Chapter – 1 (Solid State)

Exercise Questions:

Queation:1. Define the term amorphous. Give a few example of amorphous solids.

Ans –

Amorphous solids
1.) Irregular shape
2.) Do not have definite heat of fusion
3.) Isotropic in nature
4.) Gradually soften over a long range of temperature
5.) Pseudo solids
6.) Short range order

Question:2. What makes a glass different from a solid such as quartz? Under what conditions could quartz be converted into glass.

Ans –

Arrangement of constituent particles makes glass different from quartz. In glass, the constituent particles have short range order but in quartz the constituent particles have both short range and long range order. Quartz can be converted into glass by heating and cooling it rapidly.

Question:3. Classify each of the following solids as ionic, metallic, molecular, network or amorphous.

- **i.) Tetra phosphorus decoxide (P_4O_{10})**
- **ii.) Ammonium phosphate ($(NH_4)3PO_4$)**
- **iii.) SiC**
- **iv.) I_2**
- **v.) P_4**
- **vi.) Plastic**

- **vii.) Graphite**
- **viii.) Brass**
- **ix.) Rb**
- **x.) LiBr**
- **xi.) Si**

Ans:

Ionic	Ammonium phosphate, LiBr
Metallic	Brass, Rb
Molecular	Tetra phosphorus decoxide, I_2, P_4
Network	Graphite, SiC, Si
Amorphous	Plastic

Question:4.) i.) What is meant by the term coordination number?

ii.) What is the coordination number of atoms:

a.) In a cubic closed packed structure?

b.) In a body centred cubic structure?

Ans –

The number of nearest neighbours of a particle is called its coordination number.

The coordination number of atoms:

i.) In a cubic close – packed structure: 12 and

ii.) In a body centred cubic structure: 8

Question:5.) How can you determine the atomic mass of an unknown metal if you know its density and the dimension of its unit cell? Explain.

Ans –

In case of cubic crystal:

Volume of a unit cell = a^3

Mass of a unit cell = number of atoms in a unit cell x mass of each atom = z x m

(z is the no. 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 = M/NA (M is the molar mass)

Therefore, the density of the unit cell

= mass of unit cell/volume of unit cell

$= z.m/a^3 = zM/a^3N_A$

$M = da^3N_A/Z$

Question:6.) Stability of a crystal is reflected in the magnitude of its melting points. Comment. Collect melting point of solid water, ethyl alcohol, diethyl ether and methane from a data book. What can yoy say about the intermolecular forces between these molecules?

Ans –

Higher the melting point, greater the intermolecular forces of attraction, stronger the bond between atoms and higher the stability. A substance with higher melting point is more stable than a substance with lower melting point.

Substances	**Melting point**
Solid water	158.8K
Ethyl alcohol	158.8K
Diethyl ether	96.85K
Methane	89.34K

From the above table it was observed that with higher melting point solid water is more stable and the methane with lower melting point is less stable**.**

Question:7.) How many lattice point are there in one unit cell of each of the following lattice?

i.) Face centred cubic

ii.) Face centred tetragonal

iii.) Body centre

Ans –

i.) There are 14 (8 from the corners + 6 from the faces) lattice point in face centred cubic.

ii.)There are 14 (8 from the corners + 6 from the faces) lattice point in face centred tetragonal.

iii.) There are 9 (1 from the centre + 8 from the corner) lattice point in body centred cubic.

Question:8.) Explain

i.) The basis of similarities and differences b/w metallic and ionic crystals.

ii.) Ionic solids are hard and brittle.

Ans –

i.) The basis of similarities b/w metallic and ionic crystals is that both these crystal types are held by the electrostatic force of attraction. In metallic crystal the electrostatic force acts b/w the positive ions and the electrons. In ionic crystals, it acts b/w the oppositely charged icons. Hence both have high melting point.

The basis of difference b/w metallic and ionic crystal is that in metallic crystals, the electrons are free to move and so, metallic crystals can conduct electricity. However, in ionic crystals the ions are not free to move. As a result they cannot conduct electricity. However, in molten state or in aqueous solution, they do conduct electricity.

ii.) The constituent particles of ionic crystals are ions these ions are held together in dimensional arrangement by the electrostatic force of attraction. Since the electrostatic force of attraction is very strong, the charged ions are held in fixed position. This is the reason why ionic crystals are hard and brittle

Question:9.) Silver crystallises in FCC lattice. If edge length of cell is 4.07 x 10-8cm and density is 10.5gcm^{-3}. Calculate the atomic mass of silver.

Ans –

It is given that the edge length, a = 4.077 x 10^{-8}cm

Density, d = 10.5gcm^{-3}

As the lattice is fcc type, the no. of atoms per unit cell, z = 4

We also know that,

NA = 6.022 X 1023mol^{-1}

Using the relation:

$d = zM/a^3N_A$

$M = da^3N_A/ Z$

$$= \frac{10.5\text{gcm}^{-1} \times (4.077 \times 10\text{-}8\text{cm})^3 \times 6.022 \times 1023\text{mol}^{-1}}{4}$$

= 107.13gmol^{-1}

Therefore, atomic mass of silver = 107.13u

Question:10.) A cubic solid is made of two elements P and Q. Atoms of Q are at the corner of the cube and P at the body centre. What is the formula of the compound. What are the coordination number of P and Q?

Ans –

It is given that the atoms of Q are present at the concerns of the cube. Therefore the no. of atoms of Q in 1 unit cell = 8 x 1/8 = 1

It is also given that the atoms of P are present at the body centre.

Therefore, no. of atoms of P in one unit cell = 1

This means that the ratio of the no. of P atoms to the no. of Q atoms, P:Q = 1: 1

Hence the formula of the compound is PQ. The coordination no. of both P and Q is 8.

Question:11.) Niobium crystallises in body centred cubic structure. If density is 8.55gcm^{-3}, calculate atomic radius of niobium using its atomic mass 93u.

Ans –It is given that the density of niobium d = 8.55gcm^{-3}

Atomic mass M = 93gmol^{-1}

As the lattice is bcc type, the no. of atoms per unit cell, z = 2

We also know that NA = 6.022 x 10^{23} mol^{-1}

Applying the relation:

d = zM/a3NA

a^{3} = Zm/dNA

= 2.93gmol^{-1}/8.33gcm-3 x 6.022 x 1023mol^{-1}

= 3.612 x 10^{-23} cm^{3}

So, a = 3.306 x 108cm

For body centred cubic unit cell:

r = √3/4 x a = √3/4 x 3.306 x 10^{-8} cm

= 1.432 x 10^{-8}cm

= 14.32 x 10-9cm = 14.32nm

Question:12.) If the radius of the octahedral void is r and radius of the atoms in close packing is R, derive relation between r and R.

Ans –

A sphere with centre O, is fitted into the octahedral void. It can be observed that Δ BAC is right angled ΔBAC = 900

Now applying Pythagoras theorem, we can write:

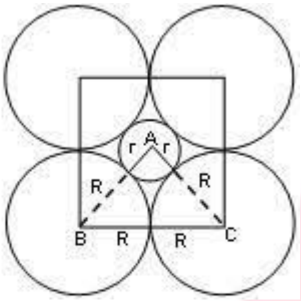
BC2 = BA2 + AC2

$= (2R)^2 = (R + r)^2 + (R + r)^2$

$= (2R)^2 = 2(R + r)^2$

$= 2R^2 = (R+ r)^2$

$= \sqrt{2}R = R + r$



$= r = \sqrt{2}R – R$

$= r = 0.414$

Question:13.) Copper crystallises into a fcc lattice with edge length 3.61 x 10-8cm. Show that the calculated density is in agreement with its measured value of 8.92gcm^{-3}.

Ans –

Edge length, a = 3.61 x 10^{-8}cm

As the lattice is fcc type, the no. of atoms per unit cell, z = 4

Atomic mass, M = 63.5gmol^{-1}

We also know that, NA = 6.022 X 1023mol^{-1}

Applying the relation:

d = z M/a3NA

$$= \frac{4 \text{ x}63.5\text{gmol}^{-1}}{(3.61 \text{ x } 10\text{-}8\text{cm})^3 \text{ x } 6.022 \text{ x } 1023\text{mol}^{-1}}$$

= 8.97gcm^{-3}

The calculated density 8.97gcm^{-3} is in agreement with its measured value.

Question:14.) Analysis shows that nickel oxide has the formula $NiO_{.98}O_{1.00}$. What fractions of nickel exist as Ni^{2+} and Ni^{3+} ions?

Ans:

The formula of nickel oxide is $NiO_{.98}O_{1.00}$

Therefore the ratio of the number of Ni atoms to the no. of O atoms.

Ni : O = 0.98 : 1.00 = 98 : 100

Now total charge on 100 O2- ions = 100 x (-2) = -200

Let the no. of Ni^{2+} ions be x.

So, the no. of Ni^{3+} ions is 98 – x

Now, total charge on Ni^{2+} ions = x (+2) = +2x

And, total charge on Ni^{3+} ions (98 – x) (+3)

= 294 – 3x

Since, the compound is neutral, we can write:

2x + (294 – 3x) + (-200) = 0

X + 94 = 0

X = 94

Therefore, no. of Ni2+ = 94 and no. of Ni^{3+} ions = 98 – 94 = 4

Hence, fraction of nickel that exit as Ni^{2+} 94/98 = 0.959

Question:15.) What is a semiconductor? Describe the two main type of semiconductors and contrast their conduction mechanism

Ans:

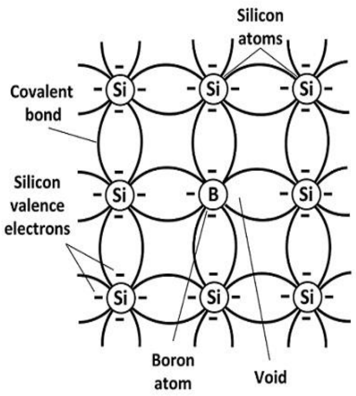
Semiconductors are substances having conductance in the intermediate range 10-6 to 104 ohm-1m-1.

The two main types of semiconductor are:

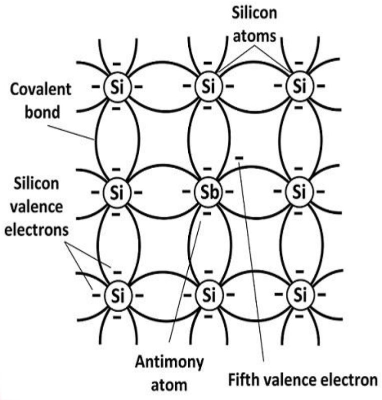
i.) n-type or
ii.) p-type

i.) N-type semiconductor: the semiconductor whose increased conductivity is a result of negatively charged electrons is called an n type semiconductor.

ii.) P – type semiconductor: the semiconductor whose increased in conductivity is a result of electron whole is called a p – type semiconductor.



P – type semiconductor



n – type semiconductor

Question:16.) Non stoichiometric cuprous oxide, Cu^2O can be prepared in laboratory. In this oxide, copper to oxygen ratio is slightly less than 2:1. Can you account for the fact that this substance is a p – type semiconductor?

Ans:

In the cuprous oxide prepared in the laboratory, copper to oxygen ratio is slightly less than 2:1. This means that the no. of Cu+ ions is slightly less than twice the no. of O2- ions. This is because some Cu+ ions have been replaced by Cu2+ ions. Every Cu2+ ion replaces two Cu+ ions, thereby creating holes. As a result, the substance conduct electricity with the help of these positive holes. Hence, the substance is a p-type semiconductor.

Question:17.) Ferric oxide crystallises in a hexagonal close – packed array of oxide ions with two out of every three octahedral holes occupied by ferric ions. Derive the formula of ferric oxide.

Ans –

Let the no. of oxide ions be x

So, no. of octahedral voids = x

It is given that 2 out of every three octahedral holes are occupied by ferric ions

So, no. of ferric ions = 2/3 x

Therefore, ratio of no. of Fe3+ ions to the no. of O2- ions,

Fe3+: O2- = 2/3 x : x

= 2 : 3

Hence, the formula of ferric oxide is Fe2O3.

Question:18.) Classify each of the following as being either a p- type or n – type semiconductor:

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

Ans:

i.) Ge (a group 14 element) is doped with In (a group 13 element).

Therefore, a hole will be created and the semiconductor generated will be a p – type semiconductor.

ii.)B (a group 13 element) is doped with Si (a group 14 element). So, there will be an extra electron and the semiconductor generated will an n- type semiconductor.

Question:19.) Gold (atomic radius = 0.144 nm) crystallises in a face – centred unit cell. What is the length of a side of the cell?

Ans –

For a face centred unit cell:

$a = 2\sqrt{2}r$

It is given that the atomic radius, r = 0.144nm

So $a = 2\sqrt{2} \times 0.144$nm

= 0.407nm

Hence, the length of the side of the cell = 0.407 nm.

Question:20.) In terms of band theory, what is the difference:

i.) Between a conductor and an insulator

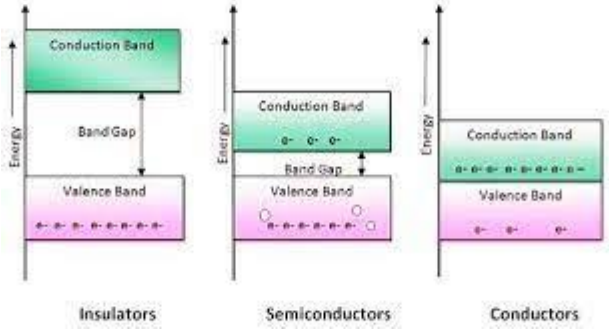
ii.) Between a conductor and semiconductor?

Ans –

i.) the valence band of a conductor is partially filled or it overlaps with a higher energy, unoccupied conduction band.

On the other hand, in the case of an insulator, the valence band is fully filled and there is a large gap b/w the valence band and the conduction band.

2.) In the case of conductor the valence band is partially filled or overlaps with a higher energy, unoccupied conduction band. So, the electrons can flow easily under an applied electric field. On the other hand, the valence band of a semiconductor is filled and there is a small gap between the valence band and the next higher conduction band. Therefore, some electrons can jump from the valence band to the conduction band and conduct electricity.



Insulators Semiconductors Conductors

Question:21.) Explain the following terms with suitable examples:

i.) Schottky defect

ii.) Frenkel defect

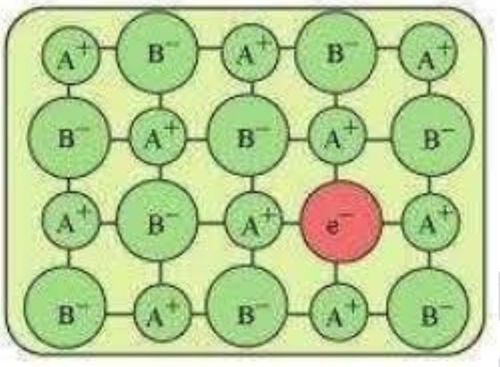
iii.) Interstitials and

iv.) F –centres

Ans –

1.) **Schottky defect**: Schottky defect is basically a vacancy defect shown by ionic solids. In this defect an equal no. of cations and anions are missing to maintain electrical neutrality. It decrease the density of a substance significant no of schottky defects is present in ionic solids.

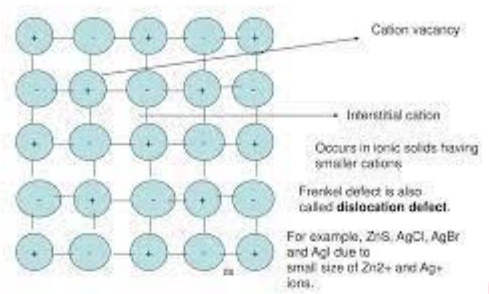
Eg. – NaCl, KCl etc.



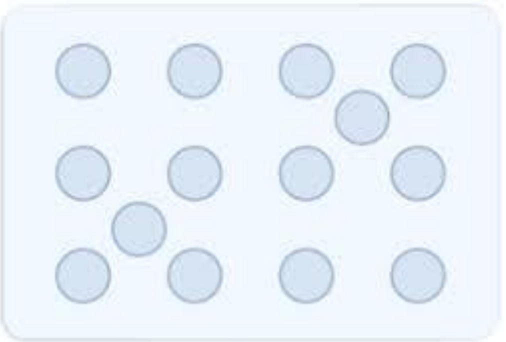
2.) Frenkel defect: Ionic solids containing large difference in the size of ions shows this type of defect. When the smaller ion is dislocated from its normal size to an interstitial site, frenkel defect is created.

Eg. – AgI, AgCl etc.

Frenkel Defect

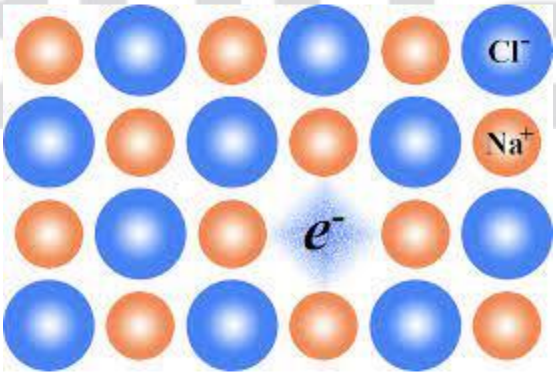


3.) Interstitial: Interstitial defect is shown by non – ionic solids. This type of defect is created when some constituent particles occupy an interstitial site of the crystal. The density of a substance increased because of this defect.



Interstitial defects

4.) F – centres: When the anionic sites of a crystal are occupied by unpaired electrons, the ionic sites are called F – centres. These unpaired electrons impart colour to the crystals. Eg. – when crystal of NaCl are heated in an atmosphere of sodium vapour, the sodium atoms are deposited on the surface of the crystal. The Cl ions defused from the crystal to its surface and combine with Na atoms, forming NaCl. During the process, the Na atoms on the surface of the crystal lost electrons. These related electrons diffuse into the crystal and occupy the vacant anionic sites, creating the F – centres.



Question:22.) Aluminium crystallises in a cubic – packed structure. Its metallic radius is 125pm.

i.) What is the length of the side of unit cell?

ii.) How many unit cells are there in 1.00 cm^3 of aluminium?

Ans –

i.) For cubic close – packed structure:

$a = 2\sqrt{2}r$

$= 2\sqrt{2} = 125pm$

$= 353.55pm$

$= 354pm$ (approx.)

ii.)Volume of one unit cell = $(354pm)^3$

$= 4.4 \times 107pm^3$

$= 4.4 \times 107 \times 10^{-30} cm^3$

$4.4 \times 10^{-23} cm^3$

Therefore no of unit cells in $1.00cm^3 = 2.27 \times 1022$

Question:23.) If NaCl is doped with 10^{-3} mol % of $SrCl^2$, what is the concentration of cation vacancies?

Ans –

It is given that NaCl is doped with 10^{-3} mol% of $SrCl^2$.

This means that 100 mol of NaCl is doped with 10^{-3} mol of $SrCl^2$.

Therefore 1 mol of NaCl is doped with $10^{-3}/100$ mol of $SrCl^2$.

$= 10^{-5}$ mol of $SrCl^2$

Cation vacancies produced by one Sr^{2+} ion = 1

Concentration of the cation vacancies

Produced by 10^{-5} mol of Sr^{2+} ions $= 10^{-5} \times 6.022 \times 10^{23}$

$= 6.022 \times 1018mol^{-1}$

Question:24.) Explain the following with suitable examples:

i.) Ferromagnetism

ii.) Paramagnetism

iii.) Ferrimagnetism

iv.) Antiferromagnetism

v.) 12 – 16 and 13 – 15 group compounds

Ans –

i. **Ferromagnetism:** A few substances which are attracted very strongly by a magnetic field. Such substances are called ferromagnetic substances. Besides strong attractions, these substances can be permanently magnetised.
Eg. – iron, cobalt, nickel etc.

ii. **Paramagnetism:** These 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.
Eg. – O^2, Cu^{2+}, Fe^{3+} etc.

iii. **Ferrimagnetism:** It is observed when the magnetic moments of the domains in the substance are aligned in parallel and antiparallel directions in unequal numbers. They are weakly attracted by magnetic field as compared to ferromagnetic substances.
Eg. – magnetite and ferrites.

iv. **Antiferromagnetism**: Substances which shows anti-ferromagnetism have domain structure similar to ferromagnetic substance, but their domains are oppositely oriented and cancel out each other's magnetic moments.
Eg. – MnO etc.

v. **12 – 16 and 13 – 15 group compounds:** The 12 – 16 group compounds are prepared by combining group 12 and group 16 elements and the 13 – 15 group compounds are prepared by combining group 13 and group 15 elements. These compounds are prepared to stimulate average valance of four as in Ge and Si.