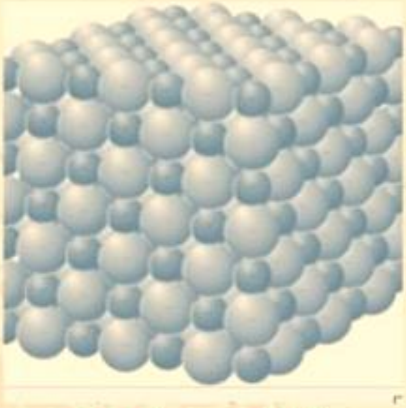
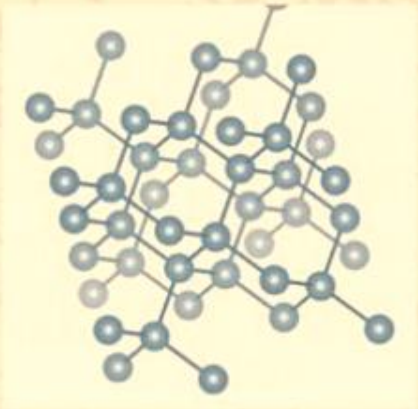
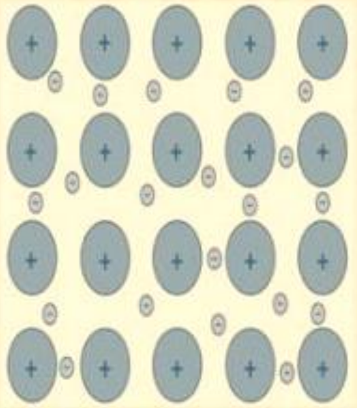
# 1. THE SOLID STATE


Ionic solid


Covalent solid


Metallic Solid

Chemistry Smart Booklet
Theory + NCERT MCQs + Topic Wise Practice
MCQs + NEET PYQs

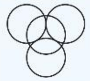
## OCTAHEDRAL VOID (OV)

Surrounded by 6 Spheres

C.N. = 6

Present on edge centre and body body centre of FCC unit

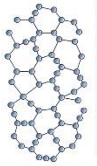
## TETRAHEDRAL VOID (TV)



Surrounded by 4 Spheres

C.N. = 4

Present on body diagonal line at a distance of $\frac{a\sqrt{3}}{4}$ from corner of FCC unit



## CRYSTALLINE & AMORPHOUS SOLID

| CRYSTALLINE | AMORPHOUS |
|---|---|
| · Have a long range order of particles | · Do not have ordered structure or have a very short order |
| · Anisotropic | · Isotropic |
| · True Solids | · Pseudo Solids |
| · Sharp melting point | · Diffused melting point |
| · NaCl, Quartz, ZnS | · Glass, Rubber, etc. |

- Molecular
- Covalent/Network
- Ionic Solid
- Metallic Solids

## CRYSTAL LATTICE / SPACE LATTICE

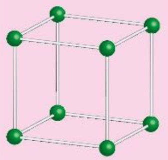
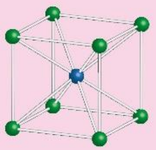
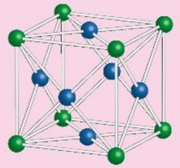
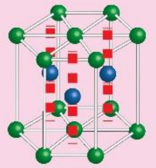
A regular 3-D arrangement of constituent particles.

UNIT CELL

Smallest repeating unit which repeats itself over and over again to generate entire crystal

## Types of Crystal Lattice/ 14 Bravis Lattices

| | | |
|---|---|---|
| Cubic | a = b = c | $\alpha = \beta = \gamma = 90°$ |
| Tetragonal | $a = b \neq c$ | $\alpha = \beta = \gamma = 90°$ |
| Orthorhombic | $a \neq b \neq c$ | $\alpha = \beta = \gamma = 90°$ |
| Monoclinic | $a \neq b \neq c$ | $\alpha = \gamma = \beta \neq 90°$ |
| Hexagonal | $a = b \neq c$ | $\alpha = \beta = 90°\ \gamma = 120°$ |
| Rhombohedral | a = b = c | $\alpha = \beta = \gamma \neq 90°$ |
| Triclinic | $a \neq b \neq c$ | $\alpha \neq \beta \neq \gamma \neq 90°$ |

| | Simple Cubic Unit Cell (S.C.C.) | Body Centered Cubic Unit Cell (B.C.C.) | Face Centered Cubic Unit Cell (F.C.C.) | Hexagonal Closed Packed Unit Cell (H.C.C.) |
|---|---|---|---|---|
| |  |  |  |  |
| Lattic Points | Corners | Corners + Body Center | Corners + All Face Center | Corners + Face Centers + 3 atoms in middle layers |
| Effective Number of atoms (Z) | $\left(8\times\frac{1}{8}\right)=1$ | $\left(8\times\frac{1}{8}+1\right)=2$ | $\left(8\times\frac{1}{8}+6\times\frac{1}{2}\right)=3$ | $\left(12\times\frac{1}{6}+2\times\frac{1}{2}+3\right)=6$ |
| Packing Efficiency (PE) | 52% | 68% | 74% | 74% |
| Coordination No. | 6 | 8 | 12 | 12 |

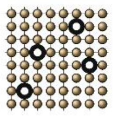
## DEFECTS IN CRYSTALS

### STOICHIOMETRIC DEFECTS

#### IN NON-IONIC SOLIDS

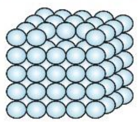
**Vacancy Defects**

- Some of the lattice sites are vacant
- Decrease in density



**Interstitial Defects**

- Some particles occupy an interstial site
- increase in density



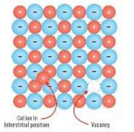
#### IN IONIC SOLIDS

**Schottky Defects**

- Equal No. of cations and anions are missing
- Decrease in density

**Frenkel Defects**

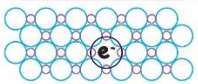
- Smaller ion is dislocated from it's normal site to an interstitial sites
- No change density



### NON STOICHIOMETRIC DEFECT

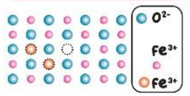
**Metal excess Defect**

- It may arise either due to anionic vacancies or due to presence of extra cations at interstitial sites
- Generate F-centres which are responsible for colour in crystal



**Metal deficiency Defects**

- Occurs due to cationic vacancy and presence of a cation having higher charge.
- Appearance in oxides of d-block metals.



**Density**

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

**Coordination No. (C.N.)**

It is No. of nearest Neighbours of a lattice point

**Packing Efficiency (P.E.)**

$$PE = \frac{Z \times \frac{4}{3}\pi r^3}{a^3} \times 100$$

## STRUCTURE OF VARIOUS IONIC CRYSTALS

| Crystal Structure | Lattice Points | C.N. | Number of formula Units per unit cell | Eg |
|---|---|---|---|---|
| Rock Salt NaCl type | $Cl^-$.-CCP<br>$Na^+$ -OV | 6:6 | 4 | LiCl, KCl RbCl, AgCl |
| Zinc-Blende ZnS type | $S^{2-}$-CCP<br>$Zn^{2+}$-Alternate TV | 4:4 | 4 | ZnS, BeS, CuCl, CuI |
| CsCl type (BCC type) | $Cl^-$-Corners<br>$Cs^+$-Body centre | 8:8 | 1 | CsBr, CsI, CsCN |
| Fluorite type ($CaF_2$) | $Ca^{2+}$-CCP<br>F-all TV | 8:4 | 4 | $SrF_2$, $BaF_2$, $SrCl_2$ |
| Anti-fluorite type ($Na_2O$) | $O^{2-}$-CCP<br>$Li^+$-all TV | 4:8 | 4 | $K_2O$, $Li_2O$, $K_2S$ |

## MAGNETIC & ELECTRICAL PROPERTIES

### MAGNETIC PROPERTIES

- Paramagnetic- weakly attracted by magnetic field. eg. $O_2$, $Cu^{2+}$ etc.
- Diamagnetic- weakly repelled by magnetic field. $H_2O$, NaCl, etc.
- Ferromagnetic- permanent magnetism even in absence of magnetic fields eg. Fe, Ni, Co, $CrO_2$, etc.
- Ferrimagnetic- Magnetic moment is smaller than that of ferromagnetic substances. eg.
- Antiferromagnetic- Zero magnetic moment due to equal No. of anti-parallel eg. domains. eg. MnO, etc.

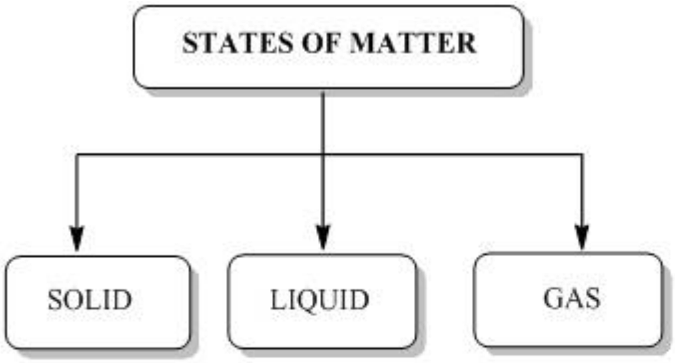
### ELECTRICAL PROPERTIES

- Conductors- Valence bond is partially filled or it overlaps with higher energy unoccupied conduction bond.
- Insulators- Large energy gap between valance and conduction bond.
- Semi-conductors- Small energy gap between valance and conduction bond.
- P-type Semiconductor (by doping e⁻ deficient impurities
- N-type Semiconductor (by doping e⁻ rich impurities

# THE SOLID STATE

## Introduction

Everything in our surroundings is known as matter that can be categorized into three states.



In our day to day life solids plays a crucial role to pursue different purposes. Different types of solids with different properties are required for different purposes. The constituent particles and the type of bonds between the particles determine the nature of a specific solid. For eg. Bucket or a container used to carry water, utensils used for cooking food, computer, vehicles, electronic gadgets, notebooks, pencils, papers etc. are all solid substances used in our day to day life.

Liquids and gases on the other hand are another state of matter and are also known as fluids due to their ability to flow. They attain the ability to flow due to the free movement of molecules.

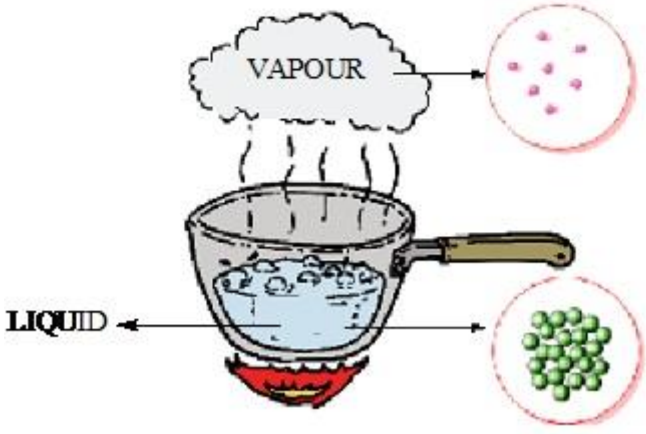


Fig. Particles of liquid (water) are loosely packed than solid and have space between them whereas particles of gas are loosely packed and have excess space between the particles

## Characteristics of solid state

- They have definite shape due to strong Intermolecular forces of attraction.
- They have distinct boundaries.
- They have a fixed volume.
- They cannot flow.
- They have negligible compressibility due to negligible distance between the neighbouring molecules.
- They possess a tendency to uphold their shape when exposed to external force.
- They break under force but it is difficult to change their shape so they are rigid.
- They have high density and do not diffuse at all.

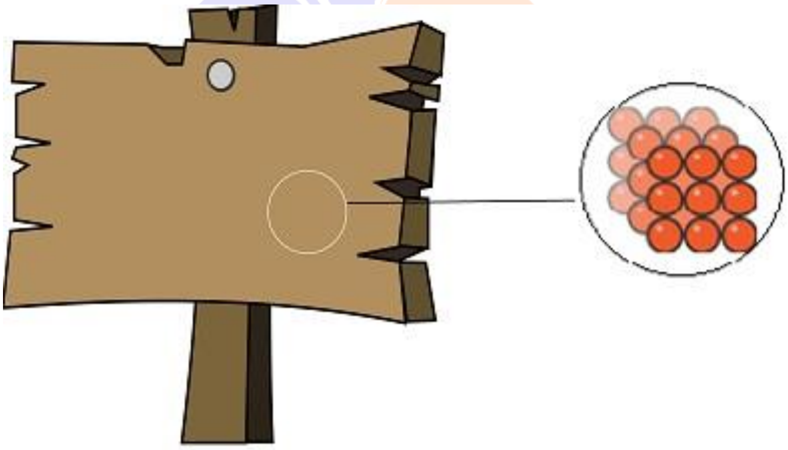


**Fig**. Particles of solid (Wooden plank) are compact together and have less space between them

## Classification of Solids

Solids are classified on the basis of two different parameters i.e.,

1. Packing of constituent particles
2. Forces of attraction among constituent particles.

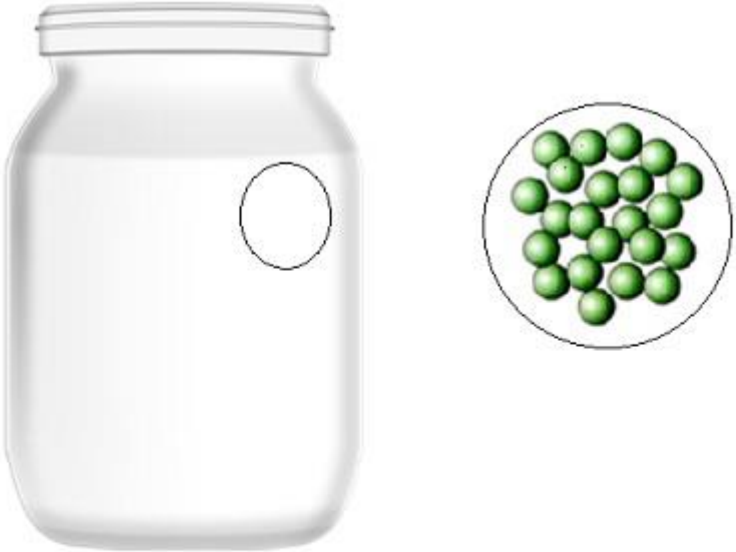
## Classification on the basis of packing

### 1. Crystalline Solids

These are the solids in which the constituent particles (atoms, ions or molecules) are arranged in a regular, three dimensional orderly arrangement, which gets repeated throughout. Hence, these are also called as long-range order solids. Quartz, diamond, Boron Nitride, NaCl, ZnS, CsCl etc.

### 3. Amorphous Solids

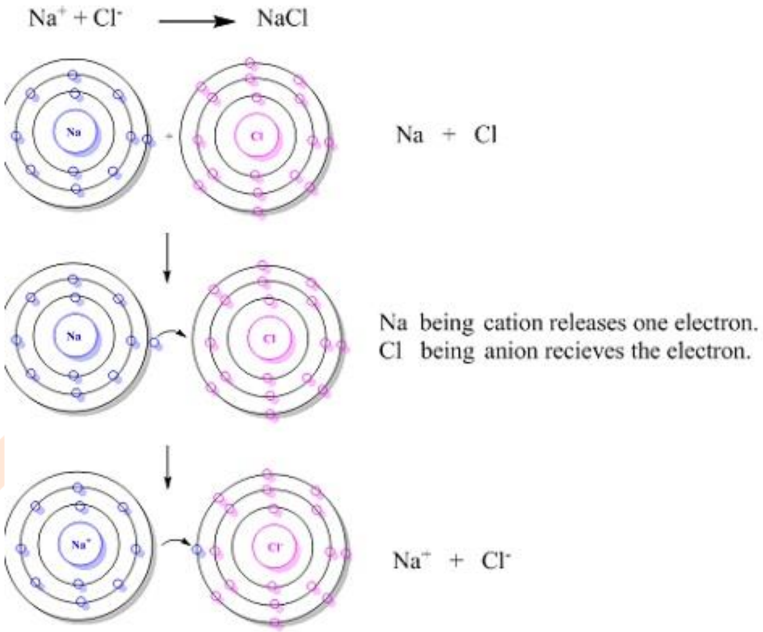
Constituent particles are randomly scattered with, no regular arrangement of particles. Therefore they do not have any definite shape or form. Rubber, glass, plastic etc. are commonly known as amorphous solids.



## Classification on the basis of Nature of Intermolecular Forces

### (i) Ionic Solids

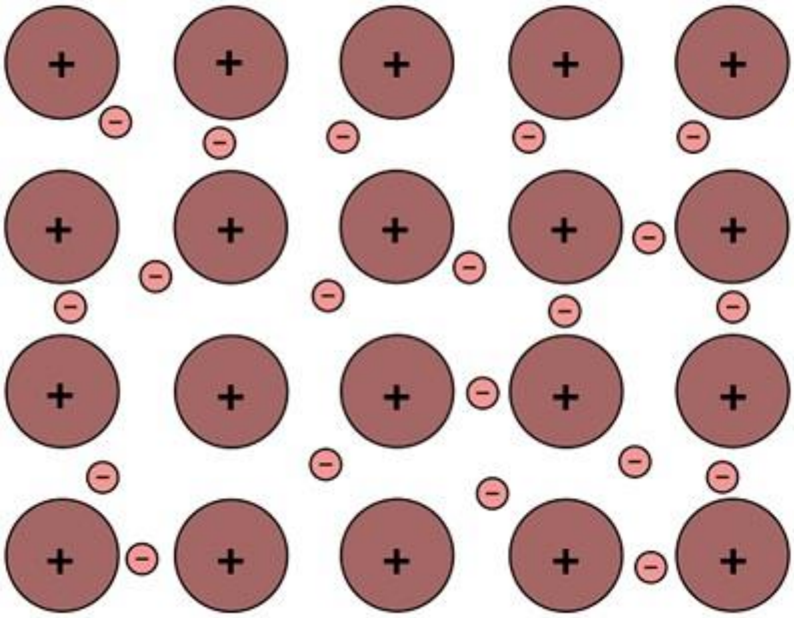
There is a regular arrangement of positively and negatively charged ions throughout the solid where ions are held together by strong coulombic or electrostatic forces. These solids are very hard and brittle and have very high melting points. In solid state, as ions are not free to move, hence they are insulators but in molten state or in aqueous state, it's ions become free to move and it becomes conductor. Ionic solids have high enthalpies of vaporisation. Ex- LiF, NaCl, $KNO_3$, MgO, etc.



## (ii) Metallic Solids

Metal cores and a sea of mobile electrons are the constituents of metallic solids. Each metal atom contributes one or more electrons towards sea of electrons. These electrons are evenly spread out throughout the crystals and weak forces of attraction or metallic bond binds together kernels and sea of electrons.

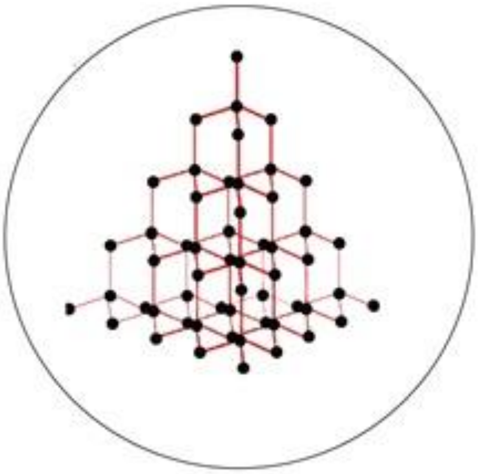
Metallic crystals may be hard as well as soft having moderate enthalpies of fusion. Mobile sea of electrons is responsible for many properties of metals such as malleability (can be beaten into thin sheets), ductility (can be drawn into wires), metallic lustre, thermal conductivity and electrical conductivity etc. Ex- Copper, Iron, Nickel etc.



Metallic Solids

## (iii) Covalent Solids (Network Solid)

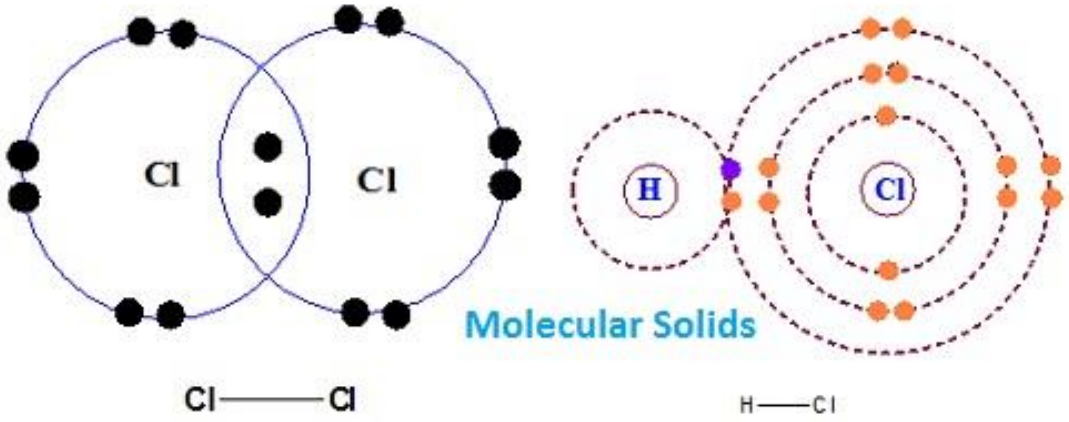
In these atoms are bonded together by covalent bond formation throughout the crystal. It means there is a continuous network of covalent bonds forming a giant three dimensional structure or giant molecule. Covalent bonds are strong and directional in nature. These solids are very hard, brittle and very high melting point. Due to absence of any free electrons or ions they are insulators. Their enthalpies of fusion are very high. Ex- Diamond, Graphite, Boron Nitride, Silicon Carbide (SiC) etc.



Covalent Solids

## (iv) Molecular Solids

Their molecules are held together by dispersion forces, London forces, dipole-dipole forces or hydrogen bonds. Either atoms or molecules are bonded together by weak dispersion forces or London forces. These are non-conductor soft solids with low m.p. and low enthalpies of vaporisation. They are volatile in nature hence, at room temperature and pressure they are available in liquid or gaseous state. Ex- Iodine, Solid $H_2$ and $CO_2$ (dry ice). Naphthalene, Camphor etc.

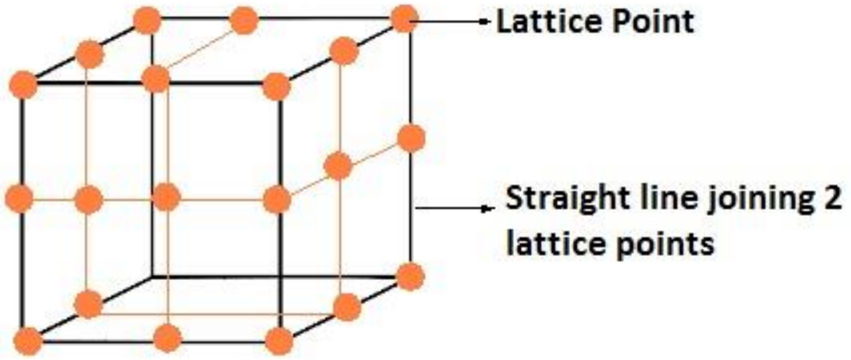


Molecular Solids

## Crystal Lattices and Unit Cells

### (i) Crystal Lattices

In a crystalline solid, constituent particles are arranged in a definite, three-dimensional regular geometrical order along all the three axes, in which each particle is depicted as a lattice point. A three-dimensional, regular arrangement of lattice points in space or in a crystal is called a crystal lattice or space lattice.

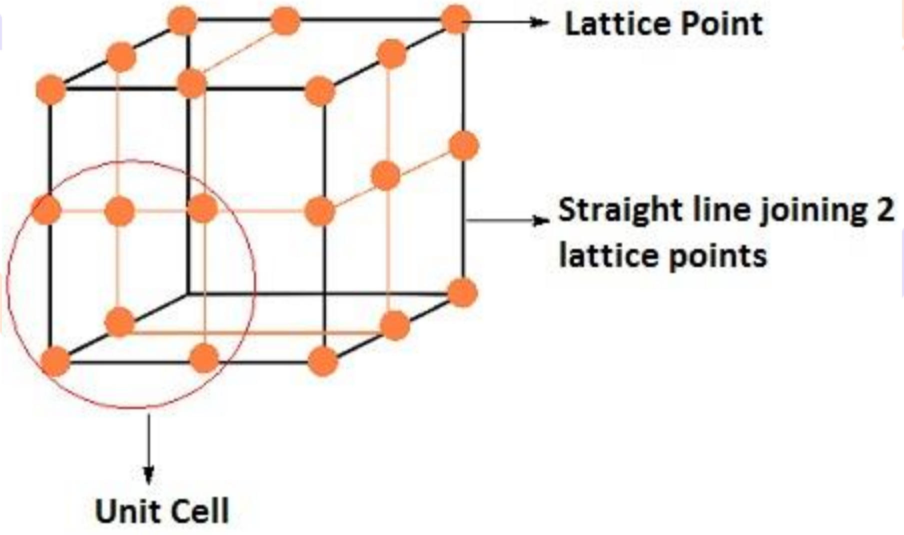


Crystal lattice have following characteristics

- Each point in lattice is called lattice site or lattice point.
- Each lattice point represents one constituent particle i.e. atom, ion or molecule.
- We join lattice points by straight lines to show geometry of the lattice.

## (ii) UNIT CELL

The smallest repeating unit in space lattice which when repeated over and over again in different directions produce complete crystal lattice. There are two important parameters of a unit cell.



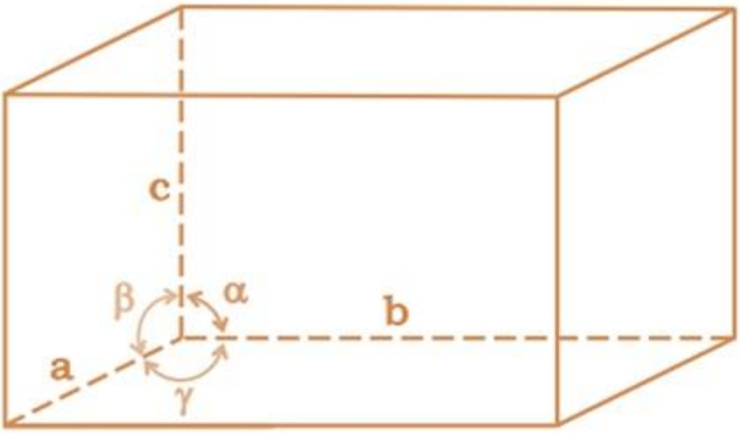
**Edge length or Axial Distance:** Lengths or dimensions along the three edges a, b and c which may or may not be mutually perpendicular.

**Interaxial Angle:** Angles α, β and γ between pair of edges are interaxial angle.

α : between axis B and C

β : between axis A and C

γ : between axis A and B



## Distinction Between Crystalline and Amorphous Solids

| S.No | Crystalline solid | Amorphous solids |
|---|---|---|
| 1 | These have definite and regular arrangement of the constituent particles in space. | These doesn’t have any regular arrangement of the constituent particles in space. |
| 2 | These are true solids. | Theseare super cooled liquids or pseudo soilds. |
| 3 | These have long order arrangement of the particles. | These have short order arrangement of particle. |
| 4 | These are anisotropic in nature, i.e., their physical properties are different in different directions. | These are isotropic in nature i.e., their physical properties are same in all the directions. |
| 5 | They have sharp melting points. | They melt over a certain range of temperature. |
| 6 | They undergo a clean cleavage when cut. | They undergo irregular cleavage when cut. |

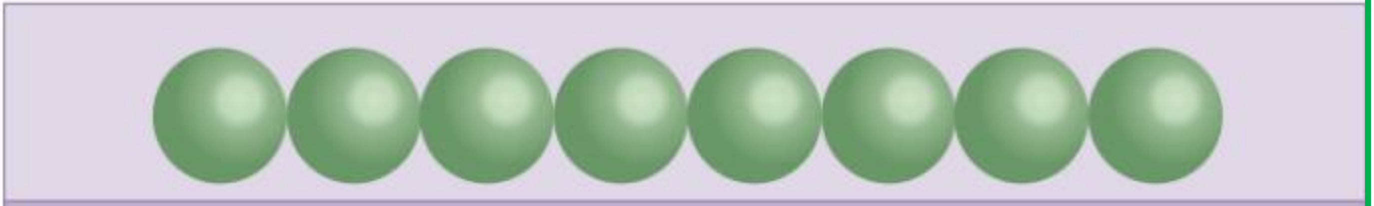
## Three-Dimensional Packing

- To understand the packing of constituent particles in a crystal, particles are assumed to be hardspheres of identical size.
- The packing of these hard spheres takes place in such a way that they cover maximum availablespace and minimum space should be left behind.
- Because of this, the crystal has maximum density. This type of packing is known as close packing.

## Close Packing in One Dimension

- Spheres are arranged in such a way that they should touch each other in the row.

- In this arrangement, each sphere touches two neighbouring spheres. Hence, the coordinationnumber is 2 in this arrangement.



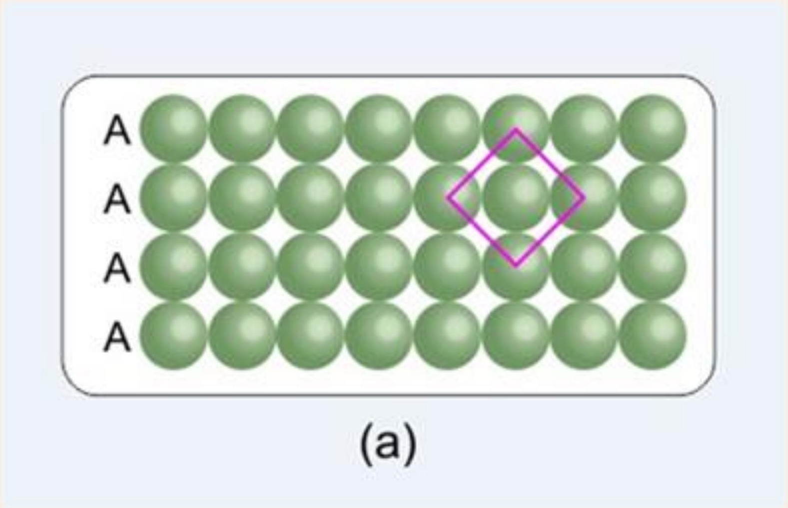
Close packing of spheres in one dimension

## Close Packing in Two Dimensions

- When the rows of one dimension packing are stacked over each other, a two-dimensional closepack structure is formed.
- This stacking is done in two ways:

### (a) Square close packing in two dimensions:

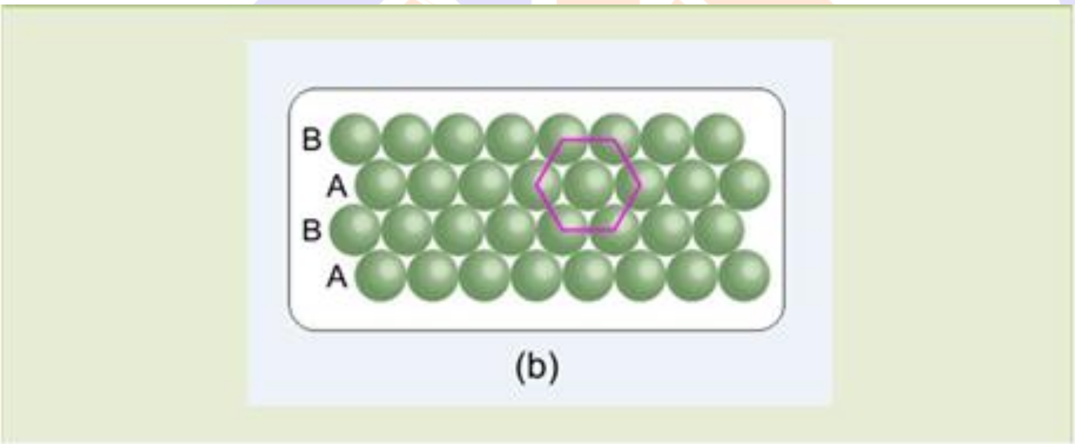
- The spheres in the second row are arranged in such a way that they touch thespheres of the first row and are exactly above the first row.
- If the first row is called the ‘A’ type row, then the second row will also be the ‘A’ typeas both rows are identical.
- These arrangements are continuous; hence, we can call this arrangement as theAAA type arrangement.
- In this arrangement, each sphere touches four other spheres; hence, thecoordination number is four.
- Also, if we join the centres of four spheres touching one particular sphere, then itforms a square; hence, it is called square close packing in two dimensions.



Square close packing

### (b) Hexagonal close packing in two dimensions:

- Spheres in the second row are placed in depressions of the first row. This gives tworows.
- Hence, if we call the first row 'A' type, then the second row will be the 'B' type.
- If a third row is placed in the depression of the second row, then it will be identical tothe first row, i.e. the 'A' type.
- The fourth row will be the 'B' type and so on. Hence, this arrangement is called theABAB type of arrangement.
- In this arrangement, each sphere touches six neighbouring spheres; hence, the coordination number is six.
- Also, if we join the centres of the spheres which touch one particular sphere, then itwill give a hexagonal structure; therefore, it is known as hexagonal close packing intwo dimensions.
- This type of packing is more effective because maximum space is covered byparticles and the space is minimum.



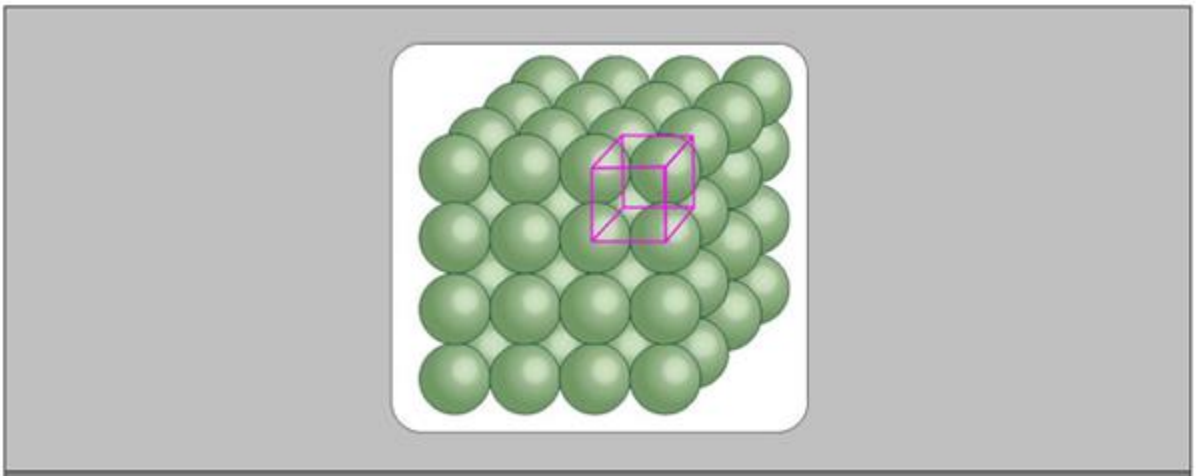
Hexagonal close packing

## Close Packing in Three Dimensions

- Three-dimensional packing can be obtained by square close packing and hexagonal close packing.

### (a) Three-dimensional close packing from two-dimensional square close packing:

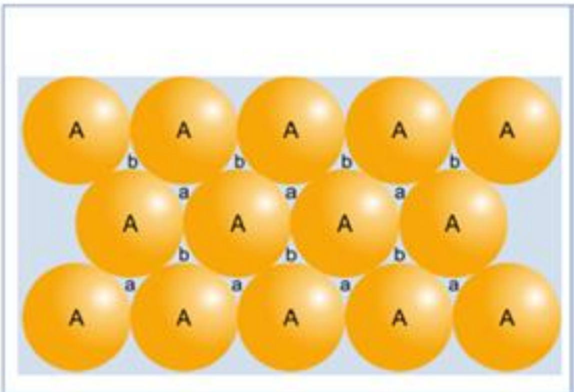
1. The second layer and all further layers are arranged in such a way that they are horizontaland vertically aligned with each other.
2. Hence, if we call the first layer as the 'A' type, then the lattice will be the AAA type.
3. This will give simple cubic lattice, and its unit cell will be a primitive cubic unit cell.



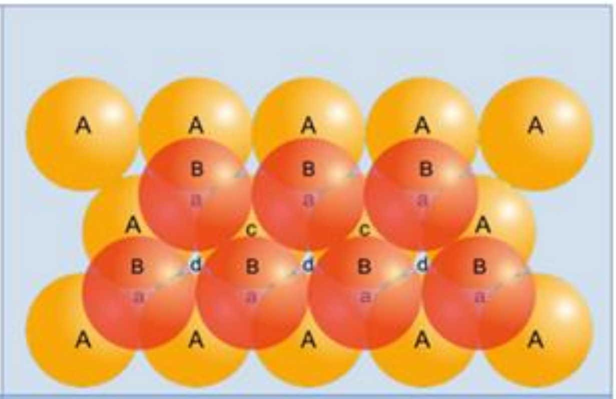
Three-dimensional packing of square close packed layers forming simple cubic lattice with AAA arrangement

**(b) Three-dimensional packing from two-dimensional hexagonal close packing:**

1. We know that more effective packing is given by hexagonal close packing.
2. Assume three-dimensional packing with a hexagonal close packed system. The base layeris called 'A' and the voids between the spheres are named 'a' and 'b' alternately.
3. Both 'a' and 'b' voids are triangular in shape. The only difference is that the apices of voids'a' point downwards and those of 'b' point upwards.
4. The second layer is placed in such a way that its spheres find place in the 'a' voids of the first layer. The 'b' voids are left unoccupied because no spheres can be placed in them.
5. There are two new types of voids in the second layer—'c' and 'd' The voids 'c' lie above thespheres of the first layer and the voids 'd' lie on the voids of the first layer.

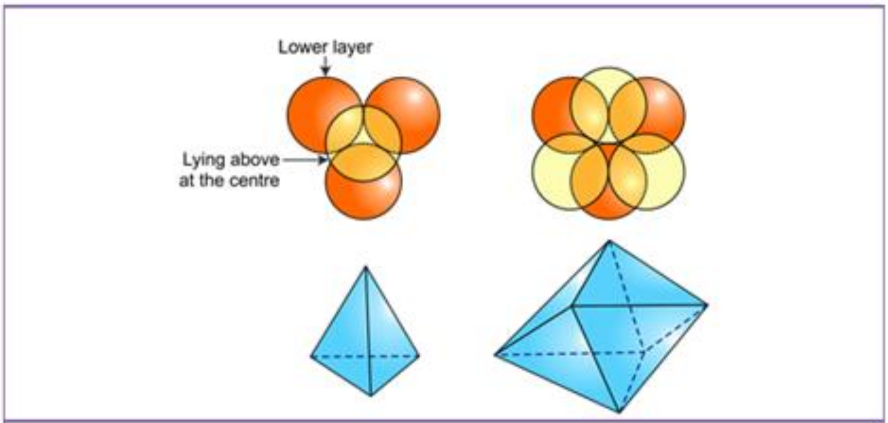


Two types of triangular voids in hexagonal close-packed system



Close packing of two layers with hexagonal close-packed base layer

6. A simple triangular void 'c' which is surrounded by four spheres is called a tetrahedral void.The double triangular void (like 'd') which is surrounded by six spheres is called an octahedral void.
7. The voids or holes in the crystals are also called interstices.



Tetrahedral and octahedral voids

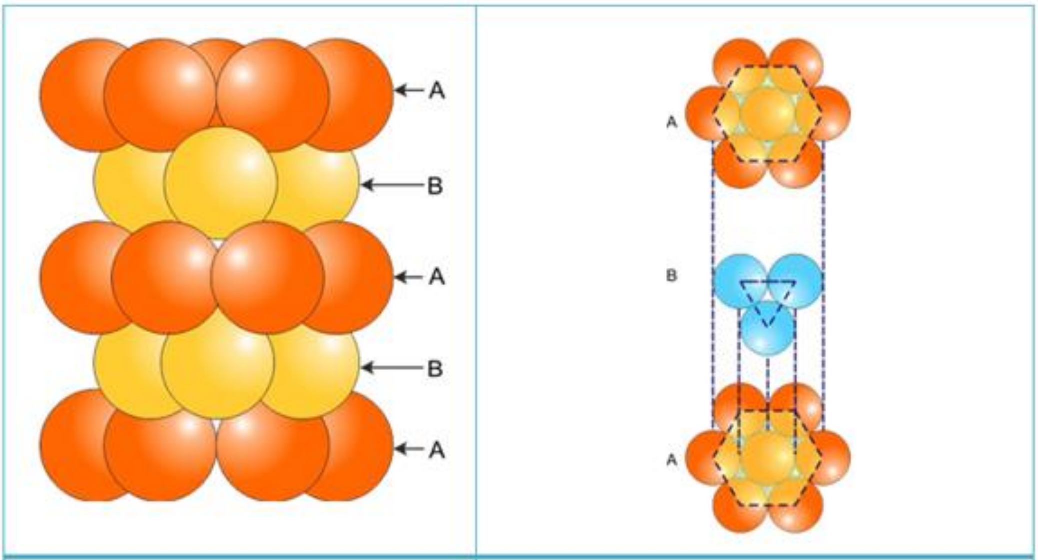
8. There are two ways of building the third layer.

**hcp structure:**

i. When the third layer is placed on the second layer in such a way that the spherescover the tetrahedral voids, three-dimensional closed packing is obtained.

ii. Consider the first layer as 'A' and the second layer as 'B', the arrangement is of theABAB type or hexagonal closed packing.

iii. Molybdenum, magnesium and beryllium crystallise in the hcp structure.



Actual view of hexagonal close packing

Simplified view of hexagonal close packing

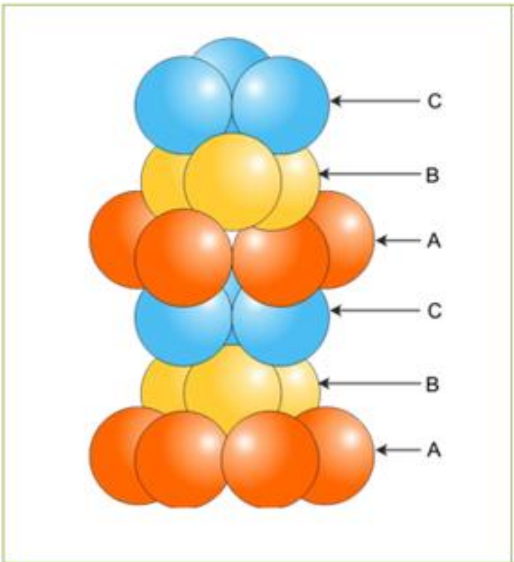
**ccp structure:**

i. When the third layer is placed on the second layer in such a way that the spheres cover the octahedral voids, two layers 'A' and 'B' are formed. Assume that the newlayer be 'C'.

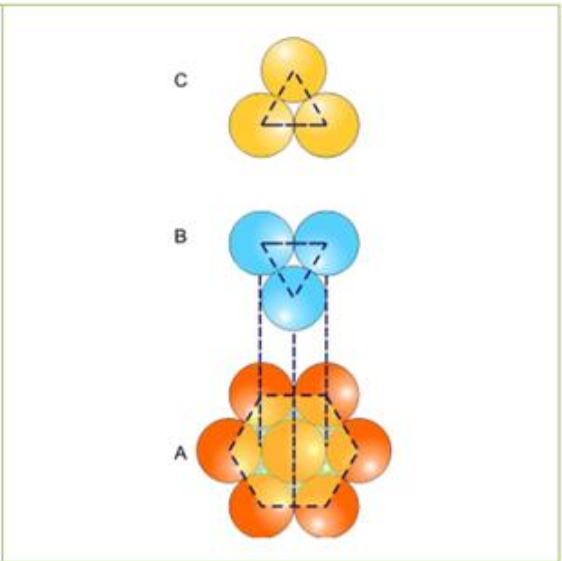
ii. On continuing, a packing is obtained where the spheres in every fourth layer will be vertically aligned. This pattern is called the ABCABC pattern or cubic close packing.

iii. It is the same as face-centred cubic close packing.

iv. Iron, nickel, copper, silver, gold and aluminium crystallise in the ccp structure.



Actual view of cubic close packing



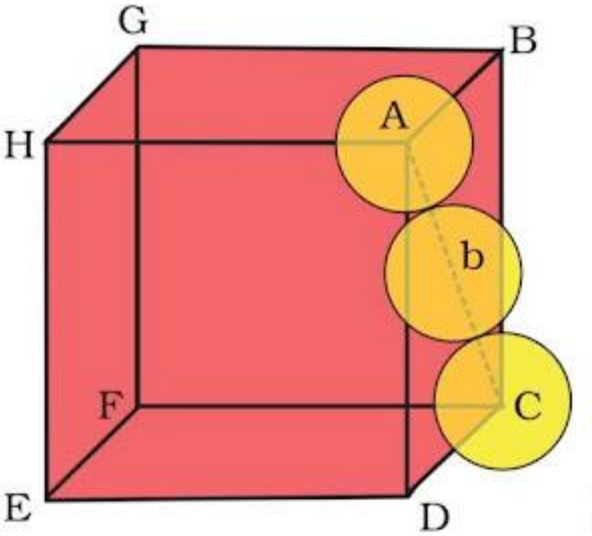
Simplified view of cubic close packing

## Packing Efficiency

In all the type of packings there is always some free space in the form of voids or vacant spaces. Packing efficiency is the percentage of total space filled by the particles.

Packing efficiency = Volume of total lattice points / Total volume of unit cell

### (i). Packing efficiency in fcc or ccp structures



suppose edge length of unit cell = a

And radius of sphere = r

In $\Delta ABC$, $AC^2 = BC^2 + AB^2$

$$AC^2 = a^2 + a^2$$

$$AC^2 = 2a^2$$

Hence, face diagonal $AC = \sqrt{2}a$

But AC = 4r $\therefore 4r = \sqrt{2}a \therefore a = \dfrac{4r}{\sqrt{2}}$

Hence, volume of unit cell = $a^3$ or

$$a^3 = \left(\frac{4r}{\sqrt{2}}\right) = 16\sqrt{2}r^3$$

As there are total 4 lattice points per unit cell.

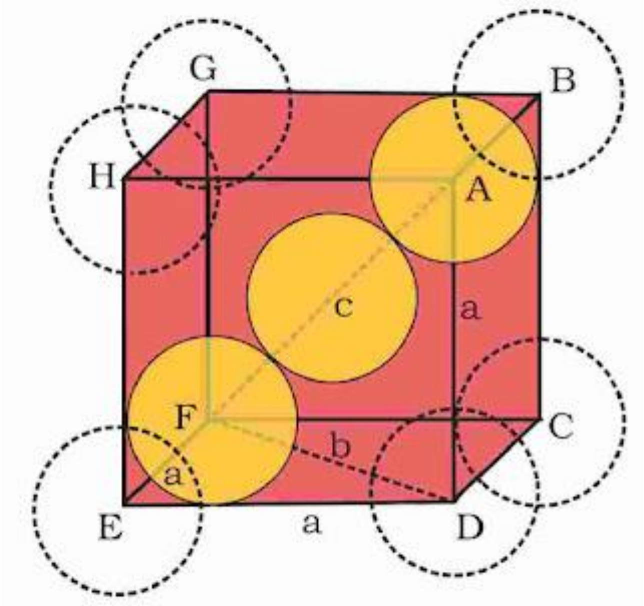
$$\text{Packing efficiency} = \frac{4 \times \frac{4}{3}\pi r^3}{16\sqrt{2}r^3}$$

$$= \frac{16\pi r^3}{3 \times 16\sqrt{2}r^3}$$

$$= \frac{\sqrt{2}\pi}{6} = 0.74$$

Hence, % Packing efficiency = 74%

### (ii). Packing Efficiency in bcc structures



Suppose the edge length = a

Radius of each sphere = r

Number of lattice points per unit cell = 2

In ΔABC, $AC^2 = BC^2 + AB^2 = a^2 + a^2 = 2a^2$

Similarly in ΔACD,

$$AD^2 = AC^2 + CD^2 = 2a^2 + a^2 = 3a^2$$

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

$$\text{Now, } AD = 4r \;\therefore\; \sqrt{3}a = 4r \text{ or } a = \frac{4r}{\sqrt{3}}$$

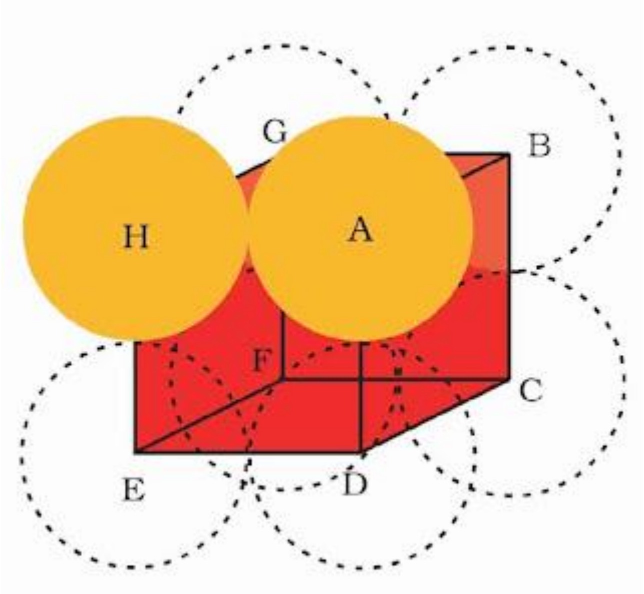
$$\text{Packing efficiency} = \frac{2 \times \frac{4}{3}\pi r^3}{\left(\frac{4r}{\sqrt{3}}\right)^3}$$

$$= \frac{8\pi r^3 \times 3\sqrt{3}}{3 \times 64 r^3}$$

$$= \frac{\sqrt{3}\pi}{8} = 0.68$$

Hence, % of Packing efficiency = 68%

### (iii). Packing Efficiency in Simple Cubic Unit Cell



Let the edge length of unit cell = a

Radius of sphere = r

As two spheres touch each other at an edge

$$\therefore a = 2r$$

Number of lattice points per unit cell = 1

$$\text{Packing efficiency} = \frac{\frac{4}{3}\pi r^3}{(2r)^3} = \frac{\pi}{6} = 0.524$$

Hence, % Packing efficiency = 52.4%

### Coordination Number

- In both hcp and ccp structures, a sphere is in contact with six other spheres in its own layer.
- It also directly touches three spheres above and three spheres below. Thus, the sphere has 12close neighbours. Hence, it is said to have coordination number 12.

**Coordination number:** Number of closest neighbours of any constituent particles in the crystal lattice

- The common coordination numbers in different types of crystals are 4, 6, 8 and 12.
- In crystals with directional bonds, the coordination number is lower than that of crystals with a non-directional bond.
- In addition to the above two types, there is another type called body-centred cubic close packing(bcc) in which the space occupied is 68%.
- The coordination number of each atom in the bcc structure is 8.

## Point defects:

Point defects explain about the imperfections of solids along with the types of point defects. Crystalline solids are formed by joining many small crystals. Different types of defects are found in crystals after the process of crystallization.

Point defects are accounted for when the crystallization process occurs at a very fast rate. These defects mainly happen due to deviation in the arrangement of constituting particles. In a crystalline solid, when the ideal arrangement of solids is distorted around a point/ atom it is called a point defect.

Defects or Imperfections in crystalline solid can be divided into four groups namely line defects, point defects, volume defects and surface defects. Historically, crystal point defects were first regarded in ionic crystals, not in metal crystals that were much simpler.

**There are 3 types of point defects:**

1. Stoichiometric defect
2. Frenkel defect
3. Schottky defect

### 1. Stoichiometric Defect:

In this kind of point defect, the ratio of positive and negative ions (Stoichiometric) and electrical neutrality of a solid is not disturbed. Sometimes it is also known as intrinsic or thermodynamic defects.

**Fundamentally, they are of two types:**

**Vacancy defect:** When an atom is not present at their lattice sites, then that lattice site is vacant and it creates a vacancy defect. Due to this, the density of a substance decreases.

**Interstitial defect:** It is a defect in which an atom or molecule occupies the intermolecular spaces in crystals. In this defect, the density of the substance increases.

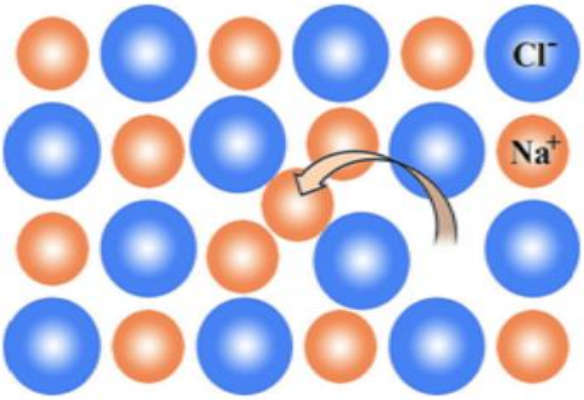
A non-ionic compound mainly shows vacancy and interstitial defects. An ionic compound shows the same in Frenkel and Schottky defect.

### 2. Frenkel Defect:

In ionic solids generally, the smaller ion (cation) moves out of its place and occupies an intermolecular space. In this case, a vacancy defect is created on its original position and the interstitial defect is experienced at its new position.

It is also known as dislocation defect, The density of a substance remains unchanged, It happens when there is a huge difference in the size of anions and cations.

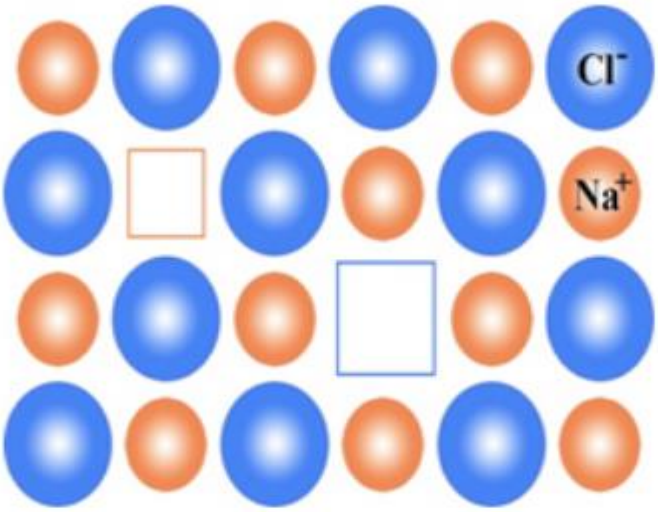
Example: ZnS and AgCl.



Frenkel defect

### 3. Schottky Defect

This kind of vacancy defects is found in Ionic Solids. But in ionic compounds, we need to balance the electrical neutrality of the compound so an equal number of anions and cations will be missing from the compound. It reduces the density of the substance. In this, the size of cations and anions are of almost the same.



Schottky defect

**Impurity Defect:** Let's understand the impurity defect by an example. If molten NaCl is crystallized with $SrCl_2$ compound then the $Sr^{2+}$ ions replace two $Na^+$ ions and occupy the place of one Na+ In this way the lattice site of one Na+ is vacant and it creates an impurity defect.

**Non-Stoichiometric Defect:** In this defect, the cations and anions ratio is disturbed either because of adding or removing of ions.

**Types of Non-Stoichiometric Defect:**

**Metal deficiency defect:** In this, the solids have less number of metals relative to the described Stoichiometric proportion.

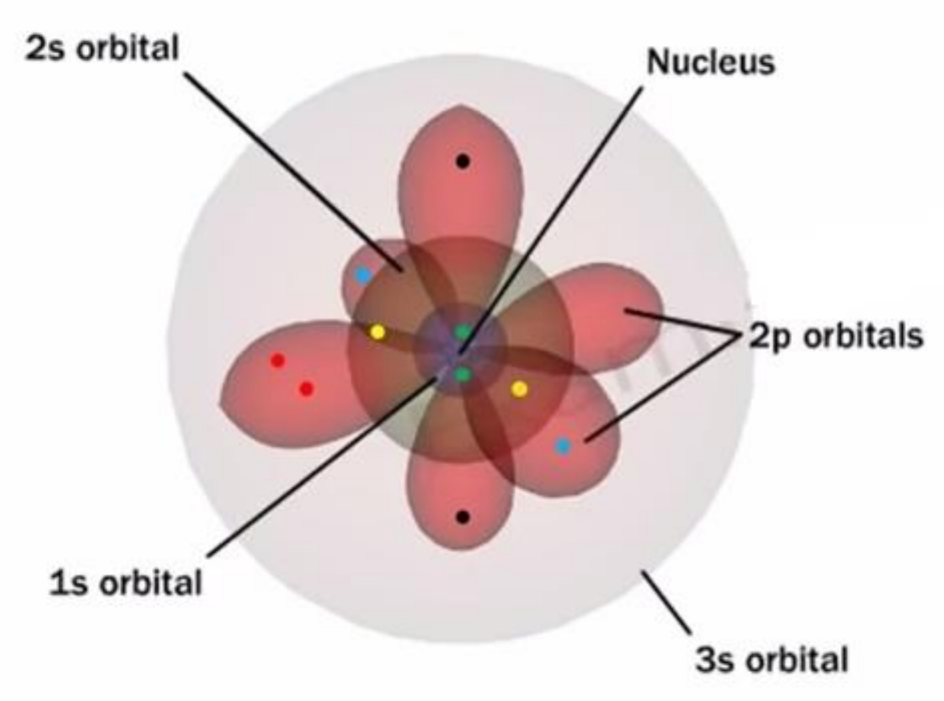
**Metal excess defect:**

There are two types of metal excess defect:

Metal excess defect due to anionic vacancies: This occurs due to the absence of anions from its original lattice site in crystals. Therefore, instead of anions, electrons occupy their position

Metal excess defect due to the presence of extra cations at interstitial sites: Here, on heating the compound, it releases extra cations. These cations occupy the interstitial sites in crystals and the same number of electrons goes to neighbouring interstitial sites.

## Magnetic Properties:



- Every substance possesses magnetic properties originated from the electrons present in them.
- Each electron in an atom behaves like a tiny magnet, The magnetic moment of these substances originates from two types of motions its orbital motion around the nucleus and its spin around its own axis.
- Electron being a charged particle undergoes these motions and can be considered as a small loop of current possessing a magnetic moment, Therefore, each electron has a permanent spin and an orbital magnetic moment associated with it.
- Magnitude of this magnetic moment is very small and is measured in the unit called Bohr magneton, μ B and is equal to 9.27 × 10 – 24A $m^2$.

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

1. **Paramagnetic:** Paramagnetic materials are materials that tend to get weakly magnetized in the direction of the magnetizing field when placed in a magnetic field. Paramagnetic materials have a permanent dipole moment or permanent magnetic moment. However, if we remove the applied field the materials tend to lose their magnetism. This is because thermal motion randomizes the spin orientations of the electrons.
2. **Diamagnetic:** The spin motion of electrons and their interaction with one another is

what is responsible for the origin of magnetism. The best way to introduce different types of magnetic materials is by describing how materials respond to magnetism. It may come as a surprise to you, but all matter is magnetic. The only difference is that some materials are more magnetic than others. The level of interactions between the magnetic moments is what distinguishes them. In a few materials, there is no collective interaction of atomic magnetic moment while other materials exhibit strong atomic magnetic moment interaction.

3. **Ferromagnetic:** There are various kinds of magnetism, out of which ferromagnetism is the strongest type. Ferromagnetic materials are those materials which exhibit a spontaneous net magnetization at the atomic level, even in the absence of an external magnetic field.

   When placed in an external magnetic field, ferromagnetic materials are strongly magnetized in the direction of the field. Ferromagnetic materials are strongly attracted to a magnet. These materials will retain their magnetization for some time even after the external magnetizing field is removed. This property is called hysteresis.

4. **Anti-ferro magnetic:** The materials that exhibit the anti-ferro magnetism are known as antiferromagnetic material. When these materials are kept in the presence of the strong magnetic field, they get magnetized weakly in the direction of the magnetic field. This is known as anti-ferro magnetism.

   The antiferromagnetic materials are commonly found among the transition metal compounds. Hematite, chromium, alloys of iron manganese and oxides of nickel are the examples of antiferromagnetic material

5. **Ferrimagnetic:** Ferrimagnetic materials definition is, in which the magnetic dipoles of the atoms on various subset are opposed, as in anti-ferro magnetism, but the opposing moments are unequal in ferrimagnetic materials, leaving a random net magnetization. Crystal ferrimagnetic materials, including antiferromagnetic materials, have populations of atoms with contrasting magnetic moments. Since the magnitudes of these moments are unequal in ferrimagnet compounds, a random magnetization exists. A mixture of dipole-dipole interactions and exchange interactions arising from the Pauli exclusion theory induce magnetization of ferrimagnetic materials. The key distinction is that in a ferrimagnetic substance, the unit cell contains various groups of atoms.

## Semiconductor

Semiconductors are substances with properties somewhere between them. ICs (integrated circuits) and electronic discrete components such as diodes and transistors are made of semiconductors. Common elemental semiconductors are silicon and germanium. Silicon is well-known of these. Silicon forms most of ICs.

Conduction of Electricity in Semiconductors In semiconductors, the gap between the valence band and conduction band is small.

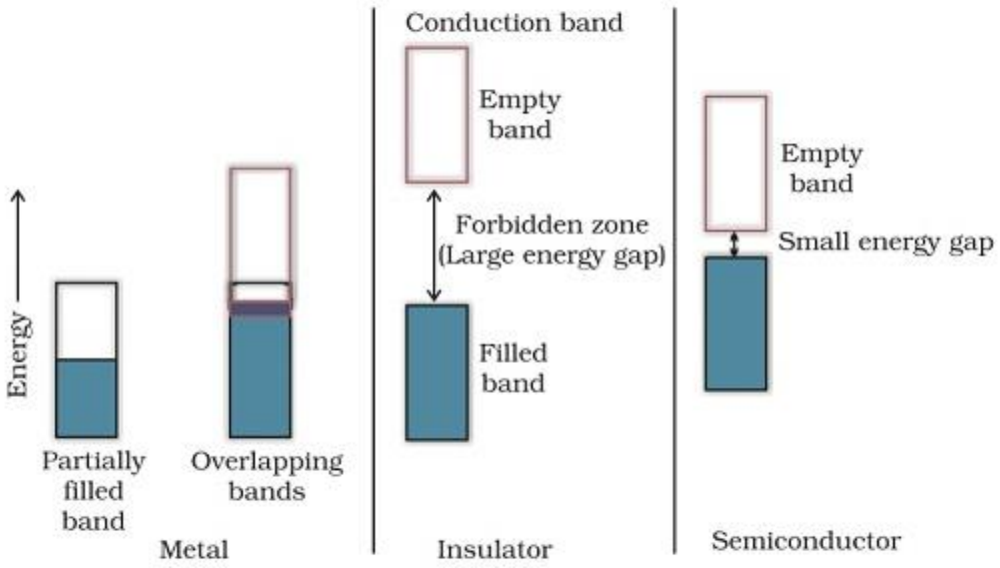
This enables some electrons to jump to conduction band and exhibit their conductivity.

Electrical conductivity of semiconductors increases with increase in temperature, since more electrons can jump to the conduction band due to small gap between the valence band and conduction band.

Silicon and germanium exhibit this behavior and are called intrinsic semiconductors. The conductivity of these intrinsic semiconductors is too low to be practically used.

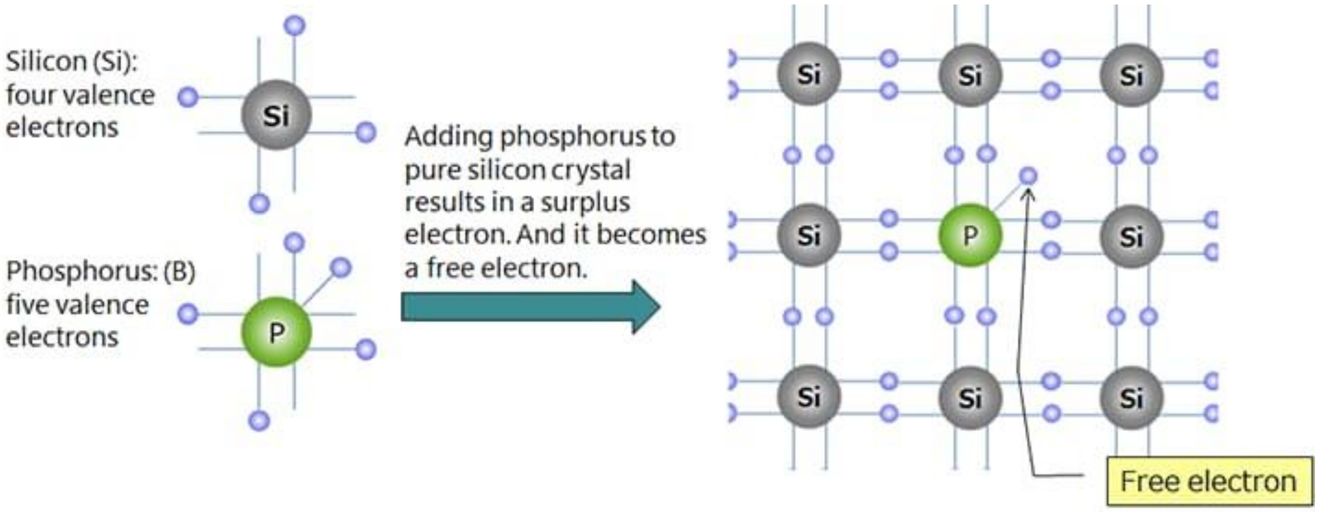
**Semiconductor materials**

Solid-state materials are commonly grouped into three classes: insulators,semiconductors, and conductors. (At low temperatures some conductors, semiconductors, and insulators may become superconductors.) The figure shows the conductivities σ (and the corresponding resistivities ρ = 1/σ) that are associated with some important materials in each of the three classes. Insulators, such as fused quartz and glass, have very low conductivities, on the order of 10−18 to 10−10 siemens per centimeter; and conductors, such as aluminum, have high conductivities, typically from 104 to 106 siemens per centimeter. The conductivities of semiconductors are between these extremes and are generally sensitive to temperature, illumination, magnetic fields, and minute amounts of impurity atoms. For example, the addition of about 10 atoms of boron (known as a dopant) per million atoms of silicon can increase its electrical conductivity a thousand fold



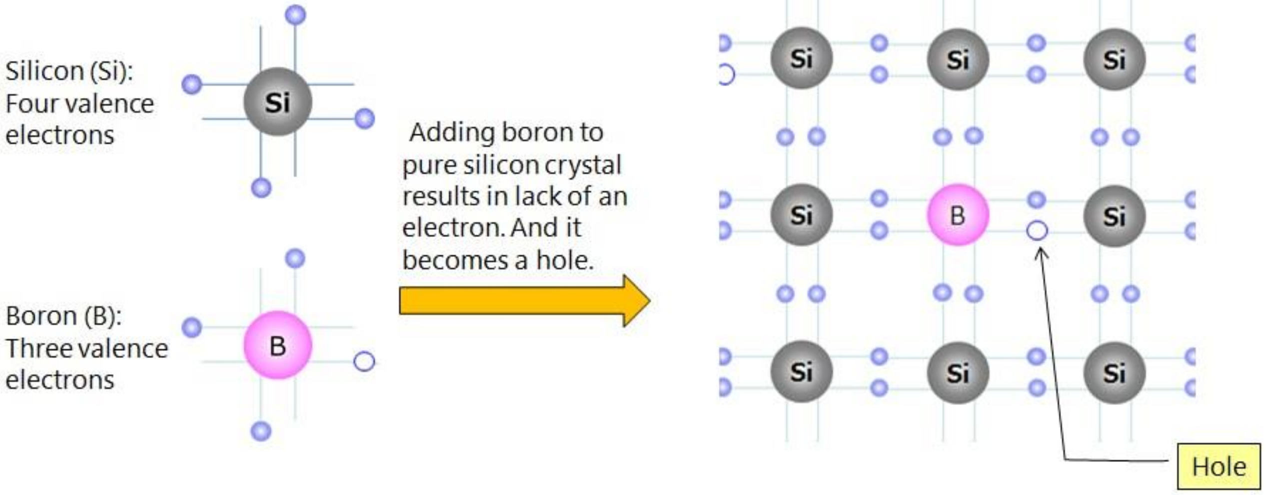
**n-type Semiconductor:**

An n-type semiconductor is an intrinsic semiconductor doped with phosphorus (P), arsenic (As), or antimony (Sb) as an impurity. Silicon of Group IV has four valence electrons and phosphorus of Group V has five valence electrons. If a small amount of phosphorus is added to a pure silicon crystal, one of the valence electrons of phosphorus becomes free to move around (free electron*) as a surplus electron. When this free electron is attracted to the "+" electrode and moves, current flows.



**p-type Semiconductor:**

A p-type semiconductor is an intrinsic semiconductor doped with boron (B) or indium (In). Silicon of Group IV has four valence electrons and boron of Group III has three valence electrons. If a small amount of boron is doped to a single crystal of silicon, valence electrons will be insufficient at one position to bond silicon and boron, resulting in holes* that lack electrons. When a voltage is applied in this state, the neighboring electrons move to the hole, so that the place where an electron was present becomes a new hole, and the holes appear to move to the "–" electrode in sequence.



**Applications of n-type and p-type semiconductors:**

n-type and p-type semiconductors finds a great use in manufacturing electronic components.

Diode is a combination of n-type and p-type semiconductors extensively used as a rectifier.

Transistors are manufactured by keeping a layer of one type of semiconductor between two layers of another type of semiconductor.

npn and pnp type of transistors are used to detect or amplify radio or audio signals.

The solar cell is an efficient photo-diode used for conversion of light energy into electrical energy.

Gallium arsenide (GaAs) semiconductors have very fast response and have transformed the design of semiconductor devices.

Transition metal oxides show marked differences in electrical properties.

TiO, $CrO_2$ and $ReO_3$ behave like metals.

Rhenium oxide, $ReO_3$ resembles metallic copper in terms of its conductivity and appearance.

Certain other oxides like VO, $VO_2$, $VO_3$ and $TiO_3$ exhibit metallic or insulating properties depending on temperature.

## NCERT LINE BY LINE QUESTIONS

**(1.)** Addition of group-13 elements to intrinsic semiconductors result in [Page: 26]

(a.) Creation of conduction band slightly above the valence band

(b.) Creation of conduction band slightly below the valence band

(c.) Creation of valence bond slightly above the conduction band

(d.) Overlapping of valence bond and conduction band

**(2.)** A metallic element crystallises into lattice containing a sequence of layers of *ABABABAB* Any packing of spheres leaves out void in the lattice. They empty space in percentage by volume in the lattice is:

(a.) 26%

(b.) 32%

(c.) $20^{\circ_\circ}\%$

(d.) 30%

**(3.)** Potassium (K) has a bcc structure with nearest neighbor distance 4.52 Å . Its atomic weight is 39. Its density will be **[Page: 18, 20]**

(a.) $910 kgm^{-3}$

(b.) $804 kgm^{-3}$

(c.) $454 kgm^{-3}$

(d.) $852 kgm^{-3}$

**(4.)** Which is (are) amorphous solids?

(a.) Rubber

(b.) Plastics

(c.) Glass

(d.) All of these

**(5.)** In a compound, atoms of element *Y* form ccp lattice and those of element *X* occupy $2/3$rd of tetrahedral voids. The formula of the compound will be:

(a.) $X_3Y_4$

(b.) $X_4Y_3$

(c.) $X_2Y_3$

(d.) $X_2Y$

**(6.)** Match the columns I and II. **[Page: 6]**

| **Column-I** | **Column- II** |
|---|---|
| **(a.)** Simple cubic and face-centred cubic | (p) have these cell parameters $a = b = c$ and $\alpha = \beta = \gamma$ |
| **(b.)** Cubic and rhombohedral | (q) are two crystal system |
| **(c.)** Cubic and tetragonal | (r) have only two crystallography angles of $90^\circ$ |

| | |
|---|---|
| **(d.)** Hexagonal and monoclinic | (s) belong to same crystal system |

(a.) a- p, s, b - r, q, c - q, d- s, r
(b.) a- r, s, b - p, s, c - q, d- p, r
(c.) a- p, s, b - p, s, c - q, d- q, r
(d.) a- p, s, b - p, q, c - q, d- q, r

**(7.)** The tetrahedral voids formed by ccp arrangement of $Cl^-$ ions in rock salt structure are **[Page: 17]**

(a.) All occupied
(b.) 50% occupied

by $Na^+$ ions by $Na^+$ ions

(c.) occupied by
(d.) vacant either $Na^+$ or $Cl^-$ ions

**(8.)** **Assertion:** Diamagnetic substances are not attached by magnetic field.
**Reason:** Diamagnetic substances have no unpaired electrons. [Page: 28]

(a.) Both A and R are true and R is the correct explanation of A.
(b.) Both A and R are true but R is not the correct explanation of A.
(c.) A is true bur R is false.
(d.) Both A and R are false.

**(9.)** In a solid '$AB$' having the NaCl structure, 'A' atoms occupy the corners of the cubic unit cell. If all the face centred atoms along one of the axis are removed, then the resultant stoichiometry of the solid is

(a.) $AB_2$
(b.) $A_2B$
(c.) $A_4B_3$
(d.) $A_3B_4$

**(10.)** **Assertion:** bcc and hcp has same packing efficiency.
**Reason:** Both have same number of atoms per unit cell and same arrangement. **[Page: 18, 19]**

(a.) Both A and R are true and R is the correct explanation of A.
(b.) Both A and R are true but R is not the correct explanation of A.
(c.) A is true but R is false.
(d.) Both A and R are false.

**(11.)** A compound alloy of gold and Cu crystallises in a cubic lattice in which the gold atoms occupy the lattice points at the comers of a cube and the copper atoms occupy the centres of each of the cube faces. What is the empirical formula of this compound?

(a.) $AuCu_3$
(b.) $Au_3Cu$
(c.) $Au_2Cu_3$
(d.) $AuCu$

**(12.)** A metal crystallises into a lattice containing a sequence of layers as ABABAB What percentage of voids are left in the lattice **[Page: 17, 18]**

(a.) 72%
(b.) 32%
(c.) 48%
(d.) 26%

**(13.)** The yellow colour in NaCl crystals is due to: [QR Code Exemplar, Page: 24]

(a.) Refraction of light from $Na^+$ ions
(b.) Excitation of electrons in F-centres
(c.) Reflection of light from $Cl^-$ ions on the surface
(d.) All of the above

**(14.)** The co-ordination number of $Ca^{2+}$ ion in fluorite crystal is:

(a.) 2
(b.) 8

(c.) 6 (d.) 4

**(15.)** If the distance between $Na^+$ and $Cl^-$ ions in NaCl crystal is a, pm, what is length of the cell edge? **[Page: 20]**

(a.) 4a pm (b.) a / 4pm

(c.) a / 2pm (d.) 2apm

**(16.)** Which type of crystals contain only one Bravais lattice **[Page: 9]**

(a.) Hexagonal (b.) Triclinic

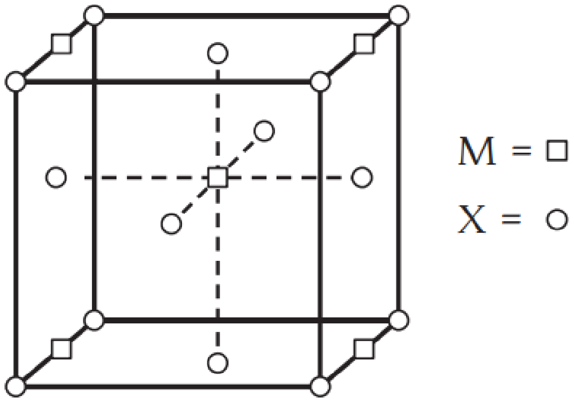
(c.) Rhombohedral (d.) All of the above

**(17.) Assertion:** The presence of a large number of Schottky defects in NaCl lowers its density.[Page: 23]
**Reason:** In NaCl, there are approximately $10^6$ Schottky pairs per $cm^3$ at room temperature.

(a.) Both A and R are true and R is the correct explanation of A. (b.) Both A and R are true but R is not the correct explanation of A.

(c.) A is true but R is false. (d.) Both A and R are false.

**(18.)** The arrangement of $X^-$ ions around $A^+$ ion in solid *AX* is given in the figure (not drawn to scale). If the radius of $X^-$ is 250 pm, the radius of $A^+$ is:



(a.) 104 pm (b.) 125 pm

(c.) 183 pm (d.) 57 pm

**(19.)** A compound is formed by cation *C* and A. The anions form hexagonal closed packed (hcp) lattice and the cations occupy 75% of octahedral voids. The formula of the compound is **[NEET-2O19, Page: 8, 1]**

(a.) $C_2A_3$ (b.) $C_3A_2$

(c.) $C_3A_4$ (d.) $C_4A_3$

**(20.)** Which defect brings in decrease in the density of the crystal)

(a.) Schotrky (b.) Frenkel

(c.) F-centre (d.) Interstitial

**(21.)** The number of atoms in 100 g of an fcc crystal with density, $d = 10 g / cm^3$ and cell edge equal to 100 pm, is equal to **[Page: 2l]**

(a.) $2 \times 10^{25}$ (b.) $4 \times 10^{25}$

(c.) $3 \times 10^{25}$ (d.) $1 \times 10^{25}$

**(22.)** **Assertion:** The total number of atoms present in a simple cubic unit cell is one.
**Reason:** Simple cubic unit cell has atoms at its comers, each of which is shared between eight adjacent unit cells. **[Page: 8, 11]**

(a.) Both A and R are true and R is the correct explanation of A.
(b.) Both A and R are true but R is not the correct explanation of A.
(c.) A is true but R is false.
(d.) Both A and R are false.

**(23.)** Which of the following exists as co-valent crystals in the solid state? **[Page: 5]**

(a.) silicon
(b.) sulphur
(c.) phosphorus
(d.) Iodine

**(24.)** Column I (Substance) Column-II (Magnetic nature) [Page: 28]

| **Column I (Substance)** | **Column-II (Magnetic nature)** |
|---|---|
| **(A)** Ferrites | (p) Ferromagneric |
| (B) $CrO_2$ | (q) Paramagnetic |
| (C) Nitric oxide | (r) Ferrimagnetic |
| (D) Manganese dioxide | (s) Antiferromagnetic |

(a.) A-r, B-q, C-p ,D-s
(b.) A-r, B-p, C-q, D-s
(c.) A-r, B-s, C-q, D-p
(d.) A-s, B-p, C-r, D-q

**(25.)** Percentages of free space in cubic close packed structure and in body centred packed structure are respectively:

(a.) 48% and 26%
(b.) 30% and 26%
(c.) 26% and 32%
(d.) 32% and 48%

**(26.)** The element of symmetry in a crystal are:

(a.) plane of symmetry
(b.) axis of symmetry
(c.) centre of symmetry
(d.) all of these

**(27.)** A cubic crystal possesses **[Page: 6]**

(a.) 9 Plane of symmetry
(b.) 13 axes of symmetry
(c.) 1 centre if symmetry
(d.) All of these

**Practice Questions Framed from IMCERT Text**

**(28.)** Which arrangement of electrons leads to ferromagnetism? [QR Code NCERT Exemplar, Page: 28]

(a.) ↑↓↑↓
(b.) ↑↑↑↑↑
(c.) ↑↑↑↓↓
(d.) None of the above

**(29.)** In zinc blende structure, the co-ordination number of the cation is **[Page: 8, 11]**

(a.) 4
(b.) 6
(c.) 8
(d.) 12

**(30.)** Given: **[Page: 6, 7]**

| Column-A | Column-B |
|---|---|
| (A) ionic solid | (I) NaCl |
| (B) metallic solid | (II) Fe |
| (C) co-valent solid | (III) C (Graphite) |

| | |
|---|---|
| (D) molecular solid | (IV) Dry ice |

(a.) A-II,B-I,C-IV,D-III
(b.) A-I,B-II,C-III,D-IV
(c.) A-III,B-II,C-I,D-IV
(d.) A-II,B-IV,C-I,D-III

**(31.)** AB crystallises in a body centred cubic lattice with edge length a, equal to 387 pm. The distance between two oppositely charged ions in the lattice is: **[Page: 19]**

(a.) 200 pm
(b.) 300 pm
(c.) 335 pm
(d.) 250 pm

**(32.)** CsBr has bcc structure with edge length 4.3Å. The shortest inter ionic distance between $Cs^+$ and Br is:

(a.) 3.72
(b.) 1.86
(c.) 7.44
(d.) 4.3

**(33.)** Sodium metal crystallizes in a body-centred cubic lattice with a unit cell edge of 4.29 Å. The radius of sodium is approximately:

(a.) 1.86Å
(b.) 3.22Å
(c.) 5.72Å
(d.) 0.93Å

**(34.)** Match the following. **[Page: 8, 9]**

| Column-I | Column- II |
|---|---|
| (Type of crystal) | (Location of cations/anions) |
| (A) NaCl | (p) cations-fcc, anions- all tetrahedral voids |
| (B) ZnS | (q) Anions-fcc, cations-all tetrahedral voids |
| (C) $CaF_2$ | (r) Anions - fcc, cations - all octahedral voids |
| (D) $Na_2O$ | (s) Anions- fcc, cations alternate tetrahedral voids |

(a.) A - p, B - r, C-s, D- q
(b.) A- q, B - r, C-s, D- q
(c.) A - r, B -s ,C-p, D- q
(d.) A- q, B -q,C -s, D- r

**(35.)** Wax is an example of.

(a.) ionic crystal
(b.) covalent crystal
(c.) molecular crystal
(d.) metallic crystal

**(36.)** The crystal with metal deficiency defect is: [Page: 24]

(a.) FeO
(b.) NaCl
(c.) KCl
(d.) ZnO

**(37.)** The edge length of a face centred cubic cell of an ionic substance is 508 pm. If the radius of the cation is 110 pm, the radius of the anion is:

(a.) 144 pm
(b.) 288 pm
(c.) 398 pm
(d.) 618 pm

**(38.)** The correct statement regarding defects in crystalline solids is: [NCERT Exemplar, Page: 24]

(a.) Frenkel defects decrease the density of crystalline solids.
(b.) Frenkel defects is a dislocation defect.

(c.) Frenkel defect is found in halides of alkaline metals.

(d.) Schottky defects have no effect on the density of crystalline solids.

**(39.)** Match the following. **[Page: 11]**

| **Column-I** | **Column-II** |
|---|---|
| **(Co-ordination number)** | **(Type of void)** |
| **(A)** 3 | (p) Cubical void |
| **(B)** 4 | (q) Trigonal planar void |
| **(C)** 6 | (r) Square planar void |
| **(D)** 8 | (s) Octahedral void |

(a.) A - p, B - r, C-s, D- q

(b.) A- q, B - r, C-s, D- q

(c.) A - r, B -q ,C-s, D- q

(d.) A- q, B -q,C -s, D- r

**(40.)** In a cubic close packing of spheres in three dimensions, the co-ordination number of each sphere is:

(a.) 6

(b.) 9

(c.) 3

(d.) 12

**(41.)** **Assertion:** CsCl has body centred cubic arrangement.

**Reason:** CsCl has one $Cs^+$ ion and $8Cl^-$ ions in its unit cell. **[Page: 20]**

(a.) Both A and R are true and R is the correct explanation of A.

(b.) Both A and R are true but R is not the correct explanation of A.

(c.) A is true but R is false.

(d.) Both A and R are false.

**(42.)** Monoclinic crystal has dimension **[Page: 8]**

(a.) $a \neq b \neq c; \alpha = \gamma = 90^o; \beta \neq 90^o$

(b.) $a = b = c; \alpha = \beta = \gamma = 90^o$

(c.) $a \neq b \neq c; \alpha \neq \beta \neq \gamma \neq 90^o$

(d.) $a = b \neq c; \alpha = \beta = \gamma = 90^o$

**(43.)** **Assertion:** Conductively of silicon increases by doping it with group-15 elements.

**Reason:** Doping means introduction of small amount of impurities like P, As or Bi into the pure crystal. [Page: 26]

(a.) Both A and R are true and R is the correct explanation of A.

(b.) Both A and R are true but R is not the correct explanation of A.

(c.) A is true but R is false.

(d.) Both A and R are false.

**(44.)** A metal crystallises with a face-centred cubic lattice. The edge of the unit cell is 408 pm. The diameter of the metal atom is **[Page: 17, 18]**

(a.) 144 pm

(b.) 288 pm

(c.) 204 pm

(d.) 408 pm

**(45.)** The empty (vacant) space in bcc lattice unit cell **[AIPNIT-2015, Page: 16, 17]**

(a.) 26$^{\%}$%

(b.) 32$^{\%}$%

(c.) 68%

(d.) 23%

**(46.)** The number of carbon atoms per unit cell of diamond unit cell is **[Page: 1l, 14]**

(a.) 6

(b.) 1

(c.) 4

(d.) 8

**(47.)** Which of the following is a covalent/network crystal? **[QR Code, NCERT Exemplar, Page: 6]**

(a.) Quartz $(SiO_2)$ (b.) SiC

(c.) AlN (d.) All

**(48.)** Solid $CO_2$ is an example of.

(a.) molecular crystal (b.) covalent crystal

(c.) metallic crystal (d.) ionic crystal

**(49.)** In which of the following crystals alternate tetrahedral voids are occupied)

(a.) NaCl (b.) ZnS

(c.) $CaP_2$ (d.) $Na_2O$

**(50.)** Match the following. **[Page: 18, 19]**

| **Column (I) (Relation)** | **Column (II) (lattice to which applicable)** |
|---|---|
| (A) $d = a/\sqrt{2}$ | (p) Simple |
| (B) $d = \frac{\sqrt{3}}{2}a$ | (q) Face-centred |
| (C) $r = 0.3535a$ | (r) Edge-centred |
| (D) $r = a/2$ | (s) Body-centred |

$(a = \text{edge}, d = \text{nearest neighbour distance}, r = \text{radius})$

(a.) A-q, B-r, C-p, D-s (b.) A-r, B-q, C-p, D-s

(c.) A-q, B-s, C-r, D-p (d.) A-q, B-s, C-r, D-p

## TOPIC WISE PRACTICE QUESTIONS

### TOPIC 1: Properties and Types of Solids

1. Solid $CH_4$ is
1) ionic solid 2) covalent solid 3) molecular solid 4) does not exist

2. Compound that will show the highest lattice energy
1) KF 2) NaF 3) CsF 4) RbF

3. An example of a covalent crystalline solid is:
1) Si 2) Al 3) NaF 4) Ar

4. Which of the following compounds is a good conductor of electricity in solution state?
1) Covalent 2) Molecular 3) Metallic 4) Ionic

5. A solid with high electrical and thermal conductivity is
1) Si 2) Li 3) NaCl 4) Ice

6. Solids which do not show the same physical properties in different directions are called
1) Pseudo solids 2) Isotropic solids 3) Polymorphic solids 4) Anisotropic solids

7. Crystals can be classified into basic crystal lattice, equal to
1) 7 2) 4 3) 14 4) 2

8. In which of the following pairs of structures, tetrahedral as well as octahedral holes are found?
1) bcc and fcc 2) hcp and simple cubic 3) hcp and ccp 4) bcc and hcp

9. How many "nearest" and "next nearest" neighbours, respectively, does potassium have in bcc lattice ?

1) 8, 8　　2) 8, 6　　3) 6, 8　　4) 6, 6

10. “Crystalline solids are anisotropic in nature. What is the meaning of anisotropic in the given statement?
1) A regular pattern of arrangement of particles which repeats itself periodically over the entire crystal.
2) Different values of some of physical properties are shown when measured along different directions in the same crystals.
3) An irregular arrangement of particles over the entire crystal.
4) Same values of some of physical properties are shown when measured along different directions in the same crystals.

11. In NaCl crystal each $Cl^-$ ion is surrounded by
1) 4 $Na^+$ ions　　2) 6 $Na^+$ ions　　3) 1 $Na^+$ ions　　4) 2 $Na^+$ ions

12. Which of the following is not a crystalline solid?
1) KCl　　2) CsCl　　3) Glass　　4) Rhombic S

13. Match the columns

| **Column-I** **(Type of solid)** | **Column-II** **(Example of solid)** |
|---|---|
| 1) Molecular solid | (p) Ag |
| 2) Ionic solid | (q) SiC |
| 3) Metallic solid | (r) CCl4 |
| 4) Covalent solid | (s) MgO |

1) A – (s), B – (r), C – (p), D – (q)
2) A – (q), B – (s), C – (p), D – (r)
3) A – (r), B – (q), C – (p), D – (s)
4) A – (r), B – (s), C – (p), D – (q)

14. The effective number of atoms per unit cell in a simple cube, face centred cube and body centred cube are respectively:
1) 1, 4, 2　　2) 1, 2, 4　　3) 8, 14, 9　　4) 8, 4, 2

15. Tetragonal crystal system has the following unit cell dimensions
1) $a = b = c,\ \alpha = \beta = \gamma = 90^0$　　2) $a = b \neq c, \alpha = \beta = \gamma = 90^0$
3) $a \neq b \neq c, \alpha = \beta = \gamma = 90^0$　　4) $a = b \neq c, \alpha = \beta = 90^0 \gamma = 120^0$

16. Which of the following metal(s) show(s) hexagonal close packed structure (hcp) and which show face centred cubic (fcc) structure?
hcp　fcc　　　hcp　fcc
1) Ag, Zn Mg, Cu　　2) Mg, Zn Ag, Cu
3) Cu, Fe Al, Sn　　4) Na, Li Zn, Cu

17. Which of the following is the incorrect statement?
1) NaCl has 6 : 6 coordination and CsCl has 8 : 8 coordination.
2) In $Na_2O$ each oxide ion is coordinated by 8Na+ ions and each Na+ ion by 4 oxide ions.
3) NaCl structure transform to CsCl structure on heating.
4) NaCl is subjected to high pressure, it transforms into CsCl.

18. The range of radius ratio (cationic to anionic) for an octahedral arrangement of ions in an ionic solid is
1) 0 – 0.155　　2) 0.155 – 0.225　　3) 0.225 – 0.414　　4) 0.414 – 0.732

19. The $Ca^{2+}$ and $F^-$ are located in $CaF_2$ crystal, respectively at face centred cubic lattice points and in
1) tetrahedral voids　　2) half of tetrahedral voids　　3) octahedral voids　　4) half of octahedral voids

20. Lattice energy of a solid increases if
1) size of ions are small　　2) charges of ions are small
3) ions are neutral　　4) none of these

21. In graphite electrons are
1) localised on each carbon atom.　　2) spread out between the sheets.
3) localised on every third carbon atom.　　4) present in antibonding orbital.

22. A crystalline solid
1) changes abruptly from solid to liquid when heated　　2) has no definite melting point
3) undergoes deformation of its geometry easily　　4) has an irregular 3-dimensional arrangements

23. Among solids, the highest melting point is exhibited by
1) covalent solids　　2) ionic solids　　3) pseudo solids　　4) molecular solids

24. The major binding force of diamond, silicon and quartz is
1) electrostatic force 2) electrical attraction 3) covalent bond force 4) non-covalent bond force

25. Which one of the following forms a molecular solid when solidified?
1) Silicon carbide 2) Calcium fluoride 3) Rock salt 4) Methane

26. A cubic crystal has
1) thirteen planes of symmetry and nine axis of symmetry
2) thirteen axis of symmetry and nine planes of symmetry
3) thirteen axis and thirteen planes of symmetry
4) nine planes and nine axis of symmetry

## TOPIC 2: Crystal Structure of Solids

27. Uncharged molecules or atoms are never crystallized in
1) ccp 2) hcp 3) bcc 4) simple cubic

28. Face-centred cubic packing of uniform spherical units is represented by
1) ABAB........ 2) ABBAAB....... 3) ABCABC....... 4) ABCACBABA.....

29. The numbers of tetrahedral and octahedral holes in a hexagonal primitive unit cell are :
1) 8, 4 2) 6, 12 3) 2, 1 4) 12, 6

30. AB; crystallizes in a body centred cubic lattice with edge length '*a*' equal to 387 pm. The distance between two oppositely charged ions in the lattice is :
1) 335 pm 2) 250 pm 3) 200 pm 4) 300 pm

31. Among the following which one has the highest cation to anion size ratio?
1) NaF 2) CsI 3) CsF 4) LiF

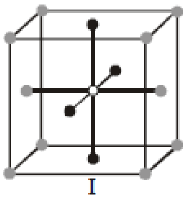
32. A solid compound XY has NaCl structure. If the radius of the cation is 100 pm, the radius of the anion (Y–) will be
1) 275.1 pm 2) 322.5 pm 3) 241.5 pm 4) 165.7 pm

33. The number of carbon atoms per unit cell of diamond unit cell is :
1) 8 2) 6 3) 1 4) 4

34. The arrangement ABC ABC .......... is referred to as
1) Octahedral close packing 2) Hexagonal close packing
3) Tetrahedral close packing 4) Cubic close packing

35. Body centered cubic lattice has a coordination number of
1) 4 2) 8 3) 12 4) 6

36. Consider the following fcc unit cells choose the correct option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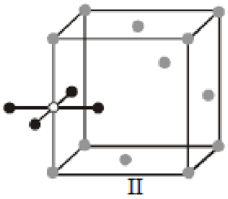
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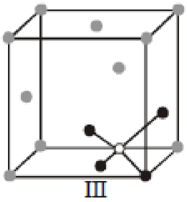
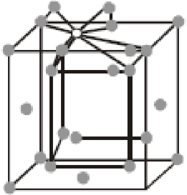

III


IV

1) I and II represent tetrahedral holes 2) II, III and IV represent tetrahedral holes
3) I and II represent octahedral holes 4) I, II and IV represent octahedral holes

37. In the crystal of CsCl, the nearest neighbours of each Cs ion are
1) Six chloride ions 2) Eight chloride ions 3) Six Cs ions 4) Eight Cs ions

38. The structure of MgO is similar to NaCl. What would be the coordination number of magnesium?
1) 2 2) 4 3) 6 4) 8

## TOPIC 3: Packing Fraction and Calculation Involving Unit Cell Dimensions

39. Polonium crystallizes in a simple cubic structure. The edge of the unit cell is 0.236 nm. What is the radius of the polonium atom:
1) 0.144 nm 2) 0.156 nm 3) 0.118 nm 4) 0.102 nm

40. CsBr has bcc type structure with edge length 4.3 pm. The shortest inter ionic distance in between $Cs^+$ and $Br^-$ is:
1) 3.72 pm 2) 1.86 pm 3) 7.44 pm 4) 4.3 pm

41. In an ionic compound $A^+ X^-$, the radii of $A^+$ and $X^-$ ions are 1.0 pm and 2.0 pm, respectively. The volume of the unit cell of the crystal AX will be :

1) 27 $pm^3$ 2) 64 $pm^3$ 3) 125 $pm^3$ 4) 216 $pm^3$

42. Percentages of free space in cubic close packed structure and in body centered packed structure are respectively

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

43. Each edge of a cubic unit cell is 400 pm long. If atomic mass of the element is 120 and its density is 6.25 $g/cm^3$, the crystal lattice is : (use $N_A = 6 \times 10^{23}\ mol^{-1}$)

1) Primitive 2) Body centered 3) Face centered 4) End centered

44. The atomic radius of strontium (Sr) is 215 pm and it crystallizes with a cubic closest packing. Edge length of the cube is:

1) 430 pm 2) 608.2 pm 3) 496.53 pm 4) none of these

45. A metal crystallises in a face centred cubic structure. If the edge length of its unit cell is 'a', the closest approach between two atoms in metallic crystal will be :

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

46. An element having an atomic radius of 0.14 nm crystallizes in an *fcc* unit cell. What is the length of a side of the cell?

1) 0.56 nm 2) 0.24 nm 3) 0.96 nm 4) 0.4 nm

47. A metal crystallizes in 2 cubic phases fcc and bcc whose unit cell lengths are 3.5 Å and 3.0Å respectively. The ratio of their densities is

1) 0.72 2) 2.04 3) 1.46 4) 3.12

48. An $AB_2$ type structure is found in

1) NaCl 2) $Al_2O_3$ 3) $CaF_2$ 4) $N_2O$

49. An element (atomic mass = 100 g / mol) having bcc structure has unit cell edge 400 pm. Then, density of the element is

1) 10.376 $g/cm^3$ 2) 5.188 $g/cm^3$ 3) 7.289 $g/cm^3$ 4) 2.144 $g/cm^{36}$

50. If pressure on a NaCl structure is increased then its coordination number will

1) increase 2) decrease 3) remain same 4) none of these

51. An element occuring in the bcc structure has $12.08 \times 10^{23}$ unit cells. The total number of atoms of the element in these cells will be

1) $24.16 \times 10^{23}$ 2) $36.18 \times 10^{23}$ 3) $6.04 \times 10^{23}$ 4) $12.08 \times 10^{23}$

52. If the number of atoms per unit in a crystal is 2, the structure of crystal is

1) Octahedral 2) Body centred cubic 3) Face centred cubic 4) simple cubic

53. The radii of $Na^+$ and $Cl^-$ ions are 95 pm and 181 pm respectively. The edge length of NaCl unit cell is

1) 276 pm 2) 138 pm 3) 552 pm 4) 415 pm

54. Which of the following contains rock salt structure?

1) $SrF_2$ 2) MgO 3) $Al_2O_3$ 4) All

55. 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 : (NA, Avogadro's constant = $6.02 \times 10^{23}\ mol^{-1}$)

1) 30 g $mol^{-1}$ 2) 27 g $mol^{-1}$ 3) 20 g $mol^{-1}$ 4) 40 g $mol^{-1}$

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

1) 1 : 1 2) 1 : 2 3) 1 : 3 4) 2 : 1

57. In the rock salt structure, the number of formula units per unit cell is equal to

1) 1 2) 2 3) 3 4) 4

58. A solid is made of two elements X and Z. The atoms Z are in CCP arrangement while the atom X occupy all the tetrahedral sites. What is the formula of the compound ?

1) XZ 2) $XZ_2$ 3) $X_2Z$ 4) $X_2Z_3$

## TOPIC 4: Bragg's Equation, Imperfection in Solids, Electrical and Magnetic Properties of Solids

59. Non-stoichiometric compound have the properties of:

1) electrical conductance 2) isolation 3) insulation 4) none of these

60. In the Bragg's equation for diffraction of X-rays, *n* represents for

1) quantum number 2) an integer 3) Avogadro's numbers 4) moles

61. Bragg's law is given by the equation
1) $nl = 2q\sin q$ 2) $nl = 2d \sin q$ 3) $2nl = d \sin q$ 4) $\sin 2\, 2n\, q = d\, q$

62. Each of the following solids show, the Frenkel defect except
1) ZnS 2) AgBr 3) AgI 4) KCl

63. Schottky defect defines imperfection in the lattice structure of
1) solid 2) gas 3) liquid 4) plasma

64. On doping Ge metal with a little of In or Ga, one gets
1) p-type semiconductor 2) n-type semiconductor 3) insulator 4) rectifier

65. When electrons are trapped into the crystal in anion vacancy, the defect is known as :
1) Schottky defect 2) Frenkel defect 3) Stoichiometric defect 4) F-centre

66. Crystal defect indicated in the diagram below is

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

1) Interstitial defect 2) Schottky defect 3) Frenkel defect 4) Frenkel and Schottky defects

67. Schottky defect generally appears in :
1) NaCl 2) KCl 3) CsCl 4) all of these

68. Which of the following statements is not correct ?
1) Vacancy defect results in decrease in density of substance.
2) Vacancy defect can develop when a substance is heated.
3) Interstitial defect decreases the density of the substance. 4) Ionic solids show interstitial defects only.

69. The non stoichiometric compound $Fe_{0.94}O$ is formed when x % of $Fe^{2+}$ ions are replaced by as many $\frac{2}{3}Fe^{+}$ ions, x is
1) 18 2) 12 3) 15 4) 6

70. Doping of AgCl crystals with $CdCl_2$ results in
1) frenkel defect 2) schottky defect
3) substitutional cation vacancy 4) formation of F–centres

## NEET PREVIOUS YEARS QUESTIONS

1. 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]**
1) $\frac{\sqrt{3}}{\sqrt{2}}$ 2) $\frac{4\sqrt{3}}{3\sqrt{2}}$ 3) $\frac{1}{2}$ 4) $\frac{3\sqrt{3}}{4\sqrt{2}}$

2. Which is the incorrect statement? **[2017]**
1) Density decreases in case of crystals with Schottky's defect.
2) NaCl(s) is insulator, silicon is semiconductor, silver is conductor, quartz is piezoelectric crystal.
3) Frenkel defect is favoured in those ionic compounds in which sizes of cation and anions are almost equal.
4) $FeO_{0.98}$ has non stoichiometric metal deficiency defect.

3. Lithium has a 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. ($N_A = 6.02 \times 10^{23}$ $mol^{-1}$) **[2016]**
1) 154 pm 2) 352 pm 3) 527 pm 4) 264 pm

4. The ionic radii of $A^+$ and $B^-$ ions are $0.98 \times 10^{-10}$ m and $1.81 \times 10^{-10}$ m. The coordination number of each ion in AB is [2016]
1) 6 2) 4 3) 8 4) 2

5. The vacant space in bcc lattice cell is : **[2015]**
1) 26 % 2) 48 % 3) 23 % 4) 32 %

6. The correct statement regarding defects in crystalline solid is : **[2015]**
1) Schottky defects have no effect on the density of crystalline solids
2) Frenkel defects decrease the density of crystalline solids
3) Frenkel defect is a dislocation defect.
4) Frenkel defect is found in halides of alkaline metals.

7. A given metal crystallizes 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]**
1) 127 pm 2) 80 pm 3) 108 pm 4) 40 pm

8. 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]**
1) $\frac{2}{\sqrt{3}}a$ 2) $\frac{4}{\sqrt{3}}a$ 3) $\frac{\sqrt{3}}{4}a$ 4) $\frac{\sqrt{3}}{2}a$

9. 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]**
(1) $C_2A_3$ (2) $C_3A_2$ (3) $C_3A_4$ (4) $C_4A_3$

10. Formula of nickel oxide with metal deficiency defect in its crystal is $Ni_{0.98}O$. The crystal contains $Ni^{2+}$ and $Ni^{3+}$ ions. The fraction of nickel existing as $Ni^{2+}$ ions in the crystal is **[2019 ODISSA]**
(1) 0.96 (2) 0.04 (3) 0.50 (4) 0.31

11. Which one of the following compounds shows both, Frenkel as well as Schottkydefects?**[2020 COVID]**
(1) AgBr (2) AgI (3) NaCl (4) ZnS

12. An element has a body centered cubic (bcc) structure with a cell edge of 288 pm. The atomic radius is **[2020]**
1) $\frac{4}{\sqrt{2}}\times 288\,\text{pm}$ 2) $\frac{\sqrt{3}}{4}\times 288\,\text{pm}$ 3) $\frac{\sqrt{2}}{4}\times 288\,\text{pm}$ 4) $\frac{4}{\sqrt{3}}\times 288\,\text{pm}$

13. The correct option for the number of body centred unit cells in all 14 types of Bravais lattice unit cells is : **[NEET-2021]**
1. 5 2. 2 3. 3 4. 7

14. Right option for the number of tetrahedral and octahedral voids in hexagonal primitive unit cell are **[NEET-2021]**
1) 6, 12 2) 2, 1 3) 12, 6 4) 8, 4

15. Given below are two statements: one is labelled as Assertion (A) and the other is labelled as Reason (R).
Assertion(A): In a particular point defect, an ionic solid is electrically neutral, even if few of its cations are missing from its unit cells. **[NEET-2022]**
Reason(R) : In an ionic solid, Frenkel defect arises due to dislocation of cation from its lattice site to interstitial site, maintaining overall electrical neutrality
In the light of the above statements, choose the most appropriate answer from the options given below.
1) Both (A) and (R) are correct and (R) is the correct explanation of (A)
2) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
3) (A) is correct but (R) is not correct
4) (A) is not correct but (R) is correct

16.. Copper crystallizes in fcc unit cell with cell edge length of $3.608\times10^{-8}$ cm. The density of copper is 8.92 $gcm^{-3}$ . Calculate the atomic mass of copper. **[NEET-2022]**
1) 63.1 u 2) 31.55 u 3) 60 u 4) 65 u

# NCERT LINE BY LINE QUESTIONS – ANSWERS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **(1.)** | a | **(2.)** | b | **(3.)** | a | **(4.)** | d | **(5.)** | a |
| **(6.)** | d | **(7.)** | d | **(8.)** | b | **(9.)** | d | **(10.)** | d |
| **(11.)** | c | **(12.)** | d | **(13.)** | b | **(14.)** | b | **(15.)** | d |
| **(16.)** | d | **(17.)** | b | **(18.)** | a | **(19.)** | c | **(20.)** | a |
| **(21.)** | b | **(22.)** | a | **(23.)** | a | **(24.)** | b | **(25.)** | c |
| **(26.)** | d | **(27.)** | d | **(28.)** | b | **(29.)** | b | **(30.)** | b |
| **(31.)** | c | **(32.)** | a | **(33.)** | a | **(34.)** | c | **(35.)** | c |
| **(36.)** | a | **(37.)** | a | **(38.)** | b | **(39.)** | b | **(40.)** | a |
| **(41.)** | c | **(42.)** | a | **(43.)** | a | **(44.)** | b | **(45.)** | b |
| **(46.)** | d | **(47.)** | d | **(48.)** | b | **(49.)** | b | **(50.)** | c |

# TOPIC WISE PRACTICE QUESTIONS - ANSWERS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1) 3 | 2) 2 | 3) 1 | 4) 4 | 5) 2 | 6) 4 | 7) 1 | 8) 3 | 9) 2 | 10) 2 |
| 11) 2 | 12) 3 | 13) 4 | 14) 1 | 15) 2 | 16) 2 | 17) 3 | 18) 4 | 19) 1 | 20) 1 |
| 21) 2 | 22) 1 | 23) 1 | 24) 3 | 25) 4 | 26) 2 | 27) 4 | 28) 3 | 29) 4 | 30) 1 |
| 31) 3 | 32) 3 | 33) 1 | 34) 4 | 35) 2 | 36) 3 | 37) 2 | 38) 3 | 39) 3 | 40) 1 |
| 41) 4 | 42) 2 | 43) 2 | 44) 2 | 45) 4 | 46) 4 | 47) 3 | 48) 3 | 49) 2 | 50) 1 |
| 51) 1 | 52) 2 | 53) 3 | 54) 2 | 55) 2 | 56) 2 | 57) 4 | 58) 3 | 59) 4 | 60) 2 |
| 61) 2 | 62) 4 | 63) 1 | 64) 1 | 65) 4 | 66) 2 | 67) 4 | 68) 4 | 69) 1 | 70) 3 |

# NEET PREVIOUS YEARS QUESTIONS-ANSWERS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1) 4 | 2) 3 | 3) 2 | 4) 1 | 5) 4 | 6) 3 | 7) 1 | 8) 4 | 9) 3 | 10) 1 |
| 11) 1 | 12) 2 | 13) 3 | 14) 3 | 15) 2 | 16) 1 | | | | |

# NCERT LINE BY LINE QUESTIONS – SOLUTIONS

**(1.)** (a) Adding electron deficient impurities creates an abundance of holes. These holes are majority carriers in p-type semi-conductors and are responsible for conduction.

**(3.)** (a) $\text{for bcc } r = \frac{\sqrt{3}}{4}a$

Nearest distance $2r = 4.52$

$\text{or} a = 4r/\sqrt{3} = 2 \times 4.52/1.732 = 5.219\ \text{Å} =$ $5.22\text{pm}$

$$\text{Density } = \frac{n \times m}{a^3 \times NA}$$

$$= \frac{2 \times 39}{\left(5.22 \times 10^{-30}\right)^3 \times 6.02 \times 10^{23}}$$

$$= 0.91\ \text{g/cm}^3 = 910\text{kgm}^{-3}$$

**(6.)** (a)a-p, s, b-p, q, c-q, d-q, r

**(7.)** (d) Tetrahedral voids are vacant. All the octahedral voids are occupied by $Na^+$ ions.

**(8.)** (b) Diamagnetic substance are not attracted by magnetic field because these substances have no unpaired electrons.

**(10.)** (d) bcc has 68% and hcp has 74% packing efficiency, bcc - 2 atoms/unit cell; hcp - 4 atoms/unit cell. In bcc particles are present at corners and one particles is present at the centre within the body of the unit cell. In hcp the packing gives a hexagonal pattern.

**(12.)** (d) ABAB packing is hexagonal close packing in which all atoms occupy 74% of the total space. Hence 26% of voids are left in the lattice.

**(13.)** (b) The anionic sites occupied by unpaired electrons are called F-centres. They impart yellow colour to the crystals of $NaCl$.

**(15.)** (d) Length of the edge of $NaCl$ unit cell

$= 2 \times \text{Distance between } Na^+ \text{and } Cl^-$

**(16.)** (d) Hexagonal triclinic and rhombohedral contain only one Bravais lattice.

**(17.)** (b)

**(19.)** (c) Anions A are in hcp. So number of anions are 6. Cations are in 75% octahedral voids. So no. of cations are $= 6 \times \frac{3}{4} = 4.5$

So formula will be $C_{4.5}A_6 = C_9A_{12} = C_3A_4$

**(21.)** (b) Mass $(m) = 100g$

Density $(d) = 10 g/cm^3$

And length $(1) = 100pm = 100 \times 10^{-12} m = 100 \times 10^{10} cm$

Volume of the unit-cell $= (1^3) = (100 \times 10^{-10} cm)^3 = 10^{-24} cm^3$

and volume of 100 g of element $= \frac{\text{mass}}{\text{density}} = \frac{10}{10} = 10 cm^3$

Therefore, number of unit cells $= \frac{10}{10^{-24}} = 10^{25}$

Since each fcc cube contains 4 atoms, therefore total no. of atoms in $100g = 4 \times 10^{25}$

**(22.)** (a)

**(23.)** (a) Silicon-Co-valent solid

Sulphur- Molecular solid

Phosphorus- Molecular solid

Iodine − Molecular solid

**(24.)** (b) Ferrites → Ferrimagnetic; $CrO_2 \rightarrow$ Ferromagnetic; $NO_2 \rightarrow$ Paramagnetic; $MnO_2 \rightarrow$ Ferromagnetic

**(27.)** (d) A cubic crystal possesses 9 plane of symmetry, 13 axes of symmetry and 1 centre of symmetry.

**(28.)** (b)

Ferromagnetism is due to spontaneous alignment of the magnetic dipoles in the same direction.

**(29.)** (b)

**(30.)** (b) Ionic solid − NaCl

Metallic solid − Fe

Covalent solid –C (graphite)

Molecular solid − Dry ice

**(31.)** (c) For a bcc lattice

$2(r^+ + r^-) = \sqrt{3}a$

where $r^+$ = radius of cation

$r^-$ = radius of anion

$n =$ edge length

$$\left(r^{+}+r^{-}\right)=\frac{\sqrt{3}\times 387}{2}=335.142 \text{ pm} \approx 335 \text{ pm}\%$$

**(34.)** A-r, B-s, C-p, D-q

**(36.)** (a) There are many solids which are difficult to prepare in the stoichiometric proportions. A typical example of this type is $FeO$ which is mostly found with a composition of $Fe_{0.950}$.

**(38.)** (b) Frenkel defect is a dislocation defect as smaller ions (usually cations) are dislocated from normal sites to interstitial sites. Frenkel defect is shown by compounds having large difference in size of cations and anions, hence alkali metal halides do not show Frenkel defect. Also, Schottky defect decreases the density of crystal while Frenkel defect has no effect on the density of crystal.

**(39.)** a-q, b-r, c-s, d-q

**(41.)** (c)

**(42.)** (a) For monoclinic crystals, axial lengths are nor equal to each other, i.e. $a \neq b \neq c$; and axial angles $\alpha = \gamma = 90^{\circ} \neq \beta$.

**(43.)** (a) Conductivity of $Si$ increases by doping it with group 15 element in doping, small amount of impurities like $P, As$ or $Bi$ are introduced into the pure crystal.

**(44.)** (b) For a fcc structure $r = \dfrac{a}{2\sqrt{2}}$

$$a = 408\text{pm}, r = \frac{408}{2\sqrt{2}} = 144\text{pm}$$

Diameter$= 2r = 2\times 144 = 288\text{pm}$

**(45.)** (b) Packing efficiency of bcc lattice =68%

Hence vacant space=100-68=32%

**(46.)** (d) Diamond is like $ZnS$. Carbon forming ccp (fcc) and also occupying half of tetrahedral voids. Total no. of carbon atoms per unit cell $=$

$$\underset{(\text{corners})}{8\times\frac{1}{8}} \quad + \quad \underset{(\text{face centre})}{6\times\frac{1}{2}} \quad + \quad \underset{\text{Tetrahedral voids}}{4} = 8$$

**(47.)** (d) Covalent crystals have extremely high melting points.

**(50.)** (c)

## TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. 3) Solid $CH_4$ is a molecular solid. In this, the constituent molecules are held together by van der Waal's forces.
2. 2) The amount of energy released when cation and anions are brought from infinity to their respective sites in the crystal lattice to form one mole of the ionic compounds is called the lattice energy. $Na^{+}$ being smallest in size have highest lattice energy.
3. 1) Si is an example of covalent crystalline solid among the given choices. Si atoms are covalently linked in tetrahedral manner.
4. 4) Ionic compounds are dissociated in solution state and form ions. Ions are good carrier of charge which make solution conducting.
5. 2) Out of the given substances, only Li has high electrical and thermal conductivity as Li is a metallic solid.
6. 4) Anisotropy arises due to the difference in kinds or densities or both of the atoms in different directions.
7. 1) Seven crystal systems.
8. 3) Tetrahedral & octahedral holes are present in hcp & ccp.

9. 2) No. of nearest neighbour = 8 (All body centre atom w.r.t. corner atom)
No. of next nearest neighbour = 6 (No. of corner atoms along edge w.r.t. to any corner).

10. 2) Crystalline solids are anisotropic in nature that is some of their physical properties like electrical resistance or refractive index show different values when measured along different directions in the same crystals.

11. 2) In NaCl crystal, each $Cl^-$ ion is surrounded by 6 $Na^+$ ions. Similarly, each $Na^+$ is surrounded by 6 $Cl^-$ ions.

12. 3) Glass is amorphous solid.

13. 4)

14. 1) For simple cubic cell, $Z = 8\times\frac{1}{8} = 1$

For face centred cubic unit cell, $Z = 8\times\frac{1}{8} + 6\times\frac{1}{2} = 4$

For body centred cubic unit cell, $Z = 1 + 8\times\frac{1}{8} = 2$

15. 2) For tetragonal $a = b \neq c$ , $\alpha = \beta = \gamma = 90^0$

16. 2) Metals such as copper and silver crystallise in fcc structure while metals Mg and Zn crystallise in hcp structure.

17. 3)

18. 4) For octahedral $r^+ / r^- = 0.414 - 0.732$.

19. 1)

20. 1) Lattice energy is inversely proportional to interionic distance (r°) i.e., ions should be of small size to give high lattice energy.

21. 2) In graphite, the electrons are spread out between the sheets.

22. 1) In crystalline solid there is perfect arrangement of the constituent particles only at 0 K. They have sharp M.P.

23. 1) Covalent as in case of diamond.

24. 3) Covalent bond force.

25. 4)

26. 2)

27. 4) Uncharged atoms and molecules pack more efficiently in closest packed structures. Simple cubic is least efficient packing.

28. 3)

29. 4) No. of octahedral hole in a unit cell = effective no. of atoms per unit cell = Z
No. of tetrahedral holes = 2 × octahedral holes.

30. 1) For *bcc* lattice, body diagonal = $a\sqrt{3}$ . The distance between the two oppositely charged ions

$$= \frac{a}{2}\sqrt{3} = \frac{387\times1.732}{2} = 335\text{pm}$$

31. 3) $\frac{M^+}{X^-}$ is highest in CsF

32. 3) Radius ratio of NaCl like crystal $= = \frac{r^+}{r^-} = 0.414$

$$r^- = \frac{100}{0.414} = 241.5\text{pm}$$

33. 1) Diamond is like ZnS. In diamond cubic unit cell, there are eight corner atoms, six face centered atoms and four more atoms inside the structure (tetrahedral voids).

Total no. of atoms present per unit cell $= \underbrace{8\times\frac{1}{8}}_{\text{(corners)}} + \underbrace{6\times\frac{1}{2}}_{\text{(face centered)}} + \underbrace{4}_{\text{(inside body)}} = 8$

34. 4) It represents ccp arrangement.

35. 2)

36. 3) Examine the nearest number of neighbours in (I) and (II). The number is six which is octahedral.

37. 2)

38. 3)

39. 3) $a = 2r\ ;\ r = \dfrac{0.236}{2} = 0.118\text{nm}$

40. 1) $r_c + r_a = \dfrac{\sqrt{3}a}{4}\ ;\ r = \dfrac{\sqrt{3}\times 4.3}{4} = 1.86\text{pm}$

shortest inter ionic distance = 2r

$1.86\times 2 = 3.72\text{pm}$

41. 4) $\dfrac{r^+}{r^-} = \dfrac{1}{2}$ = 0.5 F.C.C. lattice point

Cations are at octahedral void $\left(r^+ + r^-\right) = \dfrac{a}{2} = 3\ ;\ a = 6$

volume = $(6)^3 = 216\ \text{pm}^3$

42. 2) P.F. for *ccp* and *bcc* are 0.74 and 0.68 respectively. So, the free space in *ccp* and bcc are 26% & 32% respectively.

43. 2) $d = \dfrac{zM}{N_A a^3} \Rightarrow 6.25 = \dfrac{z\times 120}{6.02\times 10^{23}\times\left(4\times 10^{-8}\right)^3} = 2$

44. 2) $d = \dfrac{zM}{N_A a^3}$

$Z = 4, a = 2\sqrt{2r} = 2\sqrt{2}\times 215 = 608.2\text{pm}$

45. 4) For a fcc unit cell $r = \dfrac{\sqrt{2}a}{4}$

$\therefore$ closest distance (2r) = $\dfrac{\sqrt{2}a}{4} = \dfrac{a}{\sqrt{2}}$

46. 4) $r = \dfrac{\sqrt{2}a}{4}\ ;\quad a = \dfrac{4r}{\sqrt{2}} = 2\sqrt{2}\times 0.14 = 0.39 \approx 0.4\text{nm}$

47. 3) $\dfrac{d_1}{d_2} = \dfrac{(a_2)^3}{(a_1)^3}\times\dfrac{z_1}{z_2} = \left(\dfrac{3}{3.5}\right)^3\times\dfrac{4}{2} = 1.46$

48. 3)

49. 2) $\rho = \dfrac{Z\times M}{N_A\times a^3} = \dfrac{2\times 100}{6.023\times 10^{23}\times\left(400\times 10^{-10}\right)^3} = 5.188\text{g}/\text{cm}^3$

50. 1) $\underset{(6:6)}{NaCl} \xrightarrow[\text{Pressure}]{\text{High}} \underset{(8:8)}{CsCl}$

51. 1) There are two atoms in a *bcc* unit cell. So, number of atoms in 12.08 × $10^{23}$ unit cells
= 2 × 12.08 × 1023 = 24.16 × $10^{23}$ atoms.

52. 2)

53. 3) In a *fcc* lattice, the distance between the cation and anion is equal to the sum of their radii, which is equal to half of the edge length of unit cell, i.e. $r^+ + r^- = \dfrac{a}{2}$ (where *a* = edge length)

$r^+ = 95$ pm, $r^- = 181$ pm

Edge length = $2r^+ + 2r^-$ = (2 × 95 + 2 × 181) pm = (190 + 362) pm = 552 pm.

54. 2)

55. 2) Density is given by $d = \dfrac{Z\times M}{N_A a^3}$; where Z = number of formula units present in unit cell, which is 4 for *fcc*

a = edge length of unit cell. M = Molecular mass

$$2.72 = \frac{4 \times M}{6.02 \times 10^{23} \times \left(404 \times 10^{-10}\right)^3}$$

$$\left(\because 1\text{pm} = 10^{-10}\text{cm}\right)$$

$$M = \frac{2.72 \times 6.02 \times (404)^3}{4 \times 10^7} = 26.99 = 27 \text{ g mol}^{-1}$$

56. 2) Every constituent has two tetrahedral voids. In ccp lattice atoms =8 × 1/8 + 6 × 1/2 = 4
Tetrahedral void = 4 × 2 = 8 ; Thus ratio = 4 : 8 = 1 : 2

57. 4)

58. 3)

59. 4) Non-stoichiometric compounds are chemical compounds with an elemental composition that cannot be represented by a ratio of well-defined natural numbers, and are therefore in violation of the law of definite proportions. They are most often solids that contain random defects, resulting in the deficiency of one element. So, none of given option is correct.

60. 2) Bragg's equation is $n\lambda = 2d \sin \theta$ where $n$ is a positive integer i.e., 1, 2, 3, 4 etc. which stands for serial order of diffracted beams

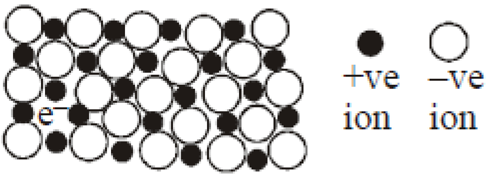
61. 2)

62. 4) In KCl, co-ordination number of cation and anion is 6 and 6 respectively. KCl is highly ionic so Schottky defect is common.
Note : Schottky defect is common in compounds having high coordination nummber while Frenkel defect is common in compounds with low coordination number.

63. 1) Schottky defects are found in solid.

64. 1) $p$-type of semiconductors are produced
(i) due to metal deficiency defects
(ii) by adding impurity containing less electrons (i.e., atoms of group 13)
Ge belongs to Group 14 and In to Group 13. Hence on doping, p-type semicondutor is obtained.

65. 4) When electrons are trapped in anion vacancies, these are called F-centre.



F- centre in crystal

66. 2) When equal number of cations ($Na^+$) and anions ($Cl^-$) are missing from their regular lattice positions, we have Schottky defect.

67. 4) Schottky defect occurs in ionic crystals of type $A^+B$, when equal number of cations and anions are missing from their lattice sites so that the electrical neutrality is maintained. This defect generally appears in highly ionic compounds which have high coordination number. NaCl, KCl and CsCl all have high coordination numbers i.e., 6, 6 and 8 respectively. So, Schottky defect appears in all of the given compounds.

68. 4) Ionic solids must always maintain electrical neutrality. Ionic solids show vacancy or interstitial defects as Frenkel and Schottky defect.

69. 1) The number of $Fe^{3+}$ ions replacing x $Fe^{2+}$ ions $= \frac{2x}{3}$

vacancies of cations = $x - \frac{2x}{3} = x/3$

But x/3 = 1 – 0.94 = 0.06, x = 0.06 × 3 = 0.18 = 18%

70. 3)

## NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. 4)

For bcc lattice : $Z=2,\ a=\frac{4r}{\sqrt{3}}$

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

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

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

2. 3) Those ionic compounds in which size of cation and anion is largely different show Frenkel defect.

3. 2)

$$\text{density }(\rho)=\frac{Z\times M}{N_A\times a^3}$$

For bcc structure

$Z=2,\ \rho=530\text{ kg m}^{-3}=0.530\text{ g cm}^{-3}$

$$0.530=\frac{2\times 6.94}{6.02\times 10^{23}\times a^3}$$

$a^3=4.348\times 10^{-23}\text{ cm}^3$

$a=3.52\times 10^{-8}\text{ cm}$

$a=352\text{ pm}$

4. 1) radii ratio $=\frac{r_+}{r_-}=\frac{0.98\times 10^{-10}}{1.81\times 10^{-10}}=0.54$

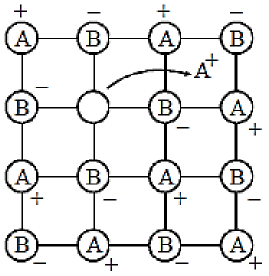
Since, the radii ratio is in between 0.414 to 0.732 so, coordination number is 6.

5. 4) Number of atoms per unit cell $=8\times(1/8)+1=2$ ; $r=\frac{\sqrt{3}a}{4}$

$$\text{Packing Fraction (P.F.)}=\frac{2\times\frac{4}{3}\pi r^3}{\left(4r/\sqrt{3}\right)^3}=\frac{\sqrt{3}\pi}{8}=0.68$$

% P.F. = 68% ; % of vacant space = 100 – 68 = 32%

6. 3)



Frenkel defect is dislocation defect

7. 1) For FCC : $r=\frac{\sqrt{2}a}{4}=\frac{1.41\times 361}{4}=127\text{pm}$

8. 4) For bcc lattice body diagonal $=a\sqrt{3}$ The distance between the body centered atom and one corner atom in cube will be $=\frac{\sqrt{3}a}{2}$

9. 3)Anion A in HCP
No of ions of A in Unit cell = 6
No of Octahedral voids = 6

75% is occupied by cations C

No of cations $C = 6\times\frac{75}{100} = 6\times\frac{3}{4} = \frac{9}{2}$

$C_{9/2}A_6$

$C_9A_{12}$

Simple ratio $C_3A_4$

10. 1)

Let, $Ni^{+2}$ in the crystal $Ni_{0.98}O$ be x.

$\therefore$ $Ni^{+3}$ in the crystal $Ni_{0.98}$ will be (0.98 – x)

$$Ni_x^{+2}Ni_{(0.98-x)}^{+3}O$$

By law of conservation of charge

$$2x + 3\times(0.98 - x) - 2 = 0$$

$$x = 0.94$$

So, the fraction of $Ni^{+2}$ ions in the crystal $= \frac{0.94}{0.98}$

$\simeq$ **0.96**

11. 1) AgBr shows both schottky and frenkel defect

12. 2) Body diagonal 4r == $\sqrt{3}a$ ; $r = \frac{\sqrt{3}\times288}{4}\ pm$

13. 3)

14. 3) $\frac{h.c.p\ \ primitive\, unit\, cell}{No\, of\ \ particles = 1}$ ;

Tetrahedral voids = 2 ; Octahedral voids = 1

15. A: is metal deficiency defect

R : it is frenkel defect

16. $a = 3.608\times10^{-8}cm$

$d = 8.92gcm^{-3}$

$d = \frac{z\times M}{No\times a^3}$

$92. = \frac{4\times n}{6\times023\times10^{23}}\times\left(3.608\times10^{-8}\right)^3$

$x = \frac{8.92\times6.023\times10^{23}\times(3.608)^3\times10^{-24}}{4} = 8.92\times6.023\times10\times10^{-1} = 631\times10^{-1} = 63.1$