

NEET-UG / AIPMT & JEE (Main)



Chemistry Vol - 2.2

For all Agricultural, Medical, Pharmacy and Engineering Entrance Examinations held across India.

1913 MCQs with Hints

NEET-UG / A
JEE (Main)

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Chemistry Vol - 2.1

For all Agricultural, Medical, Pharmacy and Engineering Entrance Examinations held across India.

2498 MCQs with Hints

Helium

Helium (He) gas is used for filling balloons as it is lighter than air and non-combustible.

NEET-UG / AIPMT &
JEE (Main)

Chemistry Vol - 2.1

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Chemistry

Vol - 2.1

Salient Features

- Precise theory for every topic.
- Exhaustive subtopic wise coverage of MCQs.
- 2498 MCQs including questions from various competitive exams.
- Includes MCQs from AIPMT & Re-Test 2015, NEET P-I & P-II 2016, JEE (Main) 2015 & 16.
- Relevant Hints provided.
- Quick Review and Additional Information to build concepts.
- Topic-wise test at the end of each chapter.

*Solutions/hints to Topic Test available in downloadable PDF format at
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PREFACE

Target's "**Chemistry Vol - 2.1**" is compiled according to the notified Std. XII syllabus for NEET-UG & JEE (Main). The content of this book is framed after reviewing various state syllabi as well as the ones prepared by CBSE, NCERT and COBSE.

The sections of **Theory**, **Quick Review**, **Formulae**, **MCQs** and **Topic Test** form the backbone of every chapter and ensure adequate revision.

These MCQs are framed considering the importance given to every topic as per the NEET-UG & JEE (Main) exam. They are a healthy mix of theoretical, numerical, multi-step reactions and graphical based questions.

The level of difficulty of these questions is at par with that of various competitive examinations like CBSE, AIIMS, CPMT, JEE, AIEEE, TS EAMCET (Med. and Engg.), BCECE, Assam CEE, AP EAMCET (Med. and Engg.) & the likes. Also to keep students updated, questions from most recent examinations such as AIPMT/NEET, MHT CET, KCET, GUJ CET, WB JEEM, JEE (Main), of years 2015 and 2016 are exclusively covered.

In the development of each chapter, we have ensured the inclusion of important points that are enclosed within a box. These topics will enhance students' knowledge and provide them an edge to score better in the highly competitive exams.

We are confident that this book will cater to needs of students across a varied background and effectively assist them to achieve their goal. We welcome readers' comments and suggestions which will enable us to refine and enrich this book further.

Please write to us at: mail@targetpublications.org

All the best to all Aspirants!

Yours faithfully,

Authors

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'Chapters 10 to 16 are a part of Chemistry Vol - 2.2'

01 Solid State

1.0 Introduction

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1.3 Unit cell and two and three dimensional lattices

*1.4 Bragg's law and its applications

1.5 Seven crystal systems

1.6 Three types of cubic lattices

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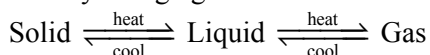
* marked section is only for JEE (Main)

**marked section is for NEET-UG

1.0 Introduction

➤ States of matter:

- i. Matter can exist in three physical states – solid, liquid and gas. One state of matter can be changed to another state by changing the conditions of temperature and pressure. The equilibrium between solid, liquid and gas is



- ii. All the above transformations can also be brought by either changing the pressure alone or changing both temperature and pressure.
- iii. **Pure substances** undergo changes in their physical state at a specific or particular temperature (eg. iron, mercury, ice, etc. have sharp melting or boiling point). However, **impure substances** undergo change in their physical state over a range of temperature.
- iv. The physical state of matter is due to presence of different intermolecular forces of attraction such as
- dipole-dipole interactions
 - dipole-induced dipole interactions
 - London forces
 - hydrogen bonding

➤ General characteristics of solid state:

- i. A **solid** is defined as that form of matter which possesses rigidity and hence possesses a definite shape and a definite volume.
- ii. Due to rigid nature, solids cannot be compressed like gases. This is due to small intermolecular distance of separation between neighbouring molecules. Also, solids cannot be poured like liquids because the positions of constituent particles, atoms or molecules cannot be changed. Thus, solids have fixed mass, volume, shape and density.
- iii. The density of solid state is greater than the density of liquid state or gaseous state. Ice (solid water) is an exception, which has density lower than that of liquid water. The density of mercury (liquid state) is very high (13.6 g mL⁻¹).
- iv. Solids are hard. Hardness is due to presence of strong intermolecular forces of attraction. These forces are stronger than those present in liquid state and gaseous state. Exceptions are sodium, potassium and phosphorus which are soft.
- v. Pure solids have characteristic melting points. Solids with strong intermolecular forces of attraction have high melting points. Solids with weak intermolecular forces of attraction have low melting points.
eg. Diamond has very high melting point (few thousand kelvin) and helium has very low melting point (almost absolute zero).
- vi. In solid state, constituent particles, atoms or molecules exhibit vibratory motion. They oscillate about their mean positions but do not have translatory motion and therefore remain stationary at one position.
- vii. In comparison with liquids and gases, solids diffuse very slowly.



1.1 Classification of solids

Solids are classified into the following two types on the basis of the presence or absence of orderly arrangement of the constituent particles: i. Crystalline solids ii. Amorphous solids

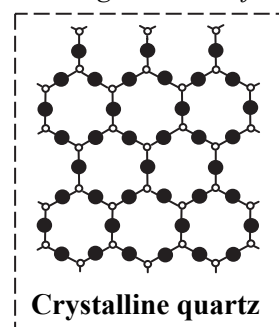
i. Crystalline solids:

- a. A **crystalline solid** is a homogeneous solid in which the constituent particles, atoms, ions or molecules are arranged in a definite repeating pattern.

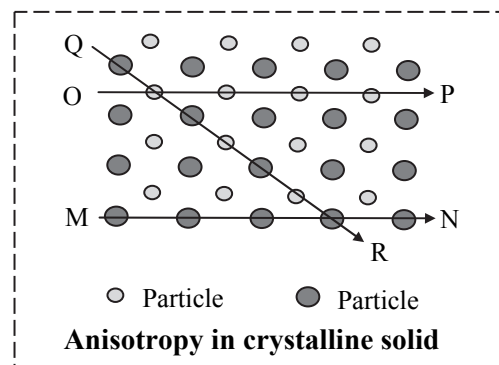
OR

The substance whose constituent particles (atoms, ions or molecules) are arranged in a definite geometric pattern in three dimensional space is called **crystalline solid**.

- b. Crystalline solids have **long range order** in which a large number of small crystals (unit cells) repeat periodically over the entire crystal.
- c. A unit cell is a basic repeating structural unit of a crystalline solid and it has a regular pattern or arrangement of particles.
- d. Crystalline solids have an arrangement that ensures maximum total intermolecular force of attraction.
- e. The stability and the properties of crystalline solids depend upon following forces of attraction between the constituent particles:
1. ionic bonds
 2. covalent bonds
 3. hydrogen bonds
 4. van der Waals forces
- f. Most of the solid substances are crystalline in nature.
- eg. 1. Elements such as copper, silver, iron, sulphur, phosphorus and iodine form crystalline solids.
2. Compounds such as sodium chloride, potassium nitrate, zinc sulphide, sugar, quartz, etc. form crystalline solids.



- g. Pure crystalline solid has sharp melting point i.e. it melts at one constant temperature. This is due to the presence of uniform orderly arrangement of constituent particles.
- h. The physical properties (refractive index, electrical conductance, dielectric constant, etc.) of crystalline solids change with change in direction of measurement. This can be understood on the basis of the different arrangement of particles in different directions, as shown in figure. Thus, crystalline solids are anisotropic.
- i. The ability of crystalline solids to change values of physical properties when measured in different directions is called **anisotropy**.



Note: Isomorphous solids and polymorphous solids:

- i. Two or more substances having the same crystal structure are said to be **isomorphous** (iso – same, morphous – form) **solids** and the phenomenon is called **isomorphism**.
- ii. The atomic ratio of the constituent atoms of the substance is same for isomorphous substances as shown in the following table:

Isomorphous substances	Atomic ratio
NaF and MgO	1 : 1
K ₂ SO ₄ and K ₂ SeO ₄	2 : 1 : 4
NaNO ₃ and CaCO ₃	1 : 1 : 3
Cr ₂ O ₃ and Fe ₂ O ₃	2 : 3

- iii. NaCl and KCl have same atomic ratio, similar molecular formula and similar chemical properties. But they have different crystal structures. Thus, NaCl and KCl are not isomorphous.
- iv. A single substance that crystallises in two or more forms under different conditions is called **polymorphous** (many forms) **solid** and the phenomenon is called **polymorphism**.
- v. Polymorphic forms are also called allotropic forms.
- eg. a. Graphite, fullerene and diamond are allotropes of carbon.



- b. Rhombic sulphur and monoclinic sulphur are polymorphic forms of sulphur.
- c. Calcium carbonate and silicon dioxide also have two polymorphic forms.

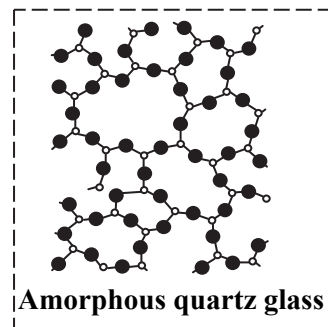
ii. Amorphous solids:

- a. *The substances that appear like solids but do not have well developed perfectly ordered crystalline structure are called **amorphous** (no form) **solids**.*

OR

*The substances whose constituent particles are not arranged in any regular arrangement are called **amorphous solids**.*

- b. Amorphous solids do not have an orderly arrangement of constituent particles, atoms, ions or molecules. Even if such an arrangement is present, it is present upto a short distance (not more than few angstroms). Thus, they have **short range order**.
eg. Tar, glass, plastic, rubber, etc. are amorphous substances.
- c. Amorphous substances do not have sharp melting point. They melt over a range of temperature. As the temperature increases, amorphous substances gradually soften, become less viscous and melt. They can be moulded or blown into different shapes. When heated to a certain temperature or when kept for long time, they may become crystalline.
- d. Amorphous substances are **super cooled liquids**. They have fluid properties and flow down very slowly under gravity. Due to this, the lower sides of glass panes of windows, photo frames, cupboards and showcases become slightly thicker and upper ends become thinner. Thus, amorphous substances are not real solids. They are called **pseudo solids**.
- e. The physical properties of amorphous solids do not change with change in direction of measurement, as the arrangement of particles is irregular in all directions. Since, there is no long range order in these solids, they are isotropic.
- f. *The ability of the amorphous solids to have the same physical properties in all directions is called **isotropy**.*



Note:i. Amorphous silicon: Photovoltaic cells (for conversion of sunlight to electricity) based on amorphous silicon provide one of the best conversion efficiency.

ii. Glass:

- a. Glass is transparent to light. It is produced by fusing together silicon dioxide with sodium oxide. The colour of glass is due to addition of boron oxide and a trace amount of transition metal oxide.
- b. Quartz glass is prepared from only silicon dioxide. About eight hundred types of glass are manufactured by changing composition.
- c. Pyrex glass is prepared by fusing together 60 to 80% SiO_2 , 10 to 25% B_2O_3 and remaining amount of Al_2O_3 .
- d. Soda lime glass is produced by fusing 75% SiO_2 , 15% Na_2O and 10% CaO .
- e. Red glass contains trace amount of gold and copper.
- f. Yellow glass contains UO_2 .
- g. Blue glass contains CoO or CuO .
- h. Green glass contains Fe_2O_3 or CuO .

➤ Differences between crystalline and amorphous solids:

	Property	Crystalline solids	Amorphous solids
i.	Shape	They have definite characteristic geometrical shape due to the orderly regular long range arrangement of constituent particles.	They have irregular shape i.e., lack characteristic geometrical shape due to the short ranged orderly arrangement of constituent particles.
ii.	Melting point	They have sharp and characteristic melting point.	They do not have sharp melting point. They gradually soften over a range of temperature.



iii.	Cleavage property	When cut with a sharp edged tool, they split into two pieces and the newly generated surfaces are plain and smooth.	When cut with a sharp edged tool, they cut into two pieces with irregular surfaces.
iv.	Heat of fusion	They have a definite and characteristic heat of fusion.	They do not have definite heat of fusion.
v.	Anisotropy	They are anisotropic, i.e., have different physical properties in different direction.	They are isotropic, i.e., have same physical properties in all directions.
vi.	Nature	They are true solids.	They are pseudo solids or super cooled liquids.
vii.	Order in arrangement of constituent particles	They have long range order.	They have only short range order.
eg.		Copper, silver, iron, zinc sulphide, common salt, potassium nitrate, etc.	Glass, rubber, plastics, etc.

1.2 Classification of crystalline solids

Crystalline solids are classified into the following four types:

- i. Molecular solids ii. Ionic solids iii. Metallic solids iv. Covalent or network solids

i. Molecular solids:

- Molecular solids** are the crystalline solids in which the constituent particles are molecules of the same compound.*
- Based on the type of molecules involved in crystal formation and the nature of intermolecular force of attraction between the neighbouring molecules, molecular solids are further classified into polar, non polar and hydrogen bonded molecular solids.

1. Polar molecular solids:

- Substances such as HCl, SO₂, etc. contain covalently bonded molecules. Under normal conditions of temperature and pressure, in gaseous state, such molecules exist as discrete molecules. On cooling and applying high pressure, these gaseous substances first liquefy and then solidify to give polar molecular solids.
- Polar molecules have permanent dipole moment. In the solid state, these molecules are held together by strong dipole–dipole interactions.
- Polar molecules have charge separation. They are aligned in such a way that opposite charges are brought closer.
- They are soft and do not conduct electricity.
- They have relatively low melting points due to relatively weak bonding.
- They have higher enthalpies of vapourisation than those of non-polar molecular solids.

2. Non-polar molecular solids:

- At very low temperatures, non-polar molecular solids are formed from non-polar molecules like CO₂, H₂, Cl₂, CH₄ and weakly polar molecules like CO and other hydrocarbons.
- Iodine (I₂) is a solid even at room temperature while other non-polar molecular solids are in gaseous state at room temperature.
- Non-polar molecular solids are soft and they do not conduct electricity.
- They have relatively low melting points, lower than polar molecular solids.
- Weak dispersion forces or London forces are present in non-polar molecular solids.
- They are volatile and have low enthalpies of vapourisation.

3. Hydrogen bonded molecular solids:

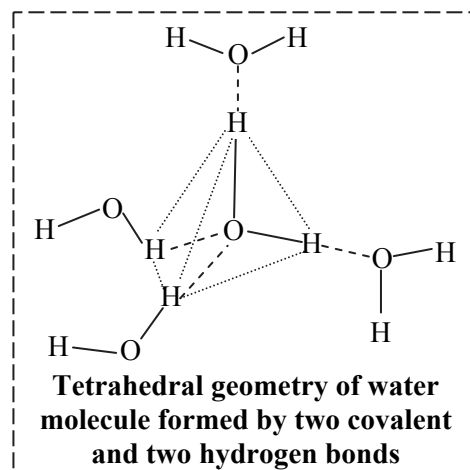
- Hydrogen bond is formed between hydrogen atom and strongly electronegative atom present in the vicinity. Hydrogen atom acquires partial positive charge when it is attached to strongly electronegative atom such as oxygen, nitrogen or fluorine.



- ii. Solid water (ice) is a hydrogen bonded molecular solid in which the hydrogen bond is formed between hydrogen atoms of one water molecule with oxygen atoms of neighbouring water molecules.
- iii. Hydrogen bonded molecular solids do not conduct electricity.
- iv. They are in liquid state or gaseous state at normal temperature and pressure. The liquids solidify only on cooling.

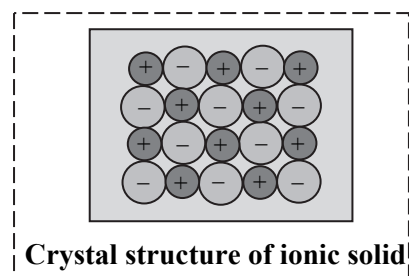
Note: Hydrogen bonding in ice and water (Anomalous behaviour):

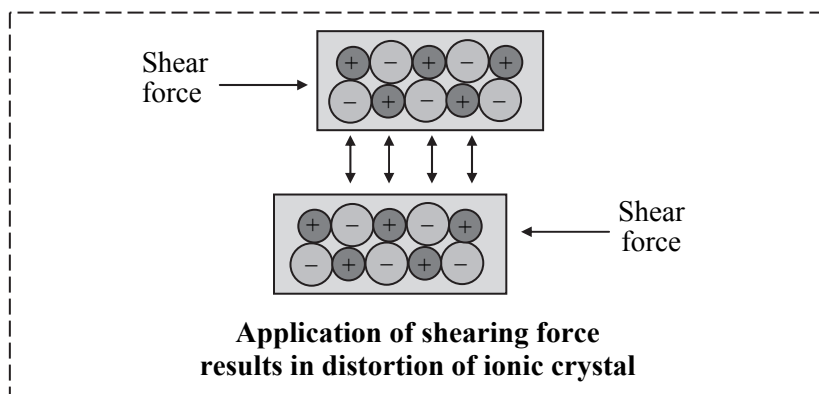
- i. The volume of single water molecule is $15 \times 10^{-24} \text{ cm}^3$. Assuming that all water molecules in liquid state are closely packed, the total volume of 1 mole (18 g) of water is $15 \times 10^{-24} \text{ cm}^3 \times 6.02 \times 10^{23} = 9 \text{ cm}^3$. This is about one half of the value 18 cm^3 calculated from mass 18 g and density 1 g mL^{-1} . Thus, one half of the total volume is unoccupied.
- ii. Ice has hexagonal three dimensional crystal structure formed by intermolecular hydrogen bonding with one half of total volume unoccupied.
- iii. Generally the density of solid state is greater than the density of liquid state. However, reverse is true for water which shows an anomalous behaviour.
- iv. Liquid water has structure which is identical to that of solid ice. On melting of ice, some of the hydrogen bonds are broken and some of the empty spaces are occupied by water molecules. Therefore, the density of liquid water is greater than the density of solid ice and thus, ice floats on water.



ii. Ionic solids:

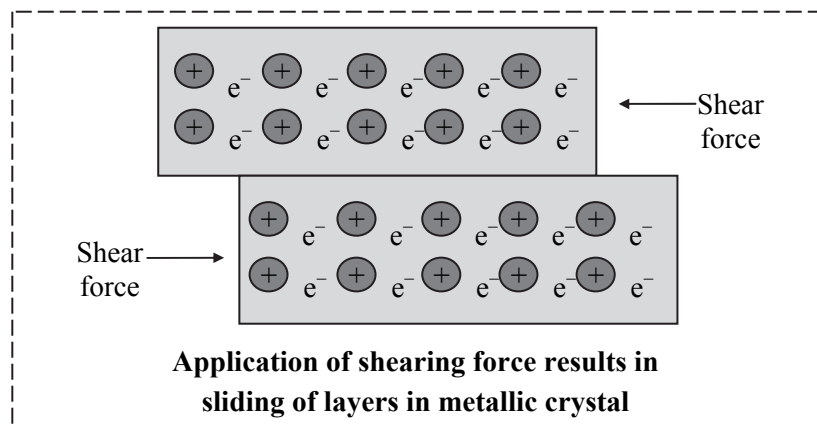
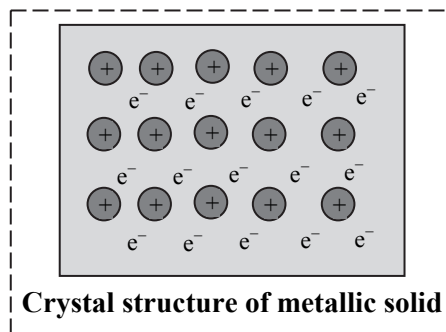
- a. **Ionic solids** are crystalline salts formed by molecules containing positively charged smaller sized cations and negatively charged relatively bigger anions.
eg. NaCl, ZnS, CuCl, LiF, etc.
- b. Electrical neutrality is maintained in the molecule due to presence of equal number of positive and negative charges and their appropriate arrangement so that they balance each other.
- c. Two types of electrostatic forces are present in ionic solids:
 - 1. Electrostatic force of attraction between ions of opposite charges.
 - 2. Electrostatic force of repulsion between ions of same charges.
- d. Due to these two forces, well ordered three dimensional arrangement is obtained and most of their properties can be explained.
- e. The arrangement of ions depends on the following three factors:
 - 1. sizes of the cation and anion,
 - 2. the charges on the ions and
 - 3. polarisability of anion.
- f. The ionic solids are hard and brittle. They have high melting points.
- g. In solid state, free electrons are not available. Therefore, ionic solids do not conduct electricity. However, in fused state or in aqueous solution, ions become free to move and conduct electricity.
- h. They have high enthalpies of vaporisation.
- i. When shearing force is applied, ionic crystals are distorted resulting in the fracture in crystal structure.





iii. Metallic solids:

- Metallic solids** are the crystalline solids formed by atoms of the same metallic element.
eg. Metals like nickel, copper, gold, etc. and alloys.
- Each metal atom contributes one or more electrons which are delocalised over the entire crystal. i.e., they can move freely from one end to the other and constitute a sea of free and mobile electrons.
- The positive core of the metal atoms remains stationary in this sea of electrons.
- Metallic bond** is the force of attraction between positively charged metallic ion and negatively charged sea of delocalised electrons.
- Metallic solids are good conductors of heat and electricity due to presence of mobile electrons. These mobile electrons can move from one place to another when electrical or thermal energy is applied.
- They have moderate enthalpies of fusion.
- When shearing force is applied, the layers of metallic solid slide on one another. Thus, the structure is not fractured.



- Metallic bonds are stronger than ionic and covalent bonds. Hence, metallic solids are tougher than other solids.
- The metals are **malleable** (can be hammered or rolled into thin sheets of desired thickness) and **ductile** (can be drawn into thin wires of required size.)
- Two or more metals can be fused together to form **alloys**. These alloys have properties that are different from their constituent metals.
- Metal surfaces have lustre of grey or silvery colour. Gold has yellow lustre and copper has reddish lustre.

iv. Covalent solids:

- Covalent solids** are formed by chemical bonds i.e. covalent bonds between the neighbouring constituent atoms of non-metallic solids.

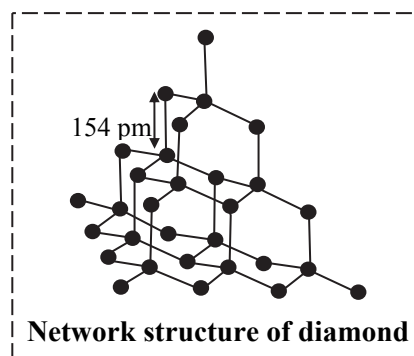


- b. They are also called **giant molecules** or **network solids** as there is a continuous network of covalent bonds forming a giant three dimensional structure.
- c. They may be hard or brittle depending on the type of covalent bonding between the atoms.
- d. They have high melting points.
- e. They are good conductors of electricity if mobile electrons are present, otherwise they are insulators.
- f. They have high enthalpies of fusion.

eg. Three allotropic modifications of carbon i.e., diamond, graphite and fullerene are covalent solids.

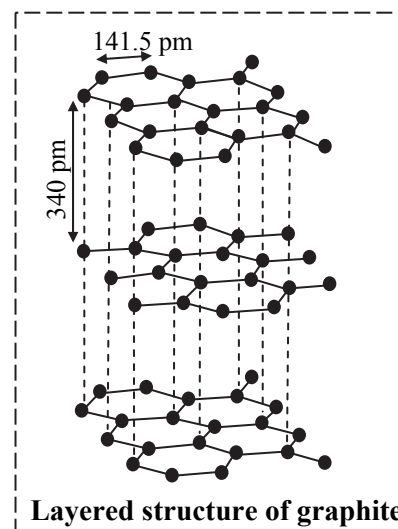
1. Diamond:

- i. Diamond is an allotrope of carbon and is used in jewellery.
- ii. Diamond is a very strong and extremely hard solid due to the presence of strong covalent bonds between sp^3 hybridised carbon atoms which continues in all directions to form a big giant network of covalent solid.
- iii. Each carbon atom lies at the centre of a regular tetrahedron and other four carbon atoms are present at the corners of the tetrahedron.
- iv. The melting point of diamond is very high (3550°C).
- v. Diamond is a poor conductor of electricity as all the valence electrons of carbon are strongly held in carbon-carbon bonds.



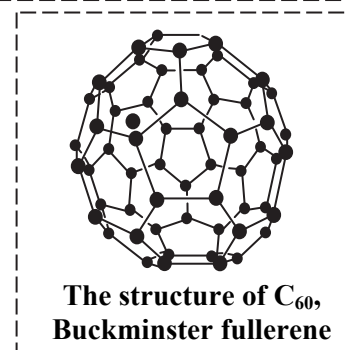
2. Graphite:

- i. Graphite is an allotropic form of carbon which contains sp^2 hybridised carbon atoms forming inter linked six membered rings of carbon atoms.
- ii. Each sp^2 hybridised carbon atom is covalently bonded to three other sp^2 hybridised carbon atoms. The remaining half filled unhybridised $2p_z$ orbital is used for π bonding, which results in formation of layers of carbon atoms in graphite.
- iii. The adjacent layers of carbon atoms are separated by a distance of 340 pm and are held together by weak van der Waals forces of attraction.
- iv. Graphite is hard due to the presence of covalent bonds between sp^2 hybridised carbon atoms.
- v. Graphite is a good conductor of electricity, due to the presence of delocalised electrons which can move freely in the π bonds of the six-membered hexagonal rings.
- vi. Graphite is used as lubricant for reducing friction because in graphite, one layer of carbon atoms can slide over another layer.
- vii. Graphite is used in the manufacture of ribbons used for printing in computers and typewriters and it is also used in lead pencils.



3. Buckminster fullerene or Buckball or fullerene:

- i. It was discovered in 1985 by focusing high power laser on carbon. It has formula C_{60} and is a hollow sphere with shape of soccer ball. Carbon atoms occupy sixty equidistant places on the sphere. They form hexagons and pentagons.
- ii. In fullerene, carbon atoms are sp^2 hybridised. Fullerene contains delocalised molecular orbitals spread over entire structure of fullerene.



**Note:**

- $K_{35}C_{60}$, a compound formed by the reaction of potassium and fullerene, is a super conductor of electricity at 18K.
- A compound formed by the reaction of fullerene with transition metal is used as catalyst.
- Nanotubes are tubes made from fullerene and graphite. They are used as high strength materials, electrical conductors, molecular sensors and semiconductors.

➤ **Summary of the characteristics of various types of crystalline solids:**

Types of crystalline solids	Constituent particles	Bonding/ attractive forces	Physical nature	Melting point	Electrical conductivity	Examples
Molecular solids	Small covalent molecules				Insulators	
i. Polar	Polar molecules	Dipole – dipole	Soft	Low		HCl, SO ₂
ii. Non-Polar	Non-polar molecules	London or dispersion forces	Soft	Very low		Ar, He, CCl ₄ , H ₂ , Cl ₂ , I ₂ , CO ₂
iii. Hydrogen bonded	Molecules capable of hydrogen bonding	Hydrogen bonding	Hard	Low		H ₂ O (ice)
Ionic solids	Positive and negative ions	Electrostatic or Coulombic	Hard and brittle	Very high	Insulators in solid state but conductors in molten state and in aqueous solutions.	NaCl, MgO, ZnS, CaF ₂
Metallic solids	Positive ions in a sea of delocalized electrons	Metallic bonding	Hard, malleable and ductile	High	Conductors	Fe, Cu, Ag, Mg
Covalent or network solids	Atoms	Covalent bonding	Hard	Very high	Insulators	SiO ₂ (quartz), SiC, C _{diamond} , AlN
			Soft	-	Conductor	C _{graphite}

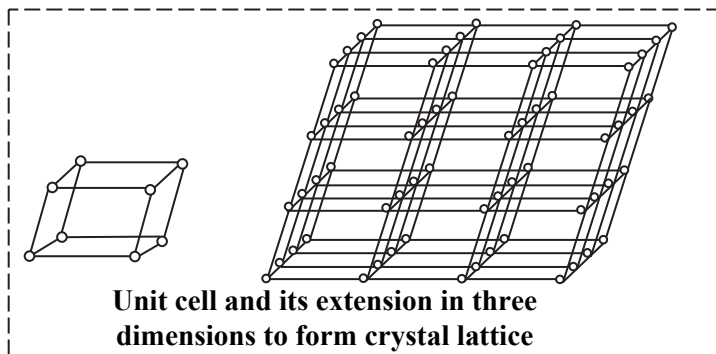
1.3 Unit cell and two and three dimensional lattices

➤ **Unit cell:**

A **unit cell** is the smallest repeating unit of a crystalline solid which when repeated over and over again produces the complete crystal lattice.

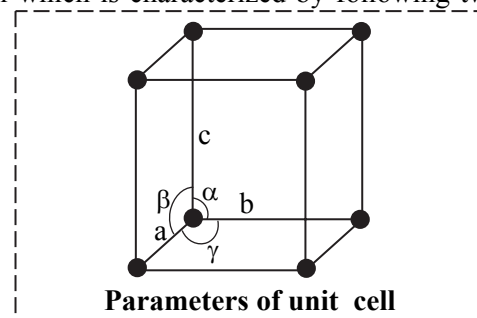
➤ **Crystal lattice or space lattice:**

- A **crystal lattice** or **space lattice** is a regular arrangement of the constituent particles (atoms, ions or molecules) of a crystalline solid in three dimensional space.





- ii. **Lattice points or lattice sites** are the positions occupied by the atoms, ions or molecules in the crystal lattice.
- iii. The crystalline solids are characterized by definite orderly arrangement of constituent particles in three dimensions. Lattice points or lattice sites represent the positions of these particles in a crystal relative to one another. Each lattice point gives the location of one particle in the three dimensional space.
- iv. Crystal lattice is the three dimensional arrangement of infinite set of lattice points. Any one lattice point is identical to a number of other lattice points in a crystal that have identical environment.
- v. The collection of all the points in the crystal having similar environment is called **space lattice**.
- vi. The geometry of lattice can be obtained by joining the lattice points with straight lines.
- vii. A crystal may be regarded as made from infinite number of repeating unit cells.
- viii. The shape of any crystal is determined by the shape of unit cell which is characterized by following two parameters:
 - a. The lengths of the three edges of unit cell. They are denoted as a , b and c .
 - b. The angles between the edges of unit cell. They are represented as α , β and γ .
 - 1. Angle α is formed by edges b and c
 - 2. Angle β is formed by edges a and c
 - 3. Angle γ is formed by edges a and b

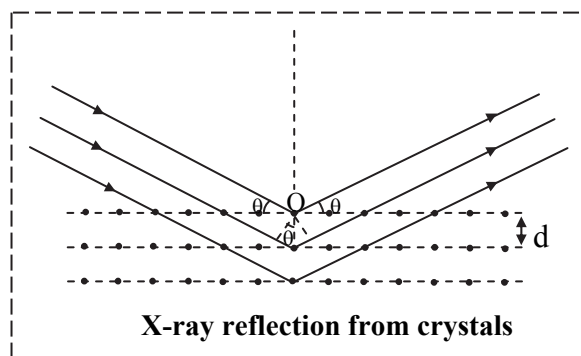


1.4 Bragg's law and its applications

- i. The arrangement of constituent particles in crystal lattice can be determined by X-ray diffraction.
- ii. X-rays of a single wavelength strike the parallel planes of the crystal at angle θ . The waves reflected by different layer planes are in phase when the difference in the path length of the wave reflected from successive planes is equal to an integral number of wavelengths. The condition for maximum reflection is given by Bragg's equation

$$n\lambda = 2d \sin \theta$$

where n is an integer ($n = 1, 2, 3, \dots$), λ is the wavelength, d is the distance between two planes and θ is the angle of incidence.



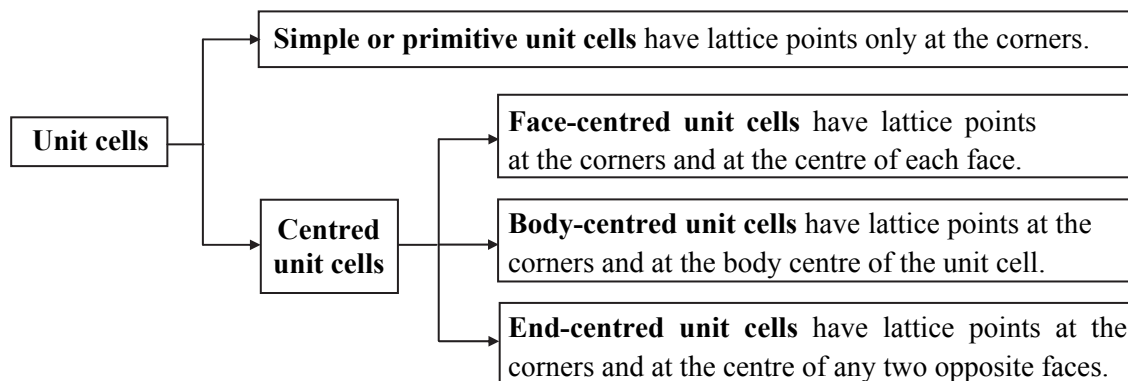
- iii. Bragg's equation can be used to determine the crystal spacings. When λ and d are constant, the value of θ depends on the value of n . For $n = 1, 2, 3, \dots$ the reflections are called first order, second order, third order and so on. As the value of n increases, the angle θ increases and the intensity of the reflected beam decreases.
- iv. The apparatus usually used for the experimental measurement is Bragg's X-ray spectrometer.



1.5 Seven crystal systems

➤ Types of unit cells:

Crystal system contains two types of unit cells: simple or primitive unit cells and centred unit cells.



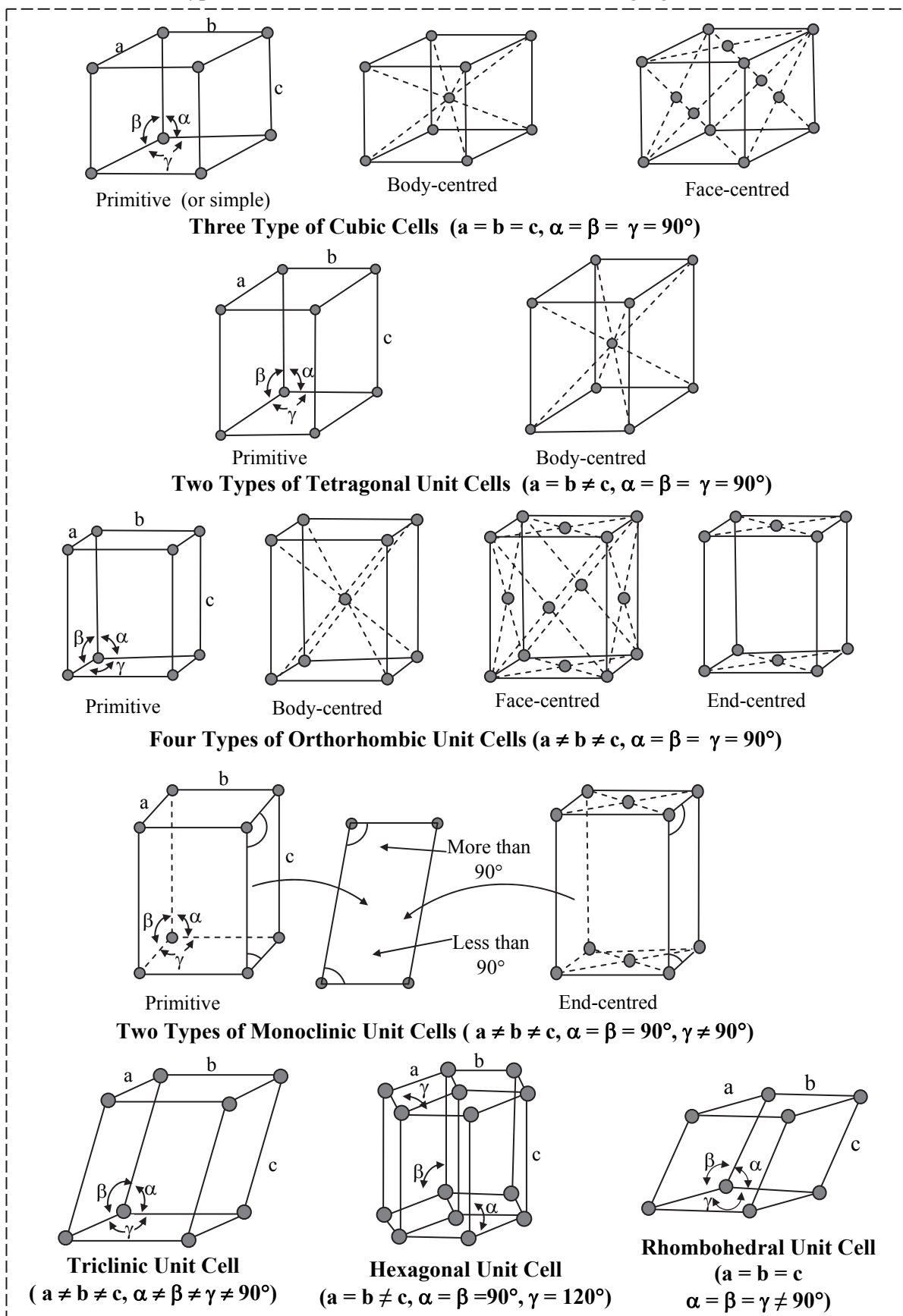
➤ Seven crystal systems:

- i. According to French mathematician Bravais, lattice points can be arranged in maximum of fourteen types known as **Bravais lattices**. These fourteen Bravais lattices form **seven crystal systems** which are also known as **crystal habits**.

No.	Crystal system	Type	Edge length	Angle	Example
1.	Cubic	Simple/primitive	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Polonium
2.		Body-centred	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Fe, Rb, Na, Ti, W, U, Zr, K
3.		Face-centred	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Cu, Al, Ni, Au, Ag, Pt
4.	Tetragonal	Primitive	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	SnO_2
5.		Body-centred	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	TiO_2 , CaSO_4
6.	Orthorhombic	Primitive	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Rhombic sulphur
7.		Body-centred	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	KNO_3
8.		Face-centred	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	BaSO_4
9.		End centred	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
10.	Monoclinic	Primitive	$a \neq b \neq c$	$\alpha = \beta = 90^\circ, \gamma \neq 90^\circ$	Monoclinic sulphur
11.		End centred	$a \neq b \neq c$	$\alpha = \beta = 90^\circ, \gamma \neq 90^\circ$	$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$
12.	Triclinic	Primitive	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	$\text{K}_2\text{Cr}_2\text{O}_7$, H_3BO_3 , $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
13.	Hexagonal	Primitive	$a = b \neq c$	$\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$	ZnO , BeO , CoS , SnS , graphite, CdS
14.	Rhombohedral or trigonal	Primitive	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	Calcite (CaCO_3), NaNO_3 , FeCO_3 , Cinnabar (HgS), quartz, Sb



- ii. The unit cells of 14 types of Bravais lattices are shown in the following figure:



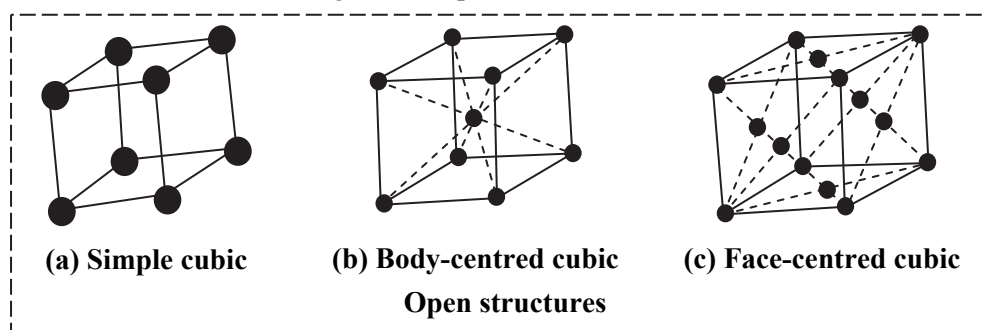
**Note:**

- i. Few more examples with their crystal system: Zinc blende \Rightarrow Cubic
White tin (Sn) \Rightarrow Tetragonal
 $\text{PbCrO}_4 \Rightarrow$ Monoclinic
- ii. **Cubic** is the most **symmetrical** system while **triclinic** is the most **unsymmetrical** system.

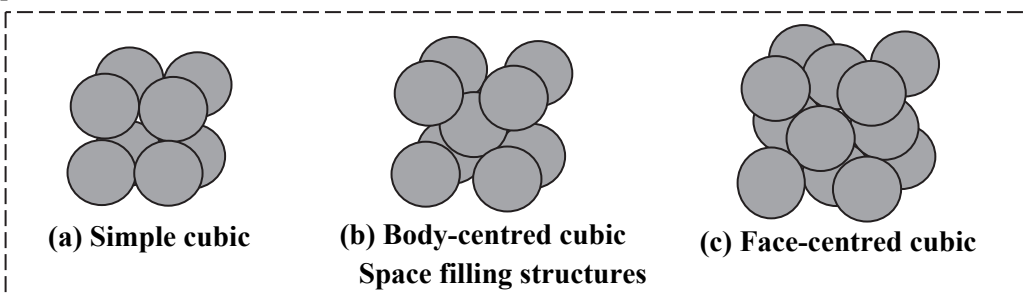
1.6 Three types of cubic lattices➤ **Open structures and space filling representation:**

The unit cell may be represented in the following two different ways:

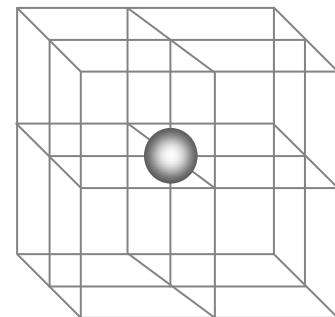
- i. Open structures ii. Space filling structures
- i. **Open structures:** Open structures are those structures where each small sphere represents only the centre of the particle occupying that position and not the actual size of the particle.
In these structures, the arrangement of particles is easier to follow as shown in the following figures.



- ii. **Space filling structures:** Space filling structures are those structures which show how the particles are packed within the solids.

➤ **Three types of cubic lattices and number of atoms per cubic unit cell:**i. **Simple cubic unit cell:**

- a. Simple cubic unit cell has lattice points at all the corners of the cubic unit cell.
- b. Total eight atoms are present at eight corners. For crystal lattice with identical sized particles, the arrangement of the particles can be represented by the spheres of equal size.
- c. Every atom is shared by eight unit cells. Thus, every atom contributes $\frac{1}{8}$ to each unit cell. $8 \text{ corner atoms} \times \frac{1}{8} \text{ atom per unit cell} = 1 \text{ atom.}$
Thus, the number of atoms per unit cell in a simple cubic unit cell is **one**.
- d. In three dimensions, each sphere is in contact with total 6 spheres. Thus in simple cubic cell, the coordination number of every sphere is **six**.



In a simple cubic unit cell, each corner atom is shared between 8 unit cells.

**Note:**

- The **coordination number** of constituent particle of the crystal lattice is the number of particles surrounding a single particle in the crystal lattice.
- Coordination number is also the measure of hardness of the crystal. More the coordination number, more tightly the particles are packed in the crystal lattice.

ii. Body-centred cubic unit cell (bcc):

- Body-centred cubic unit cell has lattice points at all the corners of the cubic unit cell. In addition, it has one lattice point at the centre of the cubic unit cell.
- Total eight atoms are present at eight corners and one atom is present at centre of the body of unit cell.
- Every corner atom is shared by eight unit cells. Thus, every corner atom contributes $\frac{1}{8}$ to each unit cell. The atom present at body-centre contributes 1 to each unit cell as it is not shared by any other unit cell.

$$8 \text{ corner atoms} \times \frac{1}{8} \text{ atom per unit cell} + 1 \text{ body-centre atom} \times 1 \text{ atom per unit cell}$$

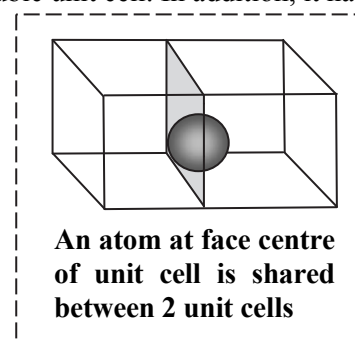
$$= (1 + 1) \text{ atoms} = \mathbf{2 \text{ atoms}}$$
 Thus, body-centred cubic unit cell has **two atoms** per unit cell.
- In three dimensions, each sphere is in contact with total 8 spheres. Thus, in body-centred cubic unit cell, the coordination number of every sphere is **eight**.

iii. Face-centred cubic unit cell (fcc):

- Face-centred cubic unit cell has lattice points at all the corners of the cubic unit cell. In addition, it has one lattice point at the centre of each face.
- Total eight atoms are present at eight corners and six atoms are present at the centres of six faces of the unit cells.
- Every corner atom is shared by eight unit cells. Thus, every corner atom contributes $\frac{1}{8}$ to each unit cell. Every face-centre atom is shared by two unit cells. Thus, every face-centre atom contributes $\frac{1}{2}$ to each unit cell.

$$8 \text{ corner atoms} \times \frac{1}{8} \text{ atom per unit cell} + 6 \text{ face-centre atoms} \times \frac{1}{2} \text{ atom per unit cell}$$

$$= (1 + 3) \text{ atoms} = \mathbf{4 \text{ atoms}}$$
 Thus, face-centred cubic unit cell has **four atoms** per unit cell.
- In three dimensions, each sphere is surrounded by six neighbouring spheres in its own layer, three spheres in the layer above and three spheres in the layer below. Thus, the coordination number is **twelve**.



Following table summarizes the number of atoms per unit cell in a cubic unit cell:

Unit cell	Simple cubic	Body-centred cubic	Face-centred cubic
Contribution of atoms at corners	$8 \times 1/8 = 1$	$8 \times 1/8 = 1$	$8 \times 1/8 = 1$
Contribution of atoms at faces	0	0	$6 \times 1/2 = 3$
Contribution of atoms in centre	0	1	0
Total	1	2	4

1.7 Packing in solids

- Closest packing** is the most efficient arrangement of spheres occupying most of the available space and reducing the empty space to minimum in crystal lattice.
- This gives stability to the packed system and has maximum possible density.



iii. Following table gives the occupied space and vacant space in cubic system:

Unit cell	Occupied space (%)	Unoccupied space (%)
Simple cubic	52.4	47.6
Body-centred cubic	68	32
Face-centred cubic	74	26

iv. The vacant or unoccupied space is called **void**.

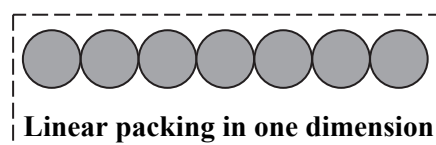
v. The mode of closest packing depends on the shape and size of constituent particles. Atoms are represented by spheres of equal size.

vi. The closest packing arrangement can be made in three stages:

- Stage I : Linear packing in one dimension
- Stage II : Planar packing in two dimensions
- Stage III : Close packing in three dimensions

a. Stage I – Linear packing in one dimension:

The linear packing arrangement in one dimension can be made in only one way. In this arrangement, the spheres are placed in a horizontal row touching each other. Each sphere is in contact with two neighbouring spheres. Thus, the coordination number is 2.



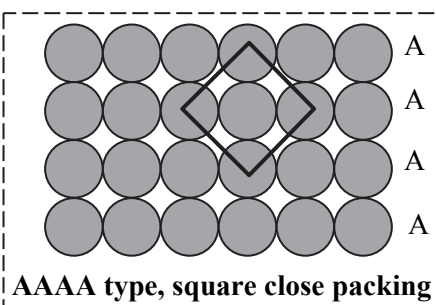
b. Stage II – Planar packing in two dimensions:

The planar packing arrangement in two dimensions can be made in the following two ways:

- AAAA type, square close packed structure
- ABAB type, hexagonal close packed structure

1. AAAA type, square close packed structure:

- This arrangement is made by several linear one dimensional identical rows.
- Each linear one dimensional row contains spheres touching each other.
- These rows are placed one over the other in such a way that they have horizontal and vertical alignment.
- Each sphere in a row is placed over another sphere of another row. All crests of the spheres are aligned and all the depressions formed by this arrangement are also aligned.

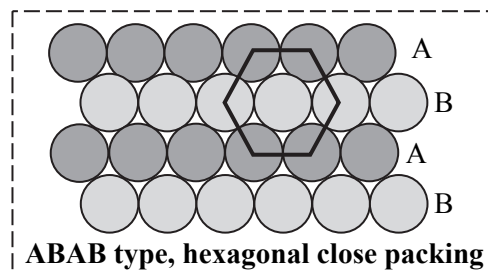


- If the first row is labelled as A type, then all other rows are labelled as A type. The two dimensional arrangement is called **AAAA type**.

- The coordination number of each sphere is **4**. A **square** is formed when the centres of four neighbouring spheres, surrounding a central sphere, are joined. Therefore, this packing is called **square close packing**.

2. ABAB type, hexagonal close packed structure:

- This arrangement is made by several linear one dimensional identical rows.
- Each linear one dimensional row contains spheres touching each other.
- These rows are placed one over the other in such a way that alternate rows (i.e. first and third row) have horizontal and vertical alignment.
- Each sphere in a row is placed over troughs or depressions between spheres of another row and so on. All crests of the spheres of one row are aligned with troughs between spheres of other row and vice versa.
- First row is different from second row, but same as third row. If first row is labelled as A type, then third row and all odd numbered rows are labelled A type. If second row is labelled as B





type, then fourth row and all even numbered rows are labelled B type. The two dimensional arrangement is called **ABAB type**.

- vi. The coordination number of each sphere is **6**. A regular **hexagon** is formed when the centres of six neighbouring spheres, surrounding a central sphere, are joined. Therefore, this packing is called **hexagonal close packing**.
- vii. It can be seen in the figure that there are some voids (empty spaces) triangular in shape in this layer. The triangular voids are of two different types. In one row, the apex of the triangles are pointing upwards and in the next layer downwards.

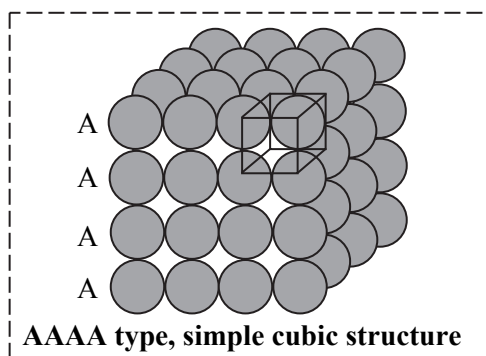
c. Stage III – Close packing in three dimensions:

Close packing in three dimensions can be made in the following three ways:

- 1. AAAA type, simple cubic structure
- 2. ABAB type, hexagonal close packed structure
- 3. ABCABC type, cubic close packed structure

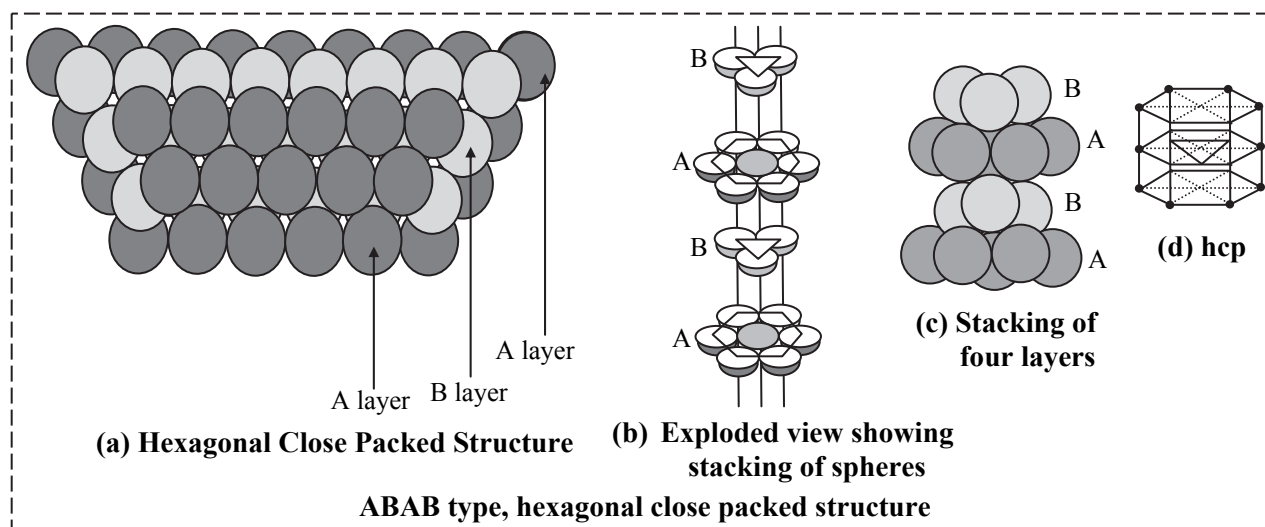
1. AAAA type, simple cubic structure:

- i. This arrangement is made by several layers of AAAA type, two dimensional square close packed structures.
- ii. These two dimensional layers are placed one above the other in such a way that they have horizontal and vertical alignment.
- iii. All the spheres of the successive layers are exactly above the spheres of the lower layers.
- iv. If first layer is labelled as A type, then all other layers are labelled as A type. The three dimensional arrangement is called **AAAA type**. This arrangement is also called as **simple cubic structure**.
- v. Each sphere is surrounded by six spheres, four spheres in the layer, one sphere above and one sphere below. This gives the coordination number **6**.
- vi. Simple cubic structure has more empty space.



2. ABAB type, hexagonal close packed structure:

- i. This arrangement is made by several layers of ABAB type, two dimensional hexagonal close packed structures.
- ii. These two dimensional layers are placed one above the other in such a way that alternate layers have horizontal and vertical alignment.
- iii. Each sphere in a layer is placed over depressions between spheres of another layer and so on. All crests of the spheres of one layer are aligned with troughs between spheres of other layer and vice versa.
- iv. Thus, first layer and third layer have horizontal and vertical alignment. Second layer and fourth layer have horizontal and vertical alignment and so on.
- v. First layer is different from second layer, but same as third layer. If first layer is labelled as A type, then third layer and all odd numbered layers are labelled A type.
- vi. If second layer is labelled as B type, then fourth layer and all even numbered layers are labelled B type. The three dimensional arrangement is called **ABAB type, hexagonal close packed (hcp) structure**.
- vii. The coordination number of each sphere in the ABAB type hexagonal close packed (hcp) structure is **12**.
- viii. This arrangement reduces the empty space between the adjacent layers. The spheres are closest packed and the packing is most efficient.



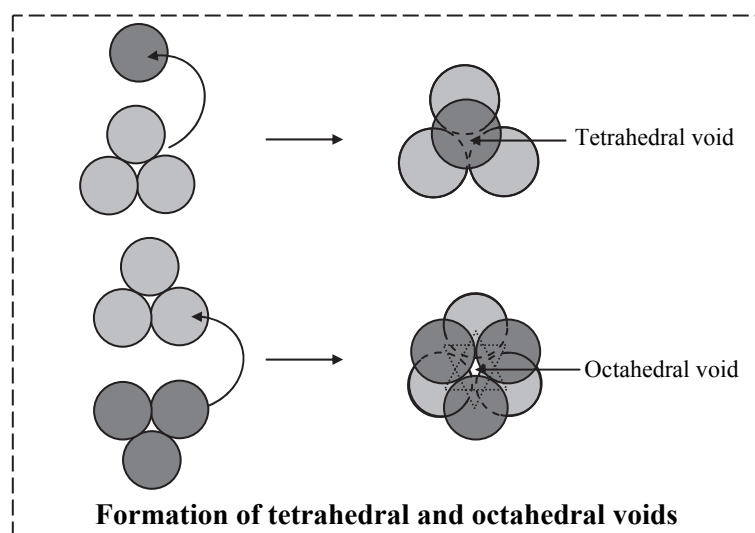
- ix. When second layer is placed above first layer, two types of depressions are formed: octahedral voids and tetrahedral voids.
- x. ABAB type hexagonal close packed (hcp) structure is obtained when spheres of third layer are placed into the tetrahedral voids.
- xi. A tetrahedral hole is formed from three spheres of first layer and one sphere of second layer. It is also formed from one sphere of first layer and three spheres of second layer. When the centres of four spheres are connected, a tetrahedron is formed.

*Thus, the vacant space among four spheres having tetrahedral arrangement is called **tetrahedral void** or **tetrahedral site**.*

- xii. Octahedral hole is formed from three spheres of first layer and three spheres of second layer. When the centres of six spheres are connected, an octahedron is formed.

*Thus, the void formed by two equilateral triangles with apices in opposite direction is called **octahedral void** or **octahedral site**.*

- xiii. When N spheres are involved in the formation of close packed structure, N octahedral voids and $2N$ tetrahedral voids are obtained.

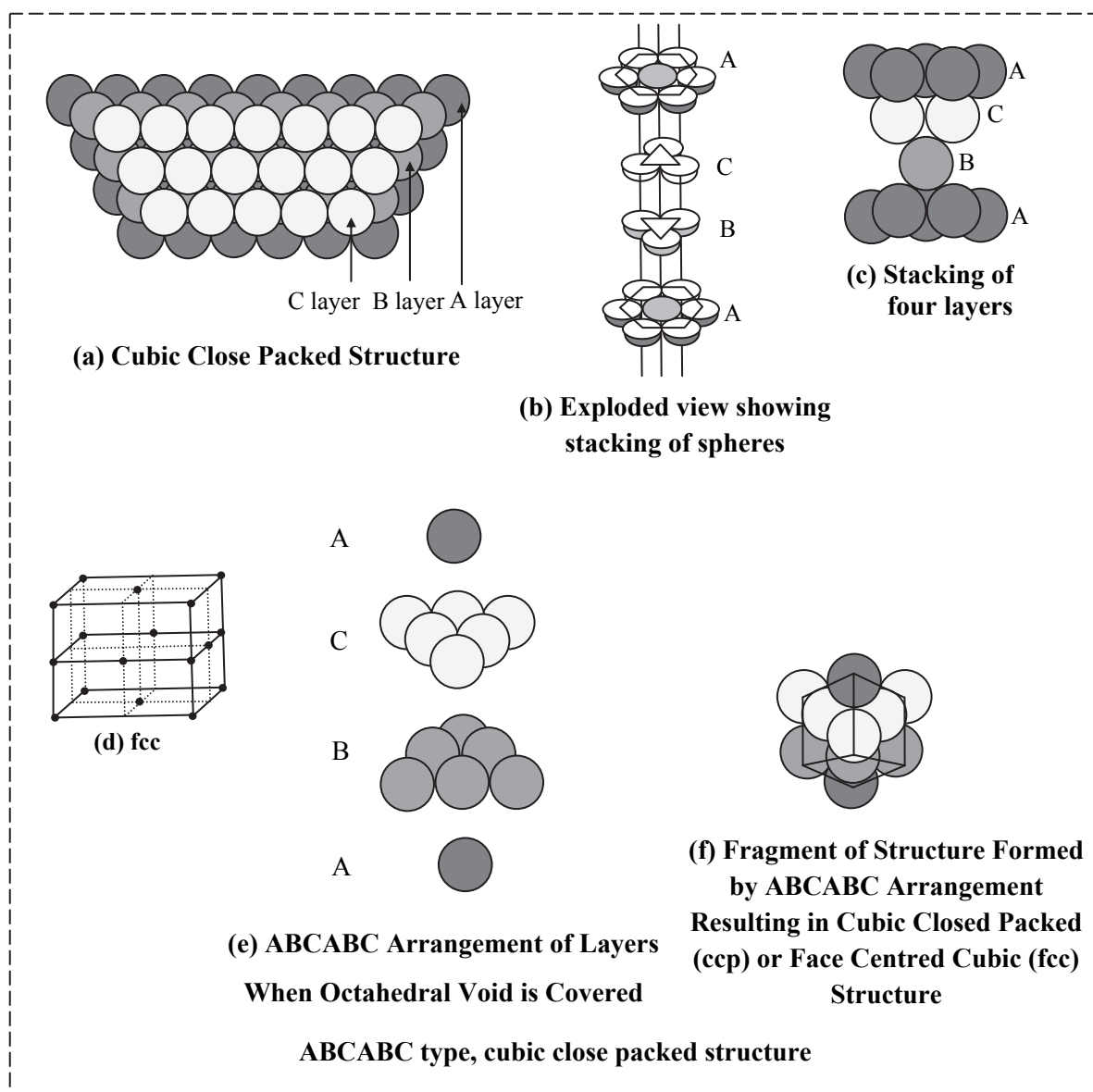


- xiv. The metals such as magnesium, zinc, etc. adopt the ABAB type of arrangement.



3. ABCABC type, cubic close packed structure:

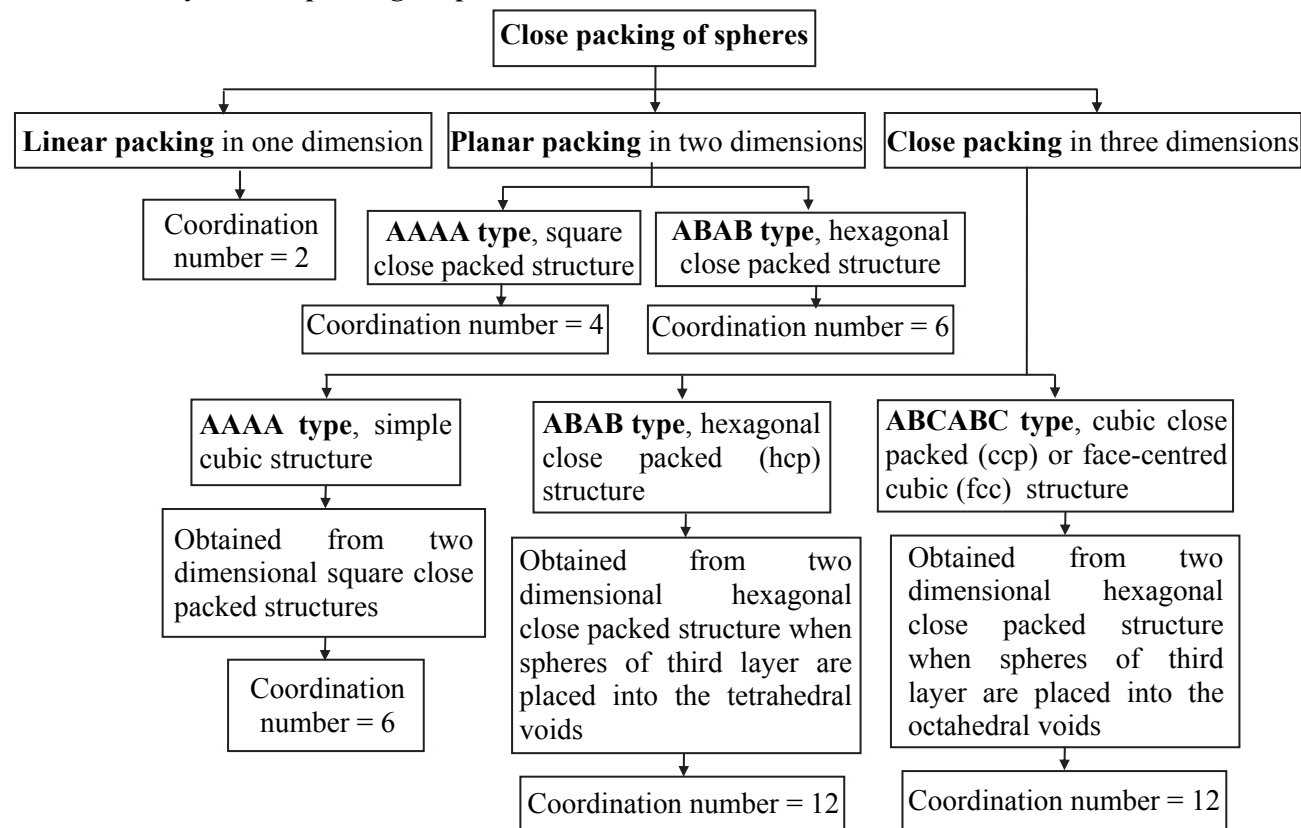
- i. ABCABC type, cubic close packed (ccp) structure is obtained when spheres of third (C type) layer are placed into the octahedral voids and the stacking of layers is continued such that every fourth layer is aligned with the first layer spheres.
- ii. This structure is also known as **face-centred cubic (fcc) structure**.



- iii. In hcp and ccp or fcc structures, each sphere is surrounded by six spheres in the layer, three spheres in the layer above and three spheres in the layer below. Thus, the coordination number is **12** and thus the packing is most efficient.
- iv. The most malleable metals such as copper, silver and gold crystallize in ABCABC type of arrangement.



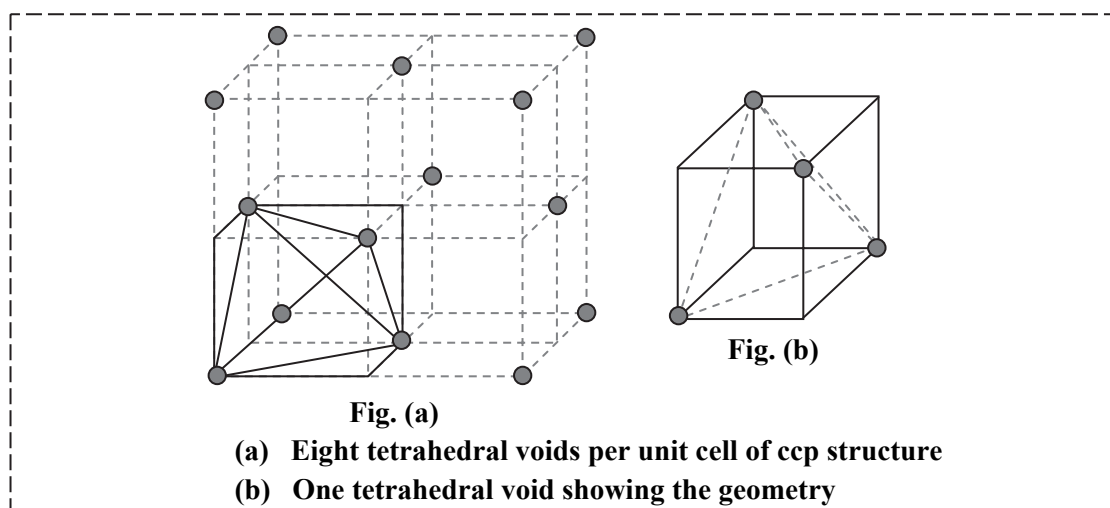
➤ **Summary of close packing of spheres in solids:**



➤ **Locating tetrahedral and octahedral voids:**

Locating voids in a crystal: In the cubic close packing (ccp) or 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. These are located at different positions as explained below:

- i. **Locating tetrahedral voids:** Consider a unit cell of ccp or fcc lattice. The unit cell is divided into eight small cubes. Each small cube has atoms at alternate corners as shown in figure (a). In all, each small cube has 4 atoms. When joined to each other, they make a regular tetrahedron. Thus, there is one tetrahedral void in each small cube and eight tetrahedral voids in total. Since, ccp structure has 4 atoms per unit cell, thus, the number of tetrahedral voids is twice the number of atoms per unit cell.

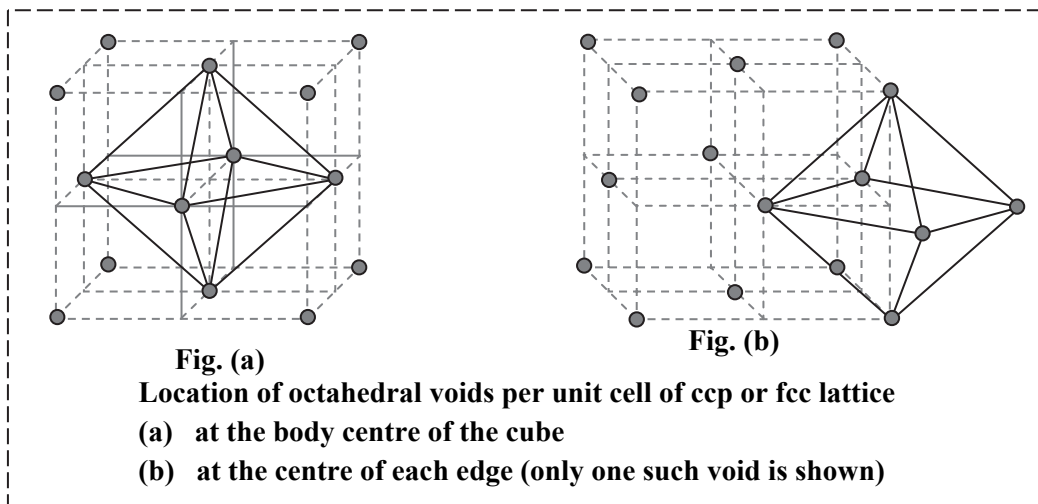


- ii. **Locating octahedral voids:** Consider a unit cell of ccp or fcc lattice as shown in figure (a). The body-centre of the cube, is not occupied but it is surrounded by six atoms on face-centres. If these



face-centres are joined, an octahedron is generated. Thus, this unit cell has one octahedral void at the body-centre of the cube.

Besides the body-centre, there is one octahedral void at the centre of each of the 12 edges as shown in figure (b). It is surrounded by six atoms, four belonging to the same unit cell (2 on the corners and 2 on face-centre) and two belonging to two adjacent unit cells. Since each edge of the cube is shared between four adjacent unit cells, only $1/4^{\text{th}}$ of each void belongs to a particular unit cell.



Thus in cubic close packed structure:

Octahedral void at the body-centre of the cube = 1

12 octahedral voids located at each edge and shared between four unit cells = $12 \times \frac{1}{4} = 3$

\therefore Total number of octahedral voids = $3 + 1 = 4$

In ccp structure, each unit cell has 4 atoms. Thus, the number of octahedral voids is equal to this number.

Note: i. Radius ratio rule for ionic solids:

- The structure of an ionic solid depends on the relative sizes of the ions and its stoichiometry.
- In simple ionic solids, the anions are present in the close packed arrangement and the cations commonly occupy the voids or holes.
- Generally, bigger cations occupy cubic or octahedral holes while smaller cations occupy tetrahedral holes.
- The ratio of radius of cation to that of anion (i.e., r^+/r^-) is called the radius ratio.

$$\text{Radius ratio} = \frac{\text{Cation radius}}{\text{Anion radius}} = \frac{r^+}{r^-}$$

- The following table gives the limiting values of radius ratio, the coordination number of the cation and the structural arrangement of anions around cations.

Radius ratio $\left(\frac{r^+}{r^-}\right)$	Coordination number of cation	Structural arrangement of anions around cations	Examples
0.155 to 0.225	3	Planar triangular	B_2O_3
0.225 to 0.414	4	Tetrahedral	ZnS
0.414 to 0.732	6	Octahedral	NaCl
0.732 to 1.0	8	Cubic	CsCl

- However, in an ionic solid, some of the voids may be empty and this depends on the chemical formula of the compound.



ii. Structures of some ionic solids:

	Ionic solid	Arrangement of ions	Coordination number
a.	NaCl (Sodium chloride)	$\text{Cl}^- \Rightarrow$ fcc arrangement $\text{Na}^+ \Rightarrow$ occupy all octahedral sites	$\text{Cl}^- = 6$ $\text{Na}^+ = 6$
b.	CsCl (Caesium chloride)	$\text{Cl}^- \Rightarrow$ simple cubic arrangement $\text{Cs}^+ \Rightarrow$ occupy cubic sites	$\text{Cl}^- = 8$ $\text{Cs}^+ = 8$
c.	ZnS (Zinc blende)	$\text{S}^{2-} \Rightarrow$ fcc arrangement $\text{Zn}^{2+} \Rightarrow$ occupy half of the tetrahedral sites	$\text{S}^{2-} = 4$ $\text{Zn}^{2+} = 4$
d.	CaF_2 (Calcium fluoride)	$\text{Ca}^{2+} \Rightarrow$ fcc arrangement $\text{F}^- \Rightarrow$ occupy all tetrahedral sites	$\text{Ca}^{2+} = 8$ $\text{F}^- = 4$

1.8 Packing efficiency

➤ Packing efficiency:

- The **packing efficiency** is the percentage of total space occupied by the particles.
- When the constituent particles are packed, some free space is left in the form of voids.
- Packing efficiency is given by following formula:

$$\text{Packing efficiency} = \frac{\text{Total volume occupied by spheres in unit cell}}{\text{Volume of the unit cell}} \times 100$$

Packing efficiency is also referred to as **volume occupied**.

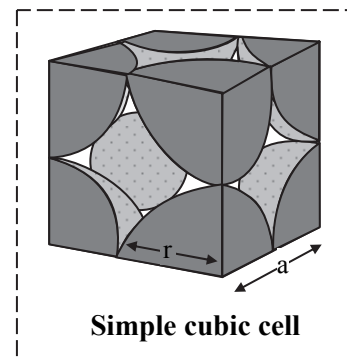
➤ Packing efficiency in a simple cubic unit cell:

- A simple cubic unit cell contains 8 corner spheres.

$$\text{Number of spheres per unit cell} = 8 \times \frac{1}{8} = 1$$

- Let 'a' represent the edge length of the unit cell and 'r' represent the radius of the sphere.
- Since the spheres touch each other, $a = 2r$
- Volume of unit cell $= a^3 = (2r)^3 = 8r^3$
- Total number of atoms in a simple cubic unit cell = 1

$$\text{Total volume of sphere} = \frac{4}{3} \pi r^3$$



$$\text{vi. Packing efficiency} = \frac{\text{Total volume of one sphere}}{\text{Volume of the unit cell}} \times 100 = \frac{\frac{4}{3} \pi r^3}{8r^3} \times 100 = \frac{\pi}{6} \times 100 = \frac{3.142}{6} \times 100 = 52.4\%$$

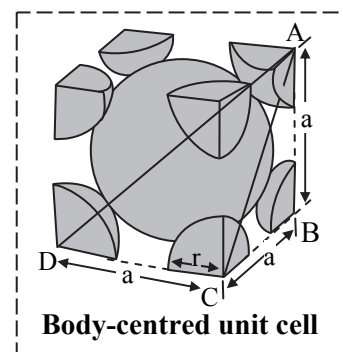
Thus, the packing efficiency in simple cubic unit cell is **52.4%**.

➤ Packing efficiency in body-centred cubic (bcc) arrangement:

- A bcc unit cell contains 8 corner spheres and 1 body-centred sphere.

$$\text{Number of spheres per unit cell} = \left(8 \times \frac{1}{8}\right) + \left(1 \times \frac{1}{1}\right) = 1 + 1 = 2$$

- Let 'a' represent the edge length of the unit cell and 'r' represent the radius of the sphere.
- Consider right angled $\triangle ABC$, AC is the hypotenus.
 $AC^2 = AB^2 + BC^2 = a^2 + a^2$
 $\therefore AC^2 = 2a^2$
- Consider right angled $\triangle ACD$, AD is the hypotenus.
 $AD^2 = AC^2 + CD^2 = 2a^2 + a^2 = 3a^2$
 $AD = \sqrt{3} a$





- v. But AD is also the body diagonal.

$$AD = 4r$$

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

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

vi. Volume of unit cell = $a^3 = \left(\frac{4}{\sqrt{3}} r\right)^3 = \frac{64}{3\sqrt{3}} r^3$

vii. Volume of sphere = $\frac{4}{3} \pi r^3$

viii. Total number of atoms in a bcc unit cell = 2

$$\text{Total volume of 2 spheres} = 2 \times \frac{4}{3} \pi r^3 = \frac{8}{3} \pi r^3$$

ix. Packing efficiency = $\frac{\text{Total volume occupied by spheres in unit cell}}{\text{Volume of the unit cell}} \times 100$

$$= \frac{\frac{8}{3} \pi r^3}{\frac{64}{3\sqrt{3}} r^3} \times 100 = \frac{\pi \sqrt{3}}{8} \times 100 = \frac{3.142 \times 1.732}{8} \times 100 = 68\%$$

Thus, the packing efficiency in body-centred cubic structure is **68%**.

➤ **Packing efficiency in cubic close packing (ccp) or face-centred cubic (fcc) arrangement:**

- i. A ccp or fcc unit cell contains 8 corner spheres and 6 face-centred spheres.

$$\text{Number of spheres per unit cell} = \left(8 \times \frac{1}{8}\right) + \left(6 \times \frac{1}{2}\right) = 1 + 3 = 4$$

- ii. Let 'a' represent the edge length of the unit cell and 'r' represent the radius of the sphere.

- iii. Consider right angled triangle ABC, AB is the hypotenus.

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

$$\text{Length of hypotenus AB} = \sqrt{2} a$$

- iv. But AB is also the face diagonal.

$$\text{Length of face diagonal AB} = 4r$$

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

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

v. Volume of the unit cell is $a^3 = (2\sqrt{2} r)^3 = 16\sqrt{2} r^3$

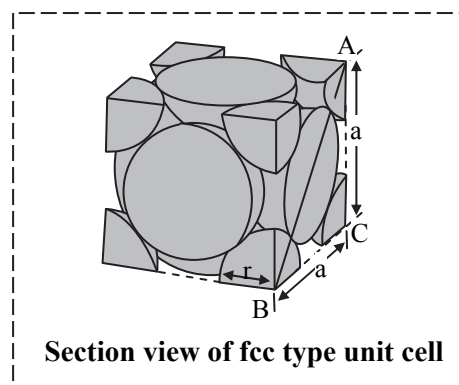
vi. Total number of atoms in a ccp or fcc unit cell = 4.

$$\text{Total volume of four spheres is, } 4 \times \frac{4}{3} \pi r^3 = \frac{16}{3} \pi r^3$$

vii. Packing efficiency = $\frac{\text{Total volume occupied by spheres in unit cell}}{\text{Volume of the unit cell}} \times 100$

$$= \frac{\frac{16}{3} \pi r^3}{16\sqrt{2} r^3} \times 100 = \frac{\pi}{3\sqrt{2}} \times 100 = \frac{3.142}{3 \times 1.414} \times 100 = 74\%$$

Thus, the packing efficiency in cubic close packing or face-centred cubic arrangement is **74%**. This is the most efficient packing.





➤ **Relationship between the nearest neighbour distance (D) and the edge length (a) of a cubic unit cell:**

No.	Type of unit cell	Relation between D and a
i.	Simple cubic	$D = \text{edge length} = a$
ii.	Body-centred cubic	$D = \frac{1}{2} \times \text{body diagonal} = \frac{1}{2} \times \sqrt{3} a$
iii.	Face-centred cubic	$D = \frac{1}{2} \times \text{face diagonal} = \frac{1}{2} \times \sqrt{2} a = \frac{a}{\sqrt{2}}$

Note: Packing efficiency in hexagonal close packing (hcp) arrangement:

- i. A hcp unit cell contains 12 corner spheres, 2 face-centered spheres and 3 body-centred spheres.

$$\text{Number of spheres per unit cell} = \left(12 \times \frac{1}{6}\right) + \left(2 \times \frac{1}{2}\right) + 3 = 2 + 1 + 3 = 6$$

- ii. Let 'r' represent the radius of the sphere

$$\text{Height of unit cell} = 4r \cdot \sqrt{\frac{2}{3}}$$

$$\text{Base area of regular hexagon} = 6 \times \frac{\sqrt{3}}{4} (2r)^2 = 6 \times \sqrt{3} r^2$$

- iii. Volume of unit cell = Base area \times height (h) = $6 \sqrt{3} r^2 \times 4r \cdot \sqrt{\frac{2}{3}} = 24 \sqrt{2} r^3$

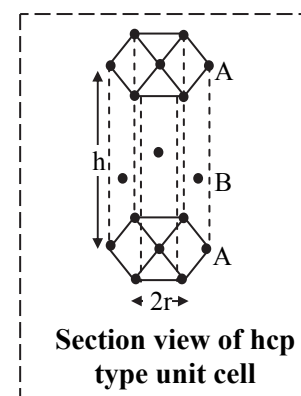
- iv. Total number of atoms in a hcp unit cell = 6.

$$\text{Total volume of 6 spheres} = 6 \times \frac{4}{3} \pi r^3 = 8\pi r^3$$

- v. Packing efficiency = $\frac{\text{Total volume occupied by spheres in unit cell}}{\text{Volume of the unit cell}} \times 100$

$$= \frac{8\pi r^3}{24\sqrt{2} r^3} \times 100 = \frac{\pi}{3\sqrt{2}} \times 100 = \frac{3.142}{3 \times 1.414} \times 100 = 74\%$$

Thus, the packing efficiency in hexagonal close packing is **74%**. This is the most efficient packing.



1.9 Calculation of density of unit cells

- i. Let 'a' represent the edge length of a unit cell in cm.

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

- ii. Let 'Z' represent the number of atoms in the unit cell and 'm' represent the mass of each atom,

$$\text{Mass of unit cell} = Z \times m$$

- iii. Let 'M' represent the atomic mass and N_0 represent the Avogadro's number,

$$\therefore m = \frac{\text{Atomic mass}}{\text{Avogadro number}} = \frac{M}{N_0}$$

$$\text{Mass of unit cell} = Z \times \frac{M}{N_0}$$

- iv. **Density of unit cell** = $\frac{\text{Mass of unit cell}}{\text{Volume of unit cell}} = \frac{Z \times M}{a^3 \times N_0} \text{ g cm}^{-3}$

**Note:**

- i. For edge length 'a' in pm,
Edge length = a pm = $a \times 10^{-12}$ m = $a \times 10^{-10}$ cm

$$\text{Volume of unit cell} = (a \times 10^{-10} \text{ cm})^3 = a^3 \times 10^{-30} \text{ cm}^3$$

$$\text{Density} = \frac{Z \times M}{a^3 \times 10^{-30} \times N_0} \text{ g cm}^{-3}$$

- ii. **In SI units:**

For 'a' in metres and 'M' in kg mol^{-1} ,

$$\text{Density} = \frac{Z \times M}{a^3 \times N_0} \text{ kg m}^{-3}$$

1.10 Imperfections in solids

- An ionic crystal which has the same unit cell containing the same lattice points throughout the whole of crystal is known as an **ideal crystal**.
 - An ideal crystal is possible only at absolute zero (0 K) temperature. At temperatures other than absolute zero, certain irregularities are observed.
 - It is very difficult to grow an ideal crystal. Even if great care is taken in growing a single crystal, some internal irregularities are always present.
 - A solid is made up of several individual small crystals which are deformed because they are highly packed among other deformed crystals.
 - Disorder or defect or imperfection is the departure from perfectly ordered state of the constituents of the crystals. These imperfections change the properties of crystals and give rise to new properties.
 - Imperfections or defects in crystals can be classified into two types:
 - Point defects
 - Line defects
- a. The defects which arise due to the irregularity or deviations from ideal arrangement of atoms around a point or an atom in a crystalline substance are called **point defects**.
- b. The defects which arise due to irregularities or deviations from ideal arrangement in entire row of lattice points are called **line defects**.

1.11 Classification of point defects

Point defects in crystals are classified into three categories:

- Stoichiometric defects
- Non-stoichiometric defects, and
- Impurity defects

➤ Stoichiometric defects:

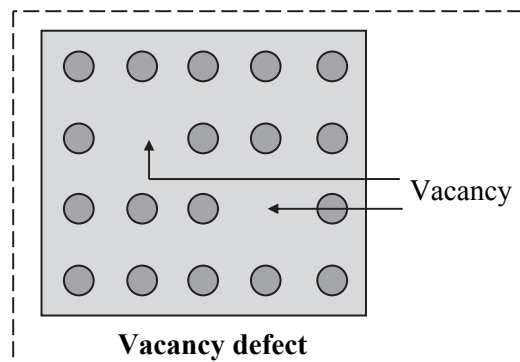
These are the point defects which do not disturb the stoichiometry of the solid. They are known as **intrinsic** or **thermodynamic defects**.

i. Non-ionic solids:

Stoichiometric defects are of two types: vacancy defect and interstitial defect.

a. Vacancy defect:

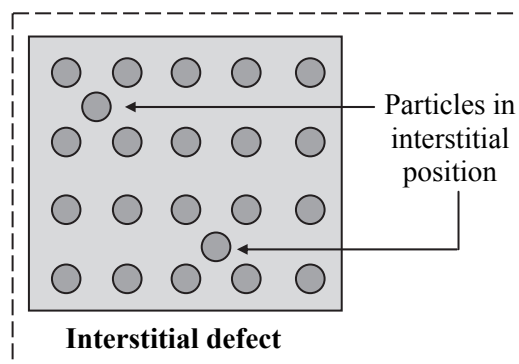
- When some of the lattice sites are vacant, the crystal is said to have **vacancy defect**. The unoccupied positions are called **vacancies**.
- Due to vacancy defect, the density of substance decreases. When a substance is heated, vacancy defect may develop.





b. Interstitial defect:

1. When some constituent particles (atoms or molecules) occupy vacant interstitial positions, the crystal is said to have **interstitial defect**.
2. Due to interstitial defect, the density of the substance increases.



ii. Ionic solids: Ionic compounds must always maintain electrical neutrality. Hence, they show vacancy and interstitial defects as Schottky and Frenkel defects, respectively.

a. Schottky defect:

1. German scientist Schottky discovered this defect in 1930.

*When some of the ions are missing from their normal lattice sites, the defect is called **Schottky defect**. The lattice sites which are unoccupied are called **lattice vacancies** or **holes**.*

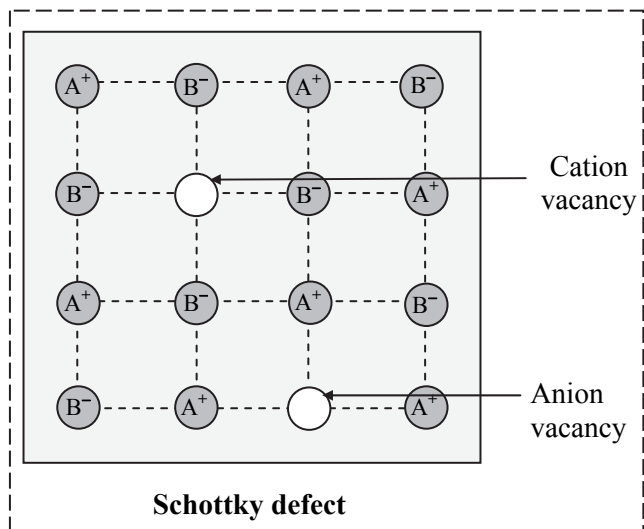
2. In order to maintain electrical neutrality, equal number of cations and anions are missing.

3. **Conditions causing Schottky defect:** Strongly ionic compounds having high coordination number and cations and anions of almost similar size show Schottky defects.

eg. NaCl, KCl, KBr, CsCl and AgBr

4. At room temperature, 1 cm³ of NaCl contains 10⁶ Schottky pairs. 1 cm³ contains 10²² ions. Thus, one Schottky defect is present for every 10¹⁶ ions.

5. Due to Schottky defect, the density of substance decreases.



b. Frenkel defect:

1. Russian scientist Frenkel discovered this defect in 1926.

*When an ion is missing from its normal position and occupies an interstitial site between the lattice points, the defect is called **Frenkel defect**.*

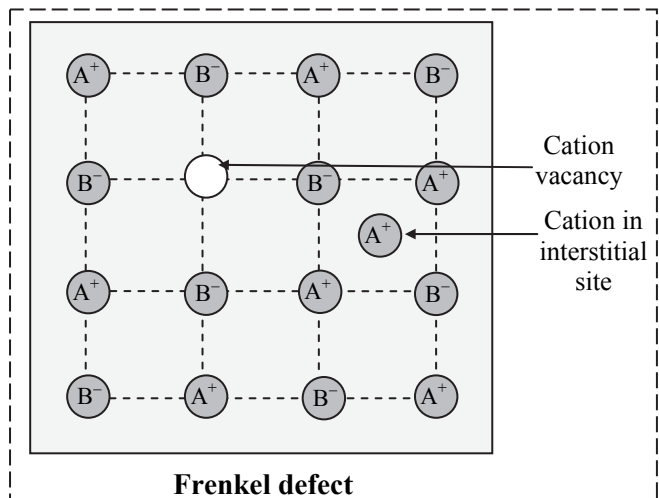
This defect is also known as **dislocation defect**.

2. In Frenkel defect, a vacancy defect is created at original position and an interstitial defect is created at new location. Electrical neutrality is maintained due to the equal number of anions and cations.

3. **Conditions causing Frenkel defects:** Ionic compounds having low coordination number and with anions having much larger size than the cations show Frenkel defects.

eg. AgCl, AgBr, AgI, ZnS, etc.

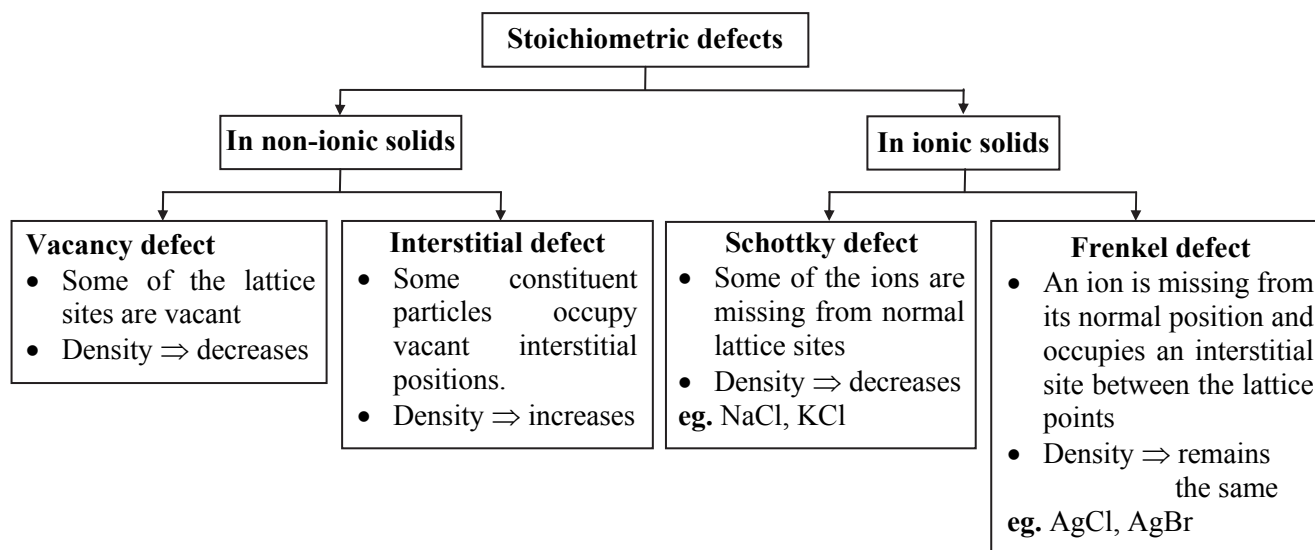
Ag⁺ and Zn²⁺ ions have small size. Hence, they can go into the interstitial sites. Ions of alkali metals have large sizes. Hence, they cannot go into the interstitial sites. Thus, alkali metal halides rarely exhibit Frenkel defect.





4. Due to Frenkel defect, the density of substance is unaffected.
5. Combination of Schottky defect and Frenkel defect gives rise to hybrid defect.
6. Both Schottky and Frenkel defects are present in AgBr.

➤ **Summary of stoichiometric defects:**



➤ **Consequences of Schottky and Frenkel defects:**

- i. Schottky and Frenkel defects increase the electrical conductivity of crystals. Under the influence of electrical field, ion moves from lattice site to a hole (i.e., vacant site). This creates a new hole in which another ion moves. This process continues and a hole moves from one end to another end, thus conducting electricity.
- ii. Due to Schottky defect, the density of substance decreases.
- iii. Lattice energy and the stability of crystal decreases due to the presence of holes in crystal. When too many holes are present, it may cause partial collapse of lattice.
- iv. The dielectric constant of the crystals increases due to closeness of similar charges in Frenkel defect.

➤ **Comparison between Schottky defect and Frenkel defect:**

	Schottky defect	Frenkel defect
i.	It is observed when atoms or ions are missing from their normal crystal sites.	It is observed when atoms or ions are displaced from their normal crystal sites and occupy interstitial sites.
ii.	Due to Schottky defect, the density of the crystal is lowered.	Frenkel defect does not affect the density of the crystal.
iii.	Strongly ionic compounds having high coordination number and cations and anions of almost similar sizes show Schottky defects. eg. NaCl, KCl, KBr, CsCl, etc.	Ionic compounds having low coordination number with anions having much larger size than the cations show Frenkel defects. eg. AgCl, AgI, ZnS, etc.

➤ **Non-stoichiometric defects:**

- i. In **non-stoichiometric compounds**, the ratio of positive and negative ions present in the compound differs from that required by ideal chemical formula of the compound.
The defects in these compounds are **non-stoichiometric defects**.
eg.
 - a. VO_x where $0.6 \leq x \leq 1.3$ is a non-stoichiometric compound.
 - b. Iron (II) oxide with range $\text{Fe}_{0.93}\text{O}$ to $\text{Fe}_{0.96}\text{O}$ is a non-stoichiometric compound.
 - c. Many transition metals, lanthanides and actinides form non-stoichiometric compounds.
- ii. These are point defects which disturb the stoichiometry of the solid.



iii. Defects in non-stoichiometric crystals are further classified into the following two types:

- a. Metal excess defects
- b. Metal deficiency defects

a. Metal excess defects:

1. *Point defects in non-stoichiometric crystals which arise due to the excess of positive ions are called metal excess defects.*

2. Conditions causing metal excess defects:

Following two conditions cause metal excess defects:

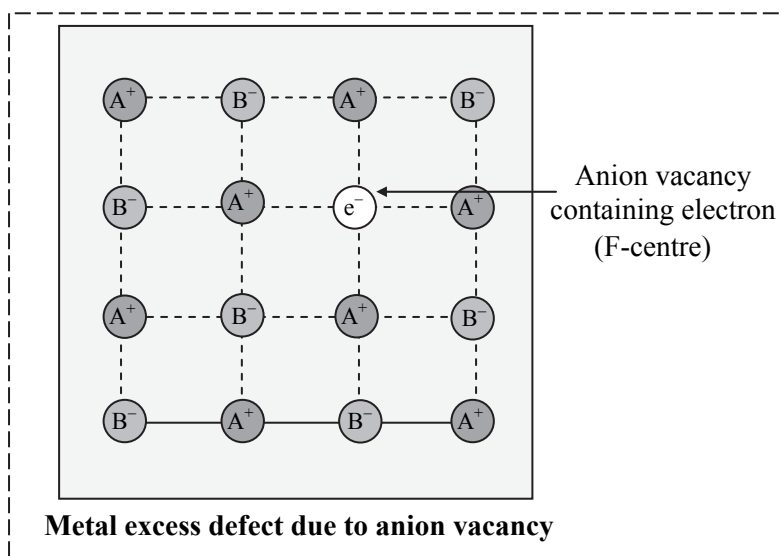
- i. Anionic vacancies ii. Presence of extra cations at interstitial sites

i. Anionic vacancies:

Negative ions which are missing from their lattice sites leave holes. The electrical neutrality is maintained due to the presence of electrons in the holes. The electrons trapped in anion vacancies are referred to as **F-centres**. They impart colour to the crystal which results due to the excitation of these electrons when they absorb energy from the visible light falling on the crystal.

eg.

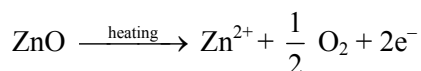
- a. Excess of sodium in NaCl (yellow colour): This can be achieved by depositing Na atoms on the surface of NaCl crystals by heating the crystals in presence of Na vapour. Cl^- ions diffuse to the surface of the crystal to combine with Na atoms and form NaCl. Due to this reaction, an electron is released by each of the Na atom that forms Na^+ ion. These electrons diffuse into the crystal and occupy anionic sites, forming F-centres.
- b. Excess of potassium in KCl (violet or lilac colour)
- c. Excess of lithium in LiCl (pink colour)



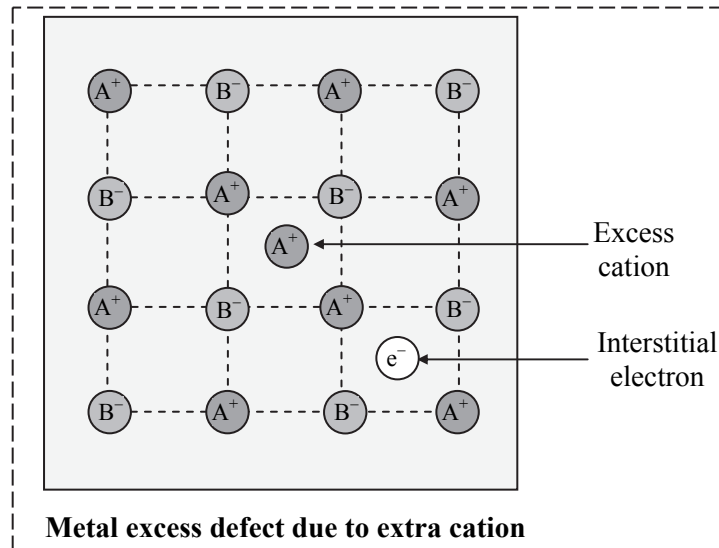
ii. Presence of extra cations at interstitial sites:

When extra cations are present at interstitial sites, the electrical neutrality is maintained due to the presence of electrons at interstitial sites, which enhance the electrical conductivity.

eg. ZnO, white in colour at room temperature, turns yellow on heating due to loss of oxygen.



Due to relatively excess zinc in the crystal, formula of the crystal becomes Zn_{1+x}O . The excess Zn^{2+} ions occupy the interstitial sites and the electrons occupy the neighbouring interstitial sites.



b. Metal deficiency defects:

1. *Point defects in non-stoichiometric crystals which arise due to the deficiency of positive ions are called **metal deficiency defects**.*
2. **Conditions causing metal deficiency defects:**

Following two conditions cause metal deficiency defects:

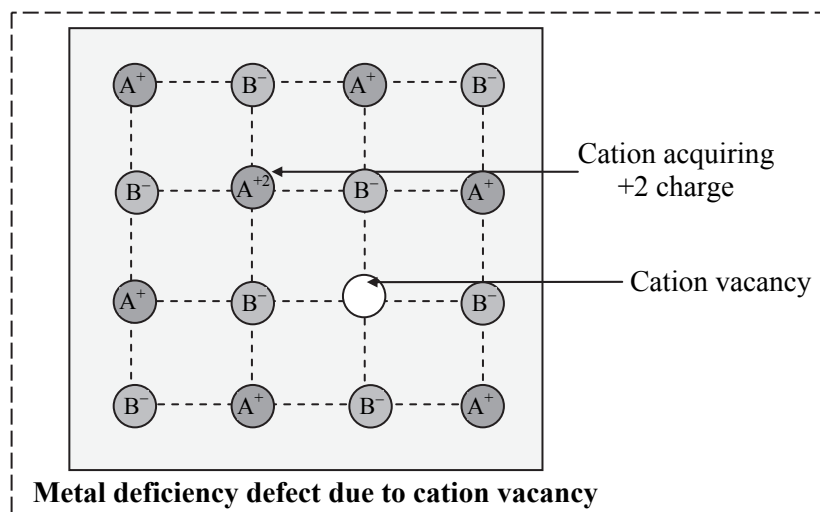
- i. Cationic vacancies
- ii. Presence of extra anions at interstitial sites

i. Cationic vacancies:

When cations are missing from their lattice sites, the electrical neutrality is maintained due to increase in the charge on another cation. Metals showing variable oxidation states exhibit this defect.

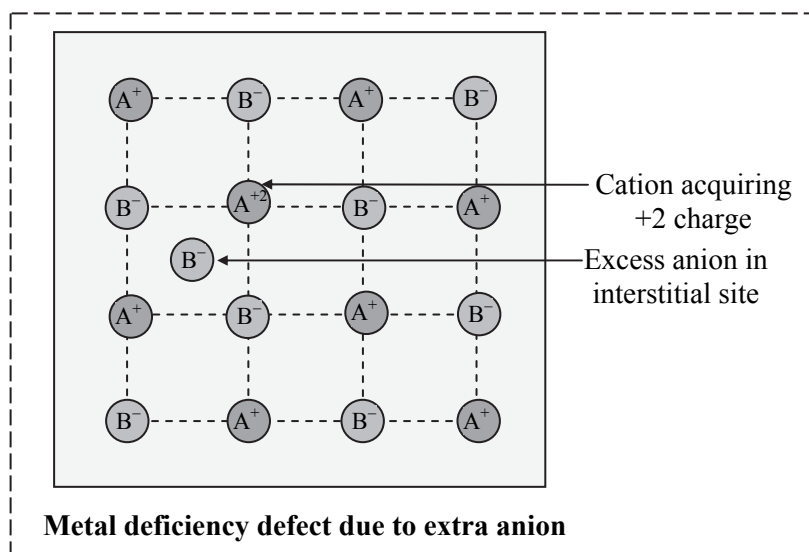
eg. FeO is found to predominantly occur as $\text{Fe}_{0.95}\text{O}$. The actual composition may vary from $\text{Fe}_{0.93}\text{O}$ to $\text{Fe}_{0.96}\text{O}$.

In these crystals of FeO, the loss of positive charge due to some of the missing Fe^{2+} cations is made up by the presence of required number of Fe^{3+} ions.

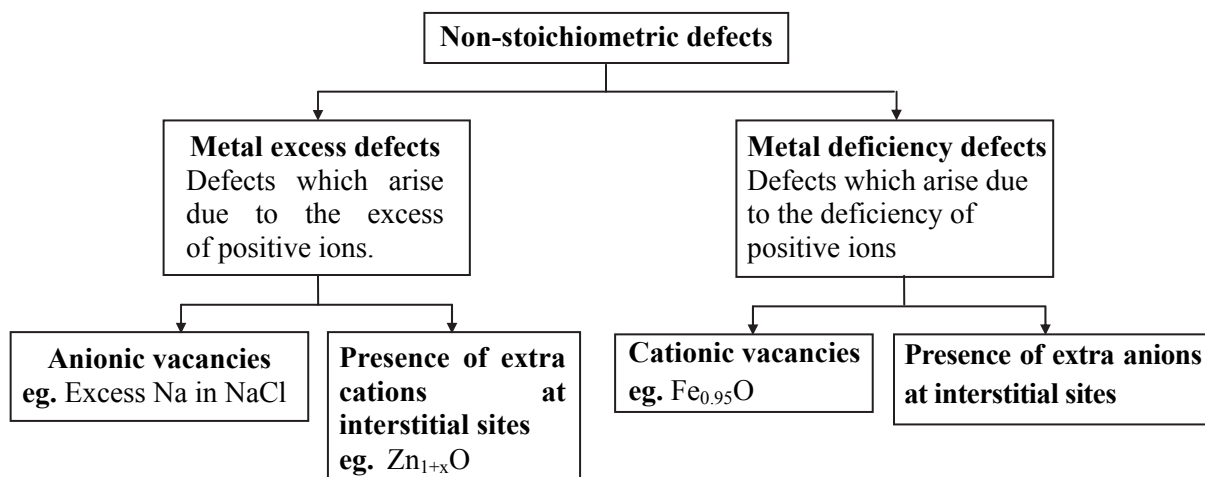


ii. Presence of extra anions at interstitial sites:

When extra anions are present at interstitial sites, the electrical neutrality is maintained due to increase in the charge on the cation. This defect is not commonly observed because negative ions cannot easily occupy interstitial sites due to large size.



➤ **Summary of non-stoichiometric defects:**

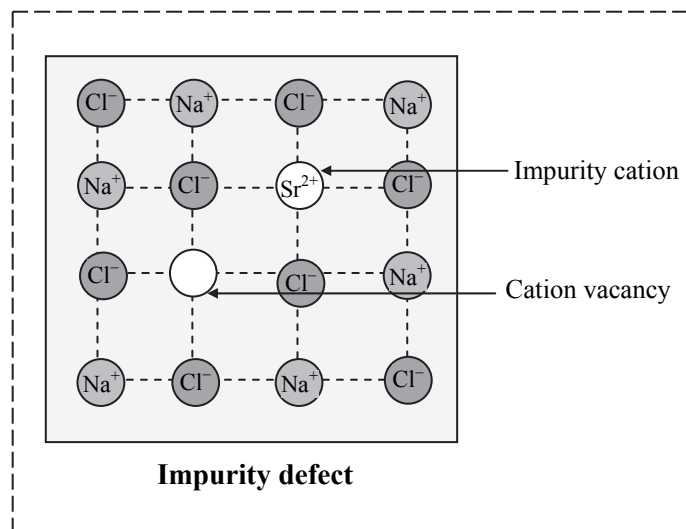


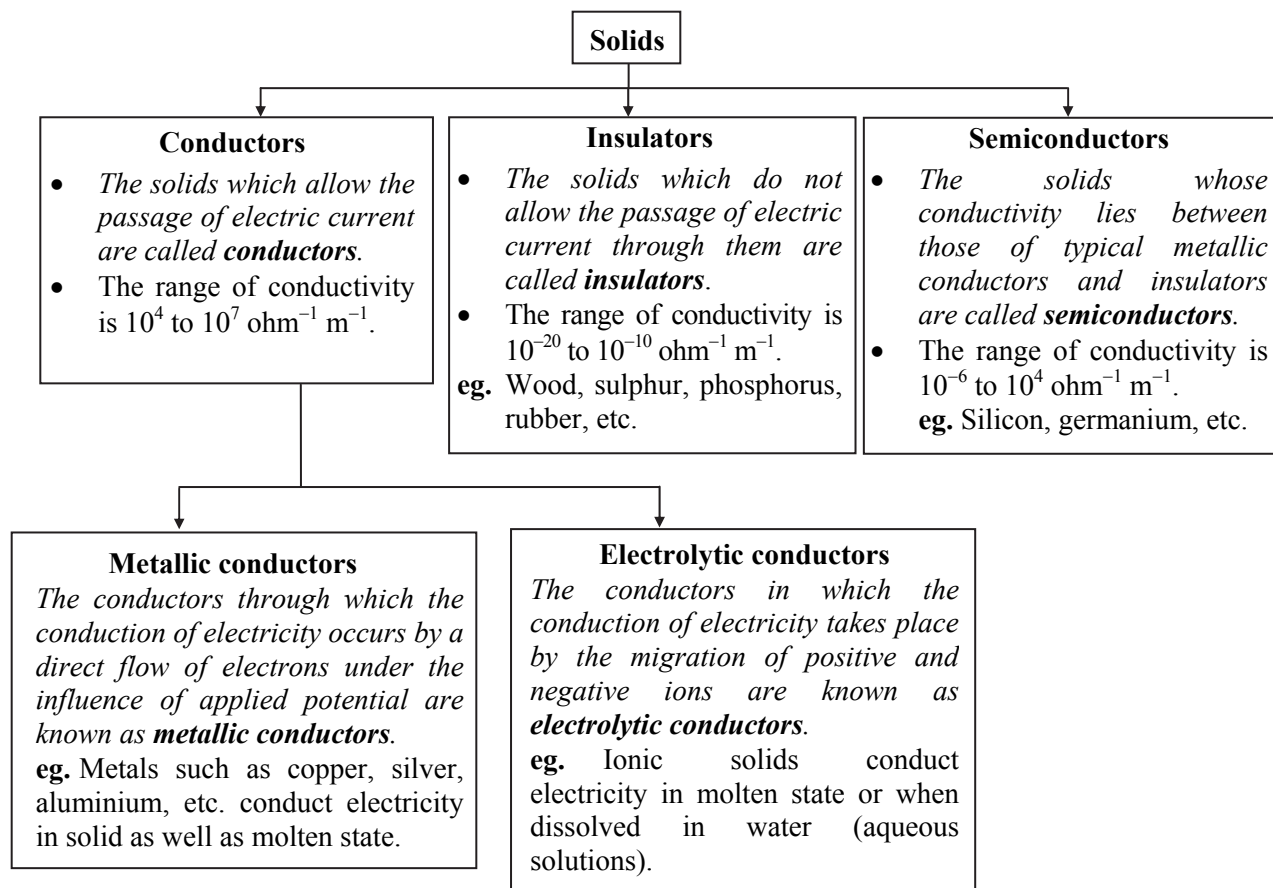
➤ **Impurity defects:**

Point defects in ionic crystals which arise due to the presence of some impurity ions at the lattice site (in place of host ions) or at the vacant interstitial sites are called **impurity defects**.

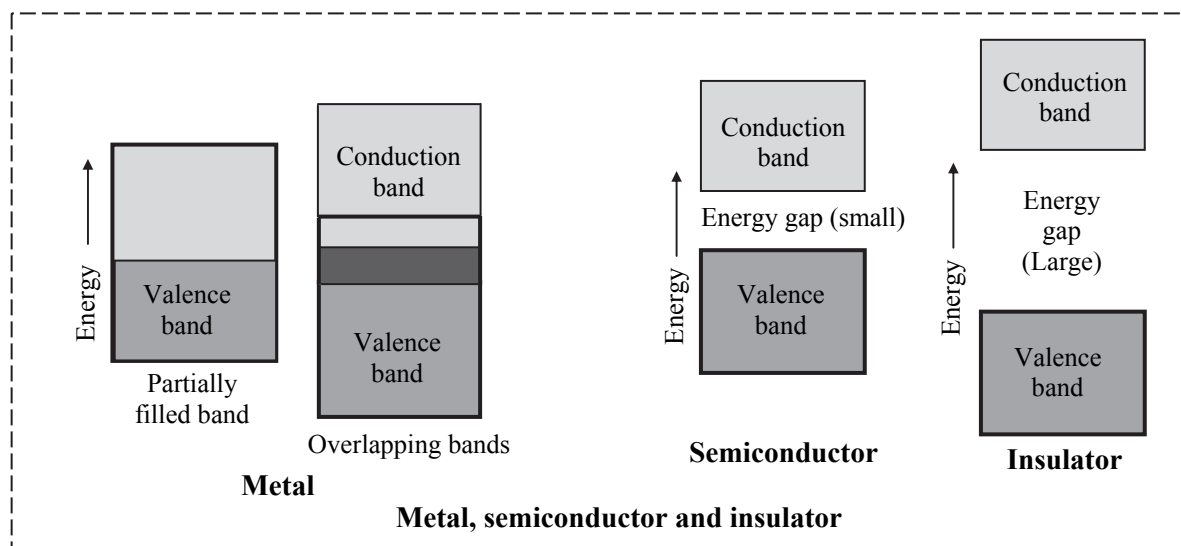
eg.

- Crystallization of molten NaCl containing a little amount of SrCl_2 results in impurity defect. Some Sr^{+2} ions occupy sites of Na^+ ions. To maintain electrical neutrality for every Sr^{+2} ion, two Na^+ ions are removed. This creates cationic vacancies which enhances electrical conductivity.
- Addition of CdCl_2 to AgCl results in impurity defect.



**1.12 Electrical properties of solids****➤ Classification of solids based on electrical conductivity:****1.13 Band theory****➤ Mechanism of electrical conduction:**

- The number of valence electrons available per atom determines the conductivity in metals.
- Band theory** explains the difference in electrical conductance of conductors, insulators and semiconductors. It is based on molecular orbital theory.
- The atomic orbitals of several metal atoms form several molecular orbitals which are so close in energy that they form a band.
- When this band is partially filled or it overlaps with higher energy empty band, then electrons are free to move under an applied electric field which results in conductivity of metal.
- The outermost filled energy band is called **valence band** and the next empty band in which electrons can move is called **conduction band**.
- The spaces between valence band and conduction band represent energies forbidden to electrons and are called **energy gaps** or **forbidden zone**.
- In metals, the energy gap or forbidden zone is negligible. Electrons can freely move from valence band into the conduction band. Thus, metals are good conductors of electricity.
- In insulators, the energy gap or forbidden zone is very large. Electrons cannot move from valence band into the conduction band. Thus, insulators are poor conductors of electricity.
- In semiconductors, the energy gap or forbidden zone is small. For semiconductors, some of the electrons may move from the valence band to the conduction band and so, the electrical conductivity is in between that of conductors and insulators. With increase in temperature, the electrical conductivity of semiconductors increases.



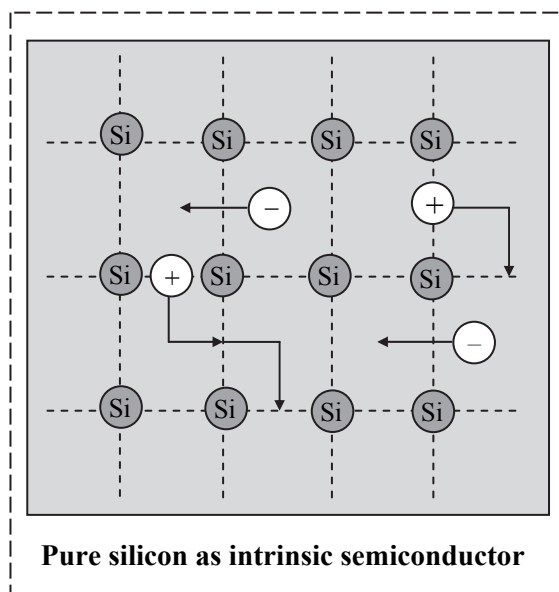
➤ **Conduction of electricity in semiconductors:**

Semiconductors are classified into the following two types:

- i. Intrinsic semiconductors
- ii. Extrinsic semiconductors

i. Intrinsic semiconductors:

- a. Pure silicon and germanium have very low conductivities and behave as poor conductors of electricity. They contain completely filled valence band with electrons and an empty conduction band.
- b. When thermal energy is supplied, some of the electrons are excited from completely filled valence band to empty conduction band.
- c. Excitation of electrons results in cleavage of covalent bonds and creation of positive holes.
- d. *In presence of an electrical field, electrons move in one direction and positive holes move in other direction. This is known as **intrinsic semiconductivity** of the crystal. The substance is known as **intrinsic semiconductor**.*
- e. The electrons move through the interstices of the lattice and the positive holes jump from one bond to another.



eg. Pure silicon and germanium are intrinsic semiconductors.

ii. Extrinsic semiconductors:

*When suitable impurity is added to pure intrinsic semiconductor, the electrical conductivity is enhanced. This process is called **doping**.*

The semiconductor thus obtained is known as extrinsic semiconductor. These impurities introduce electronic defects in the substance.

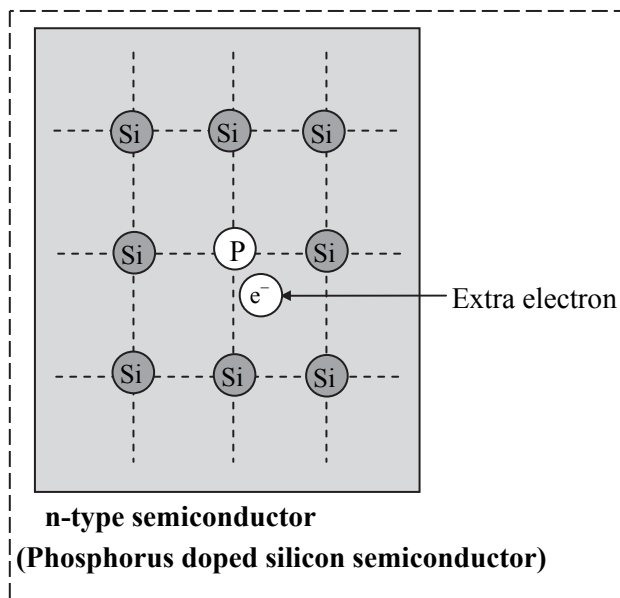
Two types of impurities can be added:

- a. Electron rich (or donor) impurities
- b. Electron deficient (or acceptor) impurities

**a. Electron rich (or donor) impurities:**

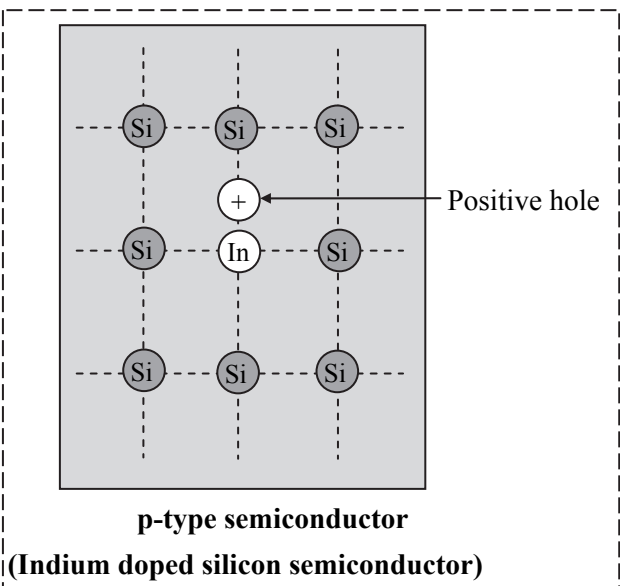
1. Silicon and germanium (group 14 elements) have four valence electrons. Each atom forms four covalent bonds with four neighbouring atoms.
2. Group 15 elements such as arsenic or phosphorus having five valence electrons are added (doped) to Si or Ge crystal.
3. In the crystal lattice, Si or Ge is replaced with As or P.
4. As or P can form four covalent bonds with four neighbouring Si or Ge. However, the fifth electron of As or P remains free. This extra electron is delocalised and conducts electricity. This type of conduction is called **n-type semiconduction** because the conduction is the result of negatively charged electrons. n represents negatively charged electrons.

eg. Si or Ge doped with traces of As, P, Sb or Bi are n-type semiconductors.

**b. Electron deficient (or acceptor) impurities:**

1. Group 13 elements such as indium (In) having three valence electrons are doped into group 14 elements such as silicon.
2. In the crystal lattice, Si atom is replaced with indium atom.
3. Indium atom can form three covalent bonds with three neighbouring Si atoms. However, fourth bond cannot be formed which creates an electron deficiency known as **electron hole** or **positive hole** or **electron vacancy**.
4. Under the influence of electrical field, an electron from adjacent atom can move to the electron hole at its original position. Thus, it would appear as if the electron holes are moving and this movement of holes is conducting electricity. This type of conduction is called **p-type semiconduction**. p represents positively charged holes.

eg. Si or Ge doped with traces of B, Al, Ga or In are p-type semiconductors.

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

- i. A combination of n-type and p-type semiconductors known as **diode** is used as a rectifier.
- ii. p-n-p or n-p-n sandwich semiconductors, known as transistors, are used to detect and amplify radio or audio signals.
- iii. A solar cell is a photo-diode which converts radiant energy into electrical energy.
- iv. Combination of elements such as Group 13 – Group 15 (**eg.** InSb, AlP, GaAs) elements or Group 12 – Group 16 (**eg.** ZnS, CdS, CdSe, HgTe) elements gives rise to a large variety of solid state materials which simulate average valence of four as in Ge or Si. Bonding in these compounds is not perfectly covalent and the extent of ionic character depends on the difference in electronegativities of the two elements. Notably, Gallium arsenide (GaAs) based semiconductors show very fast response due to which they have revolutionised the designing of modern day semiconductor devices.

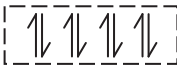




- v. Transition metal oxides show a wide range of conduction behaviour. TiO , CrO_2 , ReO_3 show metal-like behaviour with rhenium oxide (ReO_3) being comparable to metallic copper in its conductivity and appearance. Oxides such as VO , VO_2 , VO_3 and TiO_3 behave as metals or insulators depending on temperature.


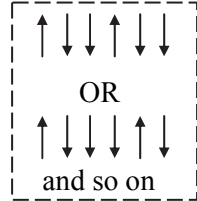
1.14 Magnetic properties of solids

- i. The magnetic properties of solids are due to the magnetic moments of electrons. The magnetic moments of electrons originates from two types of motions:
 - a. Magnetic moment due to spin of electron around its own axis. This is known as **spin magnetic moment**.
 - b. Magnetic moment due to orbital motion of electron around the nucleus. This is known as **orbital magnetic moment**.
- ii. Thus, each electron has permanent spin and orbital magnetic moments and acts as a tiny magnet.
- iii. The magnitude of this magnetic moment is very small. It is measured in the unit Bohr magneton (μ_B) and is equal to $9.27 \times 10^{-24} \text{ A m}^2$.

➤ Classification of solids based on response to magnetic field:

Substance	Characteristics	Examples	Applications
Diamagnetic materials	<ul style="list-style-type: none"> Repelled weakly by a magnetic field. All electrons are paired.  <ul style="list-style-type: none"> Weakly magnetised in a magnetic field in opposite direction. 	Benzene, NaCl , H_2O	Insulators
Paramagnetic materials	<ul style="list-style-type: none"> Weakly attracted by a magnetic field. Unpaired electrons are present.  <ul style="list-style-type: none"> Magnetised in a magnetic field in the same direction. Permanent magnetisation is not possible. They lose their magnetism in the absence of magnetic field. 	O_2 , Cu^{2+} , Fe^{3+} , Cr^{3+}	Electronic devices
Ferromagnetic materials	<ul style="list-style-type: none"> Strongly attracted by a magnetic field. Unpaired electrons are present. In solid state, the metal ions are grouped together into small regions called domains, which act as tiny magnets. In an unmagnetised ferromagnetic material, the domains are randomly oriented such that their magnetic moments get cancelled. However, in presence of a magnetic field, the domains spontaneously orient in the direction of the magnetic field producing a strong magnetic effect.  <ul style="list-style-type: none"> Permanent magnetisation is possible. i.e., they do not lose their magnetism even in the absence of magnetic field. Change to paramagnetic solid when heated. <p>Note: The characteristic temperature above which no ferromagnetism is observed is known as Curie temperature.</p>	Fe , Ni , Co , Gd , CrO_2	CrO_2 is used in audio, video tapes.



Antiferromagnetic materials	<ul style="list-style-type: none"> The domains align in such a way that resultant magnetic moment is zero. The number of domains that are aligned in parallel direction is equal to the number of domains that are aligned in anti-parallel direction.  <ul style="list-style-type: none"> Change to paramagnetic solid when heated. 	MnO	Used in instruments of magnetic susceptibility measurement.
Ferrimagnetic materials	<ul style="list-style-type: none"> The domains align in such a way that there is a small net magnetic moment. The number of domains that are aligned in parallel direction is not equal to the number of domains that are aligned in anti-parallel direction.  <ul style="list-style-type: none"> Weakly attracted by a magnetic field. Change to paramagnetic solid when heated. 	Fe ₃ O ₄ (magnetite), Ferrites like MgFe ₂ O ₄ , ZnFe ₂ O ₄ , etc.	—

Note: Dielectric properties of solids:

- A substance through which there is no net flow of electric charge when placed under an applied electrical field is defined as **dielectric material**.
- In dielectric substances, electrons are tightly held by individual atoms. In presence of an electric field, the nuclei are attracted to one side and the electron cloud is attracted to other side resulting in polarization.
- Depending upon the alignment of dipoles formed due to polarization and the permanent dipoles (which may be present in the crystal) the crystals are classified into four types:

- Piezoelectric crystals
- Pyroelectric crystals
- Ferroelectric crystals
- Antiferroelectric crystals

a. Piezoelectric crystals:

- When mechanical stress is applied, crystals deform due to displacement of ions. This generates electricity called **piezoelectricity** and the crystals are called **piezoelectric crystals**.
- When an electric field is applied to piezoelectric crystals, mechanical strain is produced due to atomic displacements. This phenomenon is called **inverse piezoelectric effect**.
eg. Titanates of barium and lead, lead zirconate (PbZrO₃), ammonium dihydrogen phosphate (NH₄H₂PO₄) and quartz are piezoelectric crystals.

b. Pyroelectric crystals: When some crystals are heated, they produce a small electric current. The electricity produced is called **pyroelectricity** and the crystals are referred as **pyroelectric crystals**.

c. Ferroelectric crystals: Even when the electric field is absent, the dipoles of some crystals are permanently polarized and when an electric field is applied, the direction of polarization changes. Such crystals are called **ferroelectric crystals**.
eg. Barium titanate (BaTiO₃), Sodium potassium tartarate (Rochelle salt) and Potassium dihydrogen phosphate (KH₂PO₄) are ferroelectric crystals.

d. Antiferroelectric crystals: In antiferroelectric crystals, the dipoles align themselves in such a way that they point up and down alternately, so that the crystals does not posses any net dipole moment.
eg. Lead zirconate (PbZrO₃)

**Formulae**

1. **Relationship between radius of atom (r) and edge length (a):**

Simple cubic unit cell	Body-centred cubic unit cell	Face-centred cubic unit cell
$r = \frac{a}{2}$	$r = \frac{\sqrt{3}}{4}a$	$r = \frac{a}{2\sqrt{2}}$

2. **Distance between the nearest neighbours (D) in a unit cell:**

Simple cubic unit cell	bcc unit cell	fcc unit cell
$D = a$	$D = \frac{\sqrt{3}a}{2}$	$D = \frac{a}{\sqrt{2}}$

3. **Packing efficiency**

$$= \frac{\text{Volume occupied by spheres in unit cell}}{\text{Volume of unit cell}} \times 100$$

4. **Density of unit cell**

$$= \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}} = \frac{Z \times M}{a^3 \times N_0} \text{ g cm}^{-3}$$

where, a is the edge length of unit cell in cm

Z is the number of atoms per unit cell

M is the molar mass

N_0 is the Avogadro's number (6.022×10^{23})

For fcc, $Z = 4$, for bcc, $Z = 2$ and for simple cubic, $Z = 1$

**Multiple Choice Questions****1.0 Introduction**

1. Which of the following statements is TRUE? **[AIIMS 1991]**
- (A) Solids change into liquid on heating to its melting point.
- (B) Liquids change into gas, on cooling to its freezing point.
- (C) Liquids change into solid on heating to its boiling point.
- (D) Solids change into gas on heating to its melting point.
2. The physical state of matter is due to presence of different intermolecular forces such as _____.
- (A) dipole-dipole interactions
- (B) London forces
- (C) hydrogen bonding
- (D) all of these

3. Which of the following conditions favours the existence of a substance in the solid state?

[NCERT Exemplar]

- (A) High temperature
- (B) Low temperature
- (C) High thermal energy
- (D) Weak cohesive forces

1.1 Classification of solids

4. A crystalline solid has _____. **[DCE 2001]**
- (A) long range order
- (B) short range order
- (C) disordered arrangement
- (D) none of these
5. The sharp melting point of crystalline solids is due to _____. **[NCERT Exemplar]**
- (A) a regular arrangement of constituent particles observed over a short distance in the crystal lattice
- (B) a regular arrangement of constituent particles observed over a long distance in the crystal lattice
- (C) same arrangement of constituent particles in different directions
- (D) different arrangement of constituent particles in different directions
6. _____ is a crystalline solid.
- (A) Glass (B) Tar
- (C) Plastic (D) Sugar
7. Which of the following properties of a crystalline solid changes with change of direction?
- (A) refractive index
- (B) electrical conductance
- (C) electrical resistance
- (D) all of these
8. Amorphous solids are _____.
- (A) super cooled solids
- (B) super cooled gases
- (C) super cooled liquids
- (D) All of these
9. Which of the following is an amorphous solid? **[NCERT Exemplar]**
- (A) Graphite (C)
- (B) Quartz glass (SiO_2)
- (C) Chrome alum
- (D) Silicon carbide (SiC)



10. Which of the following statements about amorphous solids is INCORRECT?

[KCET 2004]

- (A) They melt over a range of temperature.
 - (B) They are anisotropic.
 - (C) There is no orderly arrangement of particles.
 - (D) They are rigid and incompressible.
11. Glass is a _____.
(A) microcrystalline solid
(B) super cooled liquid
(C) gel
(D) polymeric mixture
12. Amorphous solids _____.
(A) possess sharp melting points
(B) undergo clean cleavage when cut with knife
(C) do not undergo clean cleavage when cut with knife
(D) possess orderly arrangement over long distances
13. Which of the following is NOT a characteristic of a crystalline solid?
[NCERT Exemplar]
(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
14. Which of the following statements is TRUE?
(A) Both crystalline and amorphous solids are isotropic.
(B) Both crystalline and amorphous solids are anisotropic.
(C) Crystalline solids are isotropic and amorphous solids are anisotropic.
(D) Crystalline solids are anisotropic and amorphous solids are isotropic.
15. Most crystals show good cleavage because their atoms, ions or molecules are _____.
[CBSE PMT 1991]
(A) weakly bonded together
(B) strongly bonded together
(C) spherically symmetrical
(D) arranged in planes

1.2 Classification of crystalline solids

16. The molecules of polar molecular solids are held together by _____.
(A) dipole-dipole interactions
(B) dispersion forces
(C) hydrogen bonds
(D) covalent bonds
17. Which among the following solids is a non-polar solid?
[MHT CET 2016]
(A) Hydrogen chloride
(B) Sulphur dioxide
(C) Water
(D) Carbon dioxide
18. Iodine molecules are held in the crystal lattice by _____.
[NCERT Exemplar]
(A) London forces
(B) dipole-dipole interactions
(C) covalent bonds
(D) coulombic forces
19. Which of the following is a hydrogen bonded molecular solid?
(A) HCl (B) H₂
(C) CH₄ (D) Ice
20. In ionic solids, the constituent particles are _____.
(A) cations and anions
(B) atoms
(C) molecules
(D) all of these
21. Which of the following is TRUE about ionic solids?
(A) In molten state, ionic solids do not conduct electricity.
(B) In aqueous solution, ionic solids do not conduct electricity.
(C) In solid state, ionic solids conduct electricity.
(D) In solid state, ionic solids do not conduct electricity.
22. NaCl is an example of _____.
(A) polar molecular solid
(B) ionic solid
(C) non-polar molecular solid
(D) hydrogen bonded molecular solid
23. The solid NaCl is a bad conductor of electricity since, _____.
[AIIMS 1980]
(A) in solid NaCl, there are no ions
(B) solid NaCl is covalent
(C) in solid NaCl, there is no movement of ions
(D) in solid NaCl, there are no electrons



24. Which of the following is an example of ionic solid?
 (A) SO_2 (B) LiF
 (C) Li (D) HCl
25. Which of the following is NOT characteristic of ionic solids?
[NCERT Exemplar]
 (A) Very low value of electrical conductivity in the molten state.
 (B) Brittle nature.
 (C) Very strong forces of interactions.
 (D) Anisotropic nature.
26. Which of the following is an example of metallic solid?
 (A) CO_2 (B) I_2
 (C) Ni (D) AgCl
27. A sea of free electrons is present in _____.
 (A) ionic solids
 (B) metallic solids
 (C) non-polar molecular solids
 (D) polar molecular solids
28. Which type of solid crystals will conduct heat and electricity?
[RPET 2000]
 (A) Polar molecular
 (B) Non-polar molecular
 (C) Metallic
 (D) Ionic
29. _____ solids are tougher than other solids.
 (A) Metallic (B) Ionic
 (C) Molecular (D) Covalent
30. The lustre of a metal is due to _____.
[AFMC 1998]
 (A) its high density
 (B) its high polishing
 (C) its chemical inertness
 (D) presence of free electrons
31. Copper has _____ lustre.
 (A) yellow (B) reddish
 (C) blue (D) green
32. An example of covalent solid is _____.
[TS EAMCET (Engg.) 2015]
 (A) MgO (B) Mg
 (C) SiC (D) CaF_2
33. _____ solids are also called giant molecules or network solids.
 (A) Covalent (B) Molecular
 (C) Ionic (D) Metallic
34. Which of the following is a network solid?
[NCERT Exemplar]
 (A) SO_2 (Solid) (B) I_2
 (C) Diamond (D) H_2O (Ice)
35. Which of the following is TRUE for diamond?
[AFMC 1997]
 (A) Diamond is a good conductor of electricity.
 (B) Diamond is a bad conductor of heat.
 (C) Diamond is soft.
 (D) Diamond is made up of C, H and O.
36. In diamond, each carbon atom is covalently bonded to _____ carbon atoms.
 (A) 4 (B) 8 (C) 6 (D) 12
37. In which of the following substances, the carbon atom is arranged in a regular tetrahedral structure?
[NCERT 1978]
 (A) Diamond (B) Graphite
 (C) Fullerene (D) All of these
38. In graphite, carbon atoms form interlinked _____ membered rings.
 (A) four (B) five
 (C) six (D) seven
39. In graphite, carbon atoms are joined together due to _____.
[AFMC 2002]
 (A) ionic bonding
 (B) van der Waals forces
 (C) metallic bonding
 (D) covalent bonding
40. Graphite CANNOT be classified as _____.
[NCERT Exemplar]
 (A) conducting solid
 (B) network solid
 (C) covalent solid
 (D) ionic solid
41. Graphite is a good conductor of electricity due to the presence of _____.
[NCERT Exemplar]
 (A) lone pair of electrons
 (B) free valence electrons
 (C) cations
 (D) anions
42. The melting point of _____ solids is very low.
 (A) polar molecular
 (B) non-polar molecular
 (C) hydrogen bonded molecular
 (D) ionic

**1.3 Unit cell and two and three dimensional lattices**

43. _____ is the smallest repeating unit in space lattice.
(A) A unit cell (B) A lattice point
(C) An atom (D) An ion
44. The geometry of the lattice can be obtained by joining the _____ with _____ lines.
(A) lattice points, straight
(B) lattice points, curved
(C) unit cells, straight
(D) unit cells, curved

1.4 Bragg's law and its applications

45. Calculate the angle of incidence θ for a first order diffraction of X-rays of wavelength 1.54 \AA . The distance 'd' between two successive planes is 2.01 \AA .
(A) 11.5° (B) 22.5°
(C) 27.5° (D) 33.5°
46. Calculate the distance d between two successive planes when a first order diffraction of X-rays of wavelength 1.54 \AA is reflected at an angle of 11.29° .
(A) 3.93 \AA (B) 3.13 \AA
(C) 2.57 \AA (D) 2.07 \AA
47. Calculate the wavelength when the interplanar distance in a crystal used for a first order X-ray diffraction is 2 \AA and the angle of incidence of X-rays is 9° .
(A) 0.5247 \AA (B) 0.6256 \AA
(C) 0.7238 \AA (D) 0.4123 \AA

1.5 Seven crystal systems

48. There are _____ types of centred unit cells.
(A) two (B) three
(C) four (D) five
49. According to Bravais, lattice points can be arranged in a maximum of _____ types.
[MP PMT 1996; MP PET/PMT 1998]
(A) 7 (B) 14
(C) 32 (D) 230
50. Crystals can be classified into _____ basic crystal habits.
[MP PMT 1994]
(A) 3 (B) 7
(C) 14 (D) 4

51. Which metal crystallises in a simple cubic structure? [MHT CET 2016]
(A) Polonium (B) Copper
(C) Nickel (D) Iron
52. Tetragonal crystal system has the following unit cell dimensions: [MP PMT 1993]
(A) $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$
(B) $a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$
(C) $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$
(D) $a = b \neq c$ and $\alpha = \beta = 90^\circ, \gamma = 120^\circ$
53. TiO_2 has _____ crystal system.
(A) cubic (B) tetragonal
(C) orthorhombic (D) monoclinic
54. A match box exhibits _____. [MP PET 1993, 95]
(A) cubic geometry
(B) monoclinic geometry
(C) orthorhombic geometry
(D) tetragonal geometry
55. The crystal system of BaSO_4 is _____.
(A) monoclinic (B) triclinic
(C) cubic (D) orthorhombic
56. The unit cell with crystallographic dimensions, $a \neq b \neq c$, $\alpha = \beta = 90^\circ$ and $\gamma \neq 90^\circ$ is _____. [KCET 2015]
(A) triclinic (B) monoclinic
(C) orthorhombic (D) tetragonal
57. End centred unit cell is present in _____ crystal systems.
(A) cubic and triclinic
(B) tetragonal and rhombohedral
(C) orthorhombic and monoclinic
(D) hexagonal and cubic
58. Triclinic crystal has dimensions _____.
(A) $a = b \neq c$, $\alpha = \beta = \gamma = 90^\circ$
(B) $a \neq b \neq c$, $\alpha \neq \beta \neq \gamma \neq 90^\circ$
(C) $a \neq b \neq c$, $\alpha = \beta = \gamma = 90^\circ$
(D) $a = b = c$, $\alpha = \beta = 90^\circ, \gamma \neq 90^\circ$
59. The crystal system of a compound with unit cell dimensions $a = 0.387$, $b = 0.387$ and $c = 0.504 \text{ nm}$ and $\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$ is _____. [AIIMS 2004]
(A) cubic
(B) hexagonal
(C) orthorhombic
(D) rhombohedral



60. Rhombohedral crystal system is present in _____.
 (A) CaSO_4 (B) HgS
 (C) ZnO (D) KNO_3
61. Which of the following is the most symmetrical crystal system?
 (A) Cubic (B) Tetragonal
 (C) Orthorhombic (D) Triclinic
62. Which of the following is the most unsymmetrical crystal system?
 (A) Orthorhombic (B) Monoclinic
 (C) Triclinic (D) Rhombohedral

1.6 Three types of cubic lattices

63. In a simple cubic unit cell, each atom at its corner is shared by _____.
 (A) 2 unit cells (B) one unit cell
 (C) 8 unit cells (D) 4 unit cells
64. If an atom is present in the centre of the cube, the participation of that atom per unit cell is _____.
 (A) $\frac{1}{4}$ (B) 1
 (C) $\frac{1}{2}$ (D) $\frac{1}{8}$
65. The total number of atoms contained in one body-centred cubic unit cell is _____.
 (A) 1 (B) 2
 (C) 4 (D) 6
66. An element occurring in the bcc structure has 12.08×10^{23} unit cells. The total number of atoms of the element in these cells will be _____.
[MP PET 1994]
 (A) 24.16×10^{23} (B) 36.18×10^{23}
 (C) 6.04×10^{23} (D) 12.08×10^{23}
67. Body-centred cubic lattice has a coordination number of _____.
[AIIMS 1996; MP PMT 2002]
 (A) 4 (B) 8
 (C) 12 (D) 6
68. The intermetallic compound LiAg crystallizes in cubic lattice in which both lithium and silver have coordination number of eight. The crystal class is _____. **[CBSE PMT 1997]**
 (A) simple cubic
 (B) body-centred cubic
 (C) face-centred cubic
 (D) none of these

69. In a face-centred cubic cell, an atom at the face contributes to the unit cell _____.
[Karnataka (Engg./Med.) 2000; AFMC 2001]

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

70. The number of atoms/molecules contained in one face-centred cubic unit cell of a monoatomic substance is _____.
[CPMT 1989,94; CBSE 1989, 96; NCERT 1990, MP PET 1993; Karnataka CET 1999]

(A) 1 (B) 2
 (C) 4 (D) 6

71. The number of nearest neighbours to each sphere in fcc lattice will be _____.
 (A) 6 (B) 8
 (C) 12 (D) 14

72. What is the difference between the number of atoms per unit cell in face-centred cube and the number of atoms per unit cell in body-centred cube?
[GUJ CET 2014]

(A) 2 (B) 1
 (C) 4 (D) 6

1.7 Packing in solids

73. The linear packing arrangement of the constituent particles in a crystalline solid can be made in _____.
 (A) one way (B) two ways
 (C) three ways (D) four ways
74. In the linear packing arrangement in one dimension, the coordination number is _____.
 (A) 1 (B) 2
 (C) 3 (D) 4
75. The planar packing arrangement of the constituent particles in a crystalline solid can be made in _____.
 (A) one way (B) two ways
 (C) three ways (D) four ways
76. In planar packing arrangement in two dimensions, the square close packed structure is of _____ type and the hexagonal close packed structure is of _____ type
 (A) AAAA, ABAB
 (B) ABAB, AAAA
 (C) AAAA, AAAA
 (D) ABAB, ABAB



77. What is the coordination number in a square close packed structure in two dimensions?

[NCERT Exemplar]

- (A) 2 (B) 3
(C) 4 (D) 6

78. The three dimensional arrangement AAAA type is referred to as _____.

- (A) hexagonal close packing
(B) cubic close packing
(C) simple cubic structure
(D) tetragonal close packing

79. The coordination number of a metal crystallizing in simple cubic structure is _____.

- (A) 4 (B) 6
(C) 8 (D) 10

80. Hexagonal close packed arrangement of ions is described as _____ type. [MP PMT 1994]

- (A) AAAA (B) ABCABC
(C) ABAB (D) ABBAB

81. In hexagonal close packed structure, _____ layer and _____ layer have horizontal and vertical alignment.

- (A) first, fourth (B) first, third
(C) second, third (D) second, fifth

82. The coordination number of a metal crystallizing in a hexagonal close packed structure is _____. [NCERT 1978; IIT 1999]

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

83. Hexagonal close packing is found in crystal lattice of _____. [MH CET 2002]

- (A) Cu (B) Mg
(C) Ag (D) Au

84. In a close packed lattice containing N-particles, the number of tetrahedral and octahedral voids are _____ respectively.

- (A) N, 2N (B) N, N
(C) 2N, N (D) 2N, N/2

85. The arrangement ABCABCABC..... is referred as _____. [MP PET 2001]

- (A) octahedral close packing
(B) hexagonal close packing
(C) tetragonal close packing
(D) cubic close packing

86. In cubic close packed structure, the spheres of the _____ layer are aligned with the spheres of the first layer.

- (A) second (B) third
(C) fourth (D) fifth

87. The coordination number of a metal crystallizing in cubic close packed structure is _____.

- (A) 4 (B) 6 (C) 10 (D) 12

88. Silver metal has close packing of the type _____.

- (A) AAAA (B) ABCABC
(C) ABAB (D) ABCCBA

89. Match the type of packing given in column I with the details given in column II.

	Column I		Column II
i.	Square close packing in two dimensions	a.	Triangular voids
ii.	Two dimensional ABAB type arrangement	b.	Spheres of alternate layers have horizontal and vertical alignment
iii.	Cubic close packing in three dimensions	c.	Coordination number 4
iv.	Hexagonal close packing in three dimensions	d.	Spheres of third layer are placed in octahedral voids

- (A) (i) – (a), (ii) – (c), (iii) – (b), (iv) – (d)
(B) (i) – (c), (ii) – (d), (iii) – (a), (iv) – (b)
(C) (i) – (a), (ii) – (b), (iii) – (c), (iv) – (d)
(D) (i) – (c), (ii) – (a), (iii) – (d), (iv) – (b)

90. The total number of tetrahedral voids in the face-centred unit cell is _____. [NCERT Exemplar]

- (A) 6 (B) 8 (C) 10 (D) 12

91. In the cubic close packing, the unit cell has _____. [NCERT Exemplar]

- (A) 4 tetrahedral voids each of which is shared by four adjacent unit cells
(B) 4 tetrahedral voids within the unit cell
(C) 8 tetrahedral voids each of which is shared by four adjacent unit cells
(D) 8 tetrahedral voids within the unit cell

92. A compound is formed by elements A and B. This crystallizes in the cubic structure when atoms A are at the corners of the cube and atoms B are at the centre of the body. The simplest formula of the compounds is _____. [KCET 1993; CBSE PMT 2000; Kerala PMT 2002]

- (A) AB (B) AB₂ (C) A₂B (D) AB₄



93. A compound of gold and copper crystallizes in a cubic lattice in which the gold atoms occupy the lattice points at the corners of cube and copper atoms occupy the centres of each of the cube faces. The formula of this compound is _____.

(A) AuCu (B) AuCu₂
(C) AuCu₃ (D) None of these

94. A compound contains elements X and Y. Y atoms form ccp lattice and atoms of X occupy $\frac{1}{3}$ of tetrahedral voids. What is the molecular formula of the compound?

[AP EAMCET (Med.) 2016]

(A) XY (B) X₂Y₃
(C) X₃Y₂ (D) XY₂

95. A compound is formed by elements 'X' (cations) and 'Y' (anions). Ions of 'Y' form cubic close packing (ccp) and ions of 'X' occupy all the octahedral voids. What is the molecular formula of the compound?

[TS EAMCET (Med.) 2015]

(A) XY₂ (B) XY
(C) X₂Y₃ (D) X₂Y

96. Which of the following is NOT true about the ionic solids? [NCERT Exemplar]

(A) Bigger ions form the close packed structure.
(B) Smaller ions occupy either the tetrahedral or the octahedral voids depending upon their size.
(C) Occupation of all the voids is not necessary.
(D) The fraction of octahedral or tetrahedral voids occupied depends upon the radii of the ions occupying the voids.

97. The ionic radii of A⁺ and B⁻ ions are 0.98×10^{-10} m and 1.81×10^{-10} m. The coordination number of each ion in AB is _____.

[NEET P-I 2016]

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

1.8 Packing efficiency

98. The formula of packing efficiency is _____.

(A) Packing efficiency
$$= \frac{\text{Volume of unit cell}}{\text{Volume of one sphere}} \times 100$$

(B) Packing efficiency
$$= \frac{\text{Volume of one sphere}}{\text{Volume of unit cell}}$$

- (C) Packing efficiency

Total volume occupied

$$= \frac{\text{by spheres in unit cell}}{\text{Volume of unit cell}} \times 100$$

- (D) Packing efficiency

$$= \frac{\text{Volume of unit cell}}{\text{Total volume occupied by spheres in unit cell}} \times 100$$

99. In simple cubic unit cell, the volume of cubic unit cell is _____.

(A) $2r^3$ (B) $4r^3$
(C) $6r^3$ (D) $8r^3$

100. The packing efficiency in simple cubic unit cell is _____.

(A) 52.4 % (B) 68%
(C) 74% (D) 80%

101. CsCl crystallizes in body-centred cubic lattice. If 'a' is its edge length then which of the following expressions is CORRECT?

[MP PET 2002; AIPMT 2014;
JEE (MAIN) 2014]

(A) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = 3a$ (B) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \frac{3a}{2}$
(C) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \frac{\sqrt{3}}{2}a$ (D) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \sqrt{3}a$

102. Sodium metal crystallizes in a body-centred cubic lattice with a unit cell edge of 4.29 Å. The radius of sodium atom is approximately _____.

[JEE (MAIN) 2015; KCET 2015]

(A) 1.86 Å (B) 3.22 Å
(C) 5.72 Å (D) 0.93 Å

103. A metal has bcc structure and the edge length of its unit cell is 3.04 Å. The volume of the unit cell in cm³ will be _____.

[Orrisa JEE 2005]

(A) $1.6 \times 10^{21} \text{ cm}^3$ (B) $2.81 \times 10^{-23} \text{ cm}^3$
(C) $6.02 \times 10^{-23} \text{ cm}^3$ (D) $6.6 \times 10^{-24} \text{ cm}^3$

104. Volume occupied by single CsCl ion pair in a crystal is $7.014 \times 10^{-23} \text{ cm}^3$. The smallest Cs – Cs internuclear distance is equal to length of the side of the cube corresponding to volume of one CsCl ion pair. The smallest Cs to Cs internuclear distance is nearly _____.

[KCET 2014]

(A) 4.4 Å (B) 4.3 Å
(C) 4 Å (D) 4.5 Å



105. The vacant space in bcc lattice unit cell is _____. [AIPMT RE-TEST 2015]

- (A) 23% (B) 32%
(C) 26% (D) 48%

106. In face-centred cubic unit cell, the edge length is _____. [DPMT 2005]

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

107. The edge lengths of the unit cells in terms of the radius of spheres constituting fcc, bcc and simple cubic unit cell are respectively _____. [NCERT Exemplar]

- (A) $2\sqrt{2}r, \frac{4r}{\sqrt{3}}, 2r$ (B) $\frac{4r}{\sqrt{3}}, 2\sqrt{2}r, 2r$
(C) $2r, 2\sqrt{2}r, \frac{4r}{\sqrt{3}}$ (D) $2r, \frac{4r}{\sqrt{3}}, 2\sqrt{2}r$

108. The edge of unit cell of fcc Xe crystal is 620 pm. The radius of Xe atom is _____. [MP PET 2004]

- (A) 219.20 pm (B) 235.16 pm
(C) 189.37 pm (D) 209.87 pm

109. 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? [AIPMT 2015]

- (A) 40 pm (B) 127 pm
(C) 80 pm (D) 108 pm

110. In face-centred cubic unit cell, what is the volume occupied? [MHT CET 2016]

- (A) $\frac{4}{3}\pi r^3$ (B) $\frac{8}{3}\pi r^3$
(C) $\frac{16}{3}\pi r^3$ (D) $\frac{64r^3}{3\sqrt{3}}$

111. The maximum percentage of available volume that can be filled in a face-centred cubic system by an atom is _____. [AIPMT 2015]

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

112. The CORRECT order of the packing efficiency in different types of unit cells is _____. [NCERT Exemplar]

- (A) fcc < bcc < simple cubic
(B) fcc > bcc > simple cubic
(C) fcc < bcc > simple cubic
(D) bcc > fcc > simple cubic

113. Which metal among the following has the highest packing efficiency? [MH CET 2015]

- (A) Iron (B) Tungsten
(C) Aluminium (D) Polonium

114. The packing efficiency in hexagonal close packing is _____. [AIPMT 2015]

- (A) 52.4 % (B) 68 %
(C) 74 % (D) 80 %

1.9 Calculation of density of unit cells

115. The formula for determination of density of unit cell is _____. [AIPMT 2015]

- (A) $\frac{a^3 \times N_0}{Z \times M} \text{ g cm}^{-3}$ (B) $\frac{Z \times M}{a^3 \times N_0} \text{ g cm}^{-3}$
(C) $\frac{a^3 \times M}{Z \times N_0} \text{ g cm}^{-3}$ (D) $\frac{M \times N_0}{a^3 \times Z} \text{ g cm}^{-3}$

116. **Assertion:** Mass of a unit cell depends upon the number of atoms per unit cell.

Reason: Mass of a unit cell is the product of mass of a single atom and the number of atoms per unit cell.

- (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
(B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
(C) Assertion is true, Reason is false.
(D) Assertion is false, Reason is true.

117. TiCl₃ crystallizes in simple cubic lattice with density 7.00 g cm⁻³. The molecular weight of TiCl₃ is 239.87 g mol⁻¹. The edge length of the unit cell is _____ × 10⁻⁸ cm. [AIPMT 2015]

- (A) 2.5 (B) 3.0
(C) 3.84 (D) 5.0

118. An element (atomic mass 100 g/mol) having bcc structure has unit cell edge 400 pm. Then, the density of the element is _____. [CBSE PMT 1996; AIIMS 2002]

- (A) 10.376 g / cm³ (B) 5.189 g / cm³
(C) 7.289 g / cm³ (D) 2.144 g / cm³

119. 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. (N₀ = 6.02 × 10²³ mol⁻¹) [NEET P-I 2016]

- (A) 527 pm (B) 264 pm
(C) 154 pm (D) 352 pm



120. A compound CuCl has face-centred cubic structure. Its density is 3.4 g cm^{-3} . The edge length of unit cell is _____.
 (A) 5.783 \AA (B) 6.783 \AA
 (C) 7.783 \AA (D) 8.783 \AA
121. An element crystallizes in a structure having fcc unit cell of an edge 200 pm . Calculate the density if 200 g of the element contains 24×10^{23} atoms.
 (A) 41.6 g cm^{-3} (B) 42.6 g cm^{-3}
 (C) 43.6 g cm^{-3} (D) 44.6 g cm^{-3}
122. Ferrous oxide has a cubic structure and each edge of the unit cell is 5.0 \AA . If the density of the oxide is 4.0 g cm^{-3} , then the number of Fe^{2+} and O^{2-} ions present in each unit cell will be _____. [MP PET 2000]
 (A) four Fe^{2+} and four O^{2-}
 (B) two Fe^{2+} and four O^{2-}
 (C) four Fe^{2+} and two O^{2-}
 (D) three Fe^{2+} and three O^{2-}
123. Calculate the density of silver metal having fcc unit cell with edge length 409 pm . (Atomic mass of $\text{Ag} = 108 \text{ g mol}^{-1}$, $N_0 = 6.022 \times 10^{23} \text{ mol}^{-1}$)
 (A) 8.3 g cm^{-3} (B) 9.8 g cm^{-3}
 (C) 10.5 g cm^{-3} (D) 12 g cm^{-3}

1.10 Imperfections in solids

124. The defects which arise due to irregularities or deviations from ideal arrangement in entire row of lattice points are called _____.
 (A) line defects
 (B) electronic imperfections
 (C) point defects
 (D) both (B) and (C)
125. Which of the following is TRUE about point defects?
 (A) Due to vacancy defect, the density of substance decreases and due to interstitial defect, the density of the substance increases.
 (B) Due to vacancy defect, the density of substance increases and due to interstitial defect, the density of the substance decreases.
 (C) The density of the substance increases in both vacancy defect and interstitial defect.
 (D) The density of the substance decreases in both vacancy defect and interstitial defect.

1.11 Classification of point defects

126. Which of the following represents point defects in ionic crystals?
 (A) Stoichiometric defects
 (B) Non-stoichiometric defects
 (C) Impurity defects
 (D) All of these.
127. Stoichiometric defects refers to _____.
 (A) only Schottky defect
 (B) only Frenkel defect
 (C) both Schottky defect and Frenkel defect
 (D) None of these
128. Schottky defect defines imperfection in the lattice structure of a _____. [AIIMS 2002]
 (A) solid (B) liquid
 (C) gas (D) plasma
129. Schottky defect in a crystal is observed when, _____. [KCET 2016]
 (A) unequal number of cations and anions are missing from the lattice
 (B) equal number of cations and anions are missing from the lattice
 (C) an ion leaves its normal site and occupies an interstitial site
 (D) no ion is missing from its lattice site
130. Schottky defect is noticed in _____.
 (A) NaCl (B) KCl
 (C) CsCl (D) All of these
131. In a solid lattice, the cation has left a lattice site and is located at an interstitial position. The lattice defect is _____. [AUMS 1982, 1991; DCE 2002; J & K 2005]
 (A) interstitial defect
 (B) vacancy defect
 (C) Frenkel defect
 (D) Schottky defect
132. The CORRECT statement regarding defects in crystalline solids is _____. [AIPMT RE-TEST 2015]
 (A) Frenkel defect is a dislocation defect.
 (B) Frenkel defect is found in halides of alkaline metals.
 (C) Schottky defects have no effect on the density of crystalline solids.
 (D) Frenkel defects decrease the density of crystalline solids.
133. Which one of the following crystals does NOT exhibit Frenkel defect?
 (A) AgBr (B) AgCl
 (C) KCl (D) ZnS



134. Due to Frenkel defect, the density of ionic solids _____.
[MP PET 1996; MP PMT 2002]

- (A) increases (B) decreases
(C) does not change (D) changes

135. Which of the following point defects are shown by $\text{AgBr}_{(s)}$ crystals? [NCERT Exemplar]

- i. Schottky defect
ii. Frenkel defect
iii. Metal excess defect
iv. Metal deficiency defect

- (A) (i) and (ii) (B) (iii) and (iv)
(C) (i) and (iii) (D) (ii) and (iii)

136. Non-stoichiometric defects refers to _____.

- (A) only metal excess defects
(B) only metal deficiency defects
(C) both metal excess and metal deficiency defects
(D) none of these

137. Metal excess defects are caused due to presence of _____.

- (A) anionic vacancies
(B) extra cations in interstitial sites
(C) both (A) and (B)
(D) none of these

138. Electrons trapped into the crystal in anion vacancies are known as _____.

[BHU 2005]

- (A) E-centres (B) P-centres
(C) M-centres (D) F-centres

139. ZnO with excess Zn^{2+} ions and interstitial electrons represents _____.

- (A) metal excess defect
(B) metal deficiency defect
(C) Frenkel defect
(D) Schottky defect

140. Metal deficiency defect is present in _____.

- (A) AgI (B) AgBr
(C) ZnO (D) FeO

141. **Assertion:** FeO usually occurs as $\text{Fe}_{0.95}\text{O}$.

Reason: This non-stoichiometric defect occurs due to missing O^{2-} ions from the lattice.

- (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
(B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
(C) Assertion is true, Reason is false.
(D) Assertion is false, Reason is true.

142. Addition of CdCl_2 to AgCl results in _____.

- (A) impurity defect
(B) metal excess defect
(C) Schottky defect
(D) Frenkel defect

1.12 Electrical properties of solids

143. The range of conductivity for conductors is _____.

- (A) 10^4 to $10^7 \text{ ohm}^{-1} \text{ m}^{-1}$
(B) 10^2 to $10^4 \text{ ohm}^{-1} \text{ m}^{-1}$
(C) 10^{-6} to $10^2 \text{ ohm}^{-1} \text{ m}^{-1}$
(D) 10^{-20} to $10^{-10} \text{ ohm}^{-1} \text{ m}^{-1}$

144. Which of the following is/are metallic conductors?

- (A) Copper (B) Silver
(C) Aluminium (D) All of these

145. Silicon is a/an _____. [MH CET 2004]

- (A) semiconductor
(B) insulator
(C) metallic conductor
(D) electrolytic conductor

146. The range of conductivity 10^{-6} to $10^4 \text{ ohm}^{-1} \text{ m}^{-1}$ is of _____.

- (A) metallic conductor
(B) semiconductors
(C) insulators
(D) electrolytic conductor

147. Which of the following represents CORRECT order of conductivity in solids?

[NCERT Exemplar]

- (A) $\kappa_{\text{metals}} \gg \kappa_{\text{insulators}} < \kappa_{\text{semiconductors}}$
(B) $\kappa_{\text{metals}} \ll \kappa_{\text{insulators}} < \kappa_{\text{semiconductors}}$
(C) $\kappa_{\text{metals}} ; \kappa_{\text{semiconductors}} > \kappa_{\text{insulators}} = \text{zero}$
(D) $\kappa_{\text{metals}} < \kappa_{\text{semiconductors}} > \kappa_{\text{insulators}} \neq \text{zero}$

1.13 Band theory

148. Conduction band is present in _____.

- (A) metal
(B) semiconductor
(C) insulator
(D) all of these

149. The space between the outermost filled energy band and the next higher empty band is called _____.

- (A) valence band
(B) conduction band
(C) forbidden zone
(D) none of these



150. Which of the following statements is TRUE?
 (A) In semiconductors, the forbidden zone is small and in insulators, the forbidden zone is very large.
 (B) Forbidden zone is very large in metals and insulators.
 (C) Forbidden zone is very small in metals and insulators.
 (D) In semiconductors, the forbidden zone is very large and in insulators, the forbidden zone is very small.
151. **Assertion:** Insulators are poor conductors of electricity.
Reason: According to band theory, electrons cannot move from valence band to conduction band.
 (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
 (B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
 (C) Assertion is true, Reason is false.
 (D) Assertion is false, Reason is true.
152. With increase in temperature, the electrical conductivity of semiconductors _____.
 (A) decreases
 (B) remains same
 (C) increases
 (D) none of the these
153. In an intrinsic semiconductor, _____.
 (A) equal number of holes and electrons are present
 (B) only holes are present
 (C) the number of electrons is more than that of holes
 (D) the number of holes is more than that of electrons
154. When suitable impurity is added to pure intrinsic semiconductor, the electrical conductivity _____.
 (A) is enhanced
 (B) remains same
 (C) decreases to a large extent
 (D) decreases slightly
155. To get a n-type semiconductor from silicon, it should be doped with a substance with valency _____. **[NCERT Exemplar]**
 (A) 2 (B) 1
 (C) 3 (D) 5
156. A positive hole is obtained when Si or Ge is doped with traces of _____.
 (A) P (B) Sb (C) Bi (D) Ga
157. Doping of silicon with boron leads to _____. **[UPSEAT 2004]**
 (A) n-type semiconductor
 (B) p-type semiconductor
 (C) metal
 (D) insulator
158. Which of the following is TRUE about the charge acquired by p-type semiconductors? **[NCERT Exemplar]**
 (A) positive
 (B) neutral
 (C) negative
 (D) depends on concentration of p impurity
159. Extremely pure samples of Ge and Si are poor conductors, but their conductivity increases suddenly on introducing _____ in their crystal lattice.
 (A) As (B) B
 (C) Al (D) All of these
160. p-n-p or n-p-n sandwich semiconductors are used _____.
 (A) for making electronic components
 (B) to detect or amplify radio or audio signals
 (C) both (A) and (B)
 (D) none of these
161. A solar cell _____.
 (A) converts radiant energy into electrical energy
 (B) converts radiant energy into chemical energy
 (C) converts radiant energy into mechanical energy
 (D) converts electrical energy into radiant energy
162. Which of the following statements is/are CORRECT regarding solid state materials based on combination of Group 12 – Group 16 elements?
 (A) These materials simulate the average valence of three.
 (B) In the compounds formed by the combination of Group 12 – 16 elements, bonds are purely covalent.
 (C) In the compounds formed by the combination of Group 12–16 elements, the percent ionic character of the bonds between the elements depend upon the difference in their electronegativities.
 (D) All of these



163. Match the following:

	Column I		Column II
i.	Temperature dependent metallic or insulating properties	a.	HgTe
ii.	Group 12 – Group 16 compound	b.	ReO ₃
iii.	Group 13 – Group 15 compound	c.	VO ₂
iv.	Conductivity comparable to metallic copper	d.	GaAs

- (A) (i) – (d), (ii) – (a), (iii) – (b), (iv) – (c)
 (B) (i) – (c), (ii) – (a), (iii) – (d), (iv) – (b)
 (C) (i) – (a), (ii) – (d), (iii) – (b), (iv) – (c)
 (D) (i) – (c), (ii) – (b), (iii) – (a), (iv) – (d)

164. Which of the following oxides behaves as conductor or insulator depending upon temperature?

[NCERT Exemplar]

- (A) TiO (B) SiO₂
 (C) TiO₃ (D) MgO

1.14 Magnetic properties of solids

165. Each electron has permanent _____.

- (A) spin magnetic moment
 (B) orbital magnetic moment
 (C) both (A) and (B)
 (D) none of these

166. The materials which are weakly repelled by the magnetic field are known as _____.

- (A) diamagnetic materials
 (B) paramagnetic materials
 (C) ferromagnetic materials
 (D) ferrimagnetic materials

167. Which one of the following is NOT a diamagnetic material?

- (A) NaCl (B) water
 (C) benzene (D) O₂

168. Which of the following statements is TRUE?

- (A) Paramagnetic substances are attracted by the magnetic field.
 (B) Paramagnetic substance are strongly repelled by the magnetic field.
 (C) Paramagnetic substances are neither attracted nor repelled by the magnetic field.

(D) Paramagnetic substances are either attracted or repelled by the magnetic field.

169. Which of the following is paramagnetic?

- (A) H₂O (B) Gd
 (C) CrO₂ (D) Cr³⁺

170. A ferromagnetic substance becomes a permanent magnet when it is placed in a magnetic field because _____.

[NCERT Exemplar]

- (A) all the domains get oriented in the direction of magnetic field
 (B) all the domains get oriented in the direction opposite to the direction of magnetic field
 (C) domains get oriented randomly
 (D) domains are not affected by magnetic field





171. Select a ferromagnetic material from the following.

[MH CET 2015]

- (A) Dioxide
 (B) Chromium (IV) oxide
 (C) Benzene
 (D) Dihydrogen monoxide

172. Which of the following arrangements shows schematic alignment of magnetic moments of antiferromagnetic substances?

[NCERT Exemplar]

- (A) 
 (B) 
 (C) 
 (D) 

173. Which of the following substance possesses antiferromagnetic property?

- (A) Fe₃O₄ (B) CrO₂
 (C) H₂O (D) MnO

174. A crystal of Fe₃O₄ is _____.

- (A) paramagnetic
 (B) diamagnetic
 (C) ferromagnetic
 (D) ferrimagnetic



175. **Assertion:** Ferrites like MgFe_2O_4 and ZnFe_2O_4 are weakly attracted by magnetic field as compared to ferromagnetic substances.

Reason: In ferrimagnetic substances, the magnetic moments of the domains are oppositely oriented and net magnetic moment is zero.

- (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
 (B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
 (C) Assertion is true, Reason is false.
 (D) Assertion is false, Reason is true.

Miscellaneous

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

- (A) Ionic solid (B) Covalent solid
 (C) Metallic solid (D) Molecular solid

177. For the various types of interactions the CORRECT order of increasing strength is:

- (A) covalent < hydrogen bonding < van der Waals < dipole-dipole
 (B) van der Waals < hydrogen bonding < dipole-dipole < covalent
 (C) van der Waals < dipole-dipole < hydrogen bonding < covalent
 (D) dipole-dipole < van der Waals < hydrogen bonding < covalent

178. Which of the following is NOT a property of solids? **[MP PET 1995]**

- (A) Solids are always crystalline in nature.
 (B) Solids have high density and low compressibility.
 (C) The diffusion of solids is very slow.
 (D) Solids have definite volume.

179. Which of the following is TRUE about the value of refractive index of quartz glass?

[NCERT Exemplar]

- (A) Same in all directions
 (B) Different in different directions
 (C) Cannot be measured
 (D) Always zero

180. Among the following which solid will be soft and have low melting point?

- (A) Covalent
 (B) Ionic
 (C) Metallic
 (D) Molecular

181. Which of the following statement is NOT true about amorphous solids?

[NCERT Exemplar]

- (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.

182. The contribution of particle at the edge centre to a particular unit cell is _____.

[KCET 2016]

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

183. Potassium has a bcc structure with nearest neighbour distance 4.52 Å. Its atomic weight is 39. Its density (in kg m^{-3}) will be _____.

[AIIMS 1991]

- (A) 454.36 (B) 804.64
 (C) 852.13 (D) 910.63

184. In which pair most efficient packing is present?

[NCERT Exemplar]

- (A) hcp and bcc
 (B) hcp and ccp
 (C) bcc and ccp
 (D) bcc and simple cubic cell

185. The percentage of empty space in a body-centred cubic arrangement is _____.

[NCERT Exemplar]

- (A) 74 (B) 68
 (C) 32 (D) 26

186. The number of octahedral sites per sphere in a fcc structure is _____. **[MP PMT 2000,01]**

- (A) 8 (B) 4 (C) 2 (D) 1

187. How many atoms are there in a unit cell of Mg which forms hexagonal crystals, there being a face-centred atom in each end of the unit cell and 3 completely enclosed atoms within the unit cell ?

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

188. Silicon is found in nature in the form of _____.

[MH CET 2002]

- (A) body-centred cubic structure
 (B) hexagonal close-packed structure
 (C) network solid
 (D) face-centred cubic structure



189. Na and Mg crystallize in bcc and fcc type crystals, respectively, then the number of atoms of Na and Mg present in the unit cell of their respective crystal is _____.
[AIEEE 2002]
(A) 4 and 2 (B) 9 and 14
(C) 14 and 9 (D) 2 and 4
190. How many chloride ions are there around sodium ion in sodium chloride crystal?
[NCERT 1979, 80; CPMT 1988; SHU 1982, 87; MP PET 1995, 99]
(A) 3 (B) 8
(C) 4 (D) 6
191. 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 = $6.02 \times 10^{23} \text{ mol}^{-1}$)
[NEET 2013]
(A) 40 g mol^{-1} (B) 30 g mol^{-1}
(C) 27 g mol^{-1} (D) 20 g mol^{-1}
192. The number of tetrahedral voids in the unit cell of a face-centred cubic lattice of similar atoms is _____.
[Kerala PMT 2004]
(A) 4 (B) 6 (C) 8 (D) 10
193. The ratio of close-packed atoms to tetrahedral holes in cubic close packing is _____.
[Pb. PMT 1998]
(A) 1 : 1 (B) 1 : 2
(C) 1 : 3 (D) 2 : 1
194. In cubic closest packing (ccp) structure of NaCl, the coordination number of Na^+ ion is _____.
[PM PET 1996]
(A) 2 (B) 4
(C) 6 (D) 8
195. In calcium fluoride, having the fluorite structure, the coordination numbers for calcium ion (Ca^{2+}) and fluoride ion (F^-) are _____ respectively.
[NEET P-II 2016]
(A) 4 and 8 (B) 4 and 2
(C) 6 and 6 (D) 8 and 4
196. A crystalline solid XY_3 has ccp arrangement for its element Y. X occupies _____.
[KCET 2014]
(A) 66% of tetrahedral voids
(B) 33% of tetrahedral voids
(C) 66% of octahedral voids
(D) 33% of octahedral voids
197. A solid has a structure in which 'W' atoms are located at the corners of a cubic lattice, 'O' atoms at the centre of edges and 'Na' atoms at the centre of the cube. The formula for the compound is _____.
[KCET 1996]
(A) NaWO_2 (B) NaWO_3
(C) Na_2WO_3 (D) NaWO_4
198. The atoms of element 'Y' form hexagonal close packing and the atoms of element X occupies $\frac{2}{3}$ rd portion of the number of tetrahedral voids. Write the formula of the compound formed by X and Y.
[GUJ CET 2014]
(A) X_2Y_2 (B) X_2Y
(C) X_3Y_4 (D) X_4Y_3
199. The number of atoms in 100 g of an fcc crystal with density $d = 10 \text{ g cm}^{-3}$ and cell edge equal to 100 pm, is equal to _____.
[CBSE PMT 1994; KCET 2002]
(A) 4×10^{25} (B) 3×10^{25}
(C) 2×10^{25} (D) 1×10^{25}
200. The density of KBr is 2.75 g cm^{-3} . Length of the unit cell is 654 pm. $K = 39$, $\text{Br} = 80$. Then which of the following is TRUE about the predicted nature of the solid?
(A) Solid has face-centred cubic system with $Z = 4$.
(B) Solid has simple cubic system with $Z = 4$.
(C) Solid has face-centred cubic system with $Z = 1$.
(D) Solid has body-centred cubic system with $Z = 2$.
201. Suppose the mass of a single Ag atom is 'm'. Ag metal crystallizes in fcc lattice with unit cell of length 'a'. The density of Ag metal in terms of 'a' and 'm' is _____. [WB JEEM 2015]
(A) $\frac{4m}{a^3}$ (B) $\frac{2m}{a^3}$
(C) $\frac{m}{a^3}$ (D) $\frac{m}{4a^3}$
202. A metal crystallises in body-centred cubic lattice with unit cell edge 0.429 nm. Density of the metal, if it contains 0.1 % Schottky defects, will be _____ g cm^{-3} . (Atomic mass of the metal = 27)
(A) 2.281 (B) 1.721
(C) 2.269 (D) 3.324



203. A compound ABX_4 (molecular weight 22 g mol^{-1}) crystallises in an orthorhombic system having 4 molecules per unit cell. The dimensions of unit cell are: $a = 5.42 \text{ \AA}$, $b = 4.4 \text{ \AA}$, $c = 6.83 \text{ \AA}$. This crystal will have a density of _____ g cm^{-3} .
 (A) 0.895 (B) 0.943
 (C) 5.421 (D) 8.95
204. Frenkel defect is caused due to _____.
[MP PET 1994]
 (A) an ion missing from the normal lattice site creating a vacancy
 (B) an extra positive ion occupying an interstitial position in the lattice
 (C) an extra negative ion occupying an interstitial position in the lattice
 (D) the shift of a positive ion from its normal lattice site to an interstitial site
205. The white ZnO turns yellow on heating because of _____.
 (A) Frenkel defect
 (B) metal excess defect
 (C) metal deficiency defect
 (D) Schottky defect
206. Which of the following defect is seen in FeO ?
[GUJ CET 2015]
 (A) Metal excess defect
 (B) Metal deficiency defect
 (C) Displacement defect
 (D) Impurity defect
207. Silicon doped with electron-rich impurity forms _____.
[NCERT Exemplar]
 (A) p-type semiconductor
 (B) n-type semiconductor
 (C) intrinsic semiconductor
 (D) insulator
208. The dielectric constant of the crystal increases due to closeness of similar charges in _____.
 (A) Frenkel defect
 (B) Schottky defect
 (C) both Frenkel and Schottky defect
 (D) none of these
209. Schottky defect is observed in crystals when _____.
[NCERT Exemplar]
 (A) some cations move from their lattice site to interstitial sites
 (B) equal number of cations and anions are missing from the lattice
 (C) some lattice sites are occupied by electrons
 (D) some impurity is present in the lattice
210. Which kind of defects are introduced by doping?
[NCERT Exemplar]
 (A) Dislocation defect
 (B) Schottky defect
 (C) Frenkel defects
 (D) Electronic defects
211. Band theory of metals is based on _____.
 (A) valence bond theory
 (B) molecular orbital theory
 (C) crystal field theory
 (D) ligand field theory
212. Which of the following solids is NOT an electrical conductor?
[NCERT Exemplar]
 (i) $\text{Mg}_{(s)}$ (ii) $\text{TiO}_{(s)}$
 (iii) $\text{I}_{2(s)}$ (iv) $\text{H}_2\text{O}_{(s)}$
 (A) (i) only
 (B) (ii) only
 (C) (iii) and (iv)
 (D) (ii), (iii) and (iv)
213. **Assertion:** Graphite and diamond are two allotropes of carbon but possess different physical and electrical properties.
Reason: Hybridisation of carbon atom is responsible for the nature of bonding and resulting material properties in its allotropes.
 (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
 (B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
 (C) Assertion is true, Reason is false.
 (D) Assertion is false, Reason is true.
214. To get a n-type semiconductor, the impurity to be added to silicon should have which of the following number of valence electrons?
[KCET (Engg.) 2001]
 (A) 1 (B) 2
 (C) 3 (D) 5
215. Which of the following oxides shows electrical properties like metals?
[NCERT Exemplar]
 (A) SiO_2 (B) MgO
 (C) $\text{SO}_{2(s)}$ (D) CrO_2



216. Which of the following statements is NOT true? **[NCERT Exemplar]**

- (A) Paramagnetic substances are weakly attracted by magnetic field.
- (B) Ferromagnetic substances cannot be magnetised permanently.
- (C) The domains in antiferromagnetic substances are oppositely oriented with respect to each other.
- (D) Pairing of electrons cancels their magnetic moment in the diamagnetic substances.

217. Which of the following compounds is metallic and ferromagnetic?

[JEE (MAIN) 2016]

- (A) TiO_2 (B) CrO_2
- (C) VO_2 (D) MnO_2

218. Which of the following defects is also known as dislocation defect?

[NCERT Exemplar]

- (A) Frenkel defect
- (B) Schottky defect
- (C) Non-stoichiometric defect
- (D) Simple interstitial defect

219. Match the items given in Column I with the items given in Column II.

	Column I		Column II
i.	Aluminium in solid state	a.	Electrolytic conductor
ii.	Germanium doped with Indium	b.	n-type semiconductor
iii.	Silicon doped with Bismuth	c.	p-type semiconductor
iv.	$\text{Al}(\text{NO}_3)_3$ in molten state	d.	Metallic conductor

- (A) (i) – (c), (ii) – (a), (iii) – (b), (iv) – (d)
- (B) (i) – (d), (ii) – (c), (iii) – (b), (iv) – (a)
- (C) (i) – (a), (ii) – (c), (iii) – (b), (iv) – (d)
- (D) (i) – (b), (ii) – (d), (iii) – (a), (iv) – (c)

220. The lattice site in a pure crystal CANNOT be occupied by _____.

[NCERT Exemplar]

- (A) molecule
- (B) ion
- (C) electron
- (D) atom

221. In which of the following structures coordination number for cations and anions in the packed structure will be same?

[NCERT Exemplar]

- (A) Cl^- ion form fcc lattice and Na^+ ions occupy all octahedral voids of the unit cell.
- (B) Ca^{2+} ions form fcc lattice and F^- ions occupy all the eight tetrahedral voids of the unit cell.
- (C) O^{2-} ions form fcc lattice and Na^+ ions occupy all the eight tetrahedral voids of the unit cell.
- (D) S^{2-} ions form fcc lattice and Zn^{2+} ions go into alternate tetrahedral voids of the unit cell.

222. Which of the following statement is NOT true about the hexagonal close packing?

[NCERT Exemplar]

- (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.

223. Cations are present in the interstitial sites in _____.

[NCERT Exemplar]

- (A) Frenkel defect
- (B) Schottky defect
- (C) Vacancy defect
- (D) Metal deficiency defect

**Answers to MCQs**

- | | | | | | | | | | |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 1. (A) | 2. (D) | 3. (B) | 4. (A) | 5. (B) | 6. (D) | 7. (D) | 8. (C) | 9. (B) | 10. (B) |
| 11. (B) | 12. (C) | 13. (B) | 14. (D) | 15. (D) | 16. (A) | 17. (D) | 18. (A) | 19. (D) | 20. (A) |
| 21. (D) | 22. (B) | 23. (C) | 24. (B) | 25. (A) | 26. (C) | 27. (B) | 28. (C) | 29. (A) | 30. (D) |
| 31. (B) | 32. (C) | 33. (A) | 34. (C) | 35. (B) | 36. (A) | 37. (A) | 38. (C) | 39. (D) | 40. (D) |
| 41. (B) | 42. (B) | 43. (A) | 44. (A) | 45. (B) | 46. (A) | 47. (B) | 48. (B) | 49. (B) | 50. (B) |
| 51. (A) | 52. (B) | 53. (B) | 54. (C) | 55. (D) | 56. (B) | 57. (C) | 58. (B) | 59. (B) | 60. (B) |
| 61. (A) | 62. (C) | 63. (C) | 64. (B) | 65. (B) | 66. (A) | 67. (B) | 68. (B) | 69. (D) | 70. (C) |
| 71. (C) | 72. (A) | 73. (A) | 74. (B) | 75. (B) | 76. (A) | 77. (C) | 78. (C) | 79. (B) | 80. (C) |
| 81. (B) | 82. (B) | 83. (B) | 84. (C) | 85. (D) | 86. (C) | 87. (D) | 88. (B) | 89. (D) | 90. (B) |
| 91. (D) | 92. (A) | 93. (C) | 94. (B) | 95. (B) | 96. (D) | 97. (C) | 98. (C) | 99. (D) | 100. (A) |
| 101. (C) | 102. (A) | 103. (B) | 104. (C) | 105. (B) | 106. (B) | 107. (A) | 108. (A) | 109. (B) | 110. (C) |
| 111. (A) | 112. (B) | 113. (C) | 114. (C) | 115. (B) | 116. (A) | 117. (C) | 118. (B) | 119. (D) | 120. (A) |
| 121. (A) | 122. (A) | 123. (C) | 124. (A) | 125. (A) | 126. (D) | 127. (C) | 128. (A) | 129. (B) | 130. (D) |
| 131. (C) | 132. (A) | 133. (C) | 134. (C) | 135. (A) | 136. (C) | 137. (C) | 138. (D) | 139. (A) | 140. (D) |
| 141. (C) | 142. (A) | 143. (A) | 144. (D) | 145. (A) | 146. (B) | 147. (A) | 148. (D) | 149. (C) | 150. (A) |
| 151. (A) | 152. (C) | 153. (A) | 154. (A) | 155. (D) | 156. (D) | 157. (B) | 158. (B) | 159. (D) | 160. (C) |
| 161. (A) | 162. (C) | 163. (B) | 164. (C) | 165. (C) | 166. (A) | 167. (D) | 168. (A) | 169. (D) | 170. (A) |
| 171. (B) | 172. (D) | 173. (D) | 174. (D) | 175. (C) | 176. (D) | 177. (C) | 178. (A) | 179. (A) | 180. (D) |
| 181. (D) | 182. (B) | 183. (D) | 184. (B) | 185. (C) | 186. (D) | 187. (B) | 188. (C) | 189. (D) | 190. (D) |
| 191. (C) | 192. (C) | 193. (B) | 194. (C) | 195. (D) | 196. (D) | 197. (B) | 198. (D) | 199. (A) | 200. (A) |
| 201. (A) | 202. (C) | 203. (A) | 204. (D) | 205. (B) | 206. (B) | 207. (B) | 208. (A) | 209. (B) | 210. (D) |
| 211. (B) | 212. (C) | 213. (A) | 214. (D) | 215. (D) | 216. (B) | 217. (B) | 218. (A) | 219. (B) | 220. (C) |
| 221. (A) | 222. (D) | 223. (A) | | | | | | | |

**Hints to MCQs**

- | | |
|--|---|
| <p>3. Lowering the temperature of a substance reduces the thermal energy of its particles. This allows the intermolecular forces to hold the particles close to each other and occupy fixed positions with respect to each other. The particles may still be able to oscillate about their mean positions, however, the substance will now exist in the solid state.</p> <p>4. A crystalline solid has long range order and amorphous solid has short range order.</p> <p>6. Sugar is a crystalline solid while glass, rubber and plastic are amorphous solids.</p> <p>8. Amorphous solids neither have ordered arrangement (i.e. no definite shape) nor have sharp melting point like crystals, but when heated, they become pliable until they assume the properties usually related to liquids. It is therefore, that they are regarded as super-cooled liquids.</p> <p>10. Amorphous solids are isotropic, as these substances show same properties in all directions.</p> | <p>15. Crystals show good cleavage because their constituent particles are arranged in planes (i.e., in a regular pattern).</p> <p>18. Solid I_2 is a non-polar molecular solid in which constituent particles are non-polar molecules held by weak dispersion forces or London forces.</p> <p>24. LiF is an example of ionic crystal solid, in which constituent particles are positive (Li^+) and negative (F^-) ions.</p> <p>29. Metallic solids contain metallic bonds which are stronger than ionic and covalent bonds. Hence, metallic solids are tougher than other solids.</p> <p>30. Metals contain free electrons which absorb light at one angle and transmit at a different angle. Hence, metals have lustre.</p> <p>40. Graphite is a covalent or network solid and is a good conductor of electricity. Hence, (D) is the right option.</p> |
|--|---|



42. Non-polar molecular solids contain only dispersion or London forces. Hence, they have very low melting points.
45. $n = 1, \lambda = 1.54 \text{ \AA}, d = 2.01 \text{ \AA}$
According to the Bragg's equation,
 $n\lambda = 2d \sin \theta$
 $\sin \theta = \frac{n\lambda}{2d} = \frac{1 \times 1.54}{2 \times 2.01}$
 $\sin \theta = 0.383 \quad \therefore \theta = 22.5^\circ$
46. $n = 1, \lambda = 1.54 \text{ \AA}, \theta = 11.29^\circ$
According to the Bragg's equation,
 $n\lambda = 2d \sin \theta$
 $d = \frac{n\lambda}{2 \sin \theta} = \frac{1 \times 1.54}{2 \times \sin 11.29^\circ} = \frac{1.54}{2 \times 0.1957} = 3.93 \text{ \AA}$
47. $n = 1, d = 2 \text{ \AA}, \theta = 9^\circ$
According to the Bragg's equation,
 $n\lambda = 2d \sin \theta$
 $\lambda = \frac{2d \sin \theta}{n} = \frac{2 \times 2 \times \sin 9^\circ}{1} = 4 \times 0.1564$
 $= 0.6256 \text{ \AA}$
54. Orthorhombic geometry has unit cell dimensions, $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$. The shape of a match box obeys this geometry.
61. The cubic system has all the three sides equal ($a = b = c$) and all the angles equal ($\alpha = \beta = \gamma = 90^\circ$). Hence, it is the most symmetrical crystal system.
62. The triclinic system has all the three sides different ($a \neq b \neq c$) and all the three angles different ($\alpha \neq \beta \neq \gamma \neq 90^\circ$). Hence, it is the most unsymmetrical crystal system.
66. There are two atoms in a bcc unit cell.
So, number of atoms in 12.08×10^{23} unit cells
 $= 2 \times 12.08 \times 10^{23} = 24.16 \times 10^{23}$ atoms.
69. Face-centred cubic structure has contribution of $1/8$ by each atom present at the corner and $1/2$ by each atom present at the face.
72. Number of atoms per unit cell in fcc = 4
Number of atoms per unit cell in bcc = 2
 \therefore Difference = $4 - 2 = 2$
73. The linear packing arrangement of the constituent particles (spheres) of a crystalline solid is done in one dimension and hence can be done in only one way.
92. A atoms are at eight corners of the cube. Therefore, the number of A atoms in the unit cell $= \frac{8}{8} = 1$, B atoms are at the centre of the cube. Therefore, B atoms per unit cell = 1. Hence, the formula is AB.
93. One-eighth of each corner atom (Au) and one half of each face-centered atom (Cu) are contained within the unit cell of the compound. Thus, the number of Au atoms per unit cell $= 8 \times \frac{1}{8} = 1$ and the number of Cu atoms per unit cell $= 6 \times \frac{1}{2} = 3$. The formula of the compound is AuCu_3 .
94. The number of 'Y' atoms in ccp unit cell, $n = 4$
Number of 'X' atoms
 $= \frac{1}{3} \times \text{Number of tetrahedral voids}$
 $= \frac{1}{3} \times 2n = \frac{1}{3} \times 2 \times 4 = \frac{8}{3}$
 \therefore The ratio of number of atoms of 'X' to the number of atoms of 'Y' $= \frac{8}{3} : 4 = 8 : 12$
 $= 2 : 3$
Hence, the molecular formula of the given compound is X_2Y_3 .
95. The number of ions of 'Y' in ccp unit cell = 4.
Number of octahedral voids in ccp unit cell = Number of ions of 'Y' in ccp unit cell = 4
Since, ions of 'X' occupy all the octahedral voids, the number of ions of 'X' in ccp unit cell = 4
 \therefore The ratio of number of ions of 'X' to the number of ions of 'Y' = $4 : 4$ i.e., $1 : 1$.
Hence, the molecular formula of the given compound is XY.
96. The fraction of octahedral or tetrahedral voids occupied depends upon the stoichiometry or chemical formula of the ionic compound.
97. For ionic solids, radius ratio $= \frac{r^+}{r^-} = \frac{A^+}{B^-}$
 $= \frac{0.98 \times 10^{-10} \text{ m}}{1.81 \times 10^{-10} \text{ m}}$
 $= 0.541$
 \Rightarrow Coordination number = 6



∴ For the given ionic solid, A^+B^- , having equal number of cations and anions, the coordination number of each ion is 6.

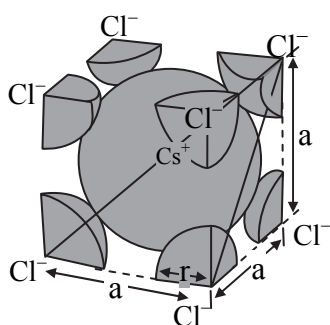
99. Let 'a' represent the edge length of the unit cell and 'r' represent the radius of the sphere.

Since the spheres touch each other,

∴ $a = 2r$

Volume of cubic unit cell $= a^3 = (2r)^3 = 8r^3$

101.



Body-centred unit cell of CsCl crystal

For a body-centred cubic lattice of CsCl with edge length 'a', the length of body diagonal $= \sqrt{3}a$.

But the length of the body diagonal is also equal to $2(r_{Cs^+} + r_{Cl^-})$

$$\therefore 2(r_{Cs^+} + r_{Cl^-}) = \sqrt{3}a$$

$$\text{or } r_{Cs^+} + r_{Cl^-} = \frac{\sqrt{3}}{2}a$$

102. Radius of Na (in bcc lattice)

$$= \frac{\sqrt{3}a}{4} = \frac{\sqrt{3} \times 4.29}{4} = 1.857 \text{ \AA} \approx 1.86 \text{ \AA}$$

103. Volume of unit cell $= a^3 = (3.04 \times 10^{-8} \text{ cm})^3$
 $= 2.81 \times 10^{-23} \text{ cm}^3$

104. According to the given condition,

Edge length (a) $= \sqrt[3]{\text{Volume of one CsCl ion pair}}$

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

$$= 4.12 \times 10^{-8} \text{ cm}$$

$$= 4.12 \times 10^{-10} \text{ m}$$

$$= 4.12 \text{ \AA} \approx 4 \text{ \AA}$$

So, the smallest Cs to Cs internuclear distance is nearly 4 Å.

105. The packing efficiency in bcc unit cell = 68%.

∴ The percentage of vacant space of bcc unit cell $= 100 - 68 = 32\%$.

108. In fcc, $4r = \sqrt{2}a$

where r = radius of the sphere

a = edge length of the unit cell = 620 pm

$$\therefore r = \frac{\sqrt{2}a}{4}; r = \frac{a}{2\sqrt{2}}; r = \frac{620}{2\sqrt{2}} = 219.20 \text{ pm}$$

109. Since, there are four metal atoms in one unit cell, the given metal crystallizes in fcc lattice.

For fcc lattice;

$$r = \frac{\sqrt{2}a}{4} = \frac{\sqrt{2} \times 361}{4} = \frac{1.414 \times 361}{4} = 127.6 \text{ pm} \approx 127 \text{ pm}$$

110. The radius of each atom = r

Number of atoms in a fcc unit cell = 4.

$$\text{Volume of each atom} = \frac{4}{3} \pi r^3$$

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

113.

Type of unit cell	Packing efficiency	Examples
Simple cubic lattice	52.4%	Polonium
Body-centred cubic lattice	68%	Iron, Tungsten
Face-centred cubic lattice	74%	Aluminium

Hence, among the given metals, aluminium has the highest packing efficiency.

$$117. \text{ Density} = \frac{Z \times M}{a^3 \times N_0} \text{ g cm}^{-3}$$

$$7.00 \text{ g cm}^{-3} = \frac{1 \times 239.87 \text{ g mol}^{-1}}{a^3 \times (6.022 \times 10^{23} \text{ mol}^{-1})}$$

$$a^3 = 5.690 \times 10^{-23}$$

$$a = 3.84 \times 10^{-8} \text{ cm}$$

$$118. \text{ Density of unit cell, } d = \frac{Z \times M}{a^3 \times N_0 \times 10^{-30}}$$

(when a is in pm)

$$= \frac{2 \times 100}{(400)^3 \times (6.022 \times 10^{23}) \times 10^{-30}} = 5.189 \text{ g cm}^{-3}$$

119. For bcc structure, Z = 2

$$\text{Density of unit cell, } d = \frac{Z \times M}{a^3 \times N_0 \times 10^{-30}}$$

(when a is in pm)

$$\therefore a = \left(\frac{Z \times M}{d \times N_0 \times 10^{-30}} \right)^{\frac{1}{3}}$$



$$\therefore a = \left(\frac{2 \times 6.94 \text{ g mol}^{-1}}{0.530 \text{ g cm}^{-3} \times 6.02 \times 10^{23} \text{ mol}^{-1} \times 10^{-30}} \right)^{1/3}$$

$$= 351.7 \text{ pm} \approx 352 \text{ pm}$$

120. For fcc unit cell, $Z = 4$

For CuCl, $M = 63.5 + 35.5 = 99 \text{ g mol}^{-1}$

$$\text{Density, } d = \frac{Z \times M}{a^3 \times N_0} \text{ g cm}^{-3}$$

$$a = \left(\frac{Z \times M}{d \times N_0} \right)^{1/3}$$

$$= \left(\frac{4 \times 99 \text{ g mol}^{-1}}{3.4 \text{ g cm}^{-3} \times 6.022 \times 10^{23} \text{ mol}^{-1}} \right)^{1/3}$$

$$= (1.934 \times 10^{-22} \text{ cm}^3)^{1/3} = 5.783 \times 10^{-8} \text{ cm}$$

$$= 5.783 \text{ \AA}$$

121. For fcc unit cell, $Z = 4$

Weight of 24×10^{23} atoms = 200 g

$$\therefore \text{Atomic weight, } M = 200 \text{ g} \times \frac{6.022 \times 10^{23}}{24 \times 10^{23}}$$

$$= 50.18$$

Edge length = $a = 200 \text{ pm}$

$N_0 = 6.022 \times 10^{23} \text{ mol}^{-1}$

$$\text{Density} = \frac{Z \times M}{a^3 \times 10^{-30} \times N_0} \text{ g cm}^{-3}$$

$$\dots \text{ [when } a \text{ is in pm]}$$

$$= \frac{4 \times 50.18}{(200)^3 \times 10^{-30} \times 6.022 \times 10^{23}} = 41.6 \text{ g cm}^{-3}$$

$$122. \text{ Density} = \frac{Z \times M}{a^3 \times N_0} \text{ g cm}^{-3}$$

$$\therefore 4.0 \text{ g cm}^{-3} = \frac{Z \times 72 \text{ g mol}^{-1}}{(5.0 \times 10^{-8} \text{ cm})^3 \times 6.022 \times 10^{23} \text{ mol}^{-1}}$$

$$\therefore Z = 4.18 \approx 4$$

Therefore, the number of ions present in each unit cell will be four Fe^{2+} ions and four O^{2-} ions.

123. For fcc structure, $Z = 4$

Edge length $a = 409 \text{ pm} = 409 \times 10^{-10} \text{ cm}$

$$\text{Density} = \frac{Z \times M}{a^3 \times N_0} \text{ g cm}^{-3}$$

$$= \frac{4 \times 108 \text{ g mol}^{-1}}{(409 \times 10^{-10} \text{ cm})^3 \times 6.022 \times 10^{23} \text{ mol}^{-1}}$$

$$= 10.5 \text{ g cm}^{-3}$$

Thus, the density of face-centred cubic unit cell of Ag is 10.5 g cm^{-3} .

128. Schottky defect is vacancy defect in ionic solids.

131. Frenkel defect is observed in ionic solids, when ions are displaced from their normal crystal sites and occupy interstitial sites.

133. AgBr, AgCl and ZnS exhibit Frenkel defect while KCl exhibits Schottky defect.

138. F-centres are the sites where anions are missing and instead, electrons are present.

158. p-type semiconductors are formed by doping Group 13 elements like Indium (having three valence electrons) into Group 14 elements (such as Si or Ge having four valence electrons). Indium forms three covalent bonds with adjacent Si atoms. Lack of the fourth bond creates electron hole or vacancy. However, the substance as a whole remains neutral. Hence, p-type semiconductors are neutral.

167. NaCl, water and benzene are diamagnetic materials while O_2 is a paramagnetic material.

171.

	Substance	Magnetic property
(A)	Dioxygen	Paramagnetic
(B)	Chromium (IV) oxide	Ferromagnetic
(C)	Benzene	Diamagnetic
(D)	Dihydrogen monoxide	Diamagnetic

172. In antiferromagnetic substances, the magnetic moments of the domains align in such a way that resultant magnetic moment is zero. This is represented by the schematic alignment shown in option (D).

175. In ferrimagnetic substances (**eg.** ferrites like MgFe_2O_4 and ZnFe_2O_4), the magnetic moment of the domains align in such a way that there is a small net magnetic moment due to which these substances are weakly attracted by magnetic field.

178. Some solids are crystalline whereas others are amorphous in nature.

179. Quartz glass is an amorphous solid and hence isotropic in nature. Thus, value of physical properties such as refractive index will be same in all directions.

180. Molecular solids are soft and have low melting point.



182. An edge of a unit cell is shared by four unit cells. Therefore, a particle placed at edge centre will have $\frac{1}{4}^{\text{th}}$ contribution to a particular unit cell.

$$183. d = \frac{\sqrt{3}}{2}a$$

$$\therefore \text{Edge length } a = \frac{2d}{\sqrt{3}} = \frac{2 \times 4.52 \text{ \AA}}{1.732} = 5.22 \text{ \AA}$$

$$= 522 \text{ pm} = 522 \times 10^{-12} \text{ m.}$$

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

$$= \frac{2 \times 39 \times 10^{-3}}{(522 \times 10^{-12})^3 \times (6.022 \times 10^{23})}$$

$$= 910.63 \text{ kg m}^{-3}$$

186. When N spheres are involved in the formation of fcc structure, N octahedral voids are obtained. The number of spheres in fcc unit cell is 4. Hence, the number of octahedral sites per sphere in a fcc structure is 1.

187. 12 atoms are present at 12 corners. Each one contributes $\frac{1}{6}$ to each unit cell. 2 atoms are present at each face. Each one contributes $\frac{1}{2}$ to each unit cell. 3 atoms are completely enclosed within the unit cell.

$$12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 = 2 + 1 + 3 = 6$$

188. In the crystal structure of silicon, atoms are linked together by a continuous system of covalent bonds throughout the crystal forming a giant three dimensional structure. Hence, silicon is found in nature in the form of network solid.

190. In the NaCl crystal, Cl^- ions form ccp arrangement and Na^+ ions occupy octahedral holes. Thus, each Na^+ ion is surrounded by 6 Cl^- ions.

191. Metal has fcc lattice, $\therefore Z = 4$
 The density of the metal, $d = 2.72 \text{ g cm}^{-3}$
 The edge length of the unit cell, $= 404 \text{ pm}$.
 Volume, $V = a^3 = (4.04 \times 10^{-8})^3 \text{ cm}^3$
 Avogadro's constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
 The molar mass of the metal, $M = ?$

$$d = \frac{Z \times M}{V \times N_A}$$

$$\therefore 2.72 = \frac{4 \times M}{(4.04 \times 10^{-8})^3 \times 6.02 \times 10^{23}}$$

$$\therefore M = \frac{2.72 \times (4.04)^3 \times 6.02 \times 10^{-1}}{4} = 27 \text{ g mol}^{-1}.$$

192. A face-centred cubic lattice has 4 atoms per unit cell. There are two tetrahedral voids for each sphere. Hence, the number of tetrahedral voids in the unit cell of a face-centred cubic lattice is $2 \times 4 = 8$.

193. Every constituent atom corresponds to two tetrahedral voids. In ccp, lattice atoms $= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

\therefore Number of tetrahedral voids $= 4 \times 2 = 8$, Thus ratio $= 4 : 8 :: 1 : 2$.

194. In ccp structure of NaCl, Cl^- forms ccp arrangement and each Na^+ ion occupies an octahedral void. Thus, each Na^+ ion is surrounded by 6 Cl^- ions. Thus, the coordination number of Na^+ ions is 6.

195. The Ca^{2+} ions are arranged in (ccp) arrangement, i.e. Ca^{2+} ions are present at all corners and at the centre of each face of the cube. The fluoride ions occupy all the tetrahedral sites. This is 8 : 4 arrangement i.e., each Ca^{2+} ion is surrounded by 8 F^- ions and each F^- ion by four Ca^{2+} ions.

196. The number of particles of Y in ccp unit cell $= 4$. The formula of the solid is XY_3 . Therefore, the ratio of number of X particles to the number of Y particles is 1 : 3. So, for the unit cell, the

$$\text{number of X particles} = \frac{4 \times 1}{3} = 1.33$$

Number of octahedral voids in ccp unit cell $=$ Number of Y particles in ccp unit cell $= 4$

\therefore Percentage of octahedral voids occupied by X particles $= \frac{1.33}{4} \times 100 = 33\%$

197. In a unit cell, W atoms at the corner $= \frac{1}{8} \times 8 = 1$

$$\text{O atoms at the centre of edges} = \frac{1}{4} \times 12 = 3$$

Na atoms at the centre of the cube $= 1$

W : O : Na $= 1 : 3 : 1$, hence formula $= \text{NaWO}_3$



198. Let the number of atoms of element Y in hcp unit cell be n .

\therefore Number of tetrahedral voids = $2n$

As $2/3^{\text{rd}}$ of the tetrahedral voids are occupied by atoms of element X,

$$\text{Number of atoms of element X} = 2n \times \frac{2}{3} = \frac{4n}{3}$$

\therefore Ratio of atoms of element X : atoms of element Y = $\frac{4n}{3} : n = 4 : 3$

The formula of the compound is X_4Y_3 .

199. Density = 10 g/cm^3 , Edge length = 100 pm , $Z = 4$ (fcc structure), $N_0 = 6.022 \times 10^{23} \text{ mol}^{-1}$

$$M = \frac{d \times a^3 \times N_0 \times 10^{-30}}{Z}$$

$$= \frac{10 \times (100)^3 \times (6.022 \times 10^{23}) \times 10^{-30}}{4} = 1.505$$

$$\text{Number of atoms in } 100 \text{ g} = \frac{6.022 \times 10^{23}}{1.505} \times 100$$

$$= 400 \times 10^{23} = 4 \times 10^{25}$$

200. $M = 39 + 80 = 119$

$$\text{Density} = \frac{Z \times M}{a^3 \times 10^{-30} \times N_0} \text{ g cm}^{-3}$$

$$2.75 \text{ g cm}^{-3} = \frac{Z \times 119}{(654)^3 \times 10^{-30} \times 6.023 \times 10^{23}}$$

$$Z = \frac{2.75 \times (654)^3 \times 10^{-30} \times 6.023 \times 10^{23}}{119}$$

$$= 3.89 \approx 4$$

$\therefore Z = 4$

(For fcc $Z = 4$, for simple cubic $Z = 1$)

201. Mass of a single Ag atom = m

\therefore Mass of fcc unit cell of silver = $4m$

(\because fcc type unit cell contains total 4 atoms)

Edge length of fcc unit cell = a

Volume of fcc unit cell = a^3

$$\text{Density of silver (Ag)} = \frac{\text{Mass of fcc unit cell}}{\text{Volume of fcc unit cell}}$$

$$\therefore \text{Density of silver (Ag)} = \frac{4m}{a^3}$$

202. Presence of 0.1% Schottky defect indicates presence of vacancies and hence, corresponding decrease in number of atoms per unit cell, Z .

$$\therefore Z = 4 - \left(\frac{0.1}{100} \times 4 \right) = 3.996$$

$$\text{Density, } d = \frac{ZM}{a^3 N_0} \text{ g cm}^{-3}$$

$$\therefore d = \frac{3.996 \times 27}{(0.429 \times 10^{-7} \text{ cm})^3 \times 6.022 \times 10^{23}}$$

$$= 2.269 \text{ g cm}^{-3}$$

203. For an orthorhombic cell, $\alpha = \beta = \gamma = 90^\circ$

$$\therefore \text{Volume of unit cell} = a \times b \times c$$

$$= (5.42 \times 10^{-8} \text{ cm}) \times (4.41 \times 10^{-8} \text{ cm})$$

$$\times (6.83 \times 10^{-8} \text{ cm})$$

$$= 1.63 \times 10^{-22} \text{ cm}^3$$

$$\therefore \text{Density, } d = \frac{ZM}{(a \times b \times c) N_0} \text{ g cm}^{-3}$$

$$= \frac{4 \times 22}{1.63 \times 10^{-22} \times 6.022 \times 10^{23}}$$

$$= 0.895 \text{ g cm}^{-3}$$

208. The closeness of similar charges in Frenkel defects tends to increase the dielectric constant of the crystals.

210. Extrinsic semiconductors are obtained on doping pure intrinsic semiconductor with electron rich or electron deficient impurities. This introduces electronic defects in the original lattice structure.

214. For n-type, impurity added to silicon should have more than 4 valence electrons.

220. A pure i.e., defect-free crystal can only have molecules, ions or atoms occupying its lattice sites. Hence, (C) is the right option.

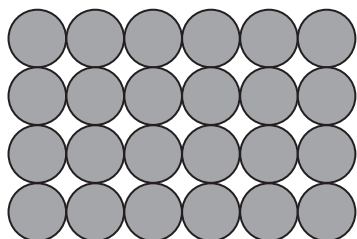


Topic Test

1. A metal atom having radius 135 pm crystallises in bcc structure. The ratio of edge length to the body diagonal of the unit cell is _____.

(A) 1 : 0.577 (B) 1 : 1.732
(C) 1 : 1.414 (D) 1 : 2.309

2. The planar packing arrangement shown in the following figure is _____.



(A) AAAA type, simple cubic structure
(B) ABAB type, hexagonal close packing
(C) AAAA type, square close packing
(D) ABCABC type, cubic close packed structure

3. Which of the following is INCORRECT for substances that exist in solid state?

(A) They are incompressible.
(B) The intermolecular forces between the particles are weak.
(C) The intermolecular distances between the particles are short.
(D) They have definite mass.

4. The crystal system of compound with unit cell dimensions $a = b = c$, $\alpha = \beta = \gamma \neq 90^\circ$ is _____.

(A) orthorhombic
(B) rhombohedral
(C) triclinic
(D) tetragonal

5. The ability of crystalline solids to change values of physical properties when measured in different directions is called _____.

(A) isotropy
(B) anisotropy
(C) isomerism
(D) none of the above

6. The number of octahedral voids in a unit cell of a cubic close packed structure is _____.

(A) 1 (B) 2
(C) 4 (D) 8

7. Rubber is _____.

(A) a metallic conductor
(B) a semiconductor
(C) an insulator
(D) electrolytic conductor

8. _____ arises when the magnetic moments, of the domains are aligned in parallel and anti-parallel directions in equal numbers.

(A) Paramagnetism
(B) Ferromagnetism
(C) Antiferromagnetism
(D) Ferrimagnetism

9. A crystalline solid _____.

(A) changes abruptly from solid to liquid when heated
(B) has no definite melting point
(C) undergoes deformation of its geometry easily
(D) has an irregular 3-dimensional arrangement

10. In the planar packing arrangement in two dimensions, the coordination number of spheres in the hexagonal closed packed structure is _____.

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

11. Crystallization of molten NaCl containing a little amount of SrCl_2 results in _____.

(A) impurity defect
(B) Frenkel defect
(C) Schottky defect
(D) interstitial defect

12. In graphite, adjacent layers of carbon atoms are held together by _____.

(A) weak van der Waals forces of attraction
(B) covalent bonds
(C) hydrogen bonds
(D) dipole-dipole interactions

13. Al (at. wt. 26.98) crystallizes in the cubic system with $a = 4.05 \text{ \AA}$. Its density is 2.7 g per cm^3 . The cell type and the radius of Al atom are _____ respectively.

(A) fcc, 1.432 \AA (B) bcc, 2.432 \AA
(C) bcc, 1.432 \AA (D) fcc, 2.432 \AA



14. Which of the following is NOT CORRECT for ionic solids?
- (A) They possess high melting points.
 (B) They possess positively and negatively charged ions.
 (C) They are hard and brittle.
 (D) They have very low boiling points.
15. Match the defects given in Column I with the statements in given Column II.

No.	Column I		Column II
i.	Schottky defect	a.	Imperfection in non-ionic solids which increases density of the solid.
ii.	Simple interstitial defect	b.	Imperfection in non-ionic solids which decreases density of the solid.
iii.	Frenkel defect	c.	Imperfection in ionic solids which causes a decrease in density of the solid.
iv.	Simple vacancy defect	d.	Imperfection in ionic solids in which density of the solid remains the same.

- (A) (i) – (b), (ii) – (d), (iii) – (a), (iv) – (c)
 (B) (i) – (a), (ii) – (b), (iii) – (d), (iv) – (c)
 (C) (i) – (c), (ii) – (a), (iii) – (d), (iv) – (b)
 (D) (i) – (d), (ii) – (c), (iii) – (a), (iv) – (b)

16. An atom is situated at the corner of a simple cubic unit cell. Its contribution towards the unit cell is _____.
 (A) $1/2$ (B) $1/4$
 (C) $1/6$ (D) $1/8$
17. The atomic radius of niobium having bcc unit cell and density 8.55 g cm^{-3} (atomic weight of niobium is 93 u) is _____.
 (A) 2.62 \AA (B) 3.3 \AA
 (C) 1.13 \AA (D) 1.43 \AA
18. Close packing is maximum in the crystal lattice of _____.
 (A) simple cubic (B) face-centred
 (C) body-centred (D) none of these

19. Cr crystallizes in bcc structure with edge length 289 pm. Calculate the density of Cr. (Atomic mass of Cr = 52 g mol^{-1} , $N_0 = 6.022 \times 10^{23} \text{ mol}^{-1}$)
 (A) 6.23 g cm^{-3} (B) 7.15 g cm^{-3}
 (C) 8.25 g cm^{-3} (D) 9.16 g cm^{-3}
20. Which amongst the following is diamagnetic?
 (A) Co (B) Fe^{3+}
 (C) NaCl (D) Magnetite



Answers to Topic Test

1. (B) 2. (C) 3. (B) 4. (B)
 5. (B) 6. (C) 7. (C) 8. (C)
 9. (A) 10. (C) 11. (A) 12. (A)
 13. (A) 14. (D) 15. (C) 16. (D)
 17. (D) 18. (B) 19. (B) 20. (C)