

SOLID STATE

Section -A: Learning points:

The characteristic properties of the solid state:

- (i) They have definite mass, volume and shape.
- (ii) Intermolecular distances are short.
- (iii) Intermolecular forces are strong.
- (iv) Their constituent particles (atoms, molecules or ions) have fixed positions and can only oscillate about their mean positions.
- (v) They are incompressible and rigid.

Classification of Solids:

On the basis of the nature of order present in the arrangement of their constituent particles,

Solids are classified as **crystalline** and **amorphous**. The properties mentioned below

Property	Crystalline solids	Amorphous solids
Shape	Definite characteristic geometrical shape	Irregular shape
Melting point	Melt at a sharp and characteristic temperature	Gradually soften over a range of temperature
Cleavage property	When cut with a sharp edged tool, they split into two pieces and the newly generated surfaces are plain and smooth	When cut with a sharp edged tool, they cut into two pieces with irregular surfaces
Heat of fusion	They have a definite and characteristic heat of fusion	They do not have definite heat of fusion
Anisotropy	Anisotropic in nature	Isotropic in nature
Nature	True solids	Pseudo solids or super cooled liquids
Order in arrangement of constituent particles	Long range order	Only short range order.

Amorphous solids :

- i) On heating they become crystalline at some temperature.
- ii) Some glass objects from ancient civilisations are found to become milky in appearance because of some crystallisation.
- iii) These are called pseudo solids or super cooled liquids because Like liquids, they have a tendency to flow.
- iv) Glass panes fixed to windows or doors of old buildings are invariably found to be slightly thicker at the bottom than at the top. This is because the glass flows down very slowly and makes the bottom portion slightly thicker.
- v) Amorphous solids are **isotropic in nature**. It is because arrangement is irregular along all the directions. Therefore, the value of any physical property (electrical resistance or refractive index) would be same along any direction. **Where as Crystalline solids are anisotropic in nature, that is, some of their physical properties like electrical resistance or refractive index show different values when measured along different directions in the same crystals.**

Classification of Crystalline solids:

All crystalline solids are classified in to 4 types. The nature , bonding with examples explained in following tabular form

Type of Solid	Constituent Particles	Bonding/ Attractive Forces	Examples		
(1) Molecular solids	Molecules				
(i) Non polar				Disperston or London forces	Ar, CCl ₄ , H ₂ , I ₂ , CO ₂
(ii) Polar				Dipole-dipole interactions	HCl, SO ₂
(iii) Hydrogen bonded	Hydrogen bonding	H ₂ O (ice)			
(2) Ionic solids	Ions	Coulombic or electrostatic	NaCl, MgO, ZnS, CaF ₂		
(3) Metallic solids	Positive ions in a sea of delocalised electrons	Metallic bonding	Fe, Cu, Ag, Mg		
(4) Covalent or network solids	Atoms	Covalent bonding	SiO ₂ (quartz), SiC, C (diamond), AlN, C (graphite)		

Crystal lattice:

A regular three dimensional arrangement of points in space is called a crystal lattice.

There are only 14 possible three dimensional lattices. These are called Bravais Lattices.

The following are the characteristics of a crystal lattice:

- (a) Each point in a lattice is called lattice point or lattice site.
- (b) Each point in a crystal lattice represents one constituent particle which may be an atom, a molecule (group of atoms) or an ion.
- (c) Lattice points are joined by straight lines to bring out the geometry of the lattice.

Seven crystal structures : Cubic , Tetragonal, Orthorhombic, Monoclinic, Hexagonal, Rhombohedral, Triclinic

Unit cell :

The unit cell is the smallest portion of a crystal lattice which, when repeated in different directions, generates the entire lattice.

A unit cell is characterised by:

- (i) Its dimensions along the three edges, a , b and c . These edges may or may not be mutually perpendicular.
- (ii) Angles between the edges, α (between b and c) β (between a and c) and γ (between a and b). Thus, a unit cell is characterised by six parameters, a , b , c , α , β and γ .

Types of Unit Cells:

Unit cells can be broadly divided into two categories, i) Primitive and ii) Centred unit cells.

(a) Primitive Unit Cells : When constituent particles are present only on the corner positions of a unit cell, it is called as primitive unit cell.

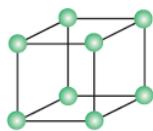
(b) Centred Unit Cells : When a unit cell contains one or more constituent particles present at positions other than corners in addition to those at corners, it is called a centred unit cell.

Centred unit cells are of three types:

- (i) **Body-Centred Unit Cells**: A unit cell contains one constituent particle (atom, molecule or ion) at its body-centre and eight particles are at its corners.
- (ii) **Face-Centred Unit Cells**: A unit cell contains one constituent particle present at the centre of each face, along with eight particles at its corners.
- (iii) **End-Centred Unit Cells**: A unit cell, one constituent particle is present at the centre of any two opposite faces along with eight particles at its corners.

Cubic crystal structure consists of three types of unit cells :

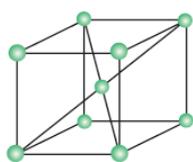
- i) **Primitive or simple cubic unit cell**: A unit cell in which all the eight corners of the cube occupied by the particles.



No of atoms present in this unit cell = $8 \times 1/8 = 1$

(Each Corner atom contributes $1/8^{\text{th}}$ portion to the unit cell)

ii) **Bodicyentred cubic unit cell (B.C.C)** : A unit cell contains one constituent particle present at the centre of each face, along with eight particles at its corners.

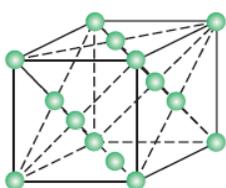


No of atoms present in this unit cell = $(8 \times 1/8) + 1 = 2$

(Each Corner atom contributes $1/8^{\text{th}}$ portion to the unit cell)

(Body centered atom is 1)

iii) **Face centeed cubic unit cell (F.C.C)**: A unit cell contains one constituent particle present at the centre of each face, along with eight particles at its corners.



No of atoms present in this unit cell = $(8 \times 1/8) + (6 \times 1/2) = 1 + 3 = 4$

(Each Corner atom contributes $1/8^{\text{th}}$ portion to the unit cell)

(Each face centered atom contributes $1/2$ portion to the unit cell)

No. atoms per unit cell (Z):

Type of unit cell	No. of atoms At corners	No. of atoms In faces	No. of atoms At the center	Total
Primitive cube	$8 \times 1 / 8 = 1$	0	0	1
Body Centered Cubic (B.C.C)	$8 \times 1 / 8 = 1$	0	1	2
Face Centered Cubic (F.C.C)	$8 \times 1 / 8 = 1$	$6 \times 1 / 2 = 3$	0	4

Close packing structures: In solids, the constituent particles are closely packed, leaving the minimum vacant space

(a) Close Packing in One Dimension:

There is only one way of arranging spheres in a one dimensional close packed structure, that is to arrange them in a row and touching each other.

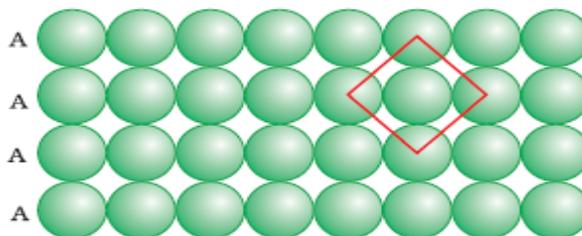


The number of nearest neighbours of a particle is called its **coordination number**. Thus, in one dimensional close packed arrangement, **the coordination number is 2**.

(b) Close Packing in Two Dimensions:

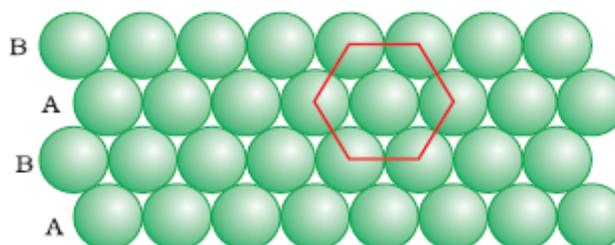
Two dimensional close packed structure can be generated two different ways.

- (a) **Square close packing:** The second row may be placed in contact with the first one such that the spheres of the second row are exactly above those of the first row.



In this arrangement, each sphere is in contact with four of its neighbours. Thus, **the two dimensional coordination number is 4**. Also, if the centres of these 4 immediate neighbouring spheres are joined, a square is formed. Hence this packing is called square close packing.

- (b) **Hexagonal close packing:** The second row may be placed above the first one in the depressions of the first row. If the arrangement of spheres in the first row is called 'A' type, the one in the second row is different and may be called 'B' type. This arrangement is of ABAB type.



In this arrangement, each sphere is in contact with six of its neighbours and **thus the coordination number is 6**. The centres of these six spheres are at the corners of a regular hexagon hence this packing is called two dimensional hexagonal close packing.

The hexagonal close packing structure is better close packing structure than square close packing structure.

Voids:

Triangular void: In the hexagonal close packing 2-dimensional structure there are some voids (empty spaces). These are triangular in shape so, these voids are called triangular voids.

(c) Close Packing in Three Dimensions :

Three dimensional close packed structure can be generated by placing **hexagonal close packed layers one over the other**.

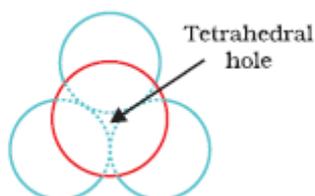
- i) **Covering Tetrahedral Voids:** Tetrahedral voids of the second layer may be covered by the spheres of the third layer. In this case, the spheres of the third layer are exactly aligned with those of the first layer. Thus, the pattern of spheres is repeated in alternate layers. This pattern is often written as **ABAB** pattern. **This structure is called hexagonal close packed (hcp).**

(ii) **Covering Octahedral Voids:** The third layer may be placed above the second layer in a manner such that its spheres cover the octahedral voids. When placed in this manner, the spheres of the third layer are not aligned with those of either the first or the second layer. This arrangement is called "C" type. Only when fourth layer is placed, its spheres are aligned with A layer. Such arrangement is called **ABCABC...** (or) **cubic closed packed (ccp)** (or) **face centred cubic (fcc) structure**.

Voids:

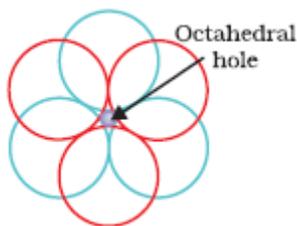
Tetrahedral void:

A tetrahedron is formed when the centres of these four spheres are joined.



Octahedral void:

Voids are surrounded by six spheres and are called octahedral voids.



Let the number of close packed spheres be N, then:

The number of octahedral voids generated = N

The number of tetrahedral voids generated = 2N

Packing Efficiency:

i) In a Simple Cubic Lattice:

In a simple cubic lattice the atoms are located only on the corners of the cube.

The edge length or side of the cube = 'a',

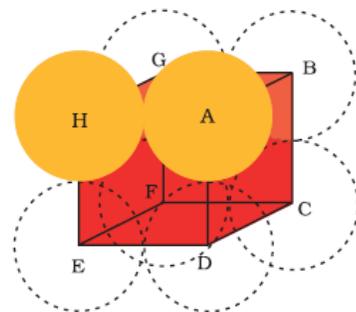
The radius of each particle = r

From the fig, $a = 2r$

The volume of the cubic unit cell = $a^3 = (2r)^3 = 8r^3$

Since a simple cubic unit cell contains only 1 atom

The volume of one atom occupied space = $\frac{4}{3}\pi r^3$



Packing efficiency = (Volume of one atom / Volume of cubic unit cell) x 100%

$$= \frac{4/3\pi r^3}{8r^3} \times 100\%$$

$$= 52.38\%$$

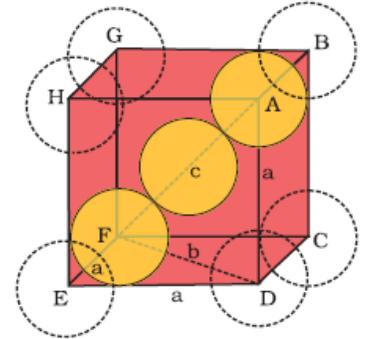
Thus, we may conclude that ccp and hcp structures have maximum packing efficiency

ii) In a Body-Centred Cubic Structures:

In a Body centered cubic lattice the atoms are located at the corners of the cube and one atom at the center of the cube.

From Fig. it is clear that the atom at the centre will be in touch with the other two atoms diagonally arranged.

$$\begin{aligned} \text{In } \Delta EFD, \\ b^2 &= a^2 + a^2 = 2a^2 \\ b &= \sqrt{2}a \\ \text{Now in } \Delta AFD \\ c^2 &= a^2 + b^2 = a^2 + 2a^2 = 3a^2 \\ c &= \sqrt{3}a \end{aligned}$$



The length of the body diagonal c is equal to $4r$,

Therefore

$$\begin{aligned} \sqrt{3}a &= 4r \\ a &= \frac{4r}{\sqrt{3}} \\ \text{thus, } r &= \frac{\sqrt{3}}{4} a \end{aligned}$$

Total number of atoms is 2, and their volume = $2 \times (4/3)\pi r^3$

$$\text{Volume of the cube, } a^3 = \left(\frac{4}{\sqrt{3}}r\right)^3.$$

Therefore,

$$\begin{aligned} \text{Packing efficiency} &= \frac{\text{Volume occupied by two spheres in the unit cell} \times 100}{\text{Total volume of the unit cell}} \% \\ &= \frac{2 \times (4/3)\pi r^3 \times 100}{\left[\left(\frac{4}{\sqrt{3}}r\right)^3\right]} \% \\ &= \frac{(8/3)\pi r^3 \times 100}{64/(3\sqrt{3})r^3} \% = 68\% \end{aligned}$$

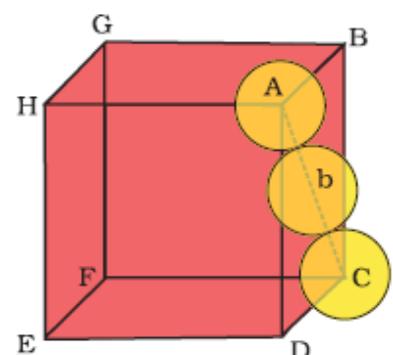
iii) In a Face-Centred Cubic (HCP and CCP) Structures:

In Fig let the unit cell edge length be 'a' and face diagonal AC = b.

$$\begin{aligned} \text{In } \Delta ABC \\ AC^2 &= b^2 = BC^2 + AB^2 \\ &= a^2 + a^2 = 2a^2 \text{ or} \\ b &= \sqrt{2}a \end{aligned}$$

If r is the radius of the sphere, we find

$$\begin{aligned} b &= 4r = \sqrt{2}a \\ \text{or } a &= \frac{4r}{\sqrt{2}} = 2\sqrt{2}r \\ r &= \frac{a}{2\sqrt{2}} \end{aligned}$$



We know, that each unit cell in fcc structure has 4 atoms.

Total volume of four spheres is equal to $4 \times (4/3)\pi r^3$

volume of the cube is a^3 or $(2\sqrt{2}r)^3$.

Therefore,

$$\begin{aligned} \text{Packing efficiency} &= \frac{\text{Volume occupied by four spheres in the unit cell} \times 100}{\text{Total volume of the unit cell}} \% \\ &= \frac{4 \times (4/3) \pi r^3 \times 100}{(2\sqrt{2}r)^3} \% \\ &= \frac{(16/3) \pi r^3 \times 100}{16\sqrt{2}r^3} \% = 74\% \end{aligned}$$

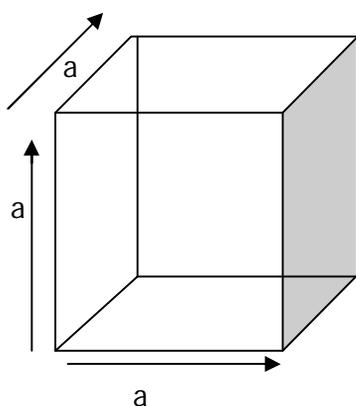
Thus, we may conclude that ccp and hcp structures have maximum packing efficiency.

CALCULATION OF DENSITY OF THE UNIT CELL:

→ Let us write the formula of density of the unit cell,

$\text{Density of the unit cell} = \frac{\text{Mass of the unit cell}}{\text{Volume of the unit cell}}$	-----→ Eq (1)
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Step1: Calculation of the volume of the unit cell:



Cell edge of the unit cell = a cm

$\begin{aligned} \text{Volume of the unit cell} &= a \text{ cm} \times a \text{ cm} \times a \text{ cm} \\ &= a^3 \text{ cm}^3 \end{aligned}$	-----→ Eq (2)
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Step2: Calculation of the mass of the unit cell

Mass of the unit cell = (No. Of atoms per unit cell) x (mass of each atom)

We know that mass of 1mole atoms/molecules is equal to its molar mass.

So, Mass of 6.023×10^{23} atoms / molecules = molar mass

∴ Mass of 1 atom = molar mass / N_0 i.e M / N_0

$\therefore \text{Mass of the unit cell} = (Z) \times (M / N_0)$	-----→ Eq (3)
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Substituting Eq(3) & Eq(2) in Eq(1),

$$\therefore \text{Density of the unit cell} = \frac{\text{Mass of the unit cell}}{\text{Volume of the unit cell}}$$

$$\rho = \frac{(Z) \times (M / N_0)}{a^3}$$

$\therefore \rho = \frac{Z \times M}{N_0 \times a^3}$

Where Z = No. of atoms per Unit cell
M = Atomic mass / Molecular mass in gm
No = Avagadro number = 6.023×10^{23} .
A = Cell edge in cm
 ρ = Density of the unit cell in gm cm^{-3}

Values of Z and a:

Name of the unit cell with Example	Value of Z	Relation of 'a' with 'd'	Relation of 'a' with 'r'	Inter ionic Distance
Simple cubic	1	$d = 2r = a$	$a = 2r \Rightarrow r = a / 2$	
B.C.C(CsCl type)	2	$d = 2r = (\sqrt{3} a) / 2$	$r = (\sqrt{3} a) / 4$	$r^+ + r^- = (\sqrt{3}a) / 2$
F.C.C(NaCl type)	4	$d = 2r = (\sqrt{2} a) / 2$	$r = a / (2 \sqrt{2})$	$r^+ + r^- = a / 2$

Where **d** -----→ Distance between the nearest neighbor.
r -----→ Radius of the atom.
r+ --→ Radius of the cation
r- -----→ Radius of the Anion.

Defects or Imperfections:

The defects are basically irregularities in the arrangement of constituent particles.

The defects are of two types:

- a) **Point defects:** The irregularities from ideal arrangement around a point or an atom in a crystalline substance.
- b) **Line defects:** The irregularities from ideal arrangement in entire rows of lattice points. These irregularities are called crystal defects.

Point defects can be classified as:

(i) Stoichiometric defects:

The defects in which stoichiometry of the compound is not disturbed. The following two types of point defects are commonly found in the crystalline ionic substances.

Schottky Defects:

- 1) The absence of a cation or anion from the position which it is expected to occupy in the periodic arrangement of ions is known as Schottky defect.
- 2) The vacant positions give rise to vacancies or voids in the structure of the substance.
- 3) The Schottky defects are more common in ionic compounds with high coordination numbers and where the positive and negative ions are of similar size.
e.g., NaCl, CsCl, KCl and KBr.
- 4) Since the solid with a Schottky defect contains lesser number of ions as compared to a perfect crystal, the density of the crystal exhibiting Schottky defect will be less as compared to that of the perfect crystal.

Frenkel Defects:

- 1) In this type of defect, the ion, instead of being in its expected location, is found in one of the interstices.
- 2) Frenkel defects are more common in ionic crystals where size of the cation is such that it can be accommodated in the interstitial sites.
- 3) This type of defect is favoured by a large difference in size between the positive and negative ions and since the size of cation is smaller than that of the anion, the former can be accommodated in the interstitial position.
Examples are ZnS, AgCl, AgBr and AgI.
- 4) The density of crystals exhibiting Frenkel defect remains unchanged as the ions are present in the interstitial sites without changing the volume of the substance.

ii) Non-Stoichiometric point defects:

The defects in which stoichiometry of the compound is disturbed.

There are two types 1) Metal excess defect 2) Metal deficiency defect.

i) Metal excess defects due to anionic vacancies:

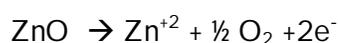
- i) Alkali halides like NaCl and KCl show this type of defect.
- ii) When crystals of NaCl are heated in an atmosphere of sodium vapour, the sodium atoms are deposited on the surface of the crystals as Na^+ ions and which traps the Cl^- ions from the lattice points. To make crystal electrically neutral electrons released will diffuse into the crystal and occupy anionic sites.

iii) The anionic sites occupied by unpaired electrons are called F-centres (from the German word Farbenzenter for colour centre).

- Ex :
- They impart yellow colour to the crystals of NaCl.
 - Excess of lithium makes LiCl crystals pink.
 - Excess of potassium makes KCl crystals violet (or lilac).

ii) Metal excess defects due to presence of cations:

Zinc oxide is white in colour at room temperature. On heating it loses oxygen and turns yellow.



Now there is excess of zinc in the crystal and its formula becomes Zn_{1+x}O . The excess Zn^{2+} ions move to interstitial sites and the electrons to neighbouring interstitial sites.

iii) Impurity Defects:

If molten NaCl containing a little amount of SrCl_2 is crystallised, some of the sites of Na^+ ions are occupied by Sr^{2+} . Each Sr^{2+} replaces two Na^+ ions. It occupies the site of one ion and the other site remains vacant. The cationic vacancies thus produced are equal in number to that of Sr^{2+} ions.

PROPERTIES OF SOLIDS:

I. Electrical properties:

Conductors:

- Good conductors are those which allow the maximum current flow through them and their conductivity is of the order $10^8 \text{ ohm}^{-1} \text{ cm}^{-1}$.
- Metals are good conductors of electricity due to the presence of mobile electrons. In the applied electric field all the electrons in the metals are directed in one direction and therefore current flows through metals.
- Conductivity of metals decrease with increase in temperature.

Insulators :

- Those which do not allow the electric current to flow through them. The electrical conductivity of insulators is the order of $10^{-22} \text{ ohm}^{-1} \text{ cm}^{-1}$.

Semiconductors:

- Electrical conductivity of a semiconductor at normal temperatures lies between a good conductor and an insulator. The range of conductivity is 10^{-9} to $10^2 \text{ ohm}^{-1} \text{ cm}^{-1}$.
- Semiconductors are perfect insulators at absolute zero.
- Silicon and germanium are semiconductors.
- At room temperature the conductivity of silicon and germanium is extremely low but at higher temperatures the bonds begin to break down ejecting the electrons and hence conductivity increases.

- 5) Unlike metals the conductivity of semiconductors increases with temperature because the weakly bound extra electron or positive hole become free by the increased temperature and can be used for conduction.
- 6) The conduction in the crystal without adding any external substance is called **intrinsic conduction**.
- 6) The conduction of intrinsic semi conductors can be increased by **doping**. Doping is a process of mixing pure silicon or germanium with an impurity.
- 7) Doping enhances the conductivity and the products are called **extrinsic semiconductors**. They are two types :

(a) n- type semiconductor:

It is obtained by doping Si or Ge with a group 15 elements (**Electron - rich impurities**) like P. Out of 5 valence electrons , only 4 are involved in bond formation and the fifth electron is delocalized and can be easily provided to the conduction band.

(b) p - type semi conductor :

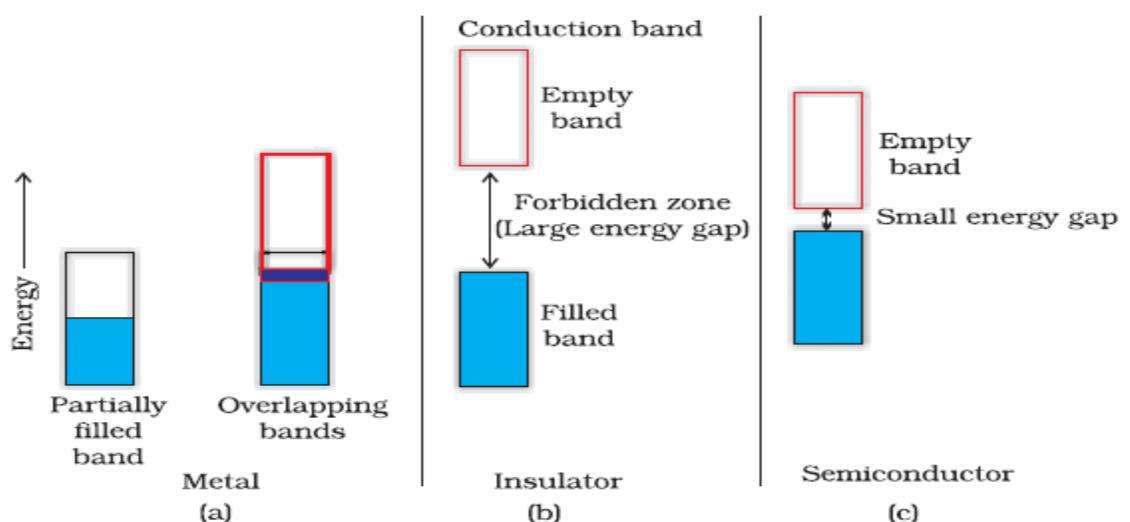
It is obtained by doping Si or Ge with a group 13th elements (**Electron - deficit impurities**) like Gallium which contains only 3 valence electrons. Due to missing of 4th valence electron, electron hole or electron vacancy is created. The movement of these positively charged hole is responsible for the conduction.

A large variety of solid state materials have been prepared by combination of **groups 13 and 15 or 12 and 16 to simulate average valence of four as in Ge or Si.**

Typical compounds of **groups 13 - 15** are InSb, AlP and GaAs. Gallium arsenide (GaAs) semiconductors have very fast response and have revolutionised the design of semiconductor devices.

Typical compounds of **groups 12 - 16** are ZnS, CdS, CdSe and HgTe .In these compounds, the bonds are not perfectly covalent and the ionic character depends on the electronegativities of the two elements.

Diagrammatic representation of conduction of an conductor, insulator and a semi conductor through a band theory:



II. Magnetic properties:

Diamagnetic solids contain paired electron ($\uparrow\downarrow$) and repel the external magnetic field.
Ex: H₂O, NaCl, C₆H₆, etc.,

Paramagnetic solids contain unpaired electrons, and are attracted into the applied external magnetic field. Ex : Fe +3, O₂, Cu+2, etc.,

In ferromagnetic solids, the metal ions are grouped together into small regions called **domains**. When the substance is placed in a magnetic field all the domains get oriented in the direction of the magnetic field ($\uparrow\uparrow\uparrow\uparrow$). This interaction leads to an increase in magnetic moment.
Ex: Iron, Cobalt and Nickel are ferromagnetic substances.

In antiferromagnetic solids, when the substance is placed in a magnetic field all the domains get oriented in the antiparallel ($\uparrow\downarrow\uparrow\downarrow$) direction of the magnetic field, which leads to a decrease in magnetic moment.
Ex: MnO, MnO₂, Mn₂O₃.

In ferromagnetic solids when the substance is placed in a magnetic field all the domains get oriented randomly ($\uparrow\uparrow\downarrow\uparrow\downarrow$) which leads to the presence of uncompensated spins in the opposite direction resulting in some magnetic moment.
Ex. Magnetite (Fe₃O₄), ferrite [M FeO₄] where M = Mg (II), Cu (II), Zn (II).

For Higher achievers: (Beyond the NCERT Text Book)

→ Radius ratio and coordination number:

Limiting radius ratio (r^+ / r^-)	Polyhedron	Structure type	Coordination number	Example
0.732 and more	Cube	CsCl type	8	CsI, CsBr
0.414 - 0.732	Octahedron	NaCl type	6	MgO, NaBr
0.225 - 0.414	Tetrahedron	ZnS type	4	CuCl, CuBr

→ Types of Crystal structure and their description:

Type of Crystal structure	Description	Coordination Number
I. AB Type :		
a) CsCl Type: →	All Cl ⁻ ions occupies ccp, and all the cubic voids are occupied by Cs ⁺ ions	Cl ⁻ = 8 Cs ⁺ = 8
b) NaCl type :→	All Cl ⁻ ions occupies ccp, and all the Octahedral voids occupied by Na ⁺ ions	Cl ⁻ = 6 Na ⁺ = 6
c) ZnS type: →	All S ⁻² ions occupies ccp, and the Zn ⁺² ions occupies alternate tetrahedral voids.	S ⁻² = 4 Zn ⁺² = 4
II. AB₂ Type:		
Fluorite structure :		
CaF ₂ Type: →	All Ca ⁺² ions occupies ccp, and the all the tetrahedral voids are occupied by F ⁻ ions	Ca ⁺² = 8 F ⁻ = 4
III. A₂B Type:		
Anti Fluorite structure:		
Na ₂ O type: →	All O ⁻² ions occupies ccp, and all the tetrahedral voids are occupied by Na ⁺ ions.	O ⁻² = 8 Na ⁺ = 4

Section – B : Important Conceptual Questions and Answers:

1Q. Classify following solids in to Molecular, Ionic, Metallic and Covalent.

Ans:

1	P ₄ O ₁₀	Molecular solid
2	Graphite	Covalent solid
3	Brass	Metallic solid
4	Ammonium Phosphate	Ionic solid
5	SiC	Covalent solid
6	Rb	Metallic solid
7	I ₂	Molecular solid
8	LiBr	Ionic solid
9	P ₄	Molecular solid
10	Si	Covalent solid

2Q) Write two differences between isotropy and anisotropy. (2 Marks)

Ans:

Isotropy	Anisotropy
i) It is property by which substances show identical, electrical and optical properties in all directions.	It is property by which substances show different electrical and optical properties in all directions.
(ii) Amorphous solids show isotropy	Crystalline solids show anisotropy.

3Q) Classify the following solids as metallic, molecular, amorphous, covalent or ionic.

(i) SO₂ (ii) Diamond (iii) I₂ (iv) MgO (v) Ag (vi) Quartz (vii) Ar (3 Marks)

(Ans) Metallic solid - Ag

Covalent solid - Quartz

Molecular solids - I₂, Ar, SO₂

Ionic solids - MgO

4Q) Atoms of element B form *hcp* lattice and those of the element A occupy 2/3rd of tetrahedral voids. What is the formula of the compound formed by the element A and B. (1 Mark)

(Ans) The number of tetrahedral voids formed is equal to twice the number of atoms of elements B.

A occupy only 2/3 of of tetrahedral voids

Thus, the ratio of number of atoms of A and B is given by

$$2 \times (2/3) : 1 = 4:3$$

Hence, The formula of the compound is A₄B₃

5Q) A compound formed by elements X and Y crystallizes in a cubic structure in which the X atoms are at the corners of a cube and the Y atoms are at the face centres. What is the formula of the compound. (1 Mark)

(Ans) For a cubic structure,

No. of X atoms at the corner of the unit cell = $8 \times \frac{1}{8} = 1$

No. of Y atoms at the face centre of the unit cell = $6 \times \frac{1}{2} = 3$

Formula of the compound = XY_3

6Q) A compound formed by elements A and B crystallises in cubic structure where A atoms are at the corners of a cube and B atoms are at the face centre. What is the formula of the compound? (1 Mark)

(Ans) As we know that stoichiometric ratio of atoms in unit cell decide the empirical formula of the compounds. Here,

A atoms occupy the corners of the cube, thus the number of A atom in unit cell is 1

B atom occupy the centre of cube, thus the number of B atom in unit cell is also 1

Hence, the simplest formula of compound is **AB**

7Q) A compound is made of two atoms X and Y. Atom X is arranged in *ccp* and atom Y occupies tetrahedral site. Find the formula of compound. (2 Marks)

(Ans) No. of atoms of X = 8

No. of atoms of Y = $(\frac{8}{8}) + (\frac{6}{2}) = 4$

\therefore Ratio of X : Y is 2: 1

- Formula of compound is X_2Y .

-

8Q) A metal oxide crystallizes in a hexagonal close packed array of oxide ions with two out of every three octahedral holes occupied by metal. Find formula of metal oxide. (1 Mark)

(Ans) Let the no. of oxide ions = x

\therefore No. of octahedral holes = x

No. of octahedral hole occupied by metal = $\frac{2}{3} x$

\therefore No. of metal ions: No. of oxide ions = $\frac{2}{3} x : x$

= 2 : 3

- Formula of metal oxide M_2O_3

9Q) A cubic solid is made of two elements P & Q. Atoms Q are at the corners of the cube and P are at the body center. What is the formula of the compound. What are the Co-ordination numbers of P & Q. (1 Mark)

Ans: No of atoms of P = 1

No of atoms of Q = $8 \times \frac{1}{8} = 1$

Formula of compound = PQ

Co-ordination no. of P = 8, & Co-ordination no. of Q = 8.

10Q) In a face centered cubic lattice atoms of A occupy corner of cell and that of B occupy face centers. One of the A atoms is missing from one corner of a unit cell. Find the simplest formula of compound. (2 Mark)

(Ans) Number of atoms of A at the corner of unit cell = $7 \times (1/8) = 7/8$

Number of atoms of B at faces of unit cell = $6 \times 1/2 = 3$

A : B = $(7/8) : 3$

Simplest ratio = $((7/8) \times 8) : (3 \times 8) = 7 : 24$

• Formula of compound = $A_7 : B_{24}$

•

11Q) Ferric oxide Crystallises in a hexagonal close packed array of oxides with two out of every three octahedral holes occupied by ferric ions. Derive the formula of ferric oxide. (1Mark)

Ans: No. of Ferric ions for each oxide ion = $2/3$

Chemical formula = $Fe_{2/3} O \cong Fe_2O_3$

12Q) A solid has bcc structure. Distance of closest approach between two atoms is $1.73A^0$. Find edge length of cell. (2 Marks)

(Ans) In bcc, distance of closest approach = $\frac{\sqrt{3}}{2} \times \text{edge length}$

$$\therefore 1.73 = \frac{\sqrt{3}}{2} \times \text{edge length}$$

$$\text{Edge length} = \frac{1.73}{\sqrt{3}} \times 2 = 2^{\circ}A = 200 \text{ pm}$$

13Q) The density of an atom is $7.2g \text{ cm}^{-3}$. It has bcc structure. The edge length is 288pm. How many atoms of element does 208g of element has? (3 Marks)

(Ans) Volume of unit cell = $(288\text{pm})^3$

$$= 28.8 \times 10^{-24} \text{ cm}^3$$

Volume of 208g of element = mass / density = $208 / 7.2 = 28.8 \text{ cm}^3$

$$\text{No. of unit cells} = \frac{\text{Volume of element}}{\text{Volume of unit cell}} = \frac{28.8}{28.8 \times 10^{-24}} = 1 \times 10^{24} \text{ unit cells}$$

∵ bcc cube has 2 atoms.

$$\therefore \text{Total number of atoms in 208g} = 2 \times 1 \times 10^{24}$$

$$= 2 \times 10^{24} \text{ atoms}$$

14Q) Find the type of lattice for cube having edge length of 400 pm, atomic wt. = 60 and density = 6.25 g/cc. (3 Marks)

(Ans) Let the no. of atoms in a unit cell = x

$$\begin{aligned} \therefore \text{Mass of one unit cell} &= \frac{\text{At. wt.} \times \text{No. of atoms}}{\text{Avogadro No.}} \\ &= \frac{60 \times x}{6.02 \times 10^{23}} \end{aligned}$$

$$\begin{aligned}\text{Volume of unit cell} &= (\text{edge length})^3 = (4 \times 10^{-8} \text{ cm})^3 \\ &= 64 \times 10^{-24} \text{ cm}^3\end{aligned}$$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Mass} = \text{density} \times \text{volume}$$

$$\frac{60x}{6.02 \times 10^{23}} = 6.25 \times 64 \times 10^{-24}$$

$$x = \frac{6.25 \times 64 \times 10^{-24} \times 6.02 \times 10^{23}}{60}$$

$$= 4$$

- The unit cell has 4 atoms, \therefore It is face centered cubic lattice.

15Q) KF has NaCl structure. Its density is 2.48 g cm^{-3} . Find distance between K^+ and F^- ions in KF. (3 Marks)

(Ans) For fcc $Z = 4$, Molecular mass of KF = 58

$$\text{In fcc, } r^+ + r^- = \frac{a}{2}$$

$$\text{K}^+ \text{ and F}^- = \frac{537.5}{2}$$

- Distance between = 268.7 pm

16Q) The density of NaCl crystal is 2.155 g cm^{-3} and distance between Na^+ and Cl^- is 280 pm. Find value of Avogadro's number. (3 Marks)

(Ans) NaCl has fcc structure.

$$\begin{aligned}\text{In fcc, } a (\text{edge length}) &= 2(r^+ + r^-) \\ &= 2 \times 280 \text{ pm} \\ &= 560 \text{ pm}\end{aligned}$$

For fcc, $Z = 4$, $N_A = \text{Avogadro number} = ?$

$$\begin{aligned}N_A &= \frac{4 \times 58.5}{(560 \times 10^{-10})^3 \times 2.155} \\ &= 6.12 \times 10^{23} \text{ mol}^{-1}\end{aligned}$$

17Q) A metallic element has cubic lattice. Edge length of lattice cell is $2A^0$. The density of metal is 2.4 g cm^{-3} . How many units cell are present in 200g of metal. (3 Marks)

(Ans) Edge length = $2A^0 = 2 \times 10^{-8} \text{ cm}$

$$\text{Volume of cell} = (\text{edge})^3 = (2 \times 10^{-8})^3 = 8 \times 10^{-24} \text{ cm}^3$$

Mass of unit cell = Volume \times density

$$= 8 \times 10^{-24} \times 2.4 \text{ g}$$

No. of unit cells in 200g of metal = Mass of the metal / Mass of the Unit cell

$$\begin{aligned}
 &= \frac{200}{8 \times 2.4 \times 10^{-24}} \\
 &= 10.4 \times 10^{24} \\
 &= 1 \times 10^{25}
 \end{aligned}$$

18Q) Silver crystallizes in FCC lattice. If edge length of unit cell is 4.077×10^{-8} cm and density is 10.5 g/cm^3 , calculate atomic mass of silver.

Ans: $\rho = (Z m) / (a^3 \times N_0)$
 $10.5 = (4 \times M) / (4.077 \times 10^{-8})^3 \times 6.023 \times 10^{23}$
 $M = 107.09 \text{ g/mol.}$

19Q) Niobium crystallizes in body centred cubic structure. If density is 8.55 g/cm^3 . If Density is 8.55 g/cm^3 . Calculate atomic radius of niobium (At. Mass of Niobium=93).

Ans: $\rho = (Zm) / (a^3 N_0)$
 $8.55 = (2 \times 93) / a^3 \times 6.023 \times 10^{23}$, $a^3 = 2 \times 93 / (8.55 \times 6.023 \times 10^{23})$,
 $a = [3.6 \times 10^{-23}]^{1/3} = \underline{\underline{3.302 \times 10^{-8} \text{ cm}}}$

20Q) Copper crystallizes in face lattice with edge length 3.61×10^{-8} cm. Show that the calculated density is in agreement with its measured value of 8.92 g/cm^3 .

Ans: $a = 3.61 \times 10^{-8} \text{ cm}$, $Z = 4$,
 $\rho = (4 \times 63.5) / (3.61 \times 10^{-8})^3 \times 6.023 \times 10^{23}$
 $= \underline{\underline{9 \text{ g/cm}^3}}$

21Q) Formula mass of NaCl is 58.45 g/mol and density of its pure form is 2.167 g/cm^3 . Average distance between adjacent sodium and chloride ions in the crystal is 2.814×10^{-8} . Calculate Avogadro constant.

Ans: $M = 58.45 \text{ g/mol}$
 $\rho = 2.167 \text{ g/cm}^3$
 $A = 2 \times \text{distance between Na}^+ \text{ and Cl}^-$
 $P = (Zm) / (a^3 \times N_0)$
 $N_0 = 4 \times 58.45 / (2.814 \times 10^{-8})^3 \times (2.167)$
 $= \underline{\underline{6.023 \times 10^{23}}}$

22Q) Thallium chloride, TlCl crystallizes in either a simple cubic lattice or a face centred cubic lattice or a face centred cubic lattice of Cl^- ion with Tl^+ ion in the holes. If the density of the solid is 9 gcm^{-3} and edge of the solid is 9 gcm^{-8} cm, what is the unit cell geometry?

Ans: $\rho = Z.m / a^3 N_0$,
 $9 = Z \times 240 / (9 \times 10^{-8})^3 \times 6.023 \times 10^{23}$
 $Z = 9 \times 3.85 \times 3.85 \times 3.85 \times 10^{-24} \times 6.023 \times 10^{23} / 240$
 $Z = 1.289 \approx 1$, So, TlCl is simple cubic.

23Q) Gold (atomic radius =0.144 nm). Crystallises in face centred Unit cell. What is the length of a side of a cell?

$$a^2 = 8 \times 0.144 \times 0.144$$

$$\Rightarrow a = \underline{0.4\text{nm.}}$$

24Q) Calculate the value of Avogadro constant from the following data. Density of NaCl= 2.165 g/cm³. Distance b/w Na⁺ & Cl⁻ 281 pm.

$$P = Z m / a^3 N_0, \quad N_0 = 4 \times 58.5 / [2.165 \times (281 \times 10^{-10})^3]$$
$$= \underline{6.023 \times 10^{23}}$$

25Q) A mineral contains Ca, O and Ti. Oxygen atoms are present at face centres, calcium atoms are present at corners and titanium atoms at centre of cube. Find the oxidation number of titanium in the mineral. (3 Marks)

(Ans)

$$\text{No. of Ca atoms} = 8 \times \frac{1}{8} = 1$$

$$\text{No. of O atoms} = 6 \times \frac{1}{2} = 3$$

$$\text{No. of Ti atoms} = 1 \times 1 = 1$$

∴ Formula of mineral is CaTiO₃

Let oxidation number of Ti = x

$$\text{So, In CaTiO}_3 + 2 + x + (-2 \times 3) = 0$$

$$\therefore x = +4$$

- Oxidation state of titanium is + 4 in this mineral.

26Q) What are voids? How a tetrahedral void differ from octahedral void? (3 Marks)

(Ans) A crystal is formed by close packing of atoms or ions, which are spherical in shape. Since, spheres touch each other only at points, some empty space is left between them. This space is called void or hole.

Tetrahedral void: Tetrahedral void is surrounded by four spheres (atoms), which lie at vertices of regular tetrahedron.

Octahedral void: Octahedral void is surrounded by six spheres (atoms).

27Q) What is doping? How does n type and p type semiconductors differ from each other? (2 M)

(Ans) The process of introducing atoms of other elements as impurity into an insulator to make it semiconductor is called doping. Doping with electron rich impurities like P, As, Sb forms n-type semiconductors whereas p type semiconductors have acceptor impurities like B, Ga.

28Q) What are-(i) Molecular solids (ii) Metallic solids .(2 Marks)

(Ans) (i) In molecular solids, the individual molecules are the constituents which are held together by van der Waals forces of attraction. e.g. I_2 .

(ii) Metallic solids consist of positive ions in a sea of electrons. The metal atoms are held together by metallic bonds. e.g. Ag, Cu.

29Q) Define: (i) Crystal lattice (ii) Co-ordination number (2 Marks)

(Ans) (i) Crystal lattice is well-defined regular arrangement of atoms, molecules or ions in three-dimensional space.

(ii) Co-ordination number is the number of atoms or ions, which surround another atom in crystal lattice.

30Q) What is rank? Find rank of face centered cubic unit cell. (2 Marks)

(Ans) Rank is the number of atoms per unit cell of a crystal.

In f c c -

Contribution of atoms of corner = $8 \times \frac{1}{8} = 1$

Contribution of atoms at faces = $6 \times \frac{1}{2} = 3$

\therefore Rank = $1 + 3 = 4$.

31Q) What happens the density of KCl crystal by the addition of $CaCl_2$ crystal. (1 Mark)

(Ans) In KCl crystal, the Ca^{2+} ion from $CaCl_2$ will replace K^+ ions. Since one Ca^{2+} ion will replace two K^+ ion in order to make the system electrically neutral. Thus, the density of KCl crystal will decrease.

32Q) How many particles are there in a fcc unit cell of a mono atomic substance? (1 Ma)

(Ans) An fcc crystal contains atoms in a unit cell = $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

(33Q) A metallic crystal crystallizes into a lattice containing a sequence of layers AB AB ABAny packing of spheres leaves out voids in the lattice. What % by volume of this lattice is empty space? (1 Mark)

(Ans) AB-AB type of packing means cubic close packing in which 74% space is occupied and 26% is empty.

34Q) Why is the window glass of the old building thick at the bottom? (1 Mark)

(Ans) Glass is a pseudo solid, that is, it is a supercooled liquid of high viscosity. It is not a true solid. So, it has the property to flow.

35Q) What do you mean by F-center? (1 Mark)

(Ans) The anion sites which are occupied by unpaired electron are called F-centres.

36Q) Sometimes, common salt is yellow instead of being pure white. Why? (1 Mark)

(Ans) Sometimes, common salt is yellow instead of being pure white due to the presence of electrons in some lattice sites in place of anions. These sites acts F-centers and impart colour to common salt.

37Q) a) What is meant by co-ordination number?

**b) What is the co-ordination number of atoms in i) Cubic close packed structure
ii) Body centred cubic structure.**

Ans: a) It is the number of nearest neighbours of each atom or ion in a solid structure.

b) 6 & 8

38Q) Distinguish between Hexagonal close packing and cubic close packing.

Ans: In a three dimensional Close packed structure of solid, the atoms of the Second layer (B) are kept in the depressions of first layer(A), two types of voids are formed - octahedral void and tetrahedral voids.

If third layer is covering the tetrahedral voids, such packing is called hexagonal close packing (ABABAB-----)

If third layer is covering the octahedral void, such packing is called cubic close packing. (ABCABCABC-----)

39Q) Analysis shows that nickel oxide has formula $Ni_{0.98} O_{1.00}$. What fractions of Nickel exist as Ni^{2+} and Ni^{3+} ion?

Ans: Let no of Ni^{2+} ions = 'p' and

The no. of Ni^{3+} ions = '98-p'.

Magnitude of the total Charge present on the Nickel = $p(+2) + (98-p)(+3)$

Magnitude of the total Charge present on the Oxygen = $(2) \times 100 = 200$

Total charge present on Metal and oxygen are equal,

$$(p \times 2) + (98-p) \times 3 = 200$$

$$2p + 294 - 3p = 200$$

$$p = 94,$$

No of Ni^{2+} ions = 94,

% of Ni^{2+} ions = $(94 / 98) \times 100 = 95.91$.

No of Ni^{3+} ions = $98 - p = 98 - 94 = 4$,

% of Ni^{3+} ions = $4/98 \times 100 = 4.08$.

40Q) Classify each of the following as P type and N-type semiconductors.

i) Ge doped with In ans: P-type

ii) B Doped with Si : P-type

41Q) In terms of band theory, what is the difference between a conductor, semiconductor and an insulator

Ans: Energy gap between filled band and conduction band is high in insulator. In conductors, there is no energy gap between filled band.

Conductors, Semi conductors & Conduction band

In semiconductors there is energy gap between conduction band and filled band, but not so high as in insulators. In conductors there is no energy gap.

42Q) Aluminium crystallises in a cubic close packed structure. Its' metallic radius is 125 pm.

(a) What is the length of the side of the unit cell.

(b) How many unit cells are there in 1cm^3 of aluminium?

Ans: A) $4r = \sqrt{3}a$, $a = 4 \times 125 / 1.71 = 292$ pm

B) Volume of one unit cell of Al = a^3 ,

$$(292 \times 10^{-10} \text{ cm})^3 = 292 \times 292 \times 292 \times 10^{-30} \text{ cm}^3$$

$$\text{No. of unit cells in } 1\text{cm}^3 = 1 / (292 \times 292 \times 292 \times 10^{-30}) = \underline{4 \times 10^{22}}$$

43Q) If NaCl is doped with 10^{-3} mol% SrCl_2 , what is the concentration of cation vacancies.

$$\text{concentration of cation vacancies} = 10^{-3} \text{ mol \%} = 10^{-3} \text{ mol} / 100 = \underline{10^{-5} \text{ mol}}$$

4Q. A compound contains two types of atoms X and Y. It crystallizes in a cubic lattice with atom X at the corners of the unit cell and atoms Y at the body centers. What is the simplest possible formula of this compound. (CBSE -Samp 2-2008 -1M)

Ans : No of atoms of X = $8 \times \frac{1}{8} = 1$
 No of atoms of Y = 1
 The formula of the compound is XY.

5Q. An element X with an atomic mass of 60g/mol has density of 6.23g cm⁻³. If the edge length of its cubic unit cell is 400 pm, identify the type of cubic unit cell. Calculate the radius of an atom of this element. (CBSE -Samp 2-2008 -3M)

Ans:

$$\delta = \frac{Z \times M}{a^3 \times N_A}$$

$$6.23 = \frac{Z \times 60}{(400)^3 \times 10^{-30} \times 6.023 \times 10^{23}}$$

$$Z = 4$$

The unit cell is face centered cubic

$$\text{radius 'r'} = \frac{a}{2\sqrt{2}}$$

$$= \frac{400}{2\sqrt{2}}$$

$$= 141.4 \text{ pm.}$$

6Q. Name the type of point defect that occurs in a crystal of zinc sulphide. (CBSE -Samp 3-2008 -1M)

Ans: Frenkel defect

7Q. How many octahedral voids are there in 1 mole of a compound having cubic close packed structure? (CBSE -Samp 3-2008 -1M)

Ans: 1 Mole or 6.023×10^{23} .

8Q. An element E crystallizes in body centered cubic structure. If the edge length of the cell is 1.469×10^{-10} m and the density is 19.3g/cm³, calculate the atomic mass of this element. Also calculate the radius of an atom of this element. (CBSE -Samp 3-2008 -2M)

Ans. Edge length, $a = 1.469 \times 10^{-10}$ m = 1.469×10^{-8} cm
 Density $d = 19.3 \text{ g cm}^{-3}$
 Since it is body centred, $Z = 2$

$$d = \frac{Z \times M}{a^3 \times N_0}$$

$$19.3 = \frac{2 \times M}{(1.469 \times 10^{-8})^3 \times (6.02 \times 10^{23})}$$

$$M = \frac{19.3 \times (1.469 \times 10^{-8})^3 \times (6.02 \times 10^{23})}{2}$$

$$= 18.42$$

For a body centred cubic structure, radius of an atom,

$$r = \frac{\sqrt{3}}{4} a$$

$$= \frac{1.732 \times 1.469 \times 10^{-10} \text{ m}}{4}$$

$$= 6.36 \times 10^{-11} \text{ m}$$

9Q. What is the coordination number of each ion in a rock-salt type structure?

(CBSE -Samp 4-2008 -2M)

Ans: Each ion has coordination number is 6.

10Q. What is a semi conductor? Name the two main types of semiconductors and explain their conduction mechanisms.

(CBSE -2008 -3M)

Ans: The solids with intermediate conductivities between insulators and conductors are termed **semiconductors**.

(i) **n-type semiconductor** : It is obtained by doping Si or Ge with a group 15 element like P. Out of 5 valence electrons, only 4 are involved in bond formation and the fifth electron is delocalized and can be easily provided to the conduction band. The conduction is thus mainly caused by the movement of electron.

(ii) **p-type semi conductor** : It is obtained by doping Si or Ge with a group 13th element like Gallium which contains only 3 valence electrons. Due to missing of 4th valence electron, electron hole or electron vacancy is created. The movement of these positively charged hole is responsible for the conduction.

11Q. What is the total number of atoms per unit cell in a face-centered cubic (fcc) crystal structure?

(CBSE -2008 -1M)

Ans: $(8 \times 1/8) + (6 \times 1/2) = 4$

12Q. Silver crystallizes in an fcc lattice. The edge length of its unit cell is 4.077×10^{-8} cm and its density is 10.5 g/cm^3 . Calculate on this basis the atomic mass of silver. ($N_0 = 6.023 \times 10^{23}$)

(CBSE -2008 -3M)

Ans: Since the lattice is fcc, the number of silver atoms per unit cell = $z = 4$

Molar mass of silver = M

Edge length of unit cell = $a = 4.077 \times 10^{-8}$ cm

Density = 10.5 g/cm^3

We know that, $\rho = (z \times M) / (N \times a^3)$

Atomic size = $M = (\rho \times N \times a^3) / z$
 $= 10.5 \times 6.023 \times 10^{23} \times (4.077 \times 10^{-8})^3 / 4$
 $= 107.1 \text{ gm/mol.}$

13Q. What is the two-dimensional coordination number of a sphere in square close packing?

(CBSE -Supply-2008 -1M)

Ans : 4

14Q. Account for the following:

i) Fe_3O_4 is ferromagnetic at room temperature but becomes paramagnetic at 850K.

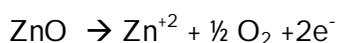
ii) Zinc oxide on heating becomes yellow.

iii) Frenkel defect does not change the density of AgCl crystals.

(CBSE -Supply-2008 -3M)

Ans: i) As the temperature increases the mixed oxide in which the metal ions in domains randomly distributed. The metal ions Fe^{+3} or Fe^{+2} contains unpaired electrons which are weakly attracted by the magnet, so they become paramagnetic in nature.

ii) Zinc oxide is white in colour at room temperature. On heating it loses oxygen and turns yellow.



Now there is excess of zinc in the crystal and its formula becomes Zn_{1+x}O . The excess Zn^{2+} ions move to interstitial sites and the electrons to neighbouring interstitial sites.

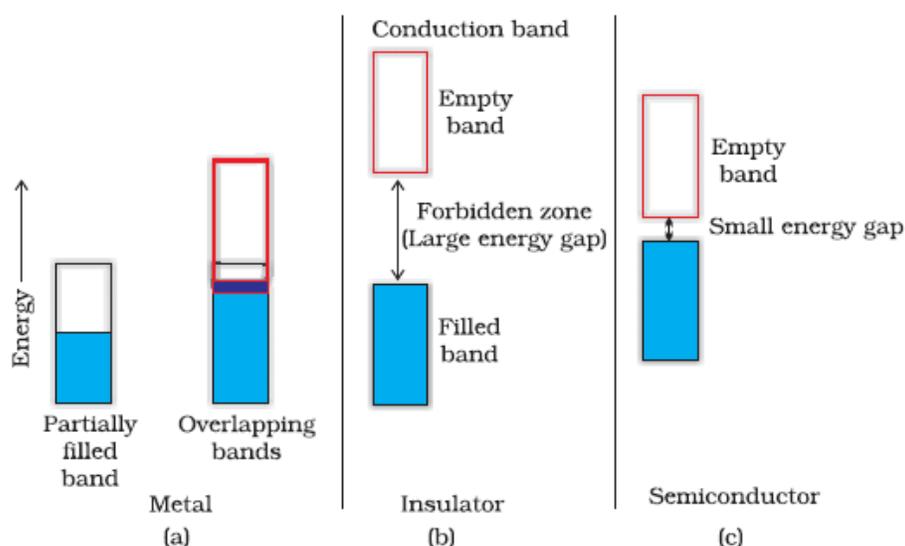
iii) In Frenkel defect one of the lattice point is missing from the regular position and occupies the interstitial position, no loss of cation or anion occurs in the crystal lattice. So, the density does not change.

15Q. With the help of suitable diagrams, on the basis of band theory, explain the difference between

- i) A conductor and an insulator.
- ii) A conductor and a semi conductor.

(CBSE -Supply-2008 -3M)

Ans:



16Q In an fcc arrangement of P and Q atoms, P atoms are at the corners of the unit cell. What is the formula of the compound? (CBSE -Samp 4-2008 -2M)

Ans. No. of P atoms per unit cell = $8 \times (1/8) = 1$ (∵ P atoms are present at the corners)
 No. of Q atoms per unit cell = $6 \times \frac{1}{2} = 3$ (∵ Q atoms are present at the corners)

- The formula of the compound = PO_3

17Q Atoms of element B form hcp lattice and those of the element A occupy 2/3rd of tetrahedral voids. What is the formula of the compound formed by the elements A and B? (CBSE -Samp 4-2008 -2M)

Ans.

Suppose atoms of element A present in hcp = x

Then, No. of tetrahedral voids = $2x$

As $\frac{2}{3}$ of the tetrahedral voids are occupied by atoms of element B,

Therefore, no. of atoms B present = $\frac{2}{3} \times 2x = \frac{4x}{3}$

∴ Ratio of A : B = $\frac{4x}{3} : x = 4x : 3x = 4 : 3$

∴ Formula of the compound = A_4B_3

18Q Atomic mass of an element is 100. It has bcc structure. Its density is 5.96 g cm^{-3} . Calculate the volume of the unit cell. (CBSE -Samp 5-2008 -2M)

Ans. Let the length of unit cell = a

∴ Volume of unit cell = a^3

$Z = 2$ (for bcc)

Molar mass (M) = 100

Avogadro's number (N_A) = 6.02×10^{23} , Density of unit cell = 5.96 g.cm^{-3}

$$\text{Density} = \frac{Z \times M}{a^3 \times N_A} = \frac{Z \times M}{V \times N_A} (\because a^3 = V)$$

$$\text{or, volume} = \frac{Z \times M}{\text{Density} \times N_A} = \frac{2 \times 100}{5.96 \times 6.02 \times 10^{23}} = 5.57 \times 10^{-23} \text{ cm}^3$$

19Q What is F-centre?

(CBSE -Samp 6-2008 -1M)

Ans. The site where electron is entrapped in the anion vacancy is called F-centre.

20Q An element crystallizes into fcc unit cell type of a structure. The edge length of unit cell is 150 pm. If 150 g of this element have 12×10^{23} atoms, then calculate the density of the element.

(CBSE -Samp 6-2008 -3M)

Ans. Volume of unit cell = (length)³ = $(150 \times 10^{-10} \text{ cm})^3 = 3.4 \times 10^{-24} \text{ cm}^3$

$$\text{Mass of an atom} = \frac{150}{12 \times 10^{23}} = 12.5 \times 10^{-23} \text{ g}$$

Z = 4 (for fcc)

$$\text{Mass of unit cell} = \text{Mass of an atom} \times Z = 12.5 \times 10^{-23} \times 4 = 50 \times 10^{-23} \text{ g}$$

$$\text{Density of unit cell} = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}} = \frac{50 \times 10^{-23}}{3.4 \times 10^{-24}} = 14.7 \times 10 \text{ g.cm}^{-3}$$

$$= 147 \text{ g.cm}^{-3}$$

21Q X-ray diffraction studies show that copper crystallizes in an fcc unit cell with cell edge of $3.608 \times 10^{-8} \text{ cm}$. In a separate experiment, copper is determined to have a density of 8.92 g/cm^3 . Calculate the atomic mass of copper.

(CBSE -Samp 7-2008 -3M)

Ans.

For fcc lattice, the number of atoms per unit cell (z) = 4

Edge of cell (a) = $3.608 \times 10^{-8} \text{ cm}$

Avogadro's number (N_A) = 6.022×10^{23}

Density of the metal (d) = 8.92 g cm^{-3}

Atomic mass of copper (M) = ?

$$d = \frac{z \cdot M}{a^3 \cdot N_A}$$

$$M = \frac{d \cdot N_A \cdot a^3}{z}$$

$$M = \frac{8.92 \times 6.022 \times 10^{23} \times (3.608 \times 10^{-8})^3}{4}$$

$$M = 63.5 \text{ g/mol}$$

22Q An element is found to have fcc structure. How many atoms are present in its one unit cell?

(CBSE -Samp 7-2008 -1M)

Ans. Four

23Q (i) Name a solid which shows both Frenkel and Schottky defect.

(ii) Why Frenkel defect is not found in pure alkali metal halides?

(iii) Name point defect a crystal which lowers the density of Crystal.

(iv) Name the nonstoichiometric point defect responsible for colour in alkali metal halides.

(CBSE -Samp 8-2008 -2M)

Ans. (i) AgBr (silver bromide)

(ii) Frenkel defect is not found in pure alkali metal halides because the size of ions is large and they do not fit into interstitial spaces.

(iii) Schottky defect

(iv) Metal excess non stoichiometric point defect.

24Q What is the difference between (i) Schottky defect (ii) Frenkel defect?

(CBSE -Samp 8-2008 -2M)

Ans.

Schottky defect	Frenkel defects
If an atom or ion is missing from its lattice site, The vacancy created is termed as a Schottky defect.	These defects are commonly found in ionic solids. Whenever an ion leaves its lattice site and occupies an interstitial site, such defect is called Frenkel defect.

25Q Distinguish between 'Face-centred, body-centred and end-centred unit cells.

(CBSE -Samp 9-2008 -2M)

Ans. A face- centred unit cell has one constituent particle present at the centre of each face in addition to the particles present at the corners. While an end-face centred has one constituent particles each at the centre of any two opposite faces in addition to the particles present at the corners.

15. ZnS is an example of
 1) Ionic crystal 2) Covalent crystal 3) Molecular crystal 4) Metallic crystal
16. LiF is an example of
 1) Ionic crystal 2) Metallic crystal 3) Covalent crystal 4) Molecular crystal
17. Graphite is an example of
 1) Ionic crystal 2) Covalent crystal 3) Molecular crystal 4) Metallic crystal
18. Solid CO₂ is an example of
 1) Ionic crystal 2) Covalent crystal 3) Molecular crystal 4) Metallic crystal
19. Wax is an example of
 1) Ionic crystal 2) Covalent crystal 3) Molecular crystal 4) Metallic crystal
20. Which of the following is an example of covalent crystalline solid?
 1) Si 2) Al 3) Ar 4) NaF
21. An example of a metallic crystalline solid is
 1) Si 2) C 3) P 4) W
22. In solids, the constituent particles may be
 1) Atoms 2) Ions 3) Molecules 4) any of the above three
23. Iodine crystals are
 1) Metallic 2) Ionic 3) Molecular 4) Covalent
24. NaCl crystal is made up of
 1) NaCl molecules 2) Na⁺ and Cl⁻ ions 3) Na and Cl atoms 4) Polymers of NaCl
25. A molecular crystalline solid
 1) is very hard 2) is volatile 3) has a high melting point 4) is a good conductor
26. Which one has the highest melting point?
 1) Ionic crystal 2) Molecular crystal 3) Covalent crystal 4) Metallic crystal
27. Ionic solids are characterised by
 1) Good conductivity in solid state 2) High vapour pressure
 3) Low melting point 4) Solubility in polar solvents
28. Crystals which are good conductors of electricity and heat are
 1) Ionic 2) Covalent 3) Metallic 4) Molecular
29. Among the following which crystal will be soft and have a low melting point
 1) SiC 2) NaCl 3) Graphite 4) Ice
30. An example of a substance possessing giant covalent structure is
 1) Iodine crystal 2) Silica 3) Solid carbon dioxide 4) White phosphorus
31. Which one of the following will have a low heat of fusion?
 1) a covalent solid 2) an ionic solid 3) a metallic solid 4) a molecular solid
32. The number of atoms present in a unit cell of a monoatomic substance (element) of a simple cubic lattice, body-centred cubic and face-centred cubic respectively are
 1) 8, 9 and 14 2) 1, 2 and 4 3) 4, 5 and 6 4) 2, 3 and 5
33. Bravais lattices are of
 1) 10 types 2) 8 types 3) 7 types 4) 14 types
34. NaCl crystal belongs to the crystal system
 1) tetragonal 2) cubic 3) orthorhombic 4) monoclinic

35. Diamond belongs to the crystal system
 1) cubic 2) triclinic 3) tetragonal 4) hexagonal
36. The substance which posses zero resistance at OK is called
 1) Conductor 2) Super conductor 3) Insulator 4) Semiconductor
37. Glass is
 1) Super cooled liquid 2) Metallic crystal, 3) Molecular crystal 4) Covalent crystal
38. Select the correct statement
 1) A cubic close packed structure has eight tetrahedral and six octahedral interstices
 2) Graphite has three dimensional crystal lattice
 3) Diamond has two dimensional crystal lattice
 4) Coordination number of body centred cubic lattice is eight
39. For the various types of interactions the correct order of increasing strength is
 1) covalent < hydrogen bonding < van der Waals < dipole-dipole
 2) van der Waals < hydrogen bonding < dipole-dipole < covalent
 3) van der Waals < dipole-dipole < hydrogen bonding < covalent
 4) dipole-dipole < van der Waals < hydrogen bonding < covalent
40. The type of bonding in ice is
 1) hydrogen bonding 2) covalent bonding 3) ionic forces 4) metallic boning
41. Germanium is an example of
 1) An instrinsic semiconductor
 2) An n-type semiconductor
 3) A p-type semiconductor
 4) Insulator
42. Which one of the following is a two dimensional covalent solid?
 1) graphite 2) quartz
 3) carborundum 4) pure germanium
43. When n and p-type semiconductors are allowed to come into contact
 1) some electrons will flow from n to p
 2) some electrons will flow from p to n
 3) the impurity element will flow from n to p
 4) the impurity element will flow from p to n
44. How many Cl^- ions are there around Na^+ ion in NaCl crystal?
 1) 3 2) 4 3) 6 4) 8
45. The 8 : 8 type of packing is present in
 1) NaCl 2) KCl 3) CsCl 4) Cu
46. The number of atoms contained in a **fcc** unit cell of a monoatomic substance is
 1) 1 2) 2 3) 4 4) 6
47. An octahedral void is surrounded by how many spheres?
 1) 6 2) 4 3) 8 4) 12
48. Most crystals show good cleavage because their atoms, ions or molecules are
 1) weakly bonded together 2) strongly bonded together
 3) spherically symmetrical 4) arranged in planes
49. In a solid lattice the cation has left a lattice site and is located at an interstitial position, the lattice defect is
 1) Interstitial defect 2) Vacancy defect
 3) Frenkel defect 4) Schottky defect

50. In the fluorite structure, the coordination number of Ca^{2+} ion is
 1) 4 2) 6 3) 8 4) 3
51. On doping Ge metal with a little of In, one gets
 1) p-type semi conductor 2) n-type semi conductor 3) insulator 4) rectifier
52. Potassium crystallizes in a **bcc** lattice, hence the coordination number of potassium in potassium metal is
 1) 0 2) 4 3) 6 4) 8
53. Space lattice of CaF_2 is
 1) **fcc** 2) **bcc**, 3) simple cubic 4) **hcp**
54. Which of the following describes the hexagonal close packed arrangement of spheres?
 1) ABCABA 2) ABCABC 3) ABABA 4) ABBABB
55. If we mix a pentavalent impurity in a crystal lattice of germanium, what type of semiconductor formation will occur?
 1) p-type 2) n-type 3) both (1) and (2) 4) none of the two
56. Schottky defect in crystals is observed when
 1) unequal number of cations and anions are missing from the lattice
 2) equal number of cations and anions are missing from the lattice
 3) an ion leaves its normal site and occupies an interstitial site
 4) density of the crystal is increased
57. How many kinds of space lattices are possible in crystals?
 1) 23 2) 7 3) 230 4) 14
58. A compound formed by elements A and B crystallises in the cubic structure where A atoms are at the corners of a cube and B atoms are at the face-centres. The formula of the compound is
 1) AB_2 2) AB 3) A_3B 4) A_2B_2
59. The number of unit cells in 58.8 g of NaCl is nearly
 1) 6×10^{20} 2) 3×10^{22} 3) 1.5×10^{23} 4) 0.5×10^{24}
60. In a solid AB having the NaCl structure, 'A' atoms occupy the corners of the cubic unit cell. If all the face-centred atoms along one of the axes are removed, then the resultant stoichiometry of the solid is
 1) AB_2 2) A_2B 3) A_4B_3 4) A_3B_4
61. When molten zinc is cooled to solid state, it assumes HCP structure. Then the number of nearest neighbours of zinc atom will be
 1) 4 2) 6 3) 8 4) 12
62. A substance A_xB_y crystallizes in a face centred cubic (FCC) lattice in which atoms 'A' occupy each corner of the cube and atoms 'B' occupy the centres of each face of the cube. Identify the correct composition of the substance A_xB_y
 1) AB_3 2) A_4B_3 3) A_3B 4) composition cannot be specified
63. Which of the following crystals does not exhibit Frenkel defect
 1) AgBr 2) AgCl 3) KBr 4) ZnS
64. Due to Frenkel defect, the density of ionic solids
 1) decreases 2) increases 3) does not change 4) changes
65. Which of the following is Bragg's equation?
 1) $n\lambda = 2\theta \sin\theta$ 2) $n\lambda = 2d \sin\theta$
 3) $2n\lambda = d \sin\theta$ 4) $n \theta/2 = d/2 \sin\theta$
66. A compound formed by elements A and B has a cubic structure in which A atoms are at the corners of the cube and B atoms are at the face centres. The formula of the compound will be
 1) $\text{A}_8\text{B}_6 = \text{A}_4\text{B}_3$ 2) $\text{A}_8\text{B}_4 = \text{A}_2\text{B}$
 3) AB_3 4) A_2B_3

67. A compound contains P and Q elements. Atoms Q are in **ccp** arrangement while P occupy all tetrahedral sites. Formula of compound is
 1) PQ 2) PQ₂ 3) P₂Q 4) P₃Q
68. A binary solid (A⁺B⁻) has zinc blende structure with B⁻ ions constituting the lattice and A⁺ ions occupying 25% tetrahedral holes. The formula of solid is
 1) AB 2) A₂B 3) AB₂ 4) AB₄
69. In a metal oxide, the oxide ions are arranged in hexagonal close packing and metal ions occupy two-third of the octahedral voids. The formula of the oxide is
 1) MO 2) M₂O₃ 3) MO₂ 4) M₂O
70. A solid AB has NaCl type structure. If the radius of the cation A is 100 pm, then the radius of the anion B will be
 1) 241 pm 2) 414 pm 3) 225 pm 4) 44.4 pm
71. The radius of Na⁺ is 95 pm and that of Cl⁻ ion is 181 pm. Hence the co-ordination number of Na⁺ will be
 1) 4 2) 6 3) 8 4) unpredictable
72. The ionic radii of Rb⁺ and I⁻ are 1.46 and 2.16 Å respectively. The most probable type of structure exhibited by it is
 1) CsCl type 2) NaCl type 3) ZnS type 4) CaF₂ type
73. If the radius of K⁺ and F⁻ are 133 pm and 136 pm respectively, the distance between K⁺ and F⁻ in KF is
 1) 269 pm 2) 134.5 pm 3) 136 pm 4) 3 pm
74. The second order Bragg diffraction of X-rays with $\lambda = 1.00 \text{ \AA}$ from a set of parallel planes in a metal occurs at an angle of 60°. The distance between the scattering planes in the crystal is
 1) 0.575 Å 2) 1.00 Å 3) 2.00 Å 4) 1.15 Å
75. The wavelength of X-rays which gives a diffraction angle, 2θ, equal to 16.80° for a first order diffraction for a crystal with interplanar distance 0.200 nm, is (given $\sin 8.4^\circ = 0.146$)
 1) 0.0584 nm 2) 0.1168 nm 3) 0.0292 nm 4) 0.2336 nm
76. If NaCl is doped with 10⁻³ mol % SrCl₂ then the concentration of cation vacancies will be
 1) 1×10⁻³ mol% 2) 2×10⁻³ mol% 3) 3×10⁻³ mol% 4) 4×10⁻³ mol%
77. A binary solid (A⁺B⁻) has a rock salt structure. If the edge length is 40 pm and radius of cation is 75 pm, the radius of anion is
 1) 100 pm 2) 125 pm 3) 250 pm 4) 325 pm
78. A metal has **bcc** structure and the edge length of its unit cell is 3.04 Å. The volume of the unit cell in cm³ will be
 1) 1.6×10⁻²¹ cm³ 2) 2.81×10⁻²³ cm³ 3) 6.02×10⁻²³ cm³ 4) 6.6×10⁻²⁴ cm³
79. The radius of an atom of an element is 500 pm. If it crystallises as a face-centred cubic lattice, the length of the side of unit cell is
 1) 176.8 cm 2) 1154.7 pm 3) 1414 pm 4) 1000 pm
80. In a face centred cubic arrangement of A and B atoms in which A atoms are at the corners of the unit cell and B atoms at the face centres, one of the A atom is missing from one corner in unit cell. The simplest formula of compound is
 1) A₇B₃ 2) AB₃ 3) A₇B₂₄ 4) A_{7/8}B₃
81. An alloy of copper, silver and gold is found have copper constituting the **ccp** lattice. If silver atoms occupy the edge centres and gold is present at body centre, the alloy has a formula
 1) Cu₄Ag₂Au 2) Cu₄Ag₄Au 3) Cu₄Ag₃Au 4) CuAgAu

82. Which of the following statements is correct in the antifluorite structure of an ionic compound?
- 1) Coordination number of anion is four and that of cation is eight
 - 2) Coordination number of anion is eight and that of cation is four
 - 3) Coordination number of each cation and anion is four
 - 4) Coordination number of each cation and anions is six
83. 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
- 1) CA
 - 2) CA₂
 - 3) C₂A₃
 - 4) C₃A₂
84. In the spinel structure, oxides ions are cubical-closest packed whereas $1/8^{\text{th}}$ of tetrahedral voids are occupied by A²⁺ cations and $1/2$ of octahedral voids are occupied by B³⁺ cations. The general formula of the compound having spinel structure is
- 1) A₂B₂O₄
 - 2) AB₂O₄
 - 3) A₂B₂O₂
 - 4) A₄B₂O₂
85. The expression to compute the density of metals crystallizing in cubic crystal is
- 1) $\rho = \frac{N}{a^3} \left(\frac{M}{N_A} \right)$
 - 2) $\rho = \frac{N}{a^3} \left(\frac{N_A}{M} \right)$
 - 3) $\rho = a^3 \left(\frac{M}{N_A} \right) \times N$
 - 4) $\rho = \frac{a^3}{N} \left(\frac{N_A}{M} \right)$
86. In the body-centred cubic unit cell of closest packed atoms, the radius of atom in terms of edge length (a) of the unit cell is
- 1) a/2
 - 2) $a\sqrt{2}$
 - 3) $a/2\sqrt{2}$
 - 4) $\sqrt{3} a/4$
87. In the face-centred cubic unit cell of closest packed atoms, the radius of atoms in terms of edge length (a) of the unit cell is
- 1) a/2
 - 2) $a\sqrt{2}$
 - 3) $a/2\sqrt{2}$
 - 4) $\sqrt{3} a/4$
88. Which of the following expressions is correct in case of a sodium chloride unit cell (edge length, a)?
- 1) $r_c + r_a = a$
 - 2) $r_c + r_a = a/2$
 - 3) $r_c + r_a = 2a$
 - 4) $r_c + r_a = \sqrt{2}a$
89. If 'a' is the edge length of unit cell of sodium chloride, the distance between two nearest Na⁺ ions is
- 1) a
 - 2) $\sqrt{2}a$
 - 3) $\sqrt{3}a$
 - 4) $a/\sqrt{2}$
90. Which of the following statements for crystals having Schottky defect is not correct?
- 1) Schottky defect arises due to the absence of a cation or anion from the position which it is expected to occupy
 - 2) Schottky defects are more common in ionic compounds with high coordination numbers
 - 3) The density of the crystals having schottky defect is larger than that of the perfect crystal
 - 4) The crystal having Schottky defect is electrical neutral as a whole .
91. Which of the following statements for crystals having Frenkel defect is not correct
- 1) Frenkel defects are observed where the difference in sizes of cations and anions is large
 - 2) The density of crystals having Frenkel defect is lesser than that of a pure perfect crystal
 - 3) In an ionic crystal having Frenkel defect may also contain Schottky defect
 - 4) Pure alkali halides do not have Frenkel defect
92. Which of the following statements is not correct?
- 1) The coordination number of each type of ion in CsCl is 8.
 - 2) A metal that crystallises in **bcc** structure has a coordination number of 12
 - 3) A unit cell of an ionic crystal shares some of its ions with other unit cells
 - 4) The length of the unit cell in NaCl is 552 pm. ($r_{\text{Na}^+} = 95 \text{ pm}$, $r_{\text{Cl}^-} = 181 \text{ pm}$)

KEY :

1) 3	2) 4	3) 3	4) 4	5) 3
6) 2	7) 2	8) 3	9) 4	10) 4
11) 1	12) 1	13) 2	14) 1	15) 1
16) 1	17) 2	18) 3	19) 3	20) 1
21) 4	22) 4	23) 3	24) 2	25) 2
26) 1	27) 4	28) 3	29) 4	30) 2
31) 4	32) 2	33) 4	34) 2	35) 1
36) 2	37) 1	38) 4	39) 3	40) 1
41) 1	42) 1	43) 1	44) 3	45) 3
46) 3	47) 1	48) 4	49) 3	50) 3
51) 1	52) 4	53) 1	54) 3	55) 2
56) 2	57) 4	58) 1	59) 3	60) 4
61) 4	62) 1	63) 3	64) 3	65) 2
66) 3	67) 3	68) 3	69) 2	70) 1
71) 2	72) 2	73) 1	74) 4	75) 4
76) 1	77) 2	78) 2	79) 3	80) 3
81) 3	82) 2	83) 3	84) 2	85) 3
86) 4	87) 3	88) 2	89) 4	90) 3
91) 2	92) 2			