

CHAPTER-1-SOLID STATE

We are mostly surrounded by solids and we use them more often than liquids and gases. For different applications we need solids with widely different properties. These properties depend upon the nature of constituent particles and the binding forces operating between them.

We know that liquids and gases are called *fluids* because of their ability to flow. The fluidity in both of these states is due to the fact that the molecules are free to move about. On the contrary, **the constituent particles in solids have fixed positions and can only oscillate about their mean positions.** This explains the rigidity in solids.

Crystalline solid-

- crystalline solid usually consists of a large number of small crystals, each of them having a definite characteristic geometrical shape. In a crystal, the arrangement of constituent particles (atoms, molecules or ions) is ordered.
- It has long range order which means that there is a regular pattern of arrangement of particles which repeats itself periodically over the entire crystal.
- Crystalline solids have a sharp melting point.
- **Crystalline solids are *anisotropic* in nature, that is, some of their physical properties like electrical resistance or refractive index show different values when measured along different directions in the same crystals.** This arises from different arrangement of particles in different directions. Crystalline solids are *anisotropic* in nature, that is, some of their physical properties like electrical resistance or refractive index show different values when measured along different directions in the same crystals. This arises from different arrangement of particles in different directions.
- When cut with a sharp edged tool, they split into two pieces and the newly generated surfaces are plain and smooth.
- They have a definite and characteristic heat of fusion.
- Sodium chloride and quartz are typical examples of crystalline solids.

Amorphous Solid-

- An amorphous solid (Greek *amorphos* = no form) consists of particles of irregular shape. The arrangement of constituent particles (atoms, molecules or ions) in such a solid has only *short range order*. In such an arrangement, a regular and periodically repeating pattern is observed over short distances only. Such portions are scattered and in between the arrangement is disordered.
- Amorphous solids soften over a range of temperature and can be moulded and blown into various shapes.
- **Like liquids, amorphous solids have a tendency to flow, though very slowly. Therefore, sometimes these are called *pseudo solids* or *super cooled liquids*.**
- Amorphous solids on the other hand are *isotropic* in nature. It is because there is no *long range* order in them and arrangement is irregular along all the directions. Therefore, value of any physical property would be same along any direction.
- When cut with a sharp edged tool, they cut into two pieces with irregular surfaces.
- They do not have definite heat of fusion. Glass, rubber and plastics find many applications in our daily lives. Amorphous silicon is one of the best photovoltaic material available for conversion of sunlight into electricity.

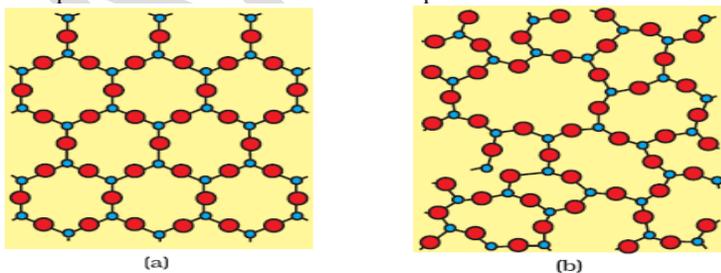


Fig. 1.1: Two dimensional structure of (a) quartz and (b) quartz glass

Classification of Crystalline Solids

Amorphous substances and that they have only short range order. However, most of the solid substances are crystalline in nature. For example, all the metallic elements like iron, copper and silver; non – metallic elements like sulphur, phosphorus and iodine and compounds like sodium chloride, zinc sulphide and naphthalene form crystalline solids. Crystalline solids can be classified on the basis of nature of intermolecular forces operating in them into four categories viz., molecular, ionic, metallic and covalent solid.

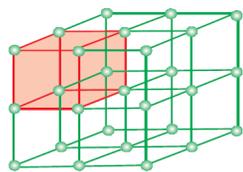
| Type of Solid | Constituent Particles | Bonding/ Attractive Forces | Examples | Physical Nature | Electrical Conductivity | Melting Point |
|--------------------------------|---|---|---|--------------------------------|---|---------------|
| (1) Molecular solids | Molecules | Dispersion or London forces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

Crystal lattice and unit cell

The main characteristic of crystalline solids is a regular and repeating pattern of constituent particles. If the three dimensional arrangement of constituent particles in a crystal is represented diagrammatically, in which each particle is depicted as a point, the arrangement is called *crystal lattice*. Thus, a regular three dimensional arrangement of points in space is called a **crystal lattice**. There are only 14 possible three dimensional lattices. These are called **Bravais Lattices**. The following are the characteristics of a crystal lattice :

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

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



A portion of a three dimensional cubic lattice and its unit cell.

Primitive and Centred Unit Cells

Unit cells can be broadly divided into two categories, primitive and centred unit cells.

(a) Primitive unit cell

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

(b) Centred unit cell

When a unit cell contains one or more constituent particles present at positions other than corners in addition to those at corners, it is called a **centred unit cell**. Centred unit cells are of three types:

(i) **Body-Centred Unit Cells:** Such a unit cell contains one constituent particle (atom, molecule or ion) at its body-centre besides the ones that are at its corners.

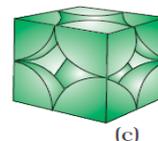
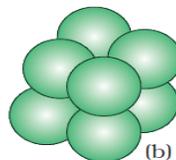
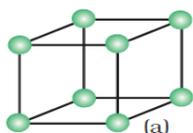
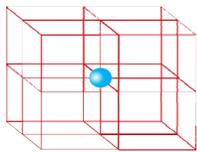
(ii) **Face-Centred Unit Cells:** Such a unit cell contains one constituent particle present at the centre of each face, besides the ones that are at its corners.

(iii) **End-Centred Unit Cells:** In such a unit cell, one constituent particle is present at the centre of any two opposite faces besides the ones present at its corners.

Number of atoms in unit cell

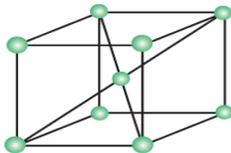
(a) Primitive Cubic Unit Cell

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



since each cubic unit cell has 8 atoms on its corners, the total number of atoms in one unit cell is

(b) Body-Centred Cubic Unit Cell



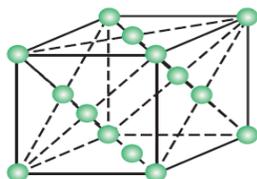
The atom at the body centre wholly belongs to the unit cell in which it is present. Thus in a body-centered cubic (bcc) unit cell:

(i) 8 corners \times per corner atom = $8 \times \frac{1}{8} = 1$ atom

(ii) 1 body centre atom = $1 \times 1 = 1$ atom

Total number of atoms per unit cell = 2 atoms

(c) Face-Centred Cubic Unit Cell



A face-centred cubic (fcc) unit cell contains atoms at all the corners and at the centre of all the faces of the cube. Each atom located at the face-centre is shared between two adjacent unit cells and only $\frac{1}{2}$ of each atom belongs to a unit cell.

Thus, in a face-centred cubic (fcc) unit cell:

(i) 8 corners atoms \times atom per unit cell = $8 \times \frac{1}{8} = 1$ atom

(ii) 6 face-centred atoms \times atom per unit cell = $6 \times \frac{1}{2} = 3$ atoms

Total number of atoms per unit cell = 4 atoms

Closed packed structures

(a) Close packing in one dimensions

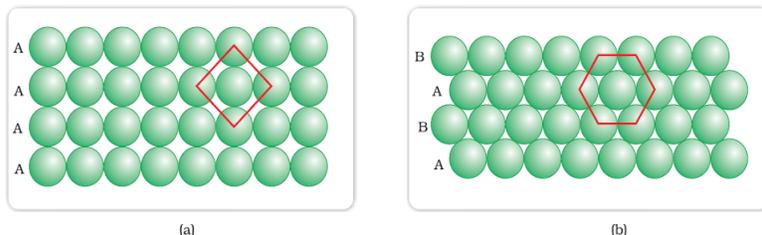


There is only one way of arranging spheres in a one dimensional close packed structure, that is to arrange them in a row and touching each other. In this arrangement, each sphere is in contact with two of its neighbours. The number of nearest neighbours of a particle is called its **coordination number**. Thus, in one dimensional close packed arrangement, the coordination number is 2.

(b) Close packing in two dimensions

Two dimensional close packed structure can be generated by stacking (placing) the rows of close packed spheres. This can be done in two different ways.

(i) The second row may be placed in contact with the first one such that the spheres of the second row are exactly above those of the first row. The spheres of the two rows are aligned horizontally as well as vertically. If we call the first row as 'A' type row, the second row being exactly the same as the first one, is also of 'A' type. Similarly, we may place more rows to obtain AAA type of arrangement. In this arrangement, each sphere is in contact with four of its neighbours. Thus, the two dimensional coordination number is 4. Also, if the centres of these 4 immediate neighbouring spheres are joined, a square is formed. Hence this packing is called **square close packing in two dimensions**.

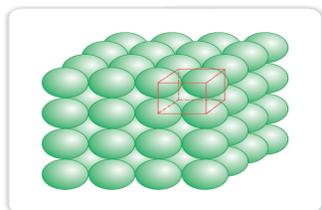


(ii) The second row may be placed above the first one in a staggered manner such that its spheres fit in the depressions of the first row. If the arrangement of spheres in the first row is called 'A' type, the one in the second row is different and may be called 'B' type. When the third row is placed adjacent to the second in staggered manner, its spheres are aligned with those of the first layer. Hence this layer is also of 'A' type. The spheres of similarly placed fourth row will be aligned with those of the second row ('B' type). Hence this arrangement is of ABAB type. In this arrangement there is less free space and this packing is more efficient than the square close packing. Each sphere is in contact with six of its neighbours and the two dimensional coordination number is 6. The centres of these six spheres are at the corners of a regular hexagon hence this packing is called **two dimensional hexagonal close packing**.

(c) Close packing in three dimensions

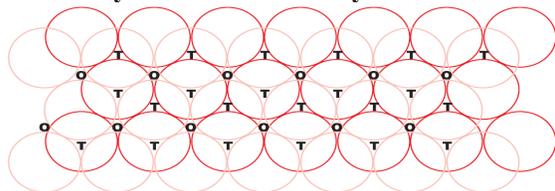
All real structures are three dimensional structures. They can be obtained by stacking two dimensional layers one above the other. Types of three dimensional close packing can be obtained from these.

(i) **Three dimensional close packing from two dimensional square close-packed layers:** While placing the second square close-packed layer above the first we follow the same rule that was followed when one row was placed adjacent to the other. The second layer is placed over the first layer such that the spheres of the upper layer are exactly above those of the first layer. In this arrangement spheres of both the layers are perfectly aligned horizontally as well as vertically. Similarly, we may place more layers one above the other. If the arrangement of spheres in the first layer is called 'A' type, all the layers have the same arrangement. Thus this lattice has AAA.... type pattern. The lattice thus generated is the simple cubic lattice, and its unit cell is the primitive cubic unit cell.

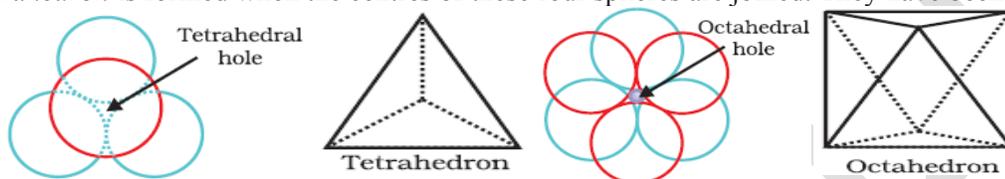


(ii) **Three dimensional close packing from two dimensional hexagonal close packed layers:** Three dimensional close packed structure can be generated by placing layers one over the other.

(a) Placing second layer over the first layer



Let us take a two dimensional hexagonal close packed layer 'A' and place a similar layer above it such that the spheres of the second layer are placed in the depressions of the first layer. Since the spheres of the two layers are aligned differently, let us call the second layer as B. It can be observed that not all the triangular voids of the first layer are covered by the spheres of the second layer. This gives rise to different arrangements. Wherever a sphere of the second layer is above the void of the first layer (or vice versa) a tetrahedral void is formed. These voids are called **tetrahedral voids** because a *tetrahedron* is formed when the centres of these four spheres are joined. They have been marked as 'T' in Fig.



At other places, the triangular voids in the second layer are above the triangular voids in the first layer, and the triangular shapes of these do not overlap. One of them has the apex of the triangle pointing upwards and the other downwards. These voids have been marked as 'O' in Fig. Such voids are surrounded by six spheres and are called **octahedral voids**. The number of these two types of voids depend upon the number of close packed spheres.

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

The number of octahedral voids generated = N

The number of tetrahedral voids generated = $2N$

(b) Placing third layer over the second layer

When third layer is placed over the second, there are two possibilities.

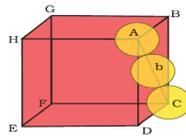
(i) **Covering Tetrahedral Voids:** Tetrahedral voids of the second layer may be covered by the spheres of the third layer. In this case, the spheres of the third layer are exactly aligned with those of the first layer. Thus, the pattern of spheres is repeated in alternate layers. This pattern is often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

(ii) **Covering Octahedral Voids:** The third layer may be placed above the second layer in a manner such that its spheres cover the octahedral voids. When placed in this manner, the spheres of the third layer are not aligned with those of either the first or the second layer. This arrangement is called "C" type. Only when fourth layer is placed, its spheres are aligned with those of the first layer. This pattern of layers is often written as ABCABC This structure is called cubic close packed (*ccp*) or face-centred cubic (*fcc*) structure. Metals such as copper and silver crystallise in this structure. Both these types of close packing are highly efficient and 74% space in the crystal is filled. In either of them, each sphere is in contact with twelve spheres. Thus, the coordination number is 12 in either of these two structures.

Packing Efficiency

In whatever way the constituent particles (atoms, molecules or ions) are packed, there is always some free space in the form of voids. Packing efficiency is the percentage of total space filled by the particles.

Packing Efficiency in *hcp* and *ccp* Structures



Both types of close packing (*hcp* and *ccp*) are equally efficient. Let us calculate the efficiency of packing in *ccp* structure. In Fig. 1.20 let the unit cell edge length be 'a' and face diagonal AC = b.

In ABC

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

$$= a^2 + a^2 = 2a^2 \quad \text{or } b = 2a$$

If *r* is the radius of the sphere, we find, $b = 4r = a$

or $a =$

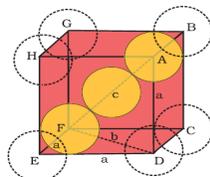
We know, that each unit cell in *ccp* structure, has effectively 4 spheres. Total volume of four spheres is equal to 4

Therefore, Packing efficiency =

=

=

Efficiency of Packing in Body-Centred Cubic Structures



The atom at the centre will be in touch with the other two atoms diagonally arranged.

In EFD, $b^2 = a^2 + a^2 = 2a^2$, $b =$

Now in AFD, $c^2 = a^2 + b^2 = a^2 + 2a^2 = 3a^2$, $C =$,

The length of the body diagonal *c* is equal to $4r$, where *r* is the radius of the sphere (atom), as all the three spheres along the diagonal touch each other.

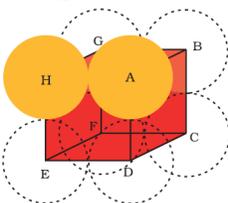
Therefore, $a =$

Packing efficiency =

=

= 68%

Packing Efficiency in Simple Cubic Lattice



In a simple cubic lattice the atoms are located only on the corners of the cube. The particles touch each other along the edge. Thus, the edge length or side of the cube 'a', and the radius of each particle, *r* are related as $a =$

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

Since a simple cubic unit cell contains only 1 atom

The volume of the occupied space =

Packing efficiency =

= =

Calculations Involving Unit cell dimensions

From the unit cell dimensions, it is possible to calculate the volume of the unit cell. Knowing the density of the metal, we can calculate the mass of the atoms in the unit cell. The determination of the mass of a single atom gives an accurate method of determination of Avogadro constant. Suppose, edge length of a unit cell of a cubic crystal determined by X-ray diffraction is *a*, *d* the density of the solid substance and *M* the molar mass. In case of cubic crystal:

Volume of a unit cell = a^3

Mass of the unit cell = number of atoms in unit cell \times mass of each atom = $z \times m$

(Here z is the number of atoms present in one unit cell and m is the mass of a single atom)

Mass of an atom present in the unit cell:

$m =$

Therefore, density of the unit cell =

$$= \frac{z \times m}{a^3} \quad (N_A = 6.022 \times 10^{23})$$

Remember, the density of the unit cell is the same as the density of the substance.

Imperfections in Solids

The defects are basically irregularities in the arrangement of constituent particles. Broadly speaking, the defects are of two types, namely, *point defects* and *line defects*. **Point defects** are the irregularities or deviations from ideal arrangement around a point or an atom in a crystalline substance, whereas the *line defects* are the irregularities or deviations from ideal arrangement in entire rows of lattice points. These irregularities are called *crystal defects*.

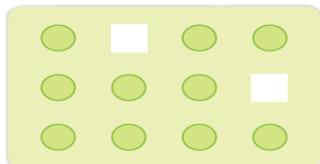
Types of Point Defects

Point defects can be classified into three types : (i) stoichiometric defects (ii) impurity defects and (iii) non-stoichiometric defects.

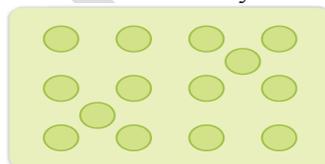
(a) **Stoichiometric defects**:- These are the point defects that do not disturb the stoichiometry of the solid. They are also called *intrinsic* or *thermodynamic defects*. Basically these are of two types, vacancy defects and interstitial defects.

(i) **Vacancy Defect**: When some of the lattice sites are vacant, the crystal is said to have **vacancy defect**. This results in decrease in density of the substance. This defect can also develop when a substance is heated.

(ii) **Interstitial Defect**: When some constituent particles (atoms or molecules) occupy an **interstitial site**, the crystal is said to have **interstitial defect**. This defect increases the density of the substance.



Vacancy defects



Interstitial defects

Vacancy and interstitial defects as explained above can be shown by non-ionic solids.

Ionic solids must always maintain electrical neutrality. Rather than simple vacancy or interstitial defects, they show these defects as **Frenkel and Schottky defects**.

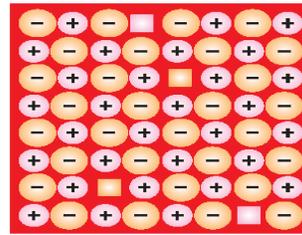
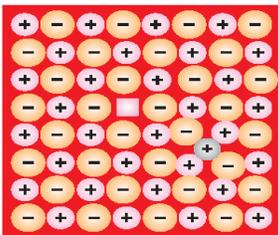
Frenkel defect(Dislocation defect):-

- This defect is shown by ionic solids. The smaller ion (usually cation) is dislocated from its normal site to an interstitial site.
- It creates a *vacancy defect* at its original site and an **interstitial defect** at its new location.
- It does not change the density of the solid.
- Frenkel defect is shown by ionic substance in which there is a large difference in the size of ions, for example, ZnS, AgCl, AgBr and AgI due to small size of Zn^{2+} and Ag^+ ions.

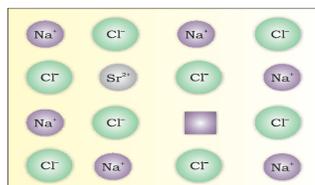
Schottky defect(vacancy defect) :-

- It is basically a vacancy defect in ionic solids. In order to maintain electrical neutrality, the number of missing cations and anions are equal.
- Schottky defect also decreases the density of the substance.

- Schottky defect is shown by ionic substances in which the cation and anion are of almost similar sizes. For example, NaCl, KCl, CsCl and AgBr. It may be noted that AgBr shows both, Frenkel as well as Schottky defect



(b) **Impurity defect** If molten NaCl containing a little amount of SrCl_2 is crystallised, some of the sites of Na^+ ions are occupied by Sr^{2+} . Each Sr^{2+} replaces two Na^+ ions. It occupies the site of one ion and the other site remains vacant. The cationic vacancies thus produced are equal in number to that of Sr^{2+} ions. Another similar example is the solid solution of CdCl_2 and AgCl .



(c) **Non-stoichiometric defects.**

A large number of nonstoichiometric inorganic solids are known which contain the constituent elements in non-stoichiometric ratio due to defects in their crystal structures.

These defects are of two types: (i) metal excess defect and (ii) metal deficiency defect.

(i) **Metal Excess Defect**

Metal excess defect due to anionic vacancies:

- Alkali halides like NaCl and KCl show this type of defect.
- When crystals of NaCl are heated in an atmosphere of sodium vapour, the sodium atoms are deposited on the surface of the crystal. The Cl^- ions diffuse to the surface of the crystal and combine with Na atoms to give NaCl. This happens by loss of electron by sodium atoms to form Na^+ ions. The released electrons diffuse into the crystal and occupy anionic sites. As a result the crystal now has an excess of sodium. The anionic sites occupied by unpaired electrons are called *F-centres* (from the German word *Farbenzenter* for colour centre). They impart yellow colour to the crystals of NaCl. The colour results by excitation of these electrons when they absorb energy from the visible light falling on the crystals.
- Similarly, excess of lithium makes LiCl crystals pink and excess of potassium makes KCl crystals violet (or lilac).

Metal excess defect due to the presence of extra cations at interstitial sites:

Zinc oxide is white in colour at room temperature. On heating it loses oxygen and turns yellow. Now there is excess of zinc in the crystal and its formula becomes Zn_{1+x}O . The excess Zn^{2+} ions move to interstitial sites and the electrons to neighbouring interstitial sites.

(ii) **Metal Deficiency Defect**

There are many solids which are difficult to prepare in the stoichiometric composition and contain less amount of the metal as compared to the stoichiometric proportion. A typical example of this type is FeO which is mostly found with a composition of $\text{Fe}_{0.95}\text{O}$. It may actually range from $\text{Fe}_{0.93}\text{O}$ to $\text{Fe}_{0.96}\text{O}$. In crystals of FeO some Fe^{2+} cations are missing and the loss of positive charge is made up by the presence of required number of Fe^{3+} ions.

Conduction of Electricity in Semiconductors

In case of semiconductors, the gap between the valence band and conduction band is small. Therefore, some electrons may jump to conduction band and show some conductivity. Electrical conductivity of semiconductors increases with rise in temperature, since more electrons can jump to the conduction band. Substances like silicon and germanium show this type of behaviour and are called *intrinsic semiconductors*.

Doping :- The conductivity of these intrinsic semiconductors is too low to be of practical use. Their conductivity is increased by adding an appropriate amount of suitable impurity. This process is called *doping*.

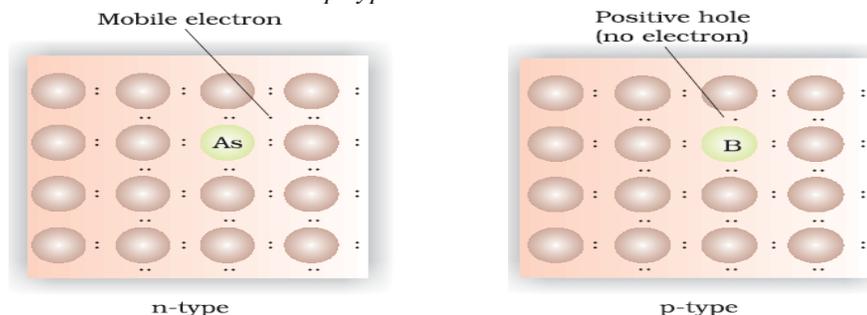
Doping can be done with an impurity which is electron rich or electron deficient as compared to the intrinsic semiconductor silicon or germanium. Such impurities introduce *electronic defects* in them.

(a) Electron rich impurities

Si and Ge doped with a group 15 element like P or As, which contains 5 valence electrons, they occupy some of the lattice sites in Si or Ge crystal. Four out of five electrons are used in the formation of four covalent bonds with the 4 neighbouring silicon atoms. The 5th electron is extra and becomes delocalised. These delocalised electrons increase the conductivity of doped Si (or Ge). Here the increase in conductivity is due to the *negatively* charged electron, hence Si doped with electron-rich impurity is called *n-type* semiconductor.

(b) Electron-deficit impurities

Si or Ge can also be doped with a group 13 element like B, Al or Ga which contains only 3 valence electrons. The place where the 5th valence e^- is missing is called *electron hole* or *electron vacancy*. An electron from a neighbouring atom can come and fill the electron hole, but in doing so it would leave an electron hole at its original position. If it happens, it would appear as if the electron hole has moved in the direction opposite to that of the electron that filled it. Under the influence of electric field, electrons would move towards the positively charged plate through electronic holes, but it would appear as if electron holes are positively charged and are moving towards negatively charged plate. This type of semi conductors are called *p-type* semiconductors.



Applications of n-type and p-type semiconductors

- Diode is a combination of *n-type* and *p-type* semiconductors and is used as a rectifier.
- Transistors are made by sandwiching a layer of one type of semiconductor between two layers of the other type of semiconductor. *nnp* and *pnp* type of transistors are used to detect or amplify radio or audio signals.
- The solar cell is an efficient photo-diode used for conversion of light energy into electrical energy.

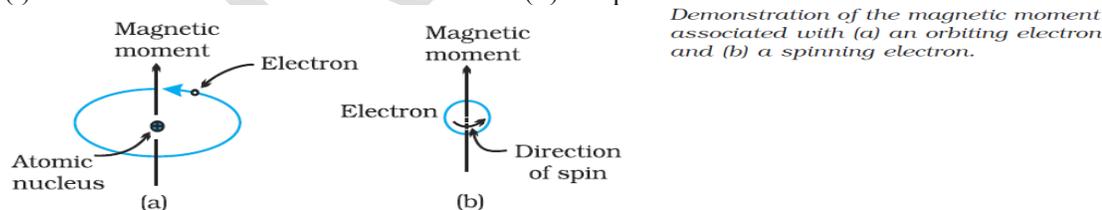
12-16 and 13-15 compounds

A large variety of solid state materials have been prepared by combination of groups 13 and 15 or 12 and 16 to simulate average valence of four as in Ge or Si. Typical compounds of groups 13 – 15 are InSb, AlP and GaAs. ZnS, CdS, CdSe and HgTe are examples of groups 12 – 16 compounds.

Magnetic properties

Every substance has some magnetic properties associated with it. The origin of these properties lies in the electrons. Each electron in an atom behaves like a tiny magnet. Its magnetic moment originates from two types of motions

- (i) its orbital motion around the nucleus and (ii) its spin around its own axis.



Electron being a charged particle and undergoing these motions can be considered as a small loop of current which possesses a magnetic moment. Thus, each electron has a permanent spin and an orbital magnetic moment associated with it. On the basis of their magnetic properties, substances can be classified into five categories:

(i) **Paramagnetism:** Paramagnetic substances are weakly attracted by a magnetic field. They are magnetised in a magnetic field in the same direction. They lose their magnetism in the absence of magnetic field. Paramagnetism is due to presence of one or more unpaired electrons which are attracted by the magnetic field. O_2 , Cu^{2+} , Fe^{3+} , Cr^{3+} are some examples of such substances.

(ii) **Diamagnetism:** Diamagnetic substances are weakly repelled by a magnetic field. They are weakly magnetised in a magnetic field in opposite direction. Diamagnetism is shown by those substances in which all the electrons are paired and there are no unpaired electrons. Pairing of electrons cancels their magnetic moments and they lose their magnetic character. H_2O , $NaCl$ and C_6H_6 are some examples of such substances.

(iii) **Ferromagnetism:** A few substances like iron, cobalt, nickel, gadolinium and CrO_2 are attracted very strongly by a magnetic field. Such substances are called ferromagnetic substances. Besides strong attractions, these substances can be permanently magnetised. In solid state, the metal ions of ferromagnetic substances are grouped together into small regions called *domains*. Thus, each domain acts as a tiny magnet. In an unmagnetised piece of a ferromagnetic substance the domains are randomly oriented and their magnetic moments get cancelled. When the substance is placed in a magnetic field all the domains get oriented in the direction of the magnetic field and a strong magnetic effect is produced. This ordering of domains persists even when the magnetic field is removed and the ferromagnetic substance becomes a permanent magnet.

(iv) **Antiferromagnetism:** Substances like MnO showing antiferromagnetism have domain structure similar to ferromagnetic substance, but their domains are oppositely oriented and cancel out each other's magnetic moment.

(v) **Ferrimagnetism:** Ferrimagnetism is observed when the magnetic moments of the domains in the substance are aligned in parallel and anti-parallel directions in unequal numbers. They are weakly attracted by magnetic field as compared to ferromagnetic substances. Fe_3O_4 (magnetite) and ferrites like $MgFe_2O_4$ and $ZnFe_2O_4$ are examples of such substances. These substances also lose ferrimagnetism on heating and become paramagnetic.

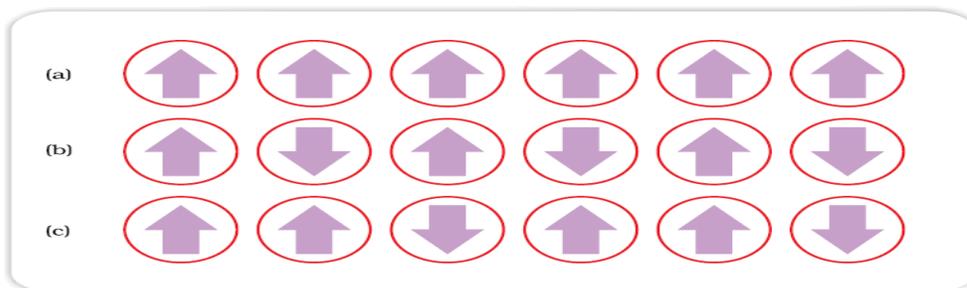


Fig 1.32: Schematic alignment of magnetic moments in (a) ferromagnetic (b) antiferromagnetic and (c) ferrimagnetic.

Assignment

Q1. What is meant by anisotropy?

Q2. Ionic solids conduct electricity in molten state but not in solid state. Explain.

Q3. Distinguish between

(i) Hexagonal and monoclinic unit cells

(ii) Face-centred and end-centred unit cells.

Q4. Which of the following lattices has the highest packing efficiency (i) simple cubic (ii) body-centred cubic and (iii) hexagonal close-packed lattice?

Q5. What type of defect can arise when a solid is heated? Which physical property is affected by it and in what way?

Q6. What type of stoichiometric defect is shown by:

(i) ZnS (ii) AgBr

Q7. Ionic solids, which have anionic vacancies due to metal excess defect, develop colour. Explain with the help of a suitable example.

Q8. A group 14 element is to be converted into n-type semiconductor by doping it with a suitable impurity. To which group should this impurity belong?

Q9. (i) What is meant by the term 'coordination number'?

(ii) What is the coordination number of atoms:

(a) in a cubic close-packed structure?

(b) in a body-centred cubic structure?

Q10. How will you distinguish between the following pairs of terms:

(i) Hexagonal close-packing and cubic close-packing?

(ii) Crystal lattice and unit cell?

(iii) Tetrahedral void and octahedral void?

Q11. How many lattice points are there in one unit cell of each of the following lattice?

(i) Face-centred cubic (ii) Face-centred tetragonal (iii) Body-centred

Q12. Calculate the efficiency of packing in case of a metal crystal for

(i) simple cubic

(ii) body-centred cubic

(iii) face-centred cubic (with the assumptions that atoms are touching each other).

Q13. Classify each of the following as being either a p-type or a n-type semiconductor:

(i) Ge doped with In (ii) B doped with Si.

Q14. Explain the following terms with suitable examples:

(i) Schottky defect (ii) Frenkel defect (iii) Interstitials and (iv) F-centres.

Q15. Explain the following with suitable examples:

(i) Ferromagnetism (ii) Paramagnetism (iii) Ferrimagnetism (iv) Antiferromagnetism

(v) 12-16 and 13-15 group compounds.