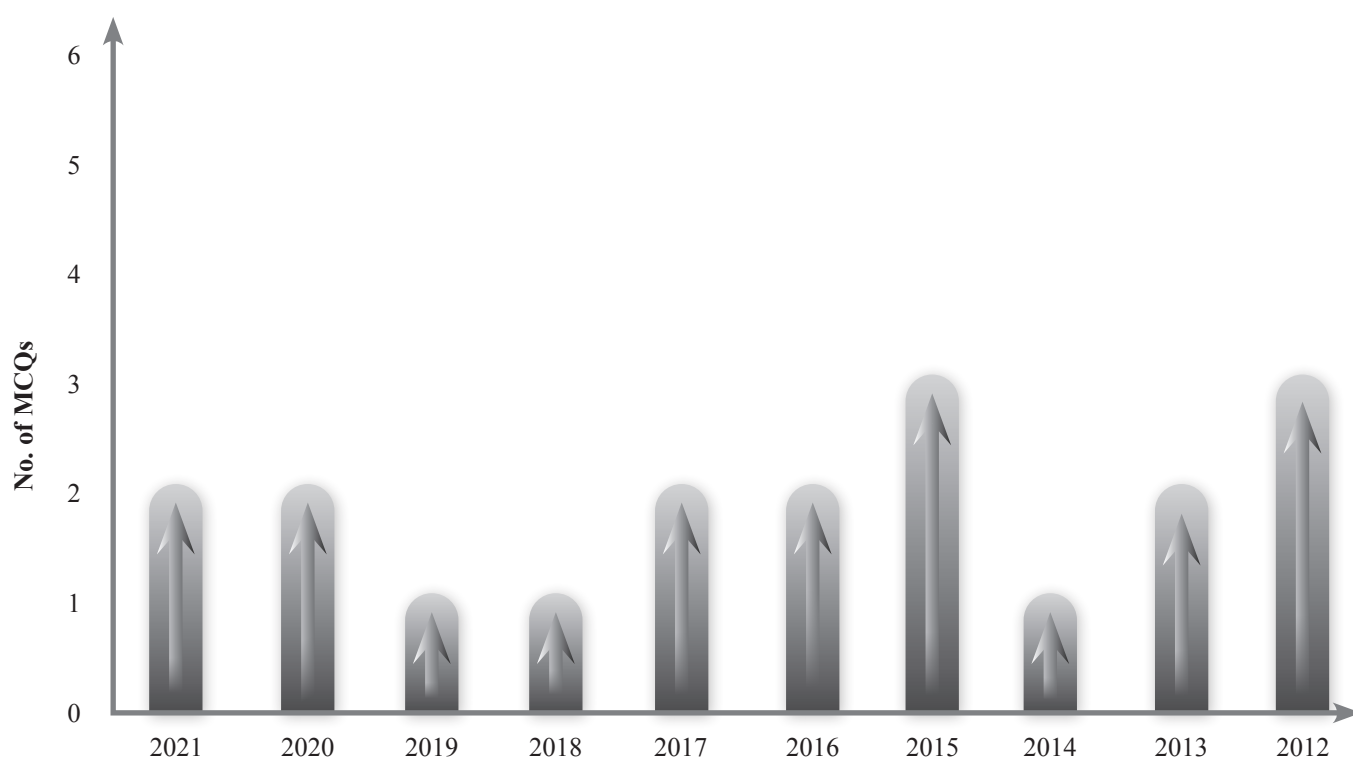


9

THE SOLID STATE

Past Years NEET Trend



Investigation Report

TARGET EXAM	PREDICTED NO. OF MCQs	CRITICAL CONCEPTS
NEET	1-2	- Packing fraction - Imperfections in solids

Perfect Practice Plan

Topicwise Questions	Learning Plus	Multiconcept MCQs	NEET Past 10 Years Questions	Total MCQs
96	37	25	19	177

INTRODUCTION

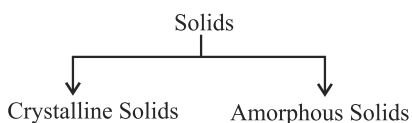
The particles in solid are closely packed and held together by strong intermolecular forces.

Properties of Solids

In solid state the particles are not able to move randomly.

- They have definite shape and volume.
- Solids have high density.
- Solids have high and sharp melting point which depend on the strength or value of binding energy.
- They are very low compressible.
- They show very slow diffusion.

TYPES OF SOLID



(1) Amorphous Solids

In amorphous solids, the arrangement of building constituents is not regular.

- They have a short range order.
- Their melting points are not sharp.
- They are isotropic in nature.
- They are known as super cooled liquids with high viscosity in which the force of attraction holding the molecules together are so large, that the material becomes rigid but there is no regularity in structure.
- The general examples of these solids are glass, rubber, plastics etc.

(2) Crystalline Solids

In crystalline solids, the arrangement of building constituents is regular throughout the entire 3-D network.

- A crystalline solid has sharp melting point
- It is anisotropic in nature.
- It has long range order.
- They are generally incompressible.
- The general examples of crystalline solids are Quartz, diamond etc.

Table: Difference between crystalline and amorphous

	Property	Crystalline solids	Amorphous solids
1.	Shape	They have definite and regular geometrical form.	They do not have definite and regular geometrical form.
2.	Melting point	They have fixed melting point.	They do not have definite melting point.
3.	Heat of fusion	They have a definite heat of fusion.	They do not have fixed heat of fusion.
4.	Compressibility	They are rigid and incompressible.	These may be compressed to any appreciable extent.
5.	Cleavage Property (cutting with a Sharp edged tool)	They break into two pieces with plane surfaces.	They break into two pieces with irregular surfaces.
6.	Anisotropy Nature	They are anisotropic.	They are isotropic.

KEY NOTE

The window glass of old buildings thick at the bottom as glass is not a true solid but is a supercooled liquid that has high viscosity (called pseudo-solid). It has the property to flow. Hence, window glass of old building is thick at bottom.

Classification of Crystalline Solids

Based upon the nature of the constituent particles and binding forces present between them, crystalline solids are further classified into following:

- (i) Ionic Crystals:** The lattices in ionic crystal consist of alternate positive and negative ions in equivalent amount that is arranged in an order.
- (ii) Covalent Crystals:** In covalent crystals, atoms at their lattice points are bound together by shared pair of electrons between them.

(iii) Molecular Crystals:

- (a) Non-Polar molecular solid:** In molecular crystals, the repeating unit is chemically identifiable atoms or molecules that do not carry a net charge.
- (b) Polar Solids:** Molecular bonds are formed for those elements or compounds whose electronic configuration is such that there is little transfer of electrons between their atoms.
- (c) H-Bonded molecular solids:** The molecules having H-atom attached on N, O or F give hydrogen bonding crystals.

(iv) Metallic crystals:

In metallic crystals, the lattice consists of collections of positive ions immersed in a sea of mobile electrons.

Table: Different Types of Solid

	Types of Solid	Constituent Particles	Bonding/Attractive Force	Examples	Physical Nature	Electrical Conductivity	Melting Point
1.	Molecular solids						
	i. Non-polar	Molecules	Dispersion or London forces	Ar, CCl ₄ , H ₂ , I ₂ , CO ₂	Soft	Insulator	Very low
	ii. Polar		Dipole-dipole interactions	HCl, SO ₂	Soft	Insulator	Low
	iii. Hydrogen bonded		Hydrogen bonding	H ₂ O(ice)	Hard	Insulator	Low
2.	Ionic solids	Ions	Coulombic or electro-static	NaCl, MgO, ZnS, CaF ₂	Hard but brittle	Insulators in solid state but conductors in molten state and in aqueous solutions.	High
3.	Metallic Solids	Positive ions in a sea of free electrons	Metallic bonding	Fe, Cu, Ag, Mg	Hard but malleable and ductile	Conductors in solid state as well as in molten state	Fairly high
4.	Covalent or network solids	Atoms	Covalent bonding	SiO ₂ (quartz), SiC, C(diamond), C(graphite)	Hard Soft	Insulators Conductor (exception)	Very high

TRAIN YOUR BRAIN

Q. A solid X melts slightly above 273K and is a poor conductor of heat and electricity. To which of the following categories does it belong :

- (a) Ionic solid (b) Covalent solid
(c) Metallic solid (d) Molecular solid

Ans. (d) Molecular Solid

Q. Graphite is an example of :

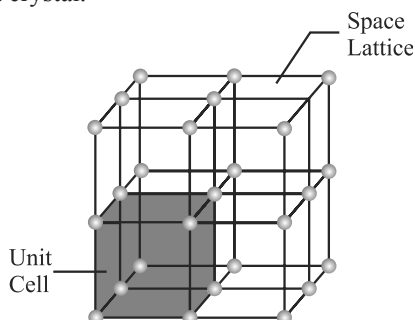
- (a) Ionic solid (b) Covalent solid
(c) Vander waal's crystal (d) Metallic crystal

Ans. (b) Covalent Solid

CRYSTAL LATTICES AND UNIT CELLS

Crystal : A crystal is a homogeneous portion of a solid substance that is made by regular pattern of structural units bonded by plane surface making definite angles with each other.

Crystal Lattice: It is the 3-D arrangement of identical points in the space which represent how the atoms, ions, molecules are arranged in a crystal.



Unit Cell: A unit cell is the smallest portion of a space lattice which, when repeated in different directions, creates the entire lattice.

Unit cell is divided into two categories:

- (i) Primitive unit cell
(ii) Centred unit cell

(i) Primitive Unit Cells:

When constituent particles are present only on the corner positions of a unit cell, it is called as primitive unit cell.

(ii) 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:

- (a) **Body-Centred Unit Cells:** Such a unit cell contains one constituent particle (atom, molecule or ion) at its body-centre besides the ones that are at its corners.
(b) **Face-Centred Unit Cells:** Such a unit cell contains one constituent particle present at the centre of each face, besides the ones that are at its corners.
(c) **End-Centred Unit Cells:** In such a unit cell, one constituent particle is present at the centre of any two opposite faces besides the ones present at its corners.

On the basis of the axial distance and the axial angles between the edges, the primitive unit cells can be divided into seven systems.

Table: Seven Primitive Unit Cells and their Possible Variations as Centred Unit Cell

Crystal System	Possible variations	Axial Distance or Edge lengths	Axial angles	Example
Cubic	Primitive, Body-centred, Face-centred	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	NaCl, Zinc blende, Cu, KCl, Diamond
Tetragonal	Primitive, Body-centred	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	White tin, SnO_2 , TiO_2 , CaSO_4
Orthorhombic or Rhombic	Primitive, Body-centred, Face-centred, End-centred	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Rhombic sulphur, KNO_3 , BaSO_4
Hexagonal	Primitive	$a = b \neq c$	$\alpha = \beta = 90^\circ; \gamma = 120^\circ$	Graphite, ZnO, CdS,
Rhombohedral or Trigonal	Primitive	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	Calcite (CaCO_3) HgS (cinabar), Sb
Monoclinic	Primitive, End-centred	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ, \beta \neq 90^\circ$	Monoclinic sulphur, PbCrO_4 , $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$
Triclinic	Primitive	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	$\text{K}_2\text{Cr}_2\text{O}_7$, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, H_3BO_3

KEY NOTE

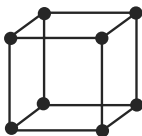
Out of the seven crystal systems, cubic is the most symmetrical ($a = b = c$, $\alpha = \beta = \gamma = 90^\circ$) while triclinic is the most unsymmetrical system ($a \neq b \neq c$, $\alpha \neq \beta \neq \gamma \neq 90^\circ$).

Number of Atoms in a Unit Cell

(i) Simple cubic:

Each corner atom is shared by eight surrounding cubes.

Therefore, it contributes for $\frac{1}{8}$ of an atom.



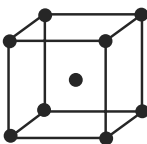
$$\therefore Z = 8 (\text{corner atoms}) \times \frac{1}{8} \text{ atom per unit cell} = 1 \text{ atom}$$

(ii) Body-centred cubic:

Eight Corner atoms contribute one atom per unit cell.

Centre atom contribute one atom per unit cell.

$$\begin{aligned} \therefore Z &= 8 (\text{corner atoms}) \times \frac{1}{8} \text{ atom per unit cell} \\ &+ 1 (\text{body centre atom}) \times 1 \text{ atom per unit cell} \\ &= 1 + 1 = 2 \text{ atoms} \end{aligned}$$

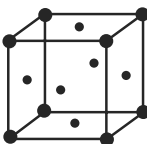


(iii) Face-centred cubic:

The eight corners atoms contribute for $\frac{1}{8}$ of an atom and thus one atom per unit cell.

Each of six face centered atoms is shared by two adjacent unit cells and therefore one face centred atom contribute half of its share.

$$\begin{aligned} \text{So, total } Z &= 8 (\text{corner atoms}) \times \frac{1}{8} \text{ atom per} \\ &\text{unit cell} + 6 (\text{face atoms}) \times \frac{1}{2} \text{ atom per unit} \\ &\text{cell} = 1 + 3 = 4 \text{ atoms} \end{aligned}$$



Contribution of n atoms present at different lattice site

- Contribution by a particle on the corner of a unit cell = $\frac{1}{8}$
- Contribution by a particle on the face of a unit cell = $\frac{1}{2}$
- Contribution by a particle within the body of a unit cell = 1
- Contribution by a particle on the edge of a unit cell = $\frac{1}{4}$

KEY NOTE

- In a cube, there are 8 corners, 6 face centres, 12 edge centres and one body centre
- The atoms on the body diagonals are not shared with any other unit cell.
- Formula of a compound is same as ratio of atoms in the unit cell.

TRAIN YOUR BRAIN

Q. 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. Derive the formula of the compound.

Ans. As A atoms are present at the 8 corners of the cube, therefore numbers of atoms of A in the unit cell

$$= \frac{1}{8} \times 8 = 1$$

As B atoms are present at the face centres of the 6 faces of the cube, therefore, numbers of atoms of B in the

$$\text{unit cell} = \frac{1}{2} \times 6 = 3$$

$\therefore$ Ratio of atoms A : B = 1 : 3

Hence, the formula of the compound is AB_3

Q. A cubic solid is made up of two elements X and Y. Atoms Y are present at the corners of the cube and atoms X at body centre. What is the formula of the compound ?

Ans. As atoms Y are present at the 8 corners of the cube, therefore, numbers of atoms of Y in the unit cell = $1/8 \times 8 = 1$
As atoms X are present at the body centre. Therefore, numbers of atoms of X in the unit cell = 1
 $\therefore$ ratio of atoms X : Y = 1 : 1

Hence, the formula of the compound is XY

CLOSE PACKED STRUCTURES

(i) Close packing in one dimension:

Spheres are arranged in a row touching each other.

In this arrangement, each sphere is in contact with two of its neighbours.

The no. of nearest neighbours of a particle is known as **coordination number**.

The coordination number in one dimension in close packing is 2.



Fig.: Close packing in one dimension

(ii) Close Packing in two dimensions

In two dimensions there are two ways of packing the spheres (in moving from one dimension to two dimensions it can be imagined that the two dimensional array will be made up of 1-D closed pack arrays/lines which are stacked one on top of other).

(a) Square Close Packing

The second row is placed directly above the first row.

In this arrangement, each sphere is in contact with four of its neighbours so, it has AAA type arrangement.

The coordination number is 4.

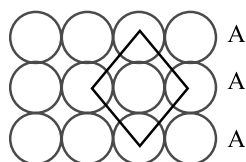


Fig.: Square close packing

(b) Hexagonal Close Packing

When second row of spheres are placed in depressions of first row and forming a pattern ABAB.

This is more efficient and leaves small space.

Coordination number is 6.

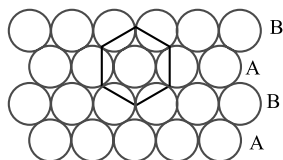


Fig.: Hexagonal close packing

(iii) Close Packing in three dimensions

(a) Hexagonal close packing (HCP)

In this arrangement, the spheres of the second layer (B) occupy the depressions of the first layer (A).

The sphere of the third layer are vertically aligned with those in the first layer (A) giving ABABAB type arrangement.

This packing is more efficient.

Coordination number is 12.

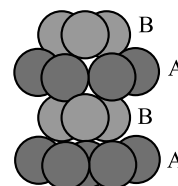


Fig.: Hexagonal

(b) Cubic close packing (ccp)

In this arrangement the spheres of second layer is placed over the voids of the first layer.

The spheres of third layer cover the octahedral voids of the second layer.

The fourth layer sphere is similar to first, fifth layer to second and sixth to third giving ABCABCABC type arrangement. This is called ccp or fcc arrangement.

Coordination number is 12.

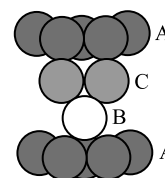


Fig.: Cubic

Types of Voids in Crystal

Voids or Holes

The empty spaces between close packed spheres are called voids or holes.

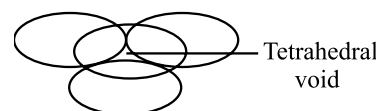
They are of three types:

(i) **Triangular void:** Void between three touching spheres.

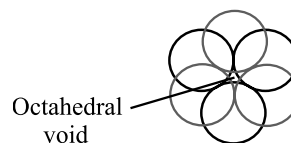
Radius ratio $\left[\frac{r_{\text{void}}}{r_{\text{sphere}}} \right]$ is 0.155.

There are 8 triangular voids per atom in a crystal.

(ii) **Tetrahedral void:** Hole/Void between four spheres that lie at the vertices of a regular tetrahedron. There are 2 tetrahedral voids per atom in a crystal. Radius ratio is 0.225.



(iii) **Octahedral void:** Void between six spheres. There is 1 octahedral void per atom in a crystal. The radius ratio is 0.414.



KEY NOTE

In the cubic close packing (ccp), i.e. face-centred cubic (fcc) unit cell, there are 4 atoms or ions per unit cell, therefore, there are 4 octahedral voids and 8 tetrahedral voids.

TRAIN YOUR BRAIN

Q. What is the formula of a compound in which the element P forms *hcp* lattice and atoms of Q occupy 2/3rd of octahedral voids?

Ans. Let the number of atoms of P in *hcp* lattice = N
So, number of octahedral voids = N

$$\therefore \text{Number of Q atoms} = \frac{2}{3} \times N = \frac{2}{3}N$$
$$\text{Q:P} = \frac{2}{3}N : N = 2:3$$

Hence, the formula of the compound is Q_2P_3 .

IONIC SOLIDS

In ionic solids, there are two type of particles that is cation and anion. The stability of ionic solids is described in terms of radius ratio.

$$\text{Radius ratio} = \frac{r}{R} = \frac{\text{radius of cation}}{\text{radius of anion}}$$

Greater the radius ratio, larger the size of the cation and hence the coordination no.

The commonly known observed coordination number in ionic solids are 3, 4, 6, 8

Table: Limiting radius ratio and structure

No.	Radius ratio	Co-ordination number	Shape
1.	0.0 – 0.155	2	Linear
2.	0.155 – 0.225	3	Triangular Planar
3.	0.225 – 0.414	4	Tetrahedral
4.	0.414 – 0.732	6	Octahedral
5.	0.732 – 1.0	8	Cubic

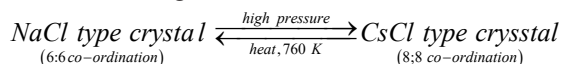
The different types of crystal structures of some Ionic Solids

Table: Crystal Structure of Some Cubic Ionic Solids

No.	Crystal Structure Units	Brief description and Examples	Co-ordination Number	No. of formula per Unit cell
1.	Rock Salt (NaCl-type)	Cl^- ions form c.c.p; Na^+ ions occupy all the octahedral voids. Examples: Halides of Li, Na, K and Rb, AgCl, AgBr, NH_4Cl etc.	$\text{Na}^+ - 6$ $\text{Cl}^- - 6$	4
2.	CsCl - type	Cl^- ions at the corners of cube and (<i>b.c.c.</i>) structure Cs^+ ions in the cubic void Examples: CsCl, CsBr, etc.	$\text{Cs}^+ - 8$ $\text{Cl}^- - 8$	1
3.	Zinc blends (ZnS)	S^{2-} ions in CCP; Zn^{2+} ions occupy alternate tetrahedral voids i.e. only half of the total number of tetrahedral voids are occupied. Examples: ZnS, CuCl, AgI etc.	$\text{Zn}^{2+} - 4$ $\text{S}^{2-} - 4$	4
4.	Fluorite structure (CaF_2 -type)	Ca^{+2} ions (+ve ions) form CCP and F^- ions(-ve ions) in all the tetrahedral voids. Example: CaF_2 , SrF_2 , BaF_2 , BaCl_2 etc.	$\text{Ca}^{+2} - 8$ $\text{F}^- - 4$	4
5.	Antifluorite structure (Na_2O -type)	Negative ions i.e. O^{2-} form CCP and positive Na^+ ions in all the tetrahedral voids. Example: K_2O	$\text{Na}^+ - 4$ $\text{O}^{2-} - 8$	4

Effect of Pressure on Crystal Structure

Increase of pressure increases the co-ordination number during crystallization e.g. by applying high pressure, the NaCl crystal structure having 6:6 co-ordination number changes to CsCl crystal structure having co-ordination number 8:8.



Effect of Temperature on Crystal Structure

Increase of temperature, decreases the co-ordination number e.g., upon heating to 760 K, the CsCl crystal structure having co-

ordination of 8:8 changes to NaCl crystal structure having co-ordination of 6 : 6

KEY NOTE

ZnS exists in two forms called zinc blende and wurtzite. Both have a close packed arrangement of S^{2-} ions. In both, Zn^{2+} ions occupy tetrahedral voids. Both have 4:4 structure. They differ only in the fact that zinc blende has *ccp* or *fcc* arrangement whereas wurtzite has *hcp* arrangement of S^{2-} ions. As a result, unit cell of wurtzite has 6 formula units of ZnS whereas zinc blende has 4.

TRAIN YOUR BRAIN

Q. In antifluorite structure, the negative ions -

- Occupy tetrahedral voids
- Occupy octahedral voids
- Are arranged in ccp
- Are arranged in hcp

Ans. (c)

PACKING EFFICIENCY

It is the percentage of total space filled by the particles.

Packing efficiency

$$= \frac{\text{volume occupied by atoms in unit cell}}{\text{Total volume of the unit cell}} \times 100\%$$

Packing efficiency in different types of structures

Simple cubic unit cell

Let edge length = a , for pure elements, radius $r = \frac{a}{2}$ (because atoms are touching each other)

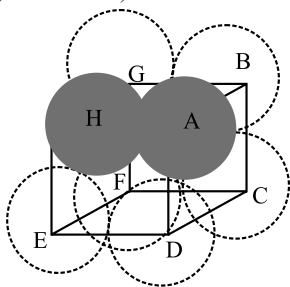


Fig.: Simple cubic unit cell

$$P.E. = \frac{\text{volume occupied by per unit cell}}{\text{volume of one unit cell}} \times 100\%$$

$$= \frac{\frac{4}{3}\pi r^3}{a^3} = \frac{4}{3(2r)^3} \pi r^3 = \frac{4\pi r^3}{3 \times 8 r^3} \times 100 = 52\%$$

Face-centred Cubic (hcp and ccp)

Let edge length = a , face diagonal $AC = b$

In $\triangle ABC$

$$AC^2 = AB^2 + BC^2 = a^2 + a^2 = 2a^2$$

$$\therefore b = \sqrt{2}a$$

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

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

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

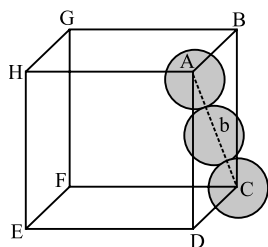


Fig.: Cubic close packing

$$P.E. = \frac{\text{Volume occupied}}{\text{Total volume of unit cell}} \times 100$$

$$= \frac{4 \times \left(\frac{4}{3}\right) \pi r^3}{(2\sqrt{2}r)^3} \times 100 = 74\%$$

Body-centred cubic

Atom at the center will be in touch with other 2 atoms diagonally arranged in BCC.

In $\triangle EFD$

$$b^2 = a^2 + a^2 = 2a^2$$

$$b = \sqrt{2}a$$

Now in $\triangle AFD$

$$c^2 = a^2 + b^2 \Rightarrow a^2 + 2a^2 = 3a^2$$

$$c = \sqrt{3}a$$

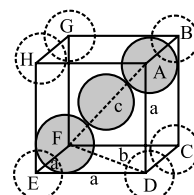


Fig.: Body-centred Cubic Unit

Length of body diagonal is $4r$, as all the three spheres along diagonal touch each other.

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

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

Total no. of atom is 2 in BCC

$$\begin{aligned} \text{Packing efficiency} &= \frac{2 \times \frac{4}{3} \pi r^3}{4 \times 4 \times 4 r^3} \times \sqrt{3} \times \sqrt{3} \times \sqrt{3} \times 100 \\ &= \frac{\pi \sqrt{3}}{8} \times 100 = 68\% \end{aligned}$$

Table: Types of Unit cell and their Packing Efficiency

Type of Unit cell	Coordination Number	Packing Efficiency	Relation b/w a and r
Simple Cubic	6	52.4%	$2r = a$
BCC	8	68 %	$4r = \sqrt{3}a$
FCC	12	74 %	$4r = \sqrt{2}a$

KEY NOTE

- Diamond has packing efficiency

$$= \frac{\pi \sqrt{3}}{16} = 0.34 \text{ or } 34\%$$

- All noble gases have ccp structure except helium which has hcp structure.
- Rhombohedral is similar to hexagonal close packing with 12 nearest neighbours and packing fraction of 0.74.

CALCULATION INVOLVING UNIT CELL DIMENSIONS

Density of Unit cells

Let edge of a unit cell of a cubic crystal is a , d is the density of the substance and M is the molar mass, then in case of cubic crystal, Mass of unit cell = Number of atoms in unit cell $\times$ Mass of each atom = $Z \times m$

$$\text{Mass of each atom (m)} = \frac{\text{Molar mass}}{\text{Avogadro number}}$$

$$m = \frac{M}{N_A}$$

$$\text{Mass of unit cell} = \frac{Z \times M}{N_A}$$

$$\text{Volume of a unit cell} = a^3$$

Therefore, density of the unit cell,

$$d = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$$

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

Where Z = number of atoms in unit cell, M = molar mass, a = edge length, $N_A = 6.022 \times 10^{23}$, d is in g/cm^3 , a in cm.

KEY NOTE

For BCC structure of pure elements, $Z = 2$ but for BCC structure of ionic compounds like CsCl, $Z = 1$

TRAIN YOUR BRAIN

Q. Sodium has a bcc structure with nearest neighbour distance 365.9 pm. Calculate its density (Atomic mass of sodium = 23)

Ans. For the bcc structure, nearest neighbour distance (d) is

$$\text{related to the edge (a) as } d = \frac{\sqrt{3}}{2}a$$

$$\text{or } a = \frac{2}{\sqrt{3}}d = \frac{2}{1.732} \times 365.9 = 422.5 \text{ pm}$$

For bcc structure, $Z = 2$

For sodium, $M = 23$

$$\therefore D = \frac{Z \times M}{a^3 \times N_0} = \frac{2 \times 23 \text{ g mol}^{-1}}{(422.5 \times 10^{-10} \text{ cm})^3 \times (6.02 \times 10^{23} \text{ mol}^{-1})}$$

$$= 1.01 \text{ g/cm}^3$$

Q. Density of Li atom is 0.53 g/cm^3 . The edge length of Li is $3.5 \text{ \AA}$. Find out the number of Li atoms in a unit cell ($N_A = 6.023 \times 10^{23}$, $M = 6.94$).

$$\text{Ans. } d = \frac{Z \times M}{a^3 \times N_A}$$

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

$$= \frac{0.53 \text{ g cm}^{-3} \times (3.5 \times 10^{-8} \text{ cm})^3 \times (6.023 \times 10^{23} \text{ mol}^{-1})}{6.94 \text{ g mol}^{-1}} = 1.97 \approx 2$$

IMPERFECTION IN SOLIDS

Point Defects: They are the irregularities or deviation from ideal arrangement around a point or an atom in a crystalline substance.

Line defects: If atoms/ions are misplaced/missing/replaced by some other ions along a line.

Interstitials: Atoms or ions which occupy normally voids in a crystal are called interstitial.

Vacancy: When one of the constituent particles is missing from the crystal lattice, this unoccupied position is called vacancy.

Types of Point Defects

(1) Stoichiometric Defects:

The point defects that do not disturb the stoichiometry of the solid are called stoichiometric defects.

(a) **Vacancy defect:** If some of the lattice sites are vacant, the crystal is said to have vacancy defect. It results in decrease in density of the substance. This defect can arise if a substance is heated.

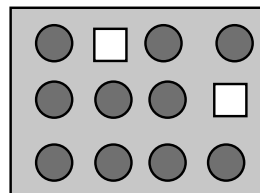


Fig.: Vacancy defect

(b) **Interstitial defect:** If some constituent particles (atoms or molecules) occupy an interstitial site, the crystal is said to have interstitial defect. Due to this defect the density of the substance increases. Ionic solids show these as Schottky and Frenkel defects.

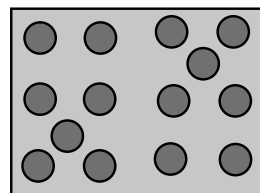


Fig.: Interstitial defects

(c) **Schottky defect:** This defect arises if equal number of cations and anions are missing from a lattice. It is a common defect in ionic compounds of high coordination number where both cations and anions are of the same size. E.g., NaCl, KCl, CsCl, AgBr, etc.

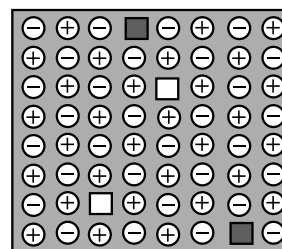


Fig.: Schottky defects

(d) **Frenkel defect:** This defect arises if some of the ions of the lattice occupy interstitial sites leaving lattice sites vacant. This defect is generally found in ionic crystals where anion size is much larger than the cation size e.g., AgBr, ZnS.

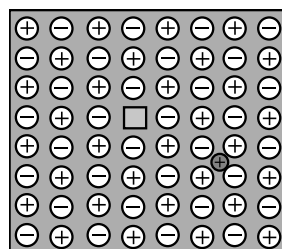


Fig.: Frenkel defects

(2) Impurity Defects

These defects arise if foreign atoms or ions are present in the lattice site (substitutional solid solutions) or in the interstitial sites (interstitial solid solutions). When molten NaCl that contain 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.

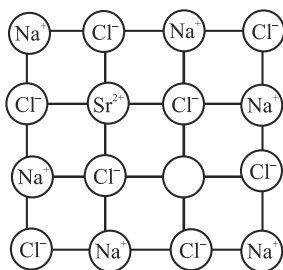


Fig.: Impurity defect

(3) Non-stoichiometric Defects

These defects arise when stoichiometry of a substance is disturbed. These are of two types:

(i) **Metal excess defect:** This may occur in either of the following two ways:

(a) **Metal excess defect due to anion vacancies:** In this defect a negative ion from the crystal lattice can be missing from its lattice site leaving a hole or vacancy which is occupied by the electron originally associated with the anion.

F-centres: The anionic sites occupied by unpaired electrons. F-centres impart colour to crystals. They impart yellow colour to NaCl crystals, violet colour to KCl crystals and pink colour to LiCl crystals.

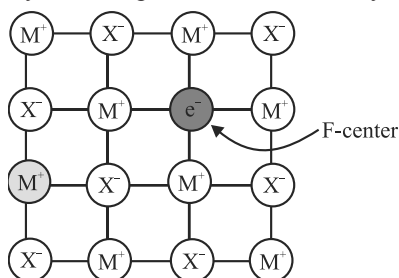
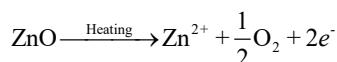


Fig.: Metal excess defects due to anion vacancies

(b) **Metal excess defect due to interstitial cation:** In this defect an extra positive ion occupies interstitial sites and the free electron is trapped in the surrounding area of this interstitial cation.



The excess of Zn^{2+} ions move to interstitial sites and the electrons to neighbouring interstitial sites.

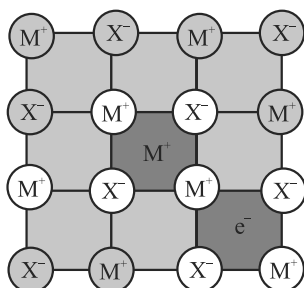


Fig.: Metal excess defects due to interstitial cation

(ii) **Metal deficiency defect:** This type of defect generally occurs if metal shows variable valency. This type of defect arises due to the missing of cation from its lattice site and the presence of the cation that have higher charge in the adjacent lattice site.

KEY NOTE

- NaCl sometimes appear yellow in colour. Yellow colour in sodium chloride is due to metal excess defect due to which unpaired electrons occupy anionic sites.
- These sites are known as F-centres. These unpaired electrons absorb some energy from the visible light for the excitation that makes crystal appear yellow.

TRAIN YOUR BRAIN

Q. What type of stoichiometric defect is shown by ZnS?

Ans. ZnS show Frenkel defect as its ions have a large size difference.

Q. In a crystal both ions are missing from normal sites in equal number. This is an example of -

- (a) F - centres (b) Interstitial defect
(c) Frenkel defect (d) Schottky defect

Ans. (d) Schottky defects are formed when one positive ion and one negative ion are missing from their respective positions leaving behind a pair of holes. These are more common in ionic compounds with high coordination number and having almost same size of cations and anions

PROPERTIES OF SOLID

Electrical Properties

Solids are classified into three groups on basis of conductivity:

- (a) Conductors
(b) Insulators
(c) Semiconductors

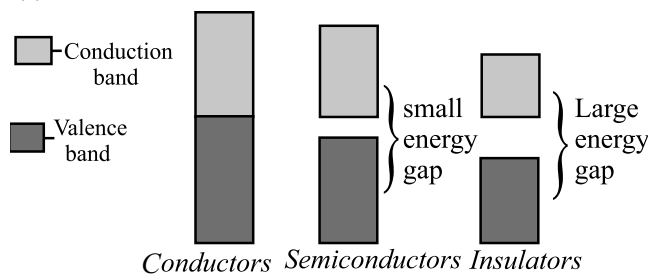


Fig.: Classification of solid on basis of conductivity

Causes of conductance in Solids

Conduction is through electron movement.

In ionic solids, conduction is by movement of free ions.

In case of insulators, the gap between valence band and conduction band is too large. So they do not conduct electricity.

Electrical conductivity of semiconductors increases with increase in temperature.

The conductivity of pure silicon and germanium is too low. So, there is need to increase the conductance by doping.

Classification of Semiconductors

- Intrinsic:** In these, conductivity increases with rise in temperature as electrons jump from valence band to conduction band. These are pure semiconductors.
- Extrinsic:** The conductivity of pure semiconductors can be increased by adding some impurities in it. These are extrinsic semiconductors.

Doping: The addition of a small amount of impurity in semiconductors is called doping.

Depending upon doping, extrinsic semiconductors are of two types.

n-type Semiconductor: When Si or Ge (having 4 valence electrons) is doped with a group 15 element like P or As with five valence electrons, four out of five electrons are used to form covalent bonds with Si or Ge atoms.

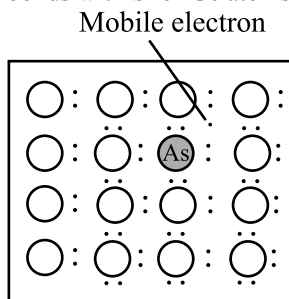


Fig.: n-type semiconductor

The fifth electron is extra and becomes delocalised and thus increases the conductivity. As conductivity is due to negatively charged electron, it is called n-type semiconductor.

p-type Semiconductor: When Si or Ge is doped with a group 13 element like B or Al (with three valence electrons), three covalent bonds are formed. At the place of fourth electron a hole is formed. An electron from neighbouring atom comes and fills the hole so it would leave a hole at its original position. Like the holes move through the crystal like a positive charge that cause electrical conductivity. Since the positive hole is responsible for conduction, it is called p-type semiconductor.

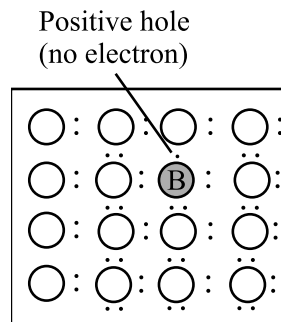


Fig.: p-type Semiconductor

Magnetic Properties

On the basis of their magnetic properties, substance can be classified into five categories:

- Paramagnetic
- Diamagnetic
- Ferromagnetic
- Antiferromagnetic and
- Ferrimagnetic.

Table: Magnetic Properties of Solid

Properties	Description	Alignment of Magnetic Dipoles	Examples	Applications
1. Diamagnetic	Feebly repelled by the magnetic field. Non-metallic elements (excepts O_2 , S) inert gases and species with paired electrons are diamagnetic	All paired electrons 	TiO_2 , V_2O_5 , $NaCl$, H_2O , C_6H_6	Insulator
2. Paramagnetic	Attracted by the magnetic field due to the presence of permanent magnetic dipoles (unpaired electrons). In magnetic field, these tend to orient themselves parallel to the direction of the field and thus, produce magnetism in the substances.	At least one unpaired electron 	O_2 , Cu^{2+} , Fe^{3+} , TiO , Ti_2O_3 , VO , VO_2 , CuO	Electronic appliances
3. Ferromagnetic	Permanent magnetism even in the absence of magnetic field, above a temperature called Curie temperature, there is no ferromagnetism.	Dipoles are aligned in the same direction 	Fe, Ni, Co, CrO_2	CrO_2 is used in audio and video tapes
4. Antiferromagnetic	This arises when the dipole alignment is zero due to equal and opposite alignment.		MnO, MnO_2 , Mn_2O , FeO, Fe_2O_3 ; NiO, Cr_2O_3 , CoO,	—
5. Ferrimagnetic	This arises when the dipole moment is not zero.		Co_3O_4 , Fe_3O_4 , ferrites	—

Curie Temperature:

When the ferromagnetic materials are heated above a particular temperature, it becomes paramagnetic. This temperature is called curie temperature.

Dielectric Properties

Table: Dielectric Properties

Material	Dielectric Constant	Loss Factor	Diel. Constant (Published)	Loss Factor (Published)
Water	77.79	7.371	77.89	6.789
Methanol	24.68	13.653	24.96	14.188
Dimethyl Sulphoxide	45.51	8.790	45.02	8.966
2-Propanol	3.80	2.909	3.89	2.724
Quartz sand	2.49	0.003	2.27	0.012
Granular Paraffin	1.71	0.001	1.77	0.011
Powdered Milk	2.06	0.072	2.12	0.068
SiC	8.57	1.289	8.49	1.335
Perlite	2.68	0.018	2.79	0.011

Piezoelectricity

Piezoelectricity is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. The word piezoelectricity means electricity resulting from pressure and latent heat.

The piezoelectric effect results from the linear electromechanical interaction between the mechanical and electrical states in crystalline materials with no inversion symmetry. The piezoelectric effect is a reversible process: materials exhibiting the piezoelectric effect (the internal generation of electrical charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect, the internal generation of a mechanical strain resulting from an applied electrical field.

For example, lead zirconate titanate crystals will generate measurable piezoelectricity when their static structure is deformed by about 0.1% of the original dimension.

Ferroelectricity

Ferroelectricity, property of certain nonconducting crystals, or dielectrics, that exhibit spontaneous electric polarization (separation of the centre of positive and negative electric charge, making one side of the crystal positive and the opposite side negative) that can be reversed in direction by the application of an appropriate electric field.

Ferroelectric materials—for example, barium titanate (BaTiO_3) and Rochelle salt—are composed of crystals in which the structural units are tiny electric dipoles; that is, in each unit the centres of positive charge and of negative charge are slightly separated. In some crystals these electric dipoles spontaneously line up in clusters called domains, and in ferroelectric crystals the domains can be oriented predominantly in one direction by a strong external electric field.

Ferroelectricity ceases in a given material above a characteristic temperature, called its Curie temperature, because the heat agitates the dipoles sufficiently to overcome the forces that spontaneously align them.

Antiferroelectricity

This is a physical property associated with antiferroelectric materials. Actually, these are materials having ions which can polarize without external field (spontaneous polarization). As a result, dipoles are ordered or arranged with alternating orientation. That is, adjacent lines will be in anti parallel direction. Electric field causes phase transition in these materials. This phase transition cause large pattern strain and energy change. Antiferroelectricity is highly linked to ferroelectricity. They are contrast with each other. So we have to know that ferroelectricity is also a physical property which polarizes quickly. By varying the direction of the field applied we can invert the direction of polarization. So, the difference is the direction of dipoles after polarization. The former will align anti parallel and latter will align in the same direction. Antiferroelectric property is steady than ferroelectric property in a plain cubic pattern.

The entire macroscopic spontaneous polarization in antiferroelectric material is zero. The reason is that the closest dipoles will cancel each other. This property can emerge or vanish depending on various parameters. The parameters are external field, pressure, growth method, temperature etc. The antiferroelectric property is not piezoelectric. That is there is no change in mechanical character of the material by the application of external field. These materials usually have high dielectric constant. The dipole orientation of this material is similar to the chess board pattern which is shown below.

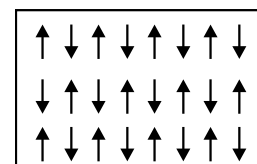


Fig.: Dipole arrangement in antiferroelectric material with the application of electric field

The examples of antiferroelectric materials are as follows

PbZrO_3 (Lead Zirconate)

$\text{NH}_4\text{H}_2\text{PO}_4$ (ADP: Ammonium dihydrogen Phosphate)

NaNbO_3 (Sodium Niobate)

Antiferroelectricity and Temperature

The antiferroelectric property will vanish above a particular temperature. This we can call as Antiferroelectric Curie point. The materials and their curie temperature are shown in Table no.1. The dielectric constant (relative permittivity) less and more than this Curie point is investigated. This is done for both first and second order transition. In the second order transition, dielectric constant is continuous all over the Curie point. In the two cases dielectric constant must not be very high.

Material	Curie Temperature, T_C in $^{\circ}\text{C}$
NaNbO_3 (Sodium Niobate)	+63
$\text{NH}_4\text{H}_2\text{PO}_4$	-125
PbZrO_3 (Lead Zirconate)	+233

Pyroelectricity

Pyroelectricity is the ability of certain materials to generate an electrical potential when they are heated or cooled.

As a result of this change in temperature, positive and negative charges move to opposite ends through migration (i.e. the material becomes polarised) and hence, an electrical potential is established.

Pyroelectricity can be visualized as one side of a triangle, where each corner represents energy states in the crystal: kinetic, electrical and thermal energy.

The side between electrical and thermal corners represents the pyroelectric effect and produces no kinetic energy.

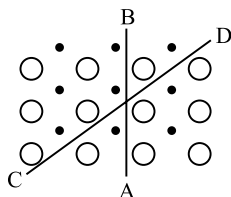
The side between kinetic and electrical corners represents the piezoelectric effect and produces no heat.

Although artificial pyroelectric materials have been engineered, the effect was first discovered in minerals such as quartz and tourmaline and other ionic crystals.

Topicwise Questions

AMORPHOUS AND CRYSTALLINE SOLIDS

- The existence of a substance in more than one solid modification is known as
(a) Isomorphism (b) Polymorphism
(c) Neomorphism (d) Crystallomorphism
- Which of the following is not the example of crystalline solids?
(a) KCl (b) CsCl
(c) Glass (d) Rhombic sulphur
- The property of crystalline solid is not:
(a) Anisotropy (b) Isotropy
(c) Hard (d) Dense
- Which of the following is amorphous in nature ?
(a) Quartz (b) $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
(c) Dry ice (d) Fused silica glass
- Silica in amorphous form is used in
(a) Photovoltaic cell
(b) Conductivity cell
(c) Standard hydrogen electrode
(d) Glass electrode
- A solid melts slightly above 273 K and is a poor conductor of heat and electricity. To which of the following categories does it belong ?
(a) Ionic solid (b) Covalent solid
(c) Metallic (d) Molecular.
- Which among the following will show anisotropy?
(a) Glass (b) NaBr
(c) Plastic (d) Rubber
- Study the figure of a solid given below depicting the arrangement of particles. Which is the appropriate term used for the figure?



- (a) Isotropy (b) Anisotropy
(c) Irregular shape (d) Amorphous nature

CLASSIFICATION OF CRYSTALLINE SOLIDS

- The major binding force in diamond, silicon and quartz is:
(a) Electrostatic force (b) Electrical attraction
(c) Covalent bond force (d) Van der waals forces

- Which of the following forms a molecular solid when solidified?
(a) Calcium fluoride (b) Silicon dioxide
(c) Carbon dioxide (d) Sodium chloride
- Which of the solids show the following properties?
(i) Electrical conductivity
(ii) Malleability
(iii) Ductility
(iv) Fairly high melting point
(a) Ionic solids (b) Covalent solids
(c) Metallic solids (d) Molecular solids
- Solid X is a very hard solid which is electrical insulator in solid as well as in molten state and has extremely high melting point. What type of solid is it?
(a) Ionic solid (b) Covalent solid
(c) Metallic solid (d) Molecular solid
- Which one of the following is a covalent crystal?
(a) Rock salt (b) Ice
(c) Quartz (d) Dry ice
- Which one of the following is used as a Piezoelectric material?
(a) Silicones (b) Graphite
(c) Silica Gel (d) Quartz
- Which one of the following is a molecular crystal?
(a) Rock salt (b) Quartz
(c) Dry ice (d) Diamond

CRYSTAL LATTICES AND UNIT CELLS

- In case of a cubic system, the number of types of space lattices are
(a) 3 (b) 7
(c) 14 (d) 12
- A match box exhibits :
(a) Cubic geometry
(b) Monoclinic geometry
(c) Orthorhombic geometry
(d) Tetragonal geometry
- In which crystal, alternate tetrahedral voids are occupied?
(a) NaCl (b) CaF_2
(c) ZnS (d) Na_2O
- The crystalline structure of NaCl is:
(a) Hexagonal close packing
(b) Face centred cubic
(c) Square planar
(d) Body centred cubic

20. A particular solid is very hard and has a high melting point. In solid state, it is a non-conductor and in molten state, it is a conductor of electricity. Classify the solid:
- (a) Metallic (b) Molecular
(c) Network (d) Ionic
21. In which of the following crystal systems F.C.C unit cells exists ?
- (a) Cubic, hexagonal
(b) Tetragonal, orthorhombic
(c) Orthorhombic, cubic
(d) Triclinic, monoclinic
22. Which of the following unit cell has maximum number of atoms?
- (a) bcc (b) hcp
(c) fcc (d) Simple cubic
23. Which type of crystals contain more than one Bravais lattice?
- (a) Hexagonal (b) Triclinic
(c) Rhombohedral (d) Monoclinic
24. Which of the following may have hexagonal or trigonal crystals :
- (a) $K_4[Fe(CN)_6]$ (b) ice
(c) $K_2Cr_2O_7$ (d) Diamond
25. Which of the following is the structure of CsCl crystal?
- (a) Body centred cubic type
(b) Simple cubic
(c) Face centred cubic
(d) Edge centred cubic
26. Monoclinic sulphur is an example of monoclinic crystal system. What are the characteristics of the crystal system?
- (a) $a \neq b \neq c, \alpha = \beta = \gamma = 90^\circ$
(b) $a \neq b \neq c, \alpha = \beta \neq \gamma \neq 90^\circ$
(c) $a = b \neq c, \alpha = \beta = \gamma = 90^\circ$
(d) $a \neq b \neq c, \alpha = \gamma = 90^\circ, \beta \neq 90^\circ$
27. Which of the following does not represent a type of crystal system?
- (a) Triclinic (b) Monoclinic
(c) Rhombohedral (d) Isotropical
28. The number of atoms in a unit cell of a cubic crystal system is 2, the arrangement of atoms is
- (a) Body centred cubic
(b) Face centred cubic
(c) End centred cubic
(d) Simple cubic
29. If three elements X, Y and Z crystallise in a ccp lattice with X atoms at the corners, Y atoms at the cube centre and Z atoms at the edges, the formula of the compound will be:
- (a) XYZ (b) XYZ_2
(c) XYZ_3 (d) X_2Y_2Z
30. If in a crystal lattice of a compound, each corner of cube is occupied by sodium, each edge of a cube has oxygen and centre of cube is occupied by Tungsten (W), then give its formula:
- (a) Na_2WO_4
(b) $NaWO_3$
(c) Na_3WO_3
(d) Na_2WO_3
31. Bravais lattices are of:
- (a) 8 types (b) 9 types
(c) 12 types (d) 14 types
32. A solid is formed by 2 elements P and Q. The element Q forms cubic close packing and atoms of P occupy one third of tetrahedral voids. The formula of the compound is:
- (a) PQ_3 (b) P_3Q
(c) P_2Q_3 (d) P_3Q_2
33. Na and Mg crystallize in BCC and FCC type of crystals respectively, then the number of atoms of Na and Mg present in the unit cell of their respective crystals is
- (a) 4, 2 (b) 9, 14
(c) 14, 9 (d) 2, 4
34. The number of atoms per unit cell of bcc structure is:
- (a) 1 (b) 2
(c) 4 (d) 6
35. A compound contains two types of atoms X and Y. It crystallises in a cubic lattice with atoms X at the corners of the unit cell and atoms Y at the body centre. The simplest possible formula of this compound is:
- (a) X_8Y (b) X_2Y
(c) XY (d) XY_8
36. A compound of "A" and "B" crystallises in a cubic lattice in which the 'A' atoms occupy the lattice points at the corners of the cube. The 'B' atom occupies the centre of each face of the cube. The probable empirical formula of the compound is:
- (a) A_3B (b) AB
(c) AB_3 (d) AB_2
37. If Z is the number of atoms in the unit cell, that represents the closest packing sequence..... ABC ABC ..., the number of tetrahedral voids in the unit cell is equal to:
- (a) Z (b) 2Z
(c) Z/2 (d) Z/4

NUMBER OF ATOMS IN A UNIT CELL

CLOSE PACKED STRUCTURE

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- (a) Body centred cubic
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34. The number of atoms per unit cell of bcc structure is:
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- (a) X_8Y (b) X_2Y
(c) XY (d) XY_8
36. A compound of "A" and "B" crystallises in a cubic lattice in which the 'A' atoms occupy the lattice points at the corners of the cube. The 'B' atom occupies the centre of each face of the cube. The probable empirical formula of the compound is:
- (a) A_3B (b) AB
(c) AB_3 (d) AB_2
37. If Z is the number of atoms in the unit cell, that represents the closest packing sequence..... ABC ABC ..., the number of tetrahedral voids in the unit cell is equal to:
- (a) Z (b) 2Z
(c) Z/2 (d) Z/4
38. A salt AB crystallises in the CsCl structure. The anions at the corners and the cation in the centre. Hence, radius ratio
- (a) 0.225 (b) 0.441
(c) 0.625 (d) 0.732
39. Calculate the number of particles (atoms) per unit cell in a FCC crystal lattice?
- (a) 2 (b) 3
(c) 4 (d) 6
40. Coordination number of Cs^+ and Cl^- in CsCl crystal are:
- (a) 8,8 (b) 4,4
(c) 6,6 (d) 8,4

41. How many chloride ions are surrounding sodium ion in sodium chloride crystal?
 (a) 4 (b) 8
 (c) 6 (d) 12
42. A unit cell of BaCl_2 (Fluorite structure) is made up of:
 (a) Four Ba^{2+} ions and four Cl^- ions
 (b) Four Ba^{2+} ions and eight Cl^- ions
 (c) Eight Ba^{2+} ions and four Cl^- ions
 (d) Four Ba^{2+} ions and six Cl^- ions
43. The radii of Na^+ and Cl^- ions are 95 pm and 181 pm respectively. The edge length of NaCl unit cell is:
 (a) 276 pm (b) 138 pm
 (c) 552 pm (d) 415 pm
44. If the radius of an octahedral void is r and radius of atoms in close packing is R , the relation between r and R is:
 (a) $r = 0.414 R$ (b) $R = 0.414 r$
 (c) $r = 2R$ (d) $r = \sqrt{2}R$
45. The greater the value of r^+/r^-
 (a) The lower will be the C.N.
 (b) The higher the value of C.N.
 (c) The higher will be the number of cations
 (d) The lower will be the number of anions
46. In the unit cell of NaCl:
 (a) All octahedral and tetrahedral sites are occupied
 (b) Only octahedral sites are occupied
 (c) Only tetrahedral sites are occupied
 (d) Neither octahedral nor tetrahedral are occupied
47. A metal crystallises into a lattice containing a sequence of layers as AB AB AB what percentage of voids are left in the lattice?
 (a) 72% (b) 48%
 (c) 26% (d) 32%
48. Copper crystallises in a face centred cubic lattice with a unit cell length of 361 pm. What is the radius of copper atom in pm?
 (a) 157 pm (b) 181 pm
 (c) 108 pm (d) 128 pm
49. The number of tetrahedral and octahedral voids in a CCP array of 100 atoms are respectively:
 (a) 200 and 100 (b) 100 and 200
 (c) 200 and 200 (d) 100 and 100
50. Zn convert it's melted state to its solid state, it has hcp structure, then find out no. of nearest atom:
 (a) 6 (b) 8
 (c) 12 (d) 4
51. Edge length of unit cell of Chromium metal is 287 pm with bcc arrangement. The atomic radius is the order of:
 (a) 124.27 pm (b) 287 pm
 (c) 574 pm (d) 143.5 pm

52. In the ionic compound AB the ratio $r_{A^+} : r_{B^-}$ is 0.414. Indicate the correct statement of the following :
 (a) Cations form close packing and anions exactly fit into the octahedral voids
 (b) Anions form close packing and cations occupy precisely half of the tetrahedral voids
 (c) Anions form close packing and cations occupy precisely all the octahedral voids
 (d) Anions form close packing and cations fit into the octahedral voids loosely

PACKING EFFICIENCY

53. In which of the following arrangements a metal could have least density?
 (a) BCC (b) CCP
 (c) HCP (d) Simple cubic
54. The intermetallic compound LiAg crystallizes in a cubic lattice in which lithium and silver atoms have co-ordination number of 8. To what crystal class does the unit cell belong?
 (a) Simple cubic
 (b) Face centred cubic
 (c) Body centred cubic
 (d) End centred cubic
55. If the distance between Na^+ and Cl^- in NaCl crystal is 265 pm, the edge of the unit cell will be:
 (a) 265 pm (b) 795 pm
 (c) 132.5 pm (d) 530 pm
56. Sodium metal crystallises in body centred cubic lattice with cell edge length, 4.29 Å. What is the radius of sodium atom?
 (a) 2.86 Å (b) 6.81 Å
 (c) 1.68 Å (d) 1.86 Å
57. If the radius of K^+ and F^- are 133 pm and 136pm respectively, the distance between K^+ and F^- in KF is:
 (a) 269 pm (b) 134.5 pm
 (c) 136 pm (d) 3 pm
58. In a structure, A atoms have fcc arrangement, B atoms occupy all the tetrahedral sites and C atoms occupy half the octahedral sites. The formula of the compound is
 (a) $\text{A}_2\text{B}_2\text{C}_2$ (b) $\text{A}_2\text{B}_4\text{C}$
 (c) AB_2C (d) $\text{A}_4\text{B}_2\text{C}$
59. AB is an ionic solid. If the ratio of ionic radius of A^+ and B^- is 0.52, what is the coordination number of B^- ?
 (a) 2 (b) 3
 (c) 6 (d) 8
60. In hcp arrangement in three dimensions, the overall coordination number of each sphere is
 (a) 4 (b) 6
 (c) 9 (d) 12

61. Total volume of atoms present in a FCC unit cell of a metal with radius r is:

(a) $\frac{12\pi r^3}{3}$ (b) $\frac{16\pi r^3}{3}$

(c) $\frac{20\pi r^3}{3}$ (d) $\frac{24\pi r^3}{3}$

62. If 'a' stands for the edge length of the cubic systems: simple cubic, Body centred cubic, and Face centred cubic, then the ratio of radius of the sphere in these systems will be respectively:

(a) $\frac{1a}{2} : \frac{\sqrt{3}a}{4} : \frac{a}{2\sqrt{2}}$ (b) $\frac{1a}{2} : \sqrt{3}a : \frac{1}{\sqrt{2}}a$

(c) $\frac{1}{2}a : \frac{\sqrt{3}a}{4} : \frac{\sqrt{2}a}{2}$ (d) $1a : \sqrt{3}a : \sqrt{2}a$

63. A fcc unit cell of aluminium contains how many effective atoms?

- (a) 1 (b) 2
(c) 3 (d) 4

64. The ratio of close packed atoms to tetrahedral holes in cubic close packing is

- (a) 1 : 1 (b) 1 : 2
(c) 1 : 3 (d) 2 : 1

65. In FCC lattice A, B, C, D atoms are arranged at corners, face centres, octahedral voids and tetrahedral voids respectively, then the body diagonal contains.

- (a) 2A, 2D (b) 2A, C, 2D
(c) 2A, 2B, D (d) 2A, 2B, 2C

66. First three nearest neighbour distances for simple cubic lattice are respectively (edge length of unit cell = a):

- (a) $a, \sqrt{2}a, \sqrt{3}a$ (b) $\sqrt{3}a, \sqrt{2}a, a$
(c) $a, \sqrt{2}a, 2a$ (d) $a, \sqrt{3}a, 2a$

67. First three nearest neighbour distances for body centered cubic lattice are respectively :

- (a) $\sqrt{2}a, a, \sqrt{3}a$ (b) $\frac{a}{\sqrt{2}}, a, \sqrt{3}a$
(c) $\frac{\sqrt{3}a}{2}, a, \sqrt{2}a$ (d) $\frac{\sqrt{3}a}{2}, a, \sqrt{3}a$

68. The number of octahedral sites per sphere in fcc structure is

- (a) 1 (b) 2
(c) 4 (d) 8

70. How many lithium atoms are present in a cubic unit cell with edge length $3.5 \text{ \AA}$ and density 0.53 g cm^{-3} ? (Atomic mass of Li = 6.94)?

- (a) 2 (b) 1
(c) 4 (d) 6

71. Crystalline CsCl has density 3.988 g cm^{-3} . The volume occupied by single CsCl pair in the crystal will be: (Molar mass CsCl = 168.4 g/mol)

- (a) $7.014 \times 10^{-3} \text{ cm}^3$ (b) $7.014 \times 10^{-23} \text{ cm}^3$
(c) $1.014 \times 10^{-3} \text{ cm}^3$ (d) $1.542 \times 10^{-5} \text{ cm}^3$

72. A unit cell of sodium chloride has four formula units. The edge length of the unit cell is 0.564 nm. What is the density of sodium chloride?

- (a) 3.89 g cm^{-3} (b) 2.16 g cm^{-3}
(c) 3 g cm^{-3} (d) 1.82 g cm^{-3}

73. The metal crystallises with a face - centred cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is:

- (a) 288 pm
(b) 408 pm
(c) 144 pm
(d) 204 pm

74. The metal has a fcc lattice. The edge length of the unit cell is 404 pm the density of the metal is 2.72 g cm^{-3} the molar mass of a metal is:

- (a) 40 g/mol (b) 30 g/mol
(c) 27 g/mol (d) 20 g/mol

75. An element with atomic mass 100 has a bcc structure and edge length 400 pm. The density of element is:

- (a) 10.37 g cm^{-3} (b) 5.19 g cm^{-3}
(c) 7.29 g cm^{-3} (d) 2.14 g cm^{-3}

76. The unit cell of aluminium is a cube with an edge length of 405 pm. The density of aluminium is 2.70 g cm^{-3} what is the structure of unit cell of aluminium?

- (a) Body - centred cubic cell
(b) Face - centred cubic cell
(c) End - centred cubic cell
(d) Simple cubic cell

77. Sodium crystallises in bcc arrangement with the interfacial separation between the atoms of the edge 53pm. The density of the solid is:

- (a) 1.23 g/cc (b) 485 g/cc
(c) 4.85 g/cc (d) 123 g/cc

CALCULATIONS INVOLVING UNIT CELL DIMENSIONS

69. An element crystallize in a structure having F.C.C. unit cell of an edge 200 pm. Calculate the density if 200 gm of it contains 24×10^{23} atoms

- (a) 41.6 gm cm^{-3} (b) 42.6 gm cm^{-3}
(c) 43.6 gm cm^{-3} (d) 44.6 gm cm^{-3}

IMPERFECTIONS IN SOLIDS

78. Germanium or silicon becomes extrinsic semiconductor due to

- (a) Schottky defect (b) Chemicals impurity
(c) Frenkel defect (d) Both (a) and (b)

79. An electron trapped in an anion site in a crystal is called:
 (a) F- centre (b) Frenkel defect
 (c) Schottky defect (d) Interstitial defect
80. Fe_3O_4 (magnetite) is an example of:
 (a) Normal spinel structure
 (b) Inverse spinel structure
 (c) Fluorite structure
 (d) Antifluorite structure
81. In a Schottky defect:
 (a) An ion moves to interstitial position between the lattice points
 (b) Electrons are trapped in lattice sites
 (c) Some lattice sites are vacant
 (d) Some extra cations are present in interstitial spaces
82. Experimentally it was found that a metal oxide has formula $\text{M}_{0.98}\text{O}_{1.00}$. Metal M is present as M^{2+} and M^{3+} . Fraction of the metal which exists as M^{3+} would be:
 (a) 5.08% (b) 7.01%
 (c) 4.08% (d) 6.05%
83. Cations are present in the interstitial sites in:
 (a) Frenkel defect (b) Schottky defect
 (c) Vacancy defect (d) Metal deficiency defect
84. Schottky defect is found in
 (a) NaCl (b) BaSO_4
 (c) MgCl_2 (d) CaCl_2
85. Silicon doped with electron-rich impurity forms:
 (a) p-type semiconductors
 (b) n-type semiconductors
 (c) Intrinsic semiconductors
 (d) Insulator
86. Which of the following defects is also known as dislocation defect?
 (a) Frenkel defect
 (b) Schottky defect
 (c) Non-stoichiometric
 (d) Simple interstitial defect
87. The appearance of colour in solid alkali metal halides is generally due to:
 (a) Frenkel defect
 (b) Interstitial positions
 (c) F-centres
 (d) Schottky defects
88. When electrons are trapped into the crystal in anion vacancy, the defect is known as:
 (a) Schottky defect (b) Frenkel defect
 (c) Stoichiometric (d) F-centres

89. With which one of the following silicon should be doped so as to give p-type of semiconductor?
 (a) Germanium
 (b) Arsenic
 (c) Selenium
 (d) Boron

ELECTRICAL PROPERTIES

90. Pure silicon and germanium behave as:
 (a) Conductors
 (b) Semiconductors
 (c) Insulators
 (d) Piezoelectric crystals
91. p-type semiconductors are formed when Si or Ge are doped with:
 (a) Group 14 elements
 (b) Group 15 elements
 (c) Group 13 elements
 (d) Group 18 elements
92. To get n-type of semiconductor, germanium should be doped with:
 (a) Gallium (b) Arsenic
 (c) Aluminium (d) Boron

MAGNETIC PROPERTIES

93. Which of the following metal oxides is antiferromagnetic in nature?
 (a) MnO_2 (b) TiO_2
 (c) NO_2 (d) CrO_2
94. Fe_3O_4 is ferrimagnetic at room temperature but at 850K, it becomes:
 (a) Diamagnetic
 (b) Ferrimagnetic
 (c) Paramagnetic
 (d) Anti-ferromagnetic
95. Some of the polar crystals when heated produce small electrical current. This phenomenon is called:
 (a) Ferroelectricity
 (b) Pyroelectricity
 (c) Piezoelectricity
 (d) Anti-ferroelectricity
96. Choose the example of paramagnetic substance:
 (a) TiO_2
 (b) O_2
 (c) NaCl
 (d) V_2O_5

Learning Plus

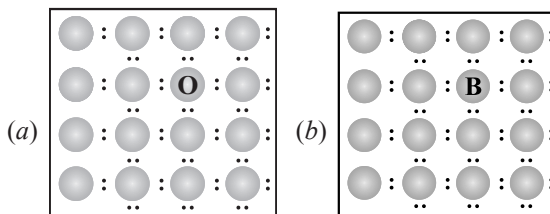
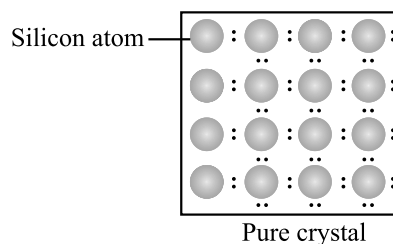
- Which of the following conditions favours the existence of a substance in the solid state?
 (a) High temperature (b) Low temperature
 (c) High thermal energy (d) Weak cohesive forces
- Which of the following is not a characteristic of a crystalline solid?
 (a) Definite and characteristic heat of fusion
 (b) Isotropic nature
 (c) A regular periodically repeated pattern of arrangement of constituent particles in the entire crystal
 (d) A true solid
- Which of the following arrangements shows schematic alignment of magnetic moments of antiferromagnetic substances?
 (a) $\uparrow \uparrow \uparrow \uparrow \uparrow \uparrow$
 (b) $\downarrow \downarrow \downarrow \downarrow \downarrow \downarrow$
 (c) $\uparrow \uparrow \downarrow \uparrow \uparrow \downarrow$
 (d) $\uparrow \downarrow \uparrow \downarrow \uparrow \downarrow$
- Which of the following is true about the value of refractive index of quartz glass?
 (a) Same in all directions
 (b) Different in different directions
 (c) Cannot be measured
 (d) Always zero
- Which of the following statement is not true about amorphous solids?
 (a) On heating they may become crystalline at certain temperature
 (b) They may become crystalline on keeping for long time
 (c) Amorphous solids can be moulded by heating
 (d) They are anisotropic in nature
- Which of the following solids is not an electrical conductor?
 1. Mg(s) 2. TiO(s)
 3. I₂(s) 4. H₂O(s)
 (a) Only 1 (b) Only 2
 (c) 3 and 4 (d) 2, 3 and 4
- Which of the following is not the characteristic of ionic solids?
 (a) Very low value of electrical conductivity in the molten state
 (b) Brittle nature
 (c) Very strong forces of interactions
 (d) Anisotropic nature
- Which of the following oxides behaves as conductor or insulator depending upon temperature?
 (a) TiO (b) SiO₂
 (c) TiO₃ (d) MgO
- Which of the following oxides shows electrical properties like metals?
 (a) SiO₂ (b) MgO
 (c) SO₂(s) (d) CrO₂
- The lattice site in a pure crystal cannot be occupied by:
 (a) Molecule
 (b) Ion
 (c) Electron
 (d) Atom
- Schottky defect is observed in crystals when:
 (a) Some cations move from their lattice site to interstitial sites
 (b) Equal number of cations and anions are missing from the lattice sites.
 (c) Some lattice sites are occupied by electrons
 (d) Some impurity is present in the lattice
- 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
- To get a *n*-type semiconductor from silicon, it should be doped with a substance with valency:
 (a) 2 (b) 1
 (c) 3 (d) 5
- In which pair most efficient packing is present?
 (a) hcp and bcc
 (b) hcp and ccp
 (c) bcc and ccp
 (d) bcc and simple cubic cell
- Which of the following statement is not true about the hexagonal close packing?
 (a) The coordination number is 12
 (b) It has 74% packing efficiency
 (c) Tetrahedral voids of the second layer are covered by the spheres of the third layer
 (d) In this arrangement spheres of the fourth layer are exactly aligned with those of the first layer

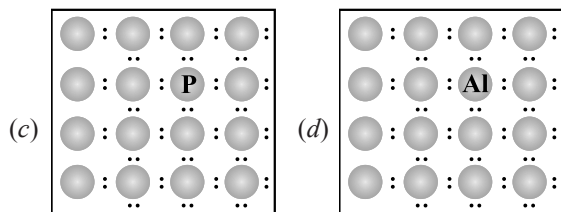
16. In which of the following structures coordination number for cations and anions in the packed structure will be same?
- Cl^- ions form fcc lattice and Na^+ ions occupy all octahedral voids of the unit cell
 - Ca^{2+} ions form fcc lattice and F^- ions occupy all the eight tetrahedral voids of the unit cell
 - O^{2-} ions form fcc lattice and Na^+ ions occupy all the eight tetrahedral voids of the unit cell
 - S^{2-} ions form fcc lattice and Zn^{2+} ions go into alternate tetrahedral voids of the unit cell
17. What is the coordination number in a square close packed structure in two dimensions?
- 2
 - 3
 - 4
 - 6
18. Which kind of defects are introduced by doping?
- Dislocation defect
 - Schottky defect
 - Frenkel defect
 - Electronic defect
19. Silicon doped with electron rich impurity forms:
- p-type semiconductor
 - n-type semiconductor
 - Intrinsic semiconductor
 - Insulator
20. Which of the following is true about the ionic solids?
- Bigger ions form the close packed structure
 - Smaller ions occupy either the tetrahedral or the octahedral voids depending upon their size
 - Occupation of all the voids is not necessary
 - The fraction of octahedral or tetrahedral voids occupied depends upon the radii of the ions occupying the voids
21. A ferromagnetic substance becomes a permanent magnet when it is placed in a magnetic field because:
- All the domains get oriented in the direction of magnetic field
 - All the domains get oriented in the direction opposite to the direction of magnetic field
 - Domains get oriented randomly
 - Domains are not affected by magnetic field
22. The correct order of the packing efficiency in different types of unit cells is:
- fcc < bcc < simple cubic
 - fcc > bcc > simple cubic
 - fcc < bcc > simple cubic
 - bcc < fcc > simple cubic
23. Which of the following defects is also known as dislocation defect?
- Frenkel defect
 - Schottky defect
 - Non-stoichiometric defect
 - Simple interstitial defect
24. In the cubic close packing, the unit cell has:
- 4 tetrahedral voids each of which is shared by four adjacent unit cells
 - 4 tetrahedral voids within the unit cell
 - 8 tetrahedral voids each of which is shared by four adjacent unit cells
 - 8 tetrahedral voids within the unit cells
25. The edge lengths of the unit cells in terms of the radius of spheres constituting fcc, bcc and simple cubic unit cells are respectively:
- $2\sqrt{2}r, \frac{4r}{\sqrt{3}}, 2r$
 - $\frac{4r}{\sqrt{3}}, 2\sqrt{2}r, 2r$
 - $2\sqrt{2}r, 2r, \frac{4r}{\sqrt{3}}$
 - $2r, \frac{4r}{\sqrt{3}}, 2\sqrt{2}r$
26. Which of the following represents correct order of conductivity in solids?
- $\kappa_{\text{metals}} \gg \kappa_{\text{insulators}} < \kappa_{\text{semiconductors}}$
 - $\kappa_{\text{metals}} \ll \kappa_{\text{insulators}} < \kappa_{\text{semiconductors}}$
 - $\kappa_{\text{metals}} < \kappa_{\text{semiconductors}} > \kappa_{\text{insulators}}$
 - $\kappa_{\text{metals}} < \kappa_{\text{semiconductors}} > \kappa_{\text{insulators}}$
27. Which of the following is not true about the voids formed in 3 dimensional hexagonal close packed structure?
- A tetrahedral void is formed when a sphere of the second layer is present above triangular void in the first layer
 - All the triangular voids are not covered by the spheres of the second layer
 - Tetrahedral voids are formed when the triangular voids in the second layer lie above the triangular voids in the first layer and the triangular shapes of these voids do not overlap
 - Octahedral voids are not formed when the triangular voids in the second layer exactly overlap with similar voids in the first layer
28. The value of magnetic moment is zero in the case of anti ferromagnetic substances because the domains:
- Get oriented in the direction of the applied magnetic field
 - Get oriented opposite to the direction of the applied magnetic field
 - Are oppositely oriented with respect to each other without the application of magnetic field
 - Not cancel out each other's magnetic moment
29. Which of the following statements are true about metals?
- Valence band overlaps with conduction band
 - The gap between valence band and conduction band is large
 - The gap between valence band and conduction band cannot be determined
 - None of these

30. Under the influence of electric field, which of the following statement is true about the movement of electrons and holes in a p-type semiconductor?
- Electron will move towards the positively charged plate through electron holes
 - Holes will appear to be moving towards the negatively charged plate
 - Both electrons and holes appear to move towards the positively charged plate
 - Movement of electrons is related to the movement of holes
31. An excess of potassium ions makes KCl crystals appear violet or lilac in colour since:
- Some of the anionic sites are occupied by an unpaired electron
 - Some of the anionic sites are occupied by a pair of electrons
 - There are vacancies at some anionic sites
 - F-centres are created which does not impart colour to the crystals
32. The number of tetrahedral voids per unit cell in NaCl crystal is:
- 4
 - 8
 - equal to number of octahedral voids
 - Four times the number of octahedral voids
33. Amorphous solids can also be called:
- Pseudo solids
 - True solids
 - Super cooled gas
 - Super cooled solids
34. Which of the following features are not shown by quartz glass?
- This is not a crystalline solid
 - Refractive index is same in all the directions
 - This has definite heat of fusion
 - This is also called super cooled liquid
35. Which of the following be regarded as molecular solid?
- SiC (silicon carbide)
 - AlN
 - Diamond
 - I₂
36. Frenkel defect is also known as:
- non-stoichiometric defect
 - Dislocation defect
 - Impurity defect
 - Non-stoichiometric defect
37. Which of the following defects decrease the density?
- Interstitial defect
 - non-vacancy defect
 - Frenkel defect
 - Schottky defect

Multiconcept MCQs

1. Which of the following statements is not true?
- Paramagnetic substances are weakly attracted by magnetic field
 - Ferromagnetic substances cannot be magnetised permanently
 - The domains in antiferromagnetic substances are oppositely oriented with respect to each other
 - Pairing of electrons cancels their magnetic moment in the diamagnetic substances
2. Which of the following statements are not true?
- Vacancy defect results in a decrease in the density of the substance
 - Interstitial defects results in an increase in the density of the substance
 - Impurity defect has no effect on the density of the substance
 - Frenkel defect does not alter the density of the substance
3. Which of the following statements are true about semiconductors?
- Silicon doped with electron rich impurity is a p -type semiconductor
 - Silicon doped with an electron rich impurity is an n-type semiconductor
 - Delocalized electrons decrease the conductivity of doped silicon
 - An electron vacancy increases the conductivity of n-type semiconductor
4. A perfect crystal of silicon (fig) is doped with some elements as given in the options. Which of these options shows n -type semiconductors?





5. Which of the following statements are correct?
- Ferrimagnetic substances given ferrimagnetism on heating and become paramagnetic
 - Ferrimagnetic substances do not lose ferrimagnetism on heating and remain ferrimagnetic
 - Antiferromagnetic substances have domain structures similar to ferromagnetic substances and their magnetic moments are not cancelled by each other
 - In ferromagnetic substances, all the domains get oriented in the direction of magnetic field and remain as such even after removing magnetic field
6. The simplest formula of a solid having CCP arrangement for 'A' atoms in which alternate face centres are occupied by 'B' atoms and alternate edge centres are occupied by 'C' atoms, is:
- ABC
 - $A_8B_3C_3$
 - A_2BC
 - A_4B_2C
7. If all Fe^{2+} ions are replaced by Sr^{4+} ions in 0.1 mole of $Fe_{0.9}O$, then the number of vacancies created are-
- $0.035 N_A$
 - $0.01 N_A$
 - $0.07 N_A$
 - $0.1 N_A$
8. In $Fe_{0.94}O$, the % age of octahedral voids occupied by vacancies is -
- 6%
 - 68.6%
 - 53%
 - 94%
9. In diamond, the lattice is fcc with C atoms occupying lattice point as well as some of the voids. Which of the following statement (s) is/are correct about diamond structure-
- In the diamond lattice, half of T. voids (tetrahedral) are occupied.
 - % age space occupied (Packing efficiency) is 74%
 - All octahedral voids are occupied in diamond
- Only I
 - Only III
 - I, II & III
 - Only II
10. A body centered cubic lattice is made up of hollow spheres of B. Spheres of solid A are present in hollow spheres of B. Radius A is half of radius of B. What is the ratio of total volume of spheres of B unoccupied by A in a unit cell and volume of unit cell is $\frac{A \times \pi \sqrt{3}}{64}$. Find the value of A.
- $\frac{7\sqrt{3}\pi}{64}$
 - $\frac{7\sqrt{3}}{128}$
 - $\frac{7\pi}{24}$
 - None of these

11. How many effective Na^+ and Cl^- ions are present respectively in a unit cell of NaCl solid (Rock salt structure) if ions along line connecting opposite face centres are absent?

- 3, 3
- $\frac{7}{2}, 4$
- $\frac{7}{2}, \frac{7}{2}$
- $4, \frac{7}{2}$

12. Match the following and select the correct option.

	Column – I		Column – II
A.	Co-ordination number of Ca^{2+} and F^- in fluorite structure	(i)	8, 4
B.	C.No. of Zn^{2+} and S^{2-} in zinc blende structure	(ii)	8, 8
C.	C.No. of Cs^+ and Cl^- in CsCl (bcc type) structure	(iii)	4, 4

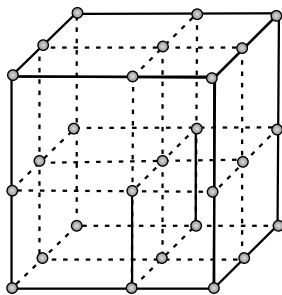
- A-(i), B-(ii), C-(iii)
 - A-(i), B-(iii), C-(ii)
 - A-(ii), B-(iii), C-(i)
 - A-(ii), B-(i), C-(iii)
13. Which of the following is incorrect about NaCl structure?
- Nearest neighbours of Na^+ ion is six Cl^- ion
 - Na^+ ion make fcc lattice
 - Cl^- ion pack in cubic close packed arrangement
 - There are eight next nearest neighbours of Na^+ ion
14. The unit cell length of NaCl is observed to be 0.5627 nm by X-ray diffraction studies, the measured density of NaCl is 2.164 g cm^{-3} . Calculate % of missing Na^+ and Cl^- ions.
- 0.882%
 - 0.920%
 - 0.775%
 - 0.351%
15. Select the correct statement w.r.t. F-centre defect.
- The defect appears in silver halides only.
 - Electrons coming from outside into the crystal are positioned in voids.
 - The colour appears due to absorption of a part of visible region.
 - This defect is related with Frenkel defect.
16. Match the following and select the correct option.

	Column-I (Substance)		Column-II (Magnetic behaviour)		
p.	O ₂ molecule	(i)	Ferrimagnetic		
q.	Zn metal	(ii)	Ferromagnetic		
r.	CrO ₂	(iii)	Paramagnetic		
s.	Fe ₃ O ₄	(iv)	Antiferromagnetic		
t.	MnO ₂	(v)	Diamagnetic		
	p	q	r	s	t
(a)	(iv)	(v)	(i)	(ii)	(iii)
(b)	(iii)	(i)	(ii)	(v)	(iv)
(c)	(iii)	(v)	(ii)	(i)	(iv)
(d)	(iii)	(v)	(i)	(iv)	(ii)

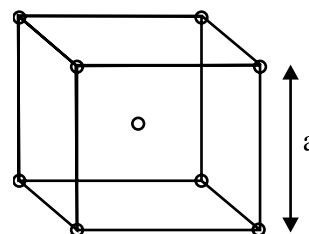
17. An element (at. wt. = 50) crystallises in fcc lattice, with $a = 0.50$ nm. What is the density of unit cell if it contains 0.25% Schottky defect (use $N_A = 6 \times 10^{23}$)?
- (a) 2.0 g/cc (b) 2.66 g/cc
(c) 3.06 g/cc (d) None of these
18. Structure of a mixed oxide is cubic close packed (ccp). The cubic unit cell of mixed oxide is composed of oxide ions in ccp. One fourth of the tetrahedral voids are occupied by divalent metal A and the octahedral voids are occupied by a monovalent metal B. The formula of the oxide is
- (a) ABO_2 (b) A_2BO_2
(c) $A_2B_3O_4$ (d) AB_2O_2
19. Which of the following statements are not true?
- (a) Vacancy defect results in a decrease in the density of the substance.
(b) Frenkel defect results in an increase in the density of the substance.
(c) Impurity defect has no effect on the density of the substance.
(d) Both (b) and (c)
20. Match the List I with the List II and select the correct answer using the code given below the lists:

	List I (Axial parameters)	List II (Crystal system)
P.	$a \neq b \neq c$, $\alpha = \beta = \gamma = 90^\circ$	1. Triclinic
Q.	$a \neq b \neq c$, $\alpha \neq \beta \neq \gamma \neq 90^\circ$	2. Hexagonal
R.	$a = b \neq c$, $\alpha = \beta = 90^\circ, \gamma = 120^\circ$	3. Orthorhombic
S.	$a \neq b \neq c$, $\alpha = \gamma = 90^\circ \neq \beta$	4. Monoclinic
	P Q R S	
(a)	1 4 2 3	
(b)	2 3 4 1	
(c)	3 2 4 1	
(d)	3 1 2 4	

21. In a sample of FeO when 12% Fe^{2+} get replaced by Fe^{3+} The composition of this sample is-
- (a) $Fe_{0.88}O$ (b) $Fe_{0.93}O$
(c) $Fe_{0.96}O$ (d) $Fe_{0.94}O$
22. The following diagram shows the arrangement of lattice points with $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$. Choose the correct options

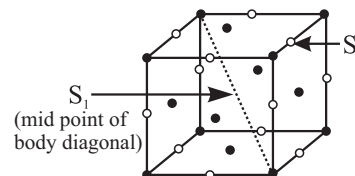


- (a) The arrangement is simple cubic with each lattice point surrounded by 6 nearest neighbours
(b) The arrangement is simple cubic with each lattice point surrounded by 8 nearest neighbours
(c) The arrangement is fcc with each lattice point surrounded by 12 nearest neighbours
(d) The arrangement is bcc with each lattice point surrounded by 8 nearest neighbours
23. The unit cell in a body centred cubic lattice is given in the figure. Each sphere has a radius r and the cube has side ' a '. What fraction of the total cube volume is empty?

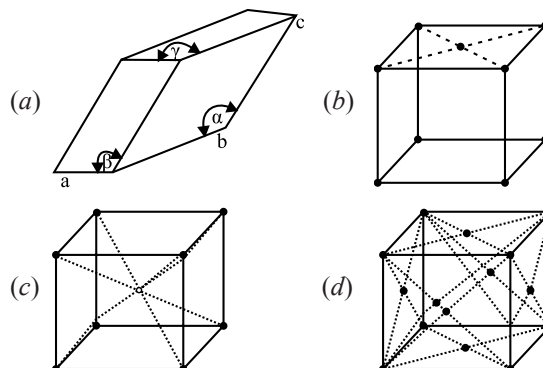


- (a) $1 - \frac{8\pi r^3}{3a^3}$
(b) $\frac{4\pi r^3}{3a^3}$
(c) $\frac{r}{a}$
(d) $2 - \frac{4\pi r^3}{3a^3}$

24. In the structure given in figure, the sites S_1 and S_2 represent.



- (a) Both octahedral voids
(b) Both tetrahedral voids
(c) S_1 -octahedral void, S_2 -tetrahedral void
(d) S_1 -tetrahedral void, S_2 -octahedral void
25. In which of the following structure unit cell shows the triclinic structure?



NEET Past 10 Years Questions

- Right option for the number of tetrahedral and octahedral voids in hexagonal primitive unit cell are: (2021)
 (a) 8, 4 (b) 6, 12
 (c) 2, 1 (d) 12, 6
- The correct option for the number of body centred unit cells in all 14 types of bravais lattice unit cells is: (2021)
 (a) 5 (b) 2
 (c) 3 (d) 7
- An element has a body centered cubic (bcc) structure with a cell edge of 288 pm. The atomic radius is: (2020)
 (a) $\frac{\sqrt{2}}{4} \times 288$ pm (b) $\frac{4}{\sqrt{3}} \times 288$ pm
 (c) $\frac{4}{\sqrt{2}} \times 288$ pm (d) $\frac{\sqrt{3}}{4} \times 288$ pm
- Which one of the following compounds shows both. Frenkel as well as Schottky defects? (2020 Covid Re-NEET)
 (a) AgI (b) NaCl
 (c) ZnS (d) AgBr
- A compound is formed by cation C and anion A. The anions form hexagonal close packed (hcp) lattice and the cations occupy 75% of octahedral voids. The formula of the compound is: (2019)
 (a) C_2A_3 (b) C_3A_2
 (c) C_3A_4 (d) C_4A_3
- Iron exhibits bcc structure at room temperature. Above 900°C , it transforms to fcc structure. The ratio of density of iron at room temperature to that at 900°C (assuming molar mass and atomic radii of iron remains constant with temperature) is (2018)
 (a) $\frac{\sqrt{3}}{\sqrt{2}}$ (b) $\frac{4\sqrt{3}}{3\sqrt{2}}$ (c) $\frac{1}{2}$ (d) $\frac{3\sqrt{3}}{4\sqrt{2}}$
- Which is the incorrect statement? (2017-Delhi)
 (a) Frenkel defect is favoured in those ionic compounds in which size of cations and anions are almost equal
 (b) $\text{FeO}_{0.98}$ has non-stoichiometric metal deficiency defect
 (c) Density decreases in case of crystals with Schottky's defect
 (d) NaCl(s) is insulator, silicon is semiconductor, silver is conductor, quartz is piezo electric crystal
- A compound formed by Mg, Al and O, is found to have cubic close array of oxide ions in which Mg^{2+} occupying $\frac{1}{8}$ of tetrahedral voids and Al^{3+} ions occupying $\frac{1}{2}$ of the octahedral voids. The formula for the compound is: (2017-Gujarat)
 (a) MgAlO (b) MgAl_4O_2
 (c) $\text{Mg}_2\text{Al}_3\text{O}_2$ (d) MgAl_2O_4
- In calcium fluoride, having the fluorite structure, the coordination numbers for calcium ion (Ca^{2+}) and fluoride ion (F^-) are: (2016-II)
 (a) 4 and 2 (b) 6 and 6
 (c) 8 and 4 (d) 4 and 8
- Lithium has bcc structure. Its density is 530 kg m^{-3} and its atomic mass is 6.94 g mol^{-1} . Calculate the edge length of a unit cell of lithium metal. ($N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$): (2016 - I)
 (a) 264 pm (b) 154 pm
 (c) 352 pm (d) 527 pm
- The vacant space in bcc lattice unit cell is: (2015 Re)
 (a) 32% (b) 26%
 (c) 48% (d) 23%
- The correct statement regarding defects in crystalline solids is: (2015 Re)
 (a) Frenkel defect is found in halides of alkaline metals
 (b) Schottky defects have no effect on the density of crystalline solids
 (c) Frenkel defects decrease the density of crystalline solids
 (d) Frenkel defect is a dislocation defect
- A given metal crystallises out with a cubic structure having edge length of 361 pm. If there are four metal atoms in one unit cell, what is the radius of one atom? (2015)
 (a) 127 pm (b) 80 pm
 (c) 108 pm (d) 40 pm
- If 'a' is the length of the side of a cube, the distance between the body centered atom and one corner atom in the cube will be: (2014)
 (a) $\frac{4}{\sqrt{3}}a$ (b) $\frac{\sqrt{3}}{4}a$
 (c) $\frac{\sqrt{3}}{2}a$ (d) $\frac{2}{\sqrt{3}}a$
- A metal has a fcc lattice. The edge length of the unit cell is 404 pm. The density of the metal is 2.72 g cm^{-3} . The molar mass of the metal is: [N_A (Avogadro's constant) = $6.02 \times 10^{23} \text{ mol}^{-1}$]: (2013)
 (a) 40 g mol^{-1} (b) 30 g mol^{-1}
 (c) 27 g mol^{-1} (d) 20 g mol^{-1}
- The number of carbon atoms per unit cell of diamond unit cell is: (2013)
 (a) 4 (b) 8
 (c) 6 (d) 1

17. Structure of a mixed oxide is cubic close-packed (c.c.p.). The cubic unit cell of mixed oxide is composed of oxide ions. One fourth of the tetrahedral voids are occupied by divalent metal A and the octahedral voids are occupied by a monovalent metal B. The formula of the oxide is: (2012 Mains)
- (a) AB_2O_2
 (b) ABO_2
 (c) A_2BO_2
 (d) $A_2B_3O_4$
18. The number of octahedral void(s) per atom present in a cubic close-packed structure is: (2012 Pre)
- (a) 4 (b) 1
 (c) 3 (d) 2
19. A metal crystallises with a face-centered cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is: (2012 Pre)
- (a) 204 pm (b) 288 pm
 (c) 408 pm (d) 144 pm

ANSWER KEYS

Topicwise Questions

- | | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (c) | 3. (b) | 4. (d) | 5. (a) | 6. (d) | 7. (b) | 8. (b) | 9. (c) | 10. (c) |
| 11. (c) | 12. (b) | 13. (c) | 14. (d) | 15. (c) | 16. (a) | 17. (c) | 18. (c) | 19. (b) | 20. (d) |
| 21. (c) | 22. (c) | 23. (d) | 24. (b) | 25. (a) | 26. (d) | 27. (d) | 28. (a) | 29. (c) | 30. (b) |
| 31. (d) | 32. (c) | 33. (d) | 34. (b) | 35. (c) | 36. (c) | 37. (b) | 38. (d) | 39. (c) | 40. (a) |
| 41. (c) | 42. (b) | 43. (c) | 44. (a) | 45. (b) | 46. (b) | 47. (c) | 48. (d) | 49. (a) | 50. (c) |
| 51. (a) | 52. (c) | 53. (d) | 54. (c) | 55. (d) | 56. (d) | 57. (a) | 58. (b) | 59. (c) | 60. (d) |
| 61. (b) | 62. (a) | 63. (d) | 64. (b) | 65. (b) | 66. (a) | 67. (c) | 68. (a) | 69. (a) | 70. (a) |
| 71. (b) | 72. (b) | 73. (a) | 74. (c) | 75. (b) | 76. (b) | 77. (a) | 78. (b) | 79. (a) | 80. (b) |
| 81. (c) | 82. (c) | 83. (a) | 84. (a) | 85. (b) | 86. (a) | 87. (c) | 88. (d) | 89. (d) | 90. (b) |
| 91. (c) | 92. (b) | 93. (a) | 94. (c) | 95. (b) | 96. (b) | | | | |

Learning Plus

- | | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (b) | 3. (d) | 4. (a) | 5. (d) | 6. (c) | 7. (a) | 8. (c) | 9. (d) | 10. (c) |
| 11. (b) | 12. (b) | 13. (d) | 14. (b) | 15. (d) | 16. (a) | 17. (c) | 18. (d) | 19. (b) | 20. (d) |
| 21. (a) | 22. (b) | 23. (a) | 24. (d) | 25. (a) | 26. (a) | 27. (c) | 28. (c) | 29. (a) | 30. (a) |
| 31. (a) | 32. (b) | 33. (a) | 34. (c) | 35. (d) | 36. (b) | 37. (d) | | | |

Multiconcept MCQs

- | | | | | | | | | | |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (b) | 2. (c) | 3. (b) | 4. (a) | 5. (d) | 6. (b) | 7. (a) | 8. (a) | 9. (a) | 10. (d) |
| 11. (a) | 12. (b) | 13. (d) | 14. (c) | 15. (c) | 16. (c) | 17. (b) | 18. (d) | 19. (d) | 20. (d) |
| 21. (c) | 22. (a) | 23. (a) | 24. (d) | 25. (a) | | | | | |

NEET Past 10 Years Questions

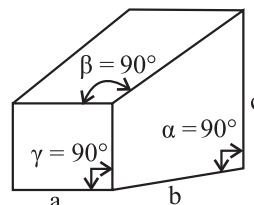
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|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1. (d) | 2. (c) | 3. (d) | 4. (d) | 5. (c) | 6. (d) | 7. (a) | 8. (d) | 9. (c) | 10. (c) |
| 11. (a) | 12. (d) | 13. (a) | 14. (c) | 15. (c) | 16. (b) | 17. (a) | 18. (b) | 19. (b) | |

Solution

Topicwise Questions

1. (b) Different crystal structures of same solid substance are polymorphs
2. (c) Glass is an amorphous solid
3. (b) Crystalline solids are not isotropic in nature. Crystalline solids are anisotropic, hard and dense in nature.
4. (d) Fused silica glass is amorphous material.
5. (a) Photo voltaic cell $\rightarrow$ solar cell.
6. (d) Molecular solid is a bad conductor of heat & electricity and has high mp.
7. (b) Anisotropy is shown only by crystalline solids.
8. (b) Crystalline solids are anisotropic in nature due to different arrangement of particles in different directions.
9. (c) In covalent solids, the force of attraction are covalent bond forces.
10. (c) Molecular solids: Atoms or molecules are bounded through Van Der Waals forces of attraction.
 $\text{CO}_2(\text{s}) \rightarrow$ London dispersion forces.
11. (c) Metallic solids conduct electricity in molten state as well as in solid state and are malleable, ductile and have fairly high melting point.
12. (b) Covalent solids or network solids are very hard with high melting point are insulators in solid as well as in molten state.
13. (c) Rock salt (Na^+Cl^-) is ionic solid. Ice and dry ice are molecular solids and quartz (SiO_2) is covalent or network solids.
14. (d) The ability of some materials to create an electric potential in response to applied mechanical stress is known as piezoelectric effect.
The commonly used piezoelectric materials are quartz (SiO_2), zinc oxide, etc.
15. (c) Dry ice is a molecular crystal as in dry ice (solid CO_2), constituents are molecules. The various molecules are held together through weak forces like dipole-induced dipole interaction, London dispersion forces etc.
16. (a) Number of different arrangement of atom in a single unit cell $\rightarrow$ corner, body centre, face centre.
17. (c) Orthorhombic geometry has $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$ so, the match box obey this geometry.
18. (c) In ZnS (Zinc Blende) crystal, S^{2-} ion occupy all (fcc) lattice points while, Zn^{2+} ions are present in alternate tetrahedral voids.
19. (b) NaCl contains 4Na^+ and 4Cl^- in the unit cell as sodium chloride (NaCl) has face centred cubic structure.
Each Na^+ is surrounded by 6Cl^- ions and vice-versa.
20. (d) A particular solid is very hard and has high melting point. In solid state, it is a non-conductor and in molten state, it is a conductor of electricity. Therefore, it is an ionic solid.
21. (c) In orthorhombic and cubic, there is FCC unit cells exist.
22. (c) There are four atoms per unit cell which is maximum in face centred cubic cell (fcc).
Number of atoms per unit cell

$$= \left(6 \times \frac{1}{2}\right) + \left(8 \times \frac{1}{8}\right) = 3 + 1 = 4$$
23. (d) Monoclinic crystal have two bravais lattices-Primitive and end centred.
24. (b) Ice has hexagonal closed packing.
25. (a) CsCl has structure with Cl^- ions at the corners and Cs^+ at the centre of the cube.
26. (d) For monoclinic crystal system,
 $a \neq b \neq c$, $\alpha = \gamma = 90^\circ$, $\beta \neq 90^\circ$
27. (d) Isotropic is not a crystal system type.



28. (a) The no. of atoms in a unit cells in BCC is 2.

29. (c) No. of X atoms = $\frac{1}{8} \times 8 = 1$

No of Y atoms = 1

No of Z atoms = $12 \times \frac{1}{4} = 3$

Formula of the compound = XYZ_3

30. (b) Sodium atom = 8 corners $\times \frac{1}{8}$ per corner = $8 \times \frac{1}{8} = 1$

Oxygen atom = 12 edges $\times \frac{1}{4}$ Per edge = $12 \times \frac{1}{4} = 3$

Tungsten atom in the centre of cube = 1

Hence; chemical formula = $NaWO_3$

31. (d) Unit cells of 14 types of lattice are called bravais lattices. These are 3 cubic, 2 tetragonal, 4 orthorhombic, 2 monoclinic, Hexagonal lattice, Rhombohedral, triclinic.

32. (c) Let the number of atoms in cubic close packing = x
 $\therefore$ Number of tetrahedral voids = 2x

Since, Q forms cubic close packing, the number of Q atoms = x; P occupy one third of tetrahedral voids, the

numbers of P atoms = $\frac{2}{3}x$

$$\frac{\text{Number of P atoms}}{\text{Number of Q atoms}} = \frac{2x}{3x} = \frac{2}{3}$$

Therefore the formula of the compound is P_2Q_3

33. (d) $BCC = \frac{1}{8} \times 8 + 1 \times 1 \Rightarrow 1 + 1 = 2$

$FCC = \frac{1}{2} \times 6 + \frac{1}{8} \times 8 \Rightarrow 3 + 1 = 4$

34. (b) In bcc structure,

The number of atoms at corners per unit cell = $\frac{1}{8} \times 8 = 1$

The number of atoms at body centre per unit cell = 1 atoms

$\therefore$ Total number of atoms per unit cell = $1 + 1 = 2$ atoms

35. (c) Contribution of X (at the corner) = $\frac{1}{8} \times 8 = 1$

contribution of Y (at the body centre) = 1

So, formula is XY.

36. (c) $\therefore$ A atoms occupy the corners of the cube,

$\therefore$ Number of atoms of A = $\frac{1}{8} \times 8 = 1$

$\therefore$ B atoms occupy the centre of each face of cube.

$\therefore$ Number of atoms of B = $\frac{1}{2} \times 6 = 3$

So, the formula is AB_3

37. (b) ABC ABC arrangement of layers is found in cubic closed pack system (ccp system). In which, total number of tetrahedral voids = $2 \times$ no. of atoms per unit cell

$\therefore$ No. of atoms/unit cell = Z

$\therefore$ No. of tetrahedral voids = 2Z

38. (d) For CsCl $r_c/r_a = 0.732$ or above

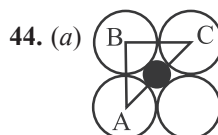
39. (c)

40. (a) Each Cs ion is surrounded by 8 Cl^- ions and each Cl^- ion is surrounded by 8 Cs^+ ions. CsCl has a bcc type structure in which Cs^+ occupy the centre of cube. Thus, the structure has 8 : 8 coordination number.

41. (c) In NaCl crystal, each Na^+ ion is surrounded by 6 Cl^- ion and each Cl^- ion is surrounded by 6 Na^+ ions.

42. (b) Four Ba^{2+} ions & eight Cl^- ions

43. (c) $a = 2(r^+ + r^-) = 2(95 + 181) = 552$ pm



In $\triangle ABC$,

$$AB = BC = 2R = a \quad \dots(i)$$

$$\text{and } AC = R + 2r + R = 2R + 2r \quad \dots(ii)$$

Also, AC

$$AC = \sqrt{AB^2 + BC^2} = \sqrt{a^2 + a^2} = \sqrt{2}a \quad \dots(iii)$$

$$\text{and } \frac{AC}{AB} = \frac{\sqrt{2}a}{a} = \sqrt{2} \quad \dots(iv)$$

Substituting values of AB & AC from (i) & (ii) in eqn (iv) :

$$\frac{2R + 2r}{2R} = \sqrt{2} \Rightarrow 1 + \frac{r}{R} = \sqrt{2} \Rightarrow r = 0.414R$$

45. (b) Greater +ve radius ratio larger +ve size of cation and hence +ve C.N.

46. (b) Octahedral sites are occupied by Na^+ ions in NaCl structure.

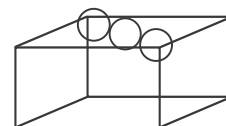
47. (c) AB AB packing is hexagonal close packing in which all atoms occupy 74% of the total space. Hence, 26% of space is empty.

48. (d) For FCC, $r = \frac{a}{2\sqrt{2}}$

$a = 361$ pm [given]

$$r = \frac{361}{2\sqrt{2}}$$

$$= 127.6 \text{ pm} \approx 128 \text{ pm}$$



49. (a) The close packed structure have both octahedral and tetrahedral voids. For n atoms, there are '2n' tetrahedral and "n" octrahedral voids.

50. (c) hcp is a closed packed arrangement in which the unit cell is hexagonal and Coordination Number is 12.

51. (a) In bcc lattice, $r = \frac{\sqrt{3}a}{4}$

$$r = \frac{1.732 \times 287}{4} = 124.27 \text{ pm}$$

52. (c) $r^+/r^- = 0.414$

$\Rightarrow$ Number of effective atom = 1

53. (d) Simple cubic structure has least packing efficiency

54. (c) In bcc, coordination no. of atoms is 8

55. (d) In NaCl crystal,

$$\begin{aligned} \text{Edge length} &= 2 \times \text{dist between Na}^+ \text{ and Cl}^- \\ &= 2 \times 265 = 530 \text{ pm} \end{aligned}$$

56. (d) For a body centred cubic lattice, the radius of atom is

$$r = \frac{\sqrt{3}a}{4}; a = 4.29 \text{ \AA}$$

$$r = \frac{1.732 \times 4.29}{4} = 1.86 \text{ \AA}$$

57. (a) Distance between K^+ and F^- in KF

$$= r_{\text{K}^+} + r_{\text{F}^-} = 133 + 136 = 269 \text{ pm}$$

58. (b) A $\rightarrow$ FCC = 4

B $\rightarrow$ 8 $\Rightarrow$ T.V

C $\rightarrow$ 2 $\Rightarrow$ 1/2 O.V

59. (c)

Radius ratio (r^+/r^-)	Coordination number
0.155 – 0.225	3
0.225 – 0.414	4
0.414 – 0.732	6
0.732 – 1.00	8

Hence, If the ratio of ionic radius is 0.52, then coordination number of B^- is 6

60. (d) With in its plane 6, above the plane 3, below the plane 3

61. (b) No. of sphere in fcc = $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4$

$$\text{Volume of 4 sphere} = 4 \times \frac{4}{3} \pi r^3 = \frac{16}{3} \pi r^3$$

62. (a) For simple cubic, $a = 2r$

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

$$\text{For body centred cubic, } a = \frac{4r}{\sqrt{3}} \Rightarrow r = \frac{\sqrt{3}a}{4}$$

$$\text{For face centred cubic, } a = 2\sqrt{2}r \Rightarrow r = \frac{a}{2\sqrt{2}}$$

Therefore, the ratio of radius of scc, bcc and fcc.

$$\frac{1}{2}a : \frac{\sqrt{3}}{4}a : \frac{1}{2\sqrt{2}}a$$

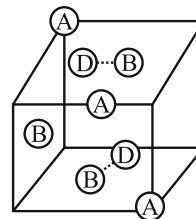
63. (d) For fcc number of atoms at corner = $\frac{1}{8} \times 8 = 1$

$$\text{Number of atoms at fcc centre} = \frac{1}{2} \times 6 = 3$$

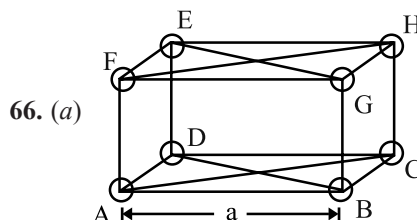
$$\therefore \text{Total number of atoms} = 1 + 3 = 4$$

64. (b) No. of tetrahedral holes are double the no. of sphere in cubic close packing.

65. (b) Body diagonal contain two atoms at corners, one octahedral void and two tetrahedral voids.



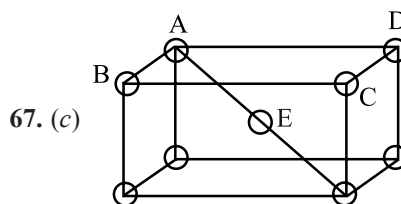
A & 3B (3B present at top, back and left face) forms tetrahedral void in which D is present.



$$AB = a \quad (1^{\text{st}} \text{ nearest})$$

$$AC = \sqrt{2}a \quad (2^{\text{nd}} \text{ nearest})$$

$$AH = \sqrt{3}a \quad (3^{\text{rd}} \text{ nearest})$$



$$AC = \sqrt{2}a \quad (3^{\text{rd}} \text{ nearest})$$

$$AB = a \quad (2^{\text{nd}} \text{ nearest})$$

$$AE = \frac{\sqrt{3}a}{2} \quad (1^{\text{st}} \text{ nearest})$$

68. (a) In any close packing, no. of spheres is equal to no. of octahedral holes.

$$69. (a) \rho = \frac{Z \cdot M}{N_A \cdot a^3}$$

$$\text{mass of } 24 \times 10^{23} \text{ atoms} = 200 \text{ g}$$

$$\text{mass of } 6 \times 10^{23} \text{ atoms} = 50 \text{ g}$$

$$m = 50, Z = 4, a = 2 \times 10^{-8} \text{ cm}$$

$$70. (a) d = \frac{Z \times M}{N_A \times a^3} \Rightarrow Z = \frac{a^3 \times d \times N_A}{M}$$

$$Z = \frac{(3.5 \times 10^{-8})^3 \times 0.53 \times 6.023 \times 10^{23}}{6.94} = 1.97002 \approx 2$$

71. (b) CsCl forms SCC lattice (BCC type), $Z = 1$

Volume of unit cell = volume of single CsCl ion pair = a^3

$$d = \frac{Z \times M}{N_A \times a^3} \Rightarrow a^3 = \frac{Z \times M}{d \times N_A} = \frac{1 \times 168.4}{3.988 \times 6.023 \times 10^{23}}$$

$$= 7.014 \times 10^{-23} \text{ cm}^3$$

72. (b) $d = \frac{Z \times M}{a^3 \times N_A}$

$$= \frac{4 \times 58.5}{(5.64 \times 10^{-8})^3 \times 6.023 \times 10^{23}} = 2.16 \text{ g cm}^{-3}$$

73. (a) Diameter = $2r$

For fcc lattice, $4r = \sqrt{2}a$

$$\Rightarrow 2r = \frac{a}{\sqrt{2}} = \frac{408}{\sqrt{2}} = 288 \text{ pm}$$

74. (c) Given cell is fcc so: $Z = 4$

Edge length, $a = 404 \text{ pm} = 4.04 \times 10^{-8} \text{ cm}$

Density of metal, $d = 2.72 \text{ g/cm}^3$

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

Molar mass of a metal, $M = ?$

We know that density

$$d = \frac{Z \times M}{a^3 \cdot N_A} \Rightarrow M = \frac{d \cdot a^3 \times N_A}{Z}$$

$$d = \frac{2.72 \times (4.04 \times 10^{-8})^3 \times 6.02 \times 10^{23}}{4} = 27 \text{ g/mol}$$

75. (b) $d = \frac{Z \times M}{a^3 \times N_A} = \frac{2 \times 100}{(400 \times 10^{-10})^3 \times 6.023 \times 10^{23}} = 5.188 \text{ g cm}^{-3}$

76. (b) $d = \frac{Z \times M}{N_A \times a^3} \Rightarrow 2.70 = \frac{Z \times 27}{6.023 \times 10^{23} (405 \times 10^{-10})^3}$

$$Z = 4$$

Hence; Structure of aluminium unit is fcc or face-centred.

77. (a) Interfacial separation as said above means that two adjacent vertices are separated by a distance of 53 pm.

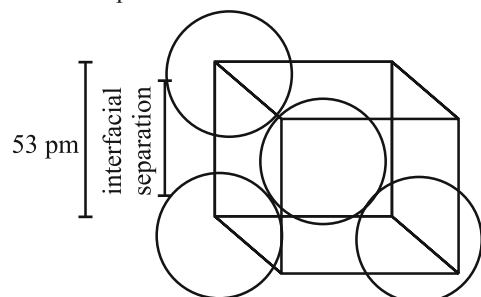
$$\therefore a - 2r = 53 \text{ pm} \quad \dots(i)$$

for bcc structure,

$$4r = \sqrt{3}a \quad \dots(ii)$$

from eqⁿ (i) & (ii)

$$a = 395.6 \text{ pm} = 3.956 \times 10^{-8} \text{ cm}$$



$$\text{density (d)} = \frac{ZM}{a^3 N_A} = \frac{2 \times 23}{6.023 \times 10^{23} \times (3.956)^3 \times 10^{-24}}$$

$$= 1.23 \text{ g/cc.}$$

78. (b) Extrinsic semiconductors are formed by addition of impurity to intrinsic semiconductors

79. (a) Electron trapped in anion site are responsible for colour and are known as F-centres.

80. (b) Fe_3O_4 is an example of inverse spinel. In Fe_3O_4 , oxide ions constitute fcc lattice and dipositive ions are present in octahedral holes and tripositive ions are equally distributed between tetrahedral and octahedral holes. A unit cell of Fe_3O_4 contain 4 O^{2-} , 2 Fe^{3+} and 1 Fe^{2+} ions.

81. (c) Some of the lattice points are unoccupied creating vacancy in the crystal. This defect is known as Schottky defect.

82. (c) Let the fractional of metal which exists as M^{3+} be x .

Then the fraction of metal as $\text{M}^{2+} = 0.98 - x$

$$\therefore 3x + 2(0.98 - x) = 2$$

$$x + 1.96 = 2$$

$$x = 0.04$$

$$\therefore \% \text{ of } \text{M}^{3+} = \frac{0.04}{0.98} \times 100 = 4.08\%$$

83. (a) Frenkel defect is shown by ionic solids. The smaller ion (usually cation) is dislocated from its interstitial site.

84. (a) In NaCl, Na^+ and Cl^- are of almost similar size.

85. (b)

86. (a) Another name of Frenkel defect is dislocation defect as in this the smaller ion (usually cation) is dislocated from its normal site to an interstitial site.

87. (c) In metal excess defect, F-centres are produced due to anionic vacancy in a crystal which is filled by one or more unpaired electrons.

Electrons in such a vacancy absorb light in visible region and impart colour.

88. (d) F-centres: When an anion is missing from its site and its position is taken by electron to maintain electrical balance, the electron thus trapped in anion vacancy is called F-centres. This imparts colours to crystal.

89. (d) p-type semiconductors are obtained when Si or Ge are doped with traces of element of group 13, i.e., indium (In), boron (B)

90. (b) Semiconductor

91. (c) Group 13 elements contain 3 valance electrons. When Si or Ge are doped with group 13 elements the fourth valence electron is missing, the hole created is called electron hole. The electricity flows through this hole. This type of semiconductors are known as p-type semiconductors.

92. (b) Germanium belongs to group 14 of periodic table and have 4 valence electrons when doped with group 15 elements like P, form n-type semiconductors due to presence of an extra valance electron.

93. (a) MnO_2 is anti-ferromagnetic in nature.
94. (c) 850 K is the 'curie temperature' responsible for the change in magnetic properties due to rearrangement of magnetic domains/ electron spins.
At 850 K, Fe_3O_4 becomes paramagnetic.

95. (b) Small electrical current are produce when some of the polar crystals are heated. This phenomenon is called pyroelectricity.
96. (b)

Learning Plus

1. (b) At low temperature existence of a substance in solid state is due to
Following two forces hold the constituent particles together thus causes existence of substance in solid state.
(a) slow molecular motion and
(b) strong cohesive forces
2. (b) Crystalline solid is anisotropic in nature because shows different physical properties such as electrical resistance, refractive index, Isotropic and anisotropic properties are related to amorphous and crystalline solid

Property	Types of solid	Physical properties
Isotropy	Amorphous solid	Same value
Anisotropy	Crystalline solid	Different values

3. (d) The substances which have domain structure are oppositely oriented and cancel each other's magnetic field are known as antiferromagnetic substances.



Antiferromagnetic substance.

4. (a) Quartz glass is an amorphous solid that having short range order. Hence, value of refractive index is same in all directions, which is not be equal to zero always.
5. (d) Amorphous solids are isotropic in nature as it has no long range order and any physical property will be same on all direction. Whereas, anisotropic nature is a feature of crystalline solid.
6. (c) Iodine is a non-polar solid in which iodine molecules are held together by dispersion force. This is soft and non-conductor of electricity.
Water is a hydrogen bonded molecular solid in which H and O are held together by polar covalent bond and each water molecule held together by hydrogen bonding. Due to non-ionic nature, they are not electrical conductor.
7. (a) Ionic solids are easily dissociated into ions in molten state and electrical conductivity. While ionic solids are anisotropic with very strong force of interactions.
8. (c) Certain metal oxides like VO_2 , VO , VO_3 and TiO_3 show metallic property depending upon temperature. As temperature varies metallic property varies. This is because of variation in energy gap between conduction band and valence band.
9. (d) CrO_2 , TiO and ReO_3 are metal oxides which show electrical conductivity similar to metal. While SiO_2 ,

MgO and SO_2 are oxides of metal, semimetal and non-metal which do not show electrical properties.

10. (c) Each point in a lattice is known as lattice point in which any constituent particles which are joined together by a straight line to bring out geometry of lattice in pure crystal constituents are arranged in fixed stoichiometric ratio.
11. (b) Schottky defect is observed in crystal when equal number of cations and anions are missing from the lattice. Thus, density of solid decreases.
When some cations move from their lattice site to interstitial site is known as Frenkel defect. When some impurity is present on crystal is known as impurity defect. When lattice site is occupied by electron, this type of defect is known as metal excess defect.
12. (b) When group 13 elements are doped in group 14 element, it creates a hole in a molecule which as a whole remain neutral. Thus, p-type semiconductor is neutral in nature.
13. (d) To get a n-type semiconductor from silicon, it should be doped with a substance with valence 5.
e.g., Si doped with P lead to formation of n-type semiconductor.
14. (b) Packing efficiency is the percentage of total filled space by particles

$$= \frac{\text{Volume occupied by four spheres in the unit cell}}{\text{Total volume of unit cell}} \times 100$$
Since, packing efficiency for hcp or ccp is calculated to be 74% which is maximum among all type of crystals.
15. (d) Hexagonal close packing can be arranged by two layers : AB AB AB
Here, we can see easily that 1st layer and 4th layer are not exactly aligned.
16. (a) NaCl crystal have rock salt structure having fcc lattice in which Cl^- ions are present at fcc lattice points and face centre and Na^+ occupies all the octahedral void of given unit cell.
Where, coordination number of $\text{Na}^+ = 6$
coordination number of $\text{Cl}^- = 6$
17. (c) Coordination number in a square closed packed structure in two dimensions is equal to 4.
18. (d) When electron rich or electron deficient impurity is added to a perfect crystal introduces electronic defect in them.

19. (b) Silicon doped with electron rich impurity such as phosphorus forms a n-type semiconductor. This is due to presence of free electron.
20. (d) The fraction of octahedral or tetrahedral voids occupied depends upon the radii of the ions present at the lattice points. As we know the radii of octahedral or tetrahedral void is related to radii of atoms (r) as
 Radius of octahedral void (R_o) = $0.414 r$
 Radius of tetrahedral void (R_t) = $0.225r$
 Where, r = radius of bigger atom involved.
21. (a) When a ferromagnetic substance is placed in a magnetic field it becomes a permanent magnet because all the domains get oriented in the direction of magnetic field even after removal of applied magnetic field.

22. (b) Packing efficiency in different types of unit cells can be tabulated as

Unit cell	Packing efficiency
fcc	74%
bcc	68%
Simple cubic	52%

Hence, correct order is fcc (74%) > bcc (68%) > simple cubic (52%).

23. (a) Frenkel defect is also called dislocation defect because in Frenkel defect atoms present in crystal lattice is dislocated to interstitial site.
24. (d) In the cubic close packing the unit cell has 8 tetrahedral voids which is located at each eight corner of unit cell.
25. (a) Edge length for different types of unit cells can be tabulated as

Types of unit cell	Edge length
Fcc	$2\sqrt{2}r$
bcc	$\frac{4}{\sqrt{3}}r$
scc	$2r$

26. (a) Conductivity of metal, insulator and semiconductors can be represented in the term of κ (Kappa) which depends upon energy gap between valence band and conduction band.
 Hence, correct order is

$$\kappa_{\text{metals}} \gg \kappa_{\text{insulators}} < \kappa_{\text{semiconductors}}$$

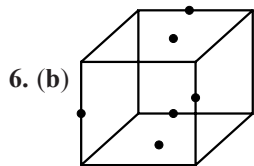
27. (c) Tetrahedral voids are formed when the triangular void in the second layer lie exactly above the first layer and the triangular shape of these voids oppositely overlap.

Octahedral voids are formed when void of second layer is not exactly overlap with similar void in first layer.

28. (c) In antiferromagnetic substances, magnetic moment becomes zero because the domains are oppositely oriented with respect to each other without the application of magnetic field which cancel out each other.
29. (a) The gap between valence band and conduction band decide the conductivity of material.
30. (a) In p -type semiconductor, the conductivity is due to existence of hole. When electric field is applied to p -type semiconductor hole starts moving towards negatively charged plate and electron towards positively charged plate.
31. (a) When KCl crystals are heated it leads the diposition of potassium ion on surface of KCl. The Cl ions diffuse to the surface of crystal and loss electron by potassium atom to form K^+ ion released electron occupies anionic site which is known as F-centre and impart colour to the crystal
32. (b) NaCl has a rock salt type structure having fcc arrangement.
 Total number of atoms per unit cell = 4
 Number of tetrahedral voids = $2 \times 4 = 8$
 Number of octahedral voids = 4
33. (a) Amorphous solid has short range order and has a tendency to flow very slowly. Hence, it is also known as pseudo solids or super cooled liquids. Glass panes fixed to windows or doors of old buildings are invariably observed to be thicker at bottom than at the top. These are examples of amorphous solids.
34. (c) Quartz glass is an amorphous solid so it has not definite heat of fusion. This is due to short range order of molecule while quartz glass is also known as super cooled liquid and isotropic in nature.
35. (d) SiC, AlN and diamond are examples of network solid as they have three dimensional structure while I_2 is a molecular solid, because such solid particles are held together by dipole-dipole interactions.
36. (b) Frenkel defect arises when the smaller ion (usually cation) is dislocated from its original site to interstitial site, this is also known as dislocation defect.
37. (d)

Multiconcept Questions

- (b) Ferromagnetic substances can be magnetised by applying magnetic field to it and magnetic property remain after removal of magnetic field.
- (c) Impurity defect changes the density of substance as impurity has different density than the ion present on perfect crystal. e.g., When SrCl_2 is added to the NaCl crystal it causes impurity defect.
- (b) Silicon doped with an electron rich impurity is an n-type semiconductor. Conductivity of n-type semiconductor is due to presence of free electron increases the conductivity of doped silicon due to increase in mobility of electron.
- (a) n-type semiconductor When group 15 elements are doped with group 16 which leads to formation of n-type semiconductor.
- (d) Ferrimagnetic substances lose ferrimagnetism on heating and become paramagnetic. In ferrimagnetic substance domains are aligned in parallel and antiparallel direction in unequal numbers.
In ferromagnetic substances, all the domains get oriented in the direction of magnetic field and remain as such even after removing magnetic field.



Alternate face centres = 2

Alternate edge centres = 4

$$A \quad B \quad C = A_4 \frac{B_3}{2} \frac{C_3}{2}$$

$$\frac{1}{2} \times \frac{1}{2} \times 6 \quad \frac{1}{4} \times 12 \times \frac{1}{2}$$

$$A_8 \quad B_3 \quad C_3$$

7. (a) $\text{Fe}_{0.9}\text{O}$

Let no. of $\text{Fe}^{2+} = x$

No. of $\text{Fe}^{3+} = 0.9 - x$

$$2x + 3(0.9 - x) = +2$$

$$2x + 2.7 - 3x = +2$$

$$-x = -0.7 \Rightarrow x = 0.7$$

No. of $\text{Fe}^{2+} = 0.7$

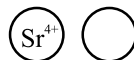
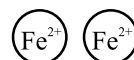
No. of $\text{Fe}^{3+} = 0.9 - 0.7 = 0.2$

1 molecule of $\text{Fe}_{0.9}\text{O}_{1.00}$ has $\text{Fe}^{2+} = 0.7$

$$0.1 \times N_A \text{ molecule of } \text{Fe}_{0.9}\text{O}_{1.00} \text{ has } \text{Fe}^{2+} = 0.7 \times 0.1 \times N_A \\ = 0.07 \times N_A$$

Now, 2 Fe^{2+} substitute $\text{Sr}^{4+} = 1$

$$0.07 \times N_A \text{ substitute } \text{Sr}^{4+} = \frac{1}{2} \times 0.07 \times N_A \text{ Sr}^{4+}$$



1 Sr^{4+} creates, cation vacancy = 1

$$\frac{0.07}{2} \times N_A \text{ Sr}^{4+} \text{ creates, cation vacancy}$$

$$= \frac{0.070}{2} \times N_A = 0.035 \times N_A$$

8. (a) $\text{Fe}_{0.94}\text{O}$

Let no. of Fe^{2+} ions = x

No. of Fe^{3+} ions = $(0.94 - x)$

$$2x + 3(0.94 - x) = +2 \Rightarrow x = 0.82$$

So, number of $\text{Fe}^{2+} = 0.82$

number of $\text{Fe}^{3+} = 0.12$

2 Fe^{3+} balance the charge carried by 3 Fe^{2+} ions

$\therefore$ 2 Fe^{3+} ions create cation vacancy = 1

0.12 Fe^{3+} ions will create cation vacancy =

$$\frac{1}{2} \times 0.12 = 0.06$$

Total octahedral sites = $0.82 + 0.12 + 0.06 = 1$

% age of octahedral sites occupied by vacancies

$$= \frac{0.06}{1} \times 100 = 6\%$$

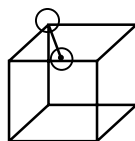
9. (a) Effective No. of C atoms per unit cell =

$$8 \times \frac{1}{8} + 6 \times \frac{1}{2} + 4$$

(at corner) (at face centres) (alt. T.V.)
= 8

% of t.v by carbon atom is 50%

$$\text{P.F.} = \frac{\text{Vol. occupied by atoms}}{\text{Total vol. of cube}} = \frac{8 \times \frac{4}{3} \pi r^3}{a^3} = \frac{8 \times \frac{4}{3} \pi r^3}{\left(\frac{8r}{\sqrt{3}}\right)^3}$$



$$2r = \frac{\sqrt{3}a}{4}$$

$$\text{P.F.} = 8 \times \frac{4}{3} \pi r^3 \times \frac{3\sqrt{3}}{8r \times 8r \times 8r}$$

$$\text{P.F.} = 0.34 \Rightarrow (34\%)$$

10. (d)

11. (a) Number of $\text{Na}^+ = 4 - 1 = 3$

$$\text{Number of } \text{Cl}^- = 4 - 2 \times \frac{1}{2} = 3$$

12. (b)

13. (d) Each Na^+ are surrounded by 6Cl^- ions as next nearest neighbour

$$14. (c) \text{Density}(\rho) = \frac{Z \times M}{N_0 \times a^3}$$

$$= \frac{4 \times 58.5}{6.023 \times 10^{23} \times (0.5627 \times 10^{-7})^3} = 2.1806 \text{ g/cm}^3$$

Observed density = 2.164 g/cm^3 which is less than calculated density because some ions are missing. Actual units per unit cell can be calculated as

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

$$= \frac{2.164 \times 6.023 \times 10^{23} \times (0.5627 \times 10^{-7})^3}{58.5} = 3.969$$

$$Z = 4 - 3.969 = 0.031$$

$$\therefore \% \text{ of missing } \text{Na}^+ \text{ and } \text{Cl}^- = \frac{0.031}{4} \times 100 = 0.775\%$$

15. (c)

16. (c)

$$17. (b) d = \frac{Z \times M}{a^3 \times N_A}$$

For fcc, $Z = 4$

$$d = \frac{4 \times 50}{(0.50 \times 10^{-9})^3 \times 6 \times 10^{23}} = 2.66 \times 10^6 \text{ g m}^{-3}$$

If it contains 0.25% Schottky defects, then

$$d' = 2.66 \times 10^6 \times \frac{0.25}{100} = 6.65 \times 10^3 \text{ gm}^{-3}$$

$$d'' = d - d' = 2.66 \times 10^6 - 6.65 \times 10^3 \text{ g m}^{-3}$$

$$\approx 2.65 \times 10^6 \text{ g m}^{-3} = 2.65 \text{ g cm}^{-3}$$

18. (d) Number of atoms in ccp = $4 = \text{O}^{2-}$
Number of tetrahedral voids = $2 \times N = 2 \times 4$

$$\text{Number of } \text{A}^{2+} \text{ ions} = 8 \times \frac{1}{4} = 2$$

Number of octahedral voids

$$= \text{Number of } \text{B}^+ \text{ ions} = N = 4$$

$$\text{Ratio, } \text{O}^{2-} : \text{A}^{2+} : \text{B}^+ = 4 : 2 : 4 = 2 : 1 : 2$$

$$\text{Formula of oxide} = \text{AB}_2\text{O}_2$$

19. (d) (c) is not true because impurity defect changes the mass but not the volume. (d) is not true because Frenkel defect neither changes mass nor volume.

20. (d)

21. (c) Let No. of Fe^{2+} & O^{2-} be 100 each
If 12% Fe^{2+} are replaced, 12 Fe^{2+} out of 100 will be replaced 3 Fe^{2+} are replaced by $\text{Fe}^{3+} = 2$

$$12 \text{ Fe}^{2+} \text{ are replaced by } \text{Fe}^{3+} = \frac{2}{3} \times 12 = 8$$

So, total Fe will be

$$\text{Fe}^{2+} = 88$$

$$\text{Fe}^{3+} = 8$$

$$\text{Fe}_{96} \text{O}_{100}$$

$$\therefore \text{total Fe} = 96 \quad \text{O}^{2-} = 100 \quad \therefore \text{Fe}_{0.96}\text{O}_{1.00}$$

22. (a)

23. (a)

24. (d)

25. (a)

NEET Past 10 Years Questions

1. (d) No. of atoms in Hexagonal primitive unit cell = 6

$$\begin{aligned} \text{No. of Tetrahedral voids} &= 2 \times \text{No. of atoms per unit cell} \\ &= 2 \times 6 \\ &= 12 \end{aligned}$$

$$\begin{aligned} \text{No. of Octahedral voids} &= \text{No. of atoms per unit cell} \\ &= 6 \end{aligned}$$

2. (c) The number of Body centred unit cells in all 14 types of Bravais lattice unit cells is 3.

3. (d) For BCC,

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

$$\text{Given : } a = 288 \text{ pm} \quad (a = \text{edge length, } r = \text{radius})$$

$$r = \frac{\sqrt{3}}{4} \times 288 \text{ pm}$$

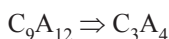
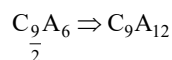
4. (d) AgBr shows both, Frenkel as well as Schottky defects.

It is because AgBr crystal has a coordination number of 6 which is neither high nor low. The radius ratio of AgBr is also intermediate, thus AgBr satisfies the conditions to exhibit both type of defects

5. (c) Anions(A) are in HCP, so number of anions (A) = 6
Cations(C) are in 75% O.V., so number of cations (C)

$$= 6 \times \frac{75}{100} = \frac{9}{2}$$

Thus formula of compound is



6. (d) For bcc lattice : $Z = 2$, $a = \frac{4r}{\sqrt{3}}$

For fcc lattice : $Z = 4$, $a = 2\sqrt{2}r$

$$\therefore \frac{d_{25^\circ \text{C}}}{d_{900^\circ \text{C}}} = \frac{\left(\frac{ZM}{N_A a^3}\right)_{\text{bcc}}}{\left(\frac{ZM}{N_A a^3}\right)_{\text{fcc}}}$$

$$= \frac{2}{4} \left(\frac{2\sqrt{2}r}{\sqrt{3}} \right)^3 = \left(\frac{3\sqrt{3}}{4\sqrt{2}} \right)$$

7. (a)

8. (d) $\text{Mg}^{+2} = 1$, $\text{Al}^{3+} = 2$, $\text{O}^{2-} = 4$
 $\therefore$ The formula of the compound is MgAl_2O_4 .

9. (c) In this structure, Ca^{2+} ions are in the FCC arrangement.
 Each Ca^{2+} is connected to 4F^- ions above it, i.e., Ca^{2+} has a C.N. = 8
 and F^- has a C.N. = 4

10. (c) According to the formula

$$d = \frac{Z.M}{N_A \times a^3} \quad \text{For bcc, } Z = 2$$

$$= \frac{2 \times 6.94 \times 10^{-3}}{6.022 \times 10^{23} \times a^3}$$

$$a^3 = 43.5 \times 10^{-30} = 352 \text{ pm}$$

11. (a) Packing fraction of bcc lattice = 68%
 Vacant space = 32%

12. (d) In Frenkel defect or dislocation defect smaller cation leaves its actual site and enters the interstitial site, or it gets dislocated from its original site.

13. (a) In fcc

$$a = 361 \text{ pm}$$

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

$$r = \frac{\sqrt{2} \times 361}{4}$$

$$= 127 \text{ pm}$$

14. (c) Body diagonal of a cube $\sqrt{3}a$ where a = side of cube
 As a body diagonal will have 3 sphere = $2r + r + r$
 $= 4r$

$$\text{Half of body diagonal} = \frac{\sqrt{3}a}{2}$$

15. (c) According to formula

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

$$2.72 = \frac{4 \times \text{Molecular Mass}}{6.022 \times 10^{23} \times (404 \times 10)^3}$$

$$M = 27 \text{ g mol}^{-1}$$

16. (b) Effective number of C atoms in a diamond unit cell

$$\frac{1}{8} \times 8 + \frac{1}{2} \times 6 + 4 = 8 \text{ atoms}$$

17. (a) O^{2-} makes closed cubic packing
 so, number of closed cubic packing $\text{O}^{2-} = 4$

As $\frac{1}{4}$ of tetrahedral voids are occupied by A^{2+}

$$= \frac{1}{4} \times 8 = 2$$

Number of octahedral void = Number of B^+ ions = $N = 4$

Ratio, $\text{O}^{2-} : \text{A}^{2+} : \text{B}^+ = 4 : 2 : 4 = 2 : 1 : 2$

Formula becomes AB_2O_2

18. (b) Octahedral voids = number of atoms per unit cell.
 4 octahedral voids are present in face centred cubic packing and in cubic closed packing, one octahedral void is present.

19. (b) In face centred cubic

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

$$r = \frac{\sqrt{2} \times 408}{4}$$

$$= 144 \text{ pm}$$

$$2r = \text{diameter} = 288 \text{ pm.}$$