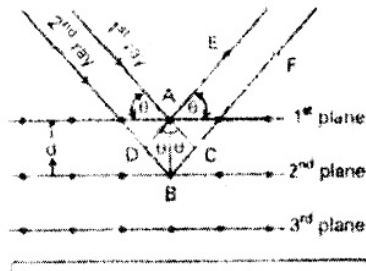


## SOLID STATE

### Short Answer Questions:

**1. Derive Bragg's equation?**

**Ans.** Bragg's equation: W.H. Bragg has proposed an equation to explain the relation between inter planar distance (d) and wave length ( $\lambda$ ) of x-rays, angle of diffraction ( $\theta$ ) of x-rays is called Bragg's equation



Let first X-rays is diffracted from a point A in the first plane

Second X-ray is diffracted from point B in the second plane

Second X-ray travels more distance than first x-ray

Extra distance travelled by second x-ray = CB + BD

Path difference in first & second x-ray = CB + BD

Path difference is equal to an integral multiple of wavelength of x-rays

$$CB + BD = n\lambda \dots\dots\dots(1) \text{ (here } n = 1,2,3,\dots\dots\dots)$$

In  $\Delta ABC$

$$\sin \theta = \frac{CB}{AB} = \frac{CB}{d}$$

$$CB = d \sin \theta \dots\dots\dots(2)$$

In  $\Delta ABD$

$$\sin \theta = \frac{BD}{AB} = \frac{BD}{d}$$

$$BD = d \sin \theta \dots\dots\dots 3$$

From Eq. (1), (2) and (3)

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

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

The above relation is known as Bragg's equation

n = order of diffraction

$n = 1, 2, 3, \dots$  represents first order, second order, and third order diffraction respectively.

**\*2. Write the main differences between crystalline solids and amorphous solids?**

Property	Crystalline solids	Amorphous solids
1. Condition of formation	Slow cooling without disturbing the liquid	Rapid cooling with churning or disturbance
2. Rigidity and hardness	Rigid and hard	Rigid and hard
3. Shape	Has definite geometrical configuration with long range forces	Has irregular geometry with short range forces
4. Melting points	Sharp and heat of fusion is characteristic of the substance	Not sharp. Solid melts over a range of temperature
5. X-ray diffraction experiment	Gives characteristic X-ray diffraction bands	Does not give X-ray diffraction bands

**3. Calculate the efficiency of packing in case of a metal of body-centered cubic crystal?**

**Ans.** In body centered cubic crystal, two atoms are present in a unit cell.

Hence volume occupied by atoms in unit cell,

$$V = 2 \times \left( \frac{4}{3} \pi r^3 \right), \text{ But radius in bcc, } r = \frac{\sqrt{3}a}{4}$$

Where  $a$  = edge length

$$\therefore V = 2 \times \frac{4}{3} \pi \left( \frac{\sqrt{3}a}{4} \right)^3 = \frac{\sqrt{3}\pi a^3}{8}$$

$V$  = total volume of the unit cell =  $a^3$

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

$$= \frac{\sqrt{3}\pi a^3}{8a^3} \times 100 = \frac{\sqrt{3}\pi}{8} \times 100 = 68$$

I.e. 68% of the unit cell is occupied by atoms and 32% is empty.

4. A cubic solid is made of two elements P and Q, atoms of Q are at the corners of the cube and P at the body centre. What is the formula of the compound? What are the coordination numbers of P and Q?

Ans. Effective number of 'Q' atoms =  $8 \times \frac{1}{8} = 1$

Effective number of 'P' atoms =  $1 \times 1 = 1$

∴ Formula = PQ

The structure of compound is body centred cubic. So, coordination number of P is 8 and Q is also 8.

\*5. Describe the two main types of semi conductors and contrast their conduction mechanism?

Ans. Semi conductors are two types. They are n-types semiconductors and p-type semi conductors.

**n-type semi conductors:** Semi conductors obtained by doping of VA-group element into IV-group element lattice are called n-type semi conductors.

When P or As is added to Si or Ge some of the Si or Ge atoms in the crystal are replaced by P (or) 'As' atoms and four out of five electrons of 'P or As' atom will be used for bonding with Si or Ge atoms while the fifth electron serve to conduct electricity.

p-type semi conductors: Semi conductors obtained by doping of IIIA-group element into IV-group element lattice are called p-type semi conductors.

When B or Al is added to pure Si or Ge some of the Si or Ge in the crystal is replaced by B or Al atoms. Three electrons of B or Al atom will be used for bonding with Si or Ge atoms while the fourth is the electron vacancy (hole) serves to conduct electricity.

\*6. Classify each of the following as either a p-type or a n-type semi conductor?

1. Ge doped with In

2. Si doped with B

Ans. Given 1 and 2 belong to extrinsic semi conductors. Both Germanium doped with Indium and Silicon doped with Boron belong to P-type semi conductors.

7. In terms of band theory, what is the difference between a conductor and insulator?

Ans.

Conductors	Insulators
1. The solids with conductivities ranging between $10^4$ to $10^7 \text{ ohm}^{-1}\text{m}^{-1}$ are called conductors	1. These are the solids with very low conductivities ranging between $10^{-29}$ to $10^{-10} \text{ ohm}^{-1}\text{m}^{-1}$
2. The gap between filled valence band and the conduction band is very small.	2. The gap between filled valence band and the conduction band is large.
3. Electrons can flow easily from valence band to the conduction band and shows conductivity.	3. Electrons cannot jump into conduction band and shows very small conductivity.

8. Niobium crystallizes in body centred cubic structure if density is  $8.55 \text{ gcm}^{-3}$ . Calculate atomic radius of Niobium using its atomic mass 93u?

Ans. density (d) =  $8.55 \text{ gcm}^{-3}$

For **body centred cubic**  $Z = 2$

Atomic mass of Niobium (M) = 93U

$$\text{Density } (d) = \frac{ZM}{a^3 \cdot N_A}$$

$$a^3 = \frac{Z \times M}{d \times N_A} = \frac{2 \times 93}{8.55 \times 6.023 \times 10^{23}}$$

$$a^3 = 3.612 \times 10^{-23}$$

$$a = (3.612 \times 10^{-23})^{1/3} = (36.12 \times 10^{-24})^{1/3} = 3.3 \times 10^{-8} \text{ cm}$$

$$\text{In **body centred cubic** structure } r = \frac{\sqrt{3}}{4} a = \frac{\sqrt{3}}{4} \times 3.3 \times 10^{-8} = 1.43 \times 10^{-8} \text{ cm} = 143 \times 10^{-10} \text{ cm}$$

$$\text{Atomic radius of Niobium } (R) = 143 \text{ pm} \quad (1 \times 10^{-10} \text{ cm} = 1 \text{ pm})$$

9. In terms of band theory, what is the difference between a conductor and a semi conductor?

Ans.

Conductors	Semi conductor
1. The solids with conductivities ranging between $10^4$ to $10^7 \text{ ohm}^{-1}\text{m}^{-1}$ are called conductors	1. These are the solids with conductivities in the intermediate range from $10^{-6}$ to $10^4 \text{ ohm}^{-1}\text{m}^{-1}$
2. The gap between filled valence band and the conduction band is very small	2. In case of semi conductor the gap between the valence band and conduction band is small
3. electrons can flow easily under an applied electric field and the metal shows conductivity	3. electrons may jump to conduction band and show some conductivity
4. Conductivity of metals decreases with increase in temperature	4. electrical conductivity of semi conductors increases with rise in temperature

10. Aluminium crystallizes in a cubic close packed structure. Its metallic radius is 125 pm

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

(ii) How many unit cells are there in  $1.00\text{cm}^3$  of aluminium?

Ans. Radius of atom ( $r$ ) = 125pm

$$r = 125 \times 10^{-12}$$

For cubic close packed structure  $r = \frac{a}{2\sqrt{2}}$

Edge length ( $a$ ) =  $r \times 2\sqrt{2}$

$$= 125 \times 10^{-12} \times 2\sqrt{2} = 125 \times 2 \times 1.414 \times 10^{-12} = 353.5 \times 10^{-12} \text{ m}$$

Edge length ( $a$ ) = 353.3 pm

Volume of unit cell =  $a^3 = (353.5 \times 10^{-12})^3 \text{ m}^3$  ( $1\text{cm}^3 = 10^{-6} \text{ m}^3$ )

$$= 4.417 \times 10^{-29} \text{ m}^3 = 4.417 \times 10^{-23} \text{ cm}^3$$

$$\text{No of unit cells in } 1\text{cm}^3 = \frac{1}{4.417 \times 10^{-23}} = 2.264 \times 10^{22}$$

### Very Short Answer Questions

**\*1. What is a Schottky defect?**

**Ans.** The defect arises when equal number of cations and anions are missing from the lattice is called Schottky defect. It is a common defect in ionic compounds of high coordination number where both cations and anions are of the same size.

**E.g.** KCl, NaCl, KBr etc.

Due to this defect density of crystal decreases.

**\*2. What is Frenkel defect?**

**Ans.** The defect arises when some of the ions of the lattice occupy interstitial sites leaving lattice sites vacant is known as Frenkel defect. This defect is generally found in ionic crystals where anion is much larger in size than the cation.

**E.g.** AgBr, ZnS etc.

Due to this defect density does not change.

**\*3. What is a semi conductor?**

**Ans.** The solids having conductivities in the intermediate range from  $10^{-6}$  to  $10^4 \text{ ohm}^{-1} \text{ m}^{-1}$  is called Semiconductors. The conductivity of a semi conductor increases with rise in the temperature because electrons from the valence band jump to conduction band.

**E.g.;** Silicon, Germanium.

**\*4. Explain the following with suitable examples:**

(i) Ferromagnetism

(ii) Paramagnetism

(iii) Ferrimagnetism

(IV) Antiferromagnetism

**Ans.** (i) **Ferromagnetism:** The substances which are strongly attracted by magnetic field are called Ferromagnetic substances.

**E.g.:** iron, cobalt, nickel,  $\text{CrO}_2$  etc

(ii) **Paramagnetism:** The substances which are weakly attracted by a magnetic field due to presence of one or more unpaired electrons are called paramagnetic substances.

**E.g.:**  $O_2$ ,  $Cu^{2+}$ ,  $Fe^{3+}$ ,  $Cr^{3+}$  etc.

(iii) **Ferrimagnetism:** In ferrimagnetic substances, the net magnetic moment is small due to unequal number of magnetic moment of domains aligned in parallel and anti parallel directions. These substances lose the ferrimagnetism on heating and become paramagnetic.

**Examples:**  $Fe_3O_4$ ,  $MgFe_2O_4$ ,  $ZnFe_2O_4$  etc.

(iv) **Anti ferromagnetism:** These substances have domain structure similar to those of ferromagnetic substances but their domains are oppositely oriented and cancel out each other's magnetic moment.  $MnO$  is an anti ferromagnetic substance.

**\*5. What is meant by the term 'coordination number? What is the coordination number of atoms in (a) a cubic close-packed structure and (b) a body-centred cubic structure?**

**Ans. Coordination number:** It is defined as the number of nearest neighbours of a particle in a close packed structure.

The coordination number of atoms in a cubic close-packed structure is 12 (as each atom is attached with 12 other atoms) and in a body-centred cubic structure are 8 (because each atom is attached with 8 other atoms)

**6. 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.

**Ans.** (i) Number of corner atoms per unit cell

$$= 8 \text{ corners atoms} \times \frac{1}{8} \text{ atom per unit cell}$$

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

Number of face centred atoms per unit cell

$$= 6 \text{ face centred atoms} \times \frac{1}{2} \text{ atom per unit cell}$$

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

∴ Total number of atoms or lattice points = 1 + 3 = 4.

(ii) No. of lattice points in Face-centred tetragonal = 4.

(iii) In bcc unit cell, number of corner atoms per unit cell

$$= 8 \text{ corners} \times \frac{1}{8} \text{ per corner atom.}$$

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

$$\text{Number of atoms at body centre} = 1 \times 1 = 1 \text{ atom}$$

∴ Total number of atoms (lattice points) = 1 + 1 = 2.

**7). Why is glass considered a super cooled liquid?**

**Ans.** Liquids have the characteristic property i.e., the tendency to flow. Glass also shows this property, though it flows very slowly. Therefore, glass is considered as a super cooled liquid.

Glass panes fixed to windows or doors of old buildings are invariably found to be slightly thicker at the bottom than the top. This is because the glass flows down very slowly and makes the bottom portion slightly thicker.