.** B **13.** 2

14. 1 **15.** 3

MOCK-TEST

1. A **2.** D **3.** B **4.** A **5.** A **6.** B **7.** A **8.** D **9.** B,C **10.** C **11.** ABCD **12.** A

13. B **14.** A **15.** C **16.** A **17.** A **18.** C **19.** C

20. $A \to p, q, s\ ; B \to p, q, r\ ; C \to s\ ; D \to p, q, s$ **21.** $A \to p, q, r, s\ ; B \to p, r, s\ ; C \to p, s\ ; D \to p, r, s$