**Question 1.1:**

Define the term 'amorphous'. Give a few examples of amorphous solids.

Answer

Amorphous solids are the solids whose constituent particles are of irregular shapes and have short range order. These solids are isotropic in nature and melt over a range of temperature. Therefore, amorphous solids are sometimes called pseudo solids or super cooled liquids. They do not have definite heat of fusion. When cut with a sharp-edged tool, they cut into two pieces with irregular surfaces. Examples of amorphous solids include glass, rubber, and plastic.

**Question 1.2:**

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

Answer

The arrangement of the constituent particles makes glass different from quartz. In glass, the constituent particles have short range order, but in quartz, the constituent particles have both long range and short range orders.

Quartz can be converted into glass by heating and then cooling it rapidly.

**Question 1.3:**

Classify each of the following solids as ionic, metallic, molecular, network (covalent) or amorphous.

**(i)** Tetra phosphorus decoxide ($P_4O_{10}$) **(vii)** Graphite

**(ii)** Ammonium phosphate $(NH_4)_3PO_4$ **(viii)** Brass

**(iii)** SiC **(ix)** Rb

**(iv)** $I_2$ **(x)** LiBr

**(v)** $P_4$ **(xi)** Si

Answer

Ionic → **(ii)** Ammonium phosphate $(NH_4)_3PO_4$, **(x)** LiBr

Metallic → **(viii)** Brass, **(ix)** Rb

Molecular → **(i)** Tetra phosphorus decoxide ($P_4O_{10}$), **(iv)** $I_2$, (v) $P_4$.

Covalent (network) → **(iii)** SiC, **(vii)** Graphite, **(xi)** Si



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Amorphous → **(vi)** Plastic

**Question 1.4:**

**(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?

Answer

**(i)** The number of nearest neighbours of any constituent particle present in the crystal lattice is called its coordination number.

**(ii)** The coordination number of atoms

**(a)** in a cubic close-packed structure is 12, and

**(b)** in a body-centred cubic structure is 8

**Question 1.5:**

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

Answer

By knowing the density of an unknown metal and the dimension of its unit cell, the atomic mass of the metal can be determined.

Let '*a*' be the edge length of a unit cell of a crystal, '*d*' be the density of the metal, '*m*' be the atomic mass of the metal and '*z*' be the number of atoms in the unit cell.

Now, density of the unit cell $= \dfrac{\text{Mass of the unit cell}}{\text{Volume of the unit cell}}$

$$\Rightarrow d = \frac{z\,m}{a^3} \qquad (i)$$

[Since mass of the unit cell = Number of atoms in the unit cell × Atomic mass]

[Volume of the unit cell = (Edge length of the cubic unit cell)$^3$]

From equation (*i*), we have:

$$m = \frac{d\,a^3}{z} \qquad (ii)$$



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Now, mass of the metal ($m$) $= \frac{\text{Atomic mass (M)}}{\text{Avogadro's number } (N_A)}$

Therefore, $M = \frac{d\,a^3\,N_A}{z} \quad (iii)$

If the edge lengths are different (say $a$, $b$ and $c$), then equation (ii) becomes:

$$m = \frac{d(abc)N_A}{z} \qquad (iv)$$

From equations (*iii*) and (*iv*), we can determine the atomic mass of the unknown metal.

**Question 1.6:**

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

Answer

Higher the melting point, greater is the intermolecular force of attraction and greater is the stability. A substance with higher melting point is more stable than a substance with lower melting point.

The melting points of the given substances are:

Solid water → 273 K

Ethyl alcohol → 158.8 K

Diethyl ether → 156.85 K

Methane → 89.34 K

Now, on observing the values of the melting points, it can be said that among the given substances, the intermolecular force in solid water is the strongest and that in methane is the weakest.

**Question 1.7:**

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?



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Answer

i. A 2-D hexagonal close-packing contains two types of triangular voids (a and b) as shown in figure 1. Let us call this 2-D structure as layer A. Now, particles are kept in the voids present in layer A (it can be easily observed from figures 2 and 3 that only one of the voids will be occupied in the process, i.e., either a or b). Let us call the particles or spheres present in the voids of layer A as layer B. Now, two types of voids are present in layer B (c and d). Unlike the voids present in layer A, the two types of voids present in layer B are not similar. Void c is surrounded by 4 spheres and is called the tetrahedral void. Void d is surrounded by 6 spheres and is called the octahedral void.

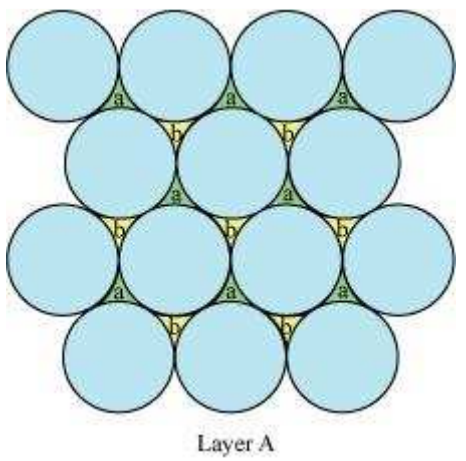


**Figure 1**



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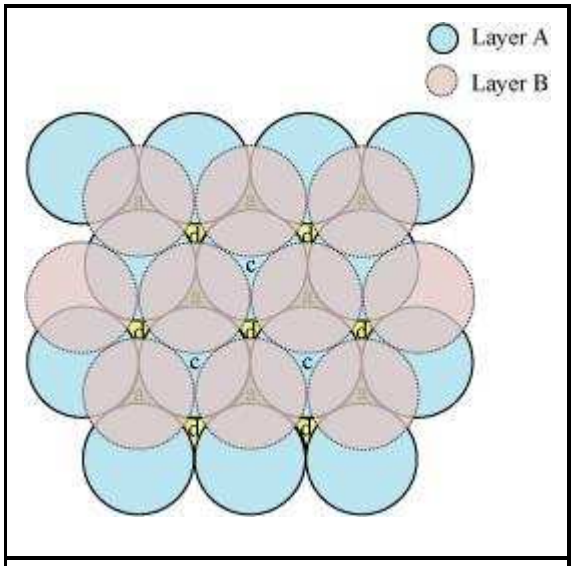



**Figure 2**

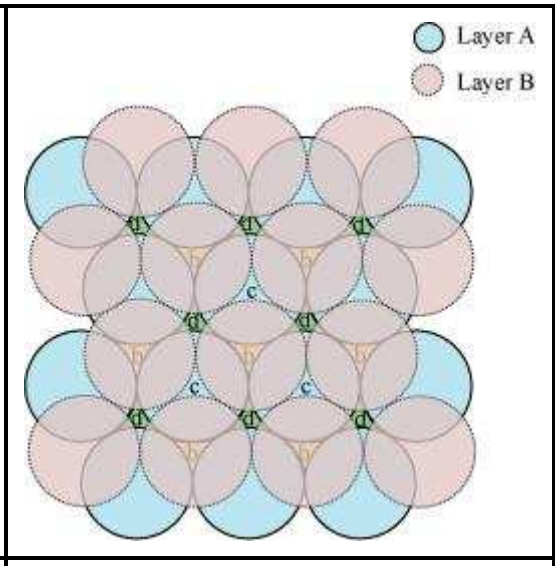
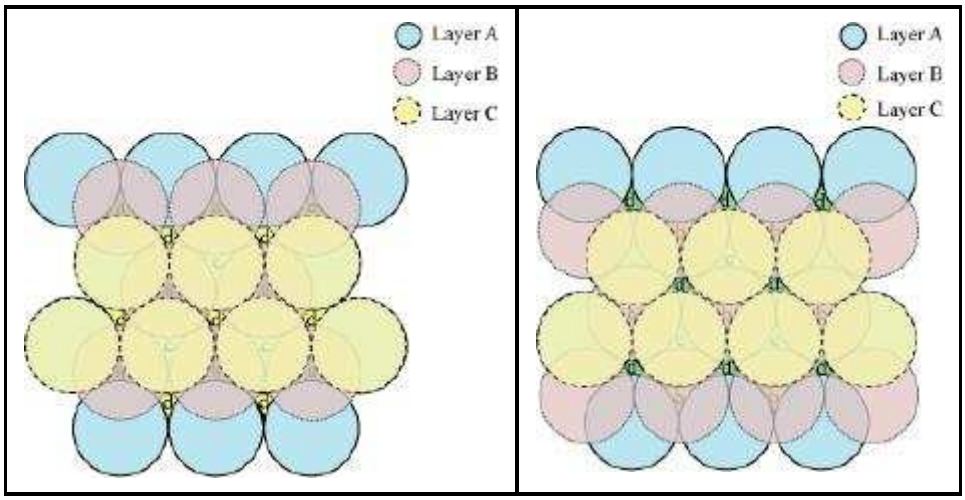



**Figure 3**

Now, the next layer can be placed over layer B in 2 ways.

**Case 1: When the third layer (layer C) is placed over the second one (layer B) in such a manner that the spheres of layer C occupy the tetrahedral voids c.**

In this case we get hexagonal close-packing. This is shown in figure 4. In figure 4.1, layer B is present over the voids a and layer C is present over the voids c. In figure 4.2, layer B is present over the voids b and layer C is present over the voids c. It can be observed from the figure that in this arrangement, the spheres present in layer C are present directly above the spheres of layer A. Hence, we can say that the layers in hexagonal close-packing are arranged in an ABAB….. pattern.



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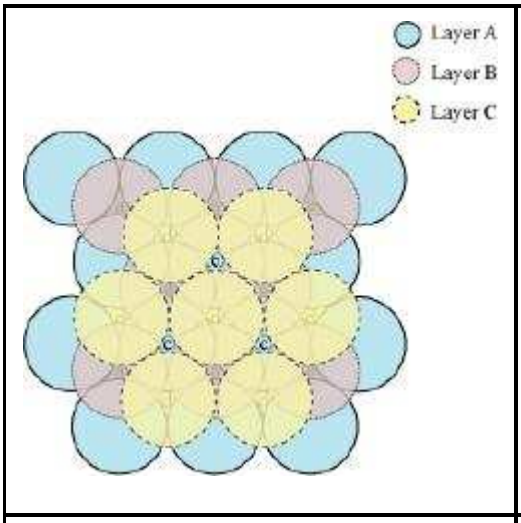
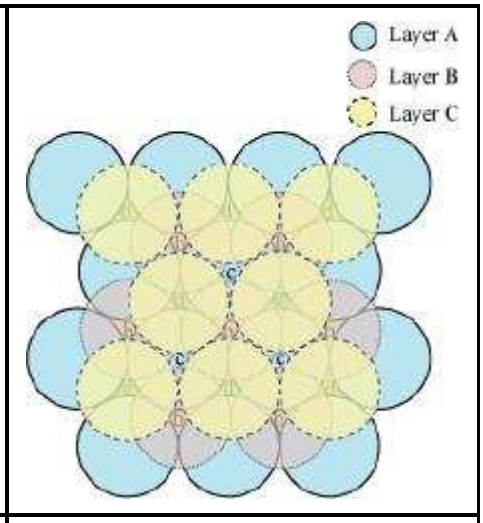
| Figure 4.1 | Figure 4.2 |
|---|---|

**Case 2: When the third layer (layer C) is placed over layer B in such a manner that the spheres of layer C occupy the octahedral voids d.**

In this case we get cubic close-packing. In figure 5.1, layer B is present over the voids a and layer C is present over the voids d. In figure 5.2, layer B is present over the voids b and layer C is present over the voids d. It can be observed from the figure that the arrangement of particles in layer C is completely different from that in layers A or B. When the fourth layer is kept over the third layer, the arrangement of particles in this layer is similar to that in layer A. Hence, we can say that the layers in cubic close-packing are arranged in an ABCABC….. pattern.




| Figure 5.1 | Figure 5.2 |
|---|---|

The side views of hcp and ccp are given in figures 6.1 and 6.2 respectively.



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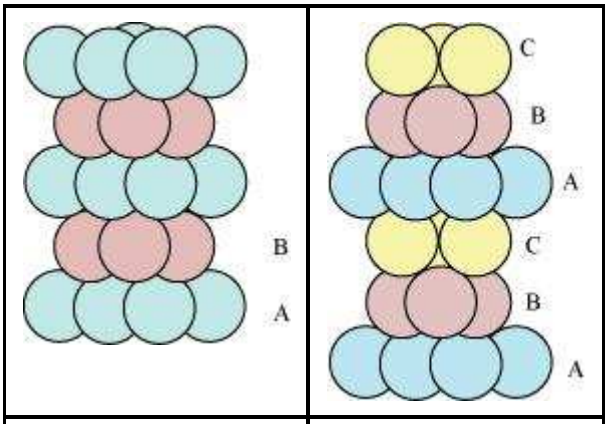
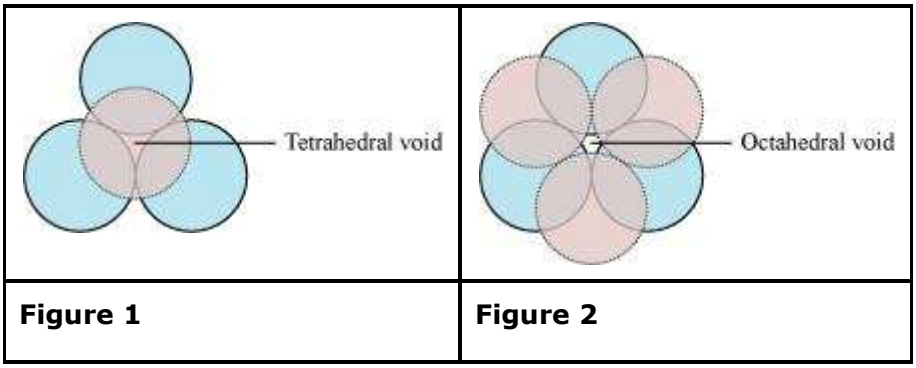



| Figure 6.1 | Figure 6.2 |
|---|---|

**(ii)** The diagrammatic representation of the constituent particles (atoms, ions, or molecules) present in a crystal in a regular three-dimensional arrangement is called crystal lattice.

A unit cell is the smallest three-dimensional portion of a crystal lattice. When repeated again and again in different directions, it generates the entire crystal lattice.

**(iii)** A void surrounded by 4 spheres is called a tetrahedral void and a void surrounded by 6 spheres is called an octahedral void. Figure 1 represents a tetrahedral void and figure 2 represents an octahedral void.




| Figure 1 | Figure 2 |
|---|---|

**Question 1.8:**

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

Answer



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

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

**(iii)** There are 9 (1 from the centre + 8 from the corners) lattice points in body-centred cubic.

**Question 1.9:**

Explain

**(i)** The basis of similarities and differences between metallic and ionic crystals.

**(ii)** Ionic solids are hard and brittle.

Answer

**(i)** The basis of similarities between metallic and ionic crystals is that both these crystal types are held by the electrostatic force of attraction. In metallic crystals, the electrostatic force acts between the positive ions and the electrons. In ionic crystals, it acts between the oppositely-charged ions. Hence, both have high melting points.

The basis of differences between metallic and ionic crystals 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 three-dimensional arrangements by the electrostatic force of attraction. Since the electrostatic force of attraction is very strong, the charged ions are held in fixed positions. This is the reason why ionic crystals are hard and brittle.

**Question 1.10:**

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).

Answer

**(i) Simple cubic**



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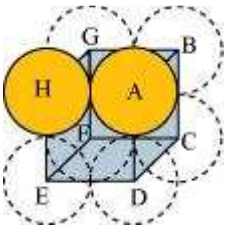
In a simple cubic lattice, the particles are located only at the corners of the cube and touch each other along the edge.




Let the edge length of the cube be '*a*' and the radius of each particle be *r*.

So, we can write:

$a = 2r$

Now, volume of the cubic unit cell = $a^3$

$= (2r)^3$

$= 8r^3$

We know that the number of particles per unit cell is 1.

Therefore, volume of the occupied unit cell $= \frac{4}{3}\pi r^3$

Hence, packing efficiency $= \frac{\text{Volume of one particle}}{\text{Volume of cubic unit cell}} \times 100\%$

$$= \frac{\frac{4}{3}\pi r^3}{8r^3} \times 100\%$$

$$= \frac{1}{6}\pi \times 100\%$$

$$= \frac{1}{6} \times \frac{22}{7} \times 100\%$$

$$= 52.4\%$$

**(ii) Body-centred cubic**



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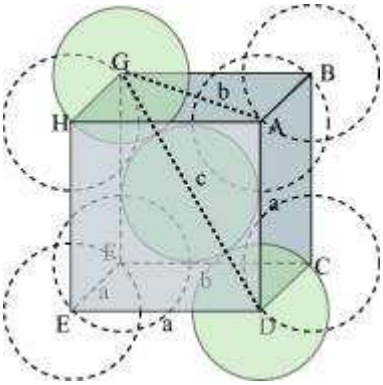


It can be observed from the above figure that the atom at the centre is in contact with the other two atoms diagonally arranged.

From ΔFED, we have:

$$b^2 = a^2 + a^2$$

$$\Rightarrow b^2 = 2a^2$$

$$\Rightarrow b = \sqrt{2}a$$

Again, from ΔAFD, we have:

$$c^2 = a^2 + b^2$$

$$\Rightarrow c^2 = a^2 + 2a^2 \qquad \left(\text{Since } b^2 = 2a^2\right)$$

$$\Rightarrow c^2 = 3a^2$$

$$\Rightarrow c = \sqrt{3}a$$

Let the radius of the atom be *r*.

Length of the body diagonal, *c* = 4п

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

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

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

Volume of the cube, $a^3 = \left(\frac{4r}{\sqrt{3}}\right)^3$

A body-centred cubic lattice contains 2 atoms.



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So, volume of the occupied cubic lattice $= 2\pi\frac{4}{3}\ r^3$

$$= \frac{8}{3}\pi r^3$$

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

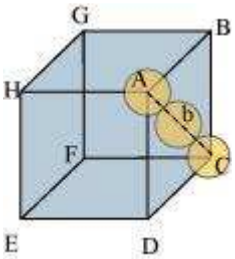
$$= \frac{\frac{8}{3}\pi r^3}{\left(\frac{4}{\sqrt{3}}r\right)^3} \times 100\%$$

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

$$= 68\%$$

**(iii) Face-centred cubic**

Let the edge length of the unit cell be '*a*' and the length of the face diagonal AC be *b*.




From ΔABC, we have:

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

$$\Rightarrow b^2 = a^2 + a^2$$

$$\Rightarrow b^2 = 2a^2$$

$$\Rightarrow b = \sqrt{2a}$$

Let *r* be the radius of the atom.

Now, from the figure, it can be observed that:



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$b = 4r$

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

$\Rightarrow a = 2\sqrt{2}r$

Now, volume of the cube, $a^3 = \left(2\sqrt{2}r\right)^3$

We know that the number of atoms per unit cell is 4.

So, volume of the occupied unit cell $= 4\pi\frac{4}{3}\ r^3$

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

$$= \frac{4\pi\frac{4}{3}\ r^3}{\left(2\sqrt{2}r\right)^3} \times 100\%$$

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

= 74%

**Question 1.11:**

Silver crystallises in fcc lattice. If edge length of the cell is 4.07 × $10^{-8}$ cm and density is 10.5 g $cm^{-3}$, calculate the atomic mass of silver.

Answer

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

Density, $d$ = 10.5 g $cm^{-3}$

As the lattice is fcc type, the number of atoms per unit cell, $z$ = 4

We also know that, $N_A$ = 6.022 × $10^{23}$ $mol^{-1}$

Using the relation:



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$$d = \frac{z\,M}{a^3\,N_A}$$

$$\Rightarrow M = \frac{d\,a^3\,N_A}{z}$$

$$= \frac{10.5\ \text{gcm}^{-3} \times \left(4.077 \times 10^{-8}\ \text{cm}\right)^3 \times 6.022 \times 10^{23}\ \text{mol}^{-1}}{4}$$

= 107.13 $\text{gmol}^{-1}$

Therefore, atomic mass of silver = 107.13 u

**Question 1.12:**

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?

Answer

It is given that the atoms of Q are present at the corners of the cube.

Therefore, number of atoms of Q in one unit cell $= 8 \times \frac{1}{8} = 1$

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

Therefore, number of atoms of P in one unit cell = 1

This means that the ratio of the number of P atoms to the number of Q atoms, P:Q = 1:1

Hence, the formula of the compound is PQ.

The coordination number of both P and Q is 8.

**Question 1.13:**

Niobium crystallises in body-centred cubic structure. If density is 8.55 g $\text{cm}^{-3}$, calculate atomic radius of niobium using its atomic mass 93 u.

Answer

It is given that the density of niobium, $d$ = 8.55 g $\text{cm}^{-3}$

Atomic mass, M = 93 $\text{gmol}^{-1}$

As the lattice is bcc type, the number of atoms per unit cell, $z$ = 2

We also know that, $N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$



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Applying the relation:

$$d = \frac{zM}{a^3 N_A}$$

$$\Rightarrow a^3 = \frac{zM}{d N_A}$$

$$= \frac{2 \times 93 \text{ gmol}^{-1}}{8.55 \text{ gcm}^{-3} \times 6.022 \times 10^{23} \text{mol}^{-1}}$$

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

So, $a = 3.306 \times 10^{-8}$ cm

For body-centred cubic unit cell:

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

$$= \frac{\sqrt{3}}{4} \times 3.306 \times 10^{-8} \text{ cm}$$

$= 1.432 \times 10^{-8}$ cm

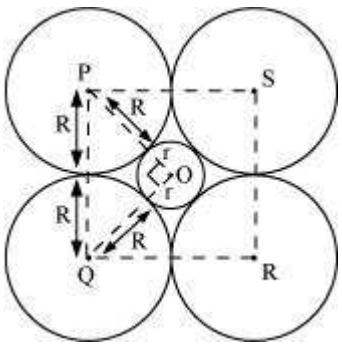
$= 14.32 \times 10^{-9}$ cm

= 14.32 nm

**Question 1.14:**

If the radius of the octachedral void is r and radius of the atoms in close packing is R, derive relation between r and R.

Answer




A sphere with centre O, is fitted into the octahedral void as shown in the above figure. It can be observed from the figure that ΔPOQ is right-angled

$\angle POQ = 90^0$



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Now, applying Pythagoras theorem, we can write:

$$PQ^2 = PO^2 + OQ^2$$
$$\Rightarrow (2R)^2 = (R + r)^2 + (R + r)^2$$
$$\Rightarrow (2R)^2 = 2(R + r)^2$$
$$\Rightarrow 2R^2 = (R + r)^2$$
$$\Rightarrow \sqrt{2}R = R + r$$
$$\Rightarrow r = \sqrt{2}R - R$$
$$\Rightarrow r = (\sqrt{2} - 1)R$$
$$\Rightarrow r = 0.414\ R$$

**Question 1.15:**

Copper crystallises into a fcc lattice with edge length $3.61 \times 10^{-8}$ cm. Show that the calculated density is in agreement with its measured value of 8.92 g $cm^{-3}$.

Answer

Edge length, $a = 3.61 \times 10^{-8}$ cm

As the lattice is fcc type, the number of atoms per unit cell, $z = 4$

Atomic mass, M = 63.5 g $mol^{-1}$

We also know that, $N_A = 6.022 \times 10^{23}$ $mol^{-1}$

Applying the relation:

$$d = \frac{zM}{a^3 N_A}$$
$$= \frac{4 \times 63.5\ \text{g mol}^{-1}}{(3.61 \times 10^{-8}\ \text{cm})^3 \times 6.022 \times 10^{23}\text{mol}^{-1}}$$

= 8.97 g $cm^{-3}$

The measured value of density is given as 8.92 g $cm^{-3}$. Hence, the calculated density 8.97 g $cm^{-3}$ is in agreement with its measured value.

**Question 1.16:**

Analysis shows that nickel oxide has the formula $Ni_{0.98}O_{1.00}$. What fractions of nickel exist as $Ni^{2+}$ and $Ni^{3+}$ ions?



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Answer

The formula of nickel oxide is $Ni_{0.98}O_{1.00}$.

Therefore, the ratio of the number of Ni atoms to the number of O atoms, Ni : O = 0.98 : 1.00 = 98 : 100

Now, total charge on 100 $O^{2-}$ ions = 100 × (−2)

= −200

Let the number of $Ni^{2+}$ ions be $x$.

So, the number of $Ni^{3+}$ ions is 98 − $x$.

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

= +2$x$

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

= 294 − 3$x$

Since, the compound is neutral, we can write:

2$x$ + (294 − 3$x$) + (−200) = 0

⇒ −$x$ + 94 = 0

⇒ $x$ = 94

Therefore, number of $Ni^{2+}$ ions = 94

And, number of $Ni^{3+}$ ions = 98 − 94 = 4

Hence, fraction of nickel that exists as $Ni^{2+}$ $= \frac{94}{98}$

= 0.959

And, fraction of nickel that exists as $Ni^{3+} = \frac{4}{98}$

= 0.041

Alternatively, fraction of nickel that exists as $Ni^{3+}$ = 1 − 0.959

= 0.041

**Question 1.17:**

What is a semiconductor? Describe the two main types of semiconductors and contrast their conduction mechanism.

Answer



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Semiconductors are substances having conductance in the intermediate range of $10^{-6}$ to $10^{4}$ $ohm^{-1}m^{-1}$.

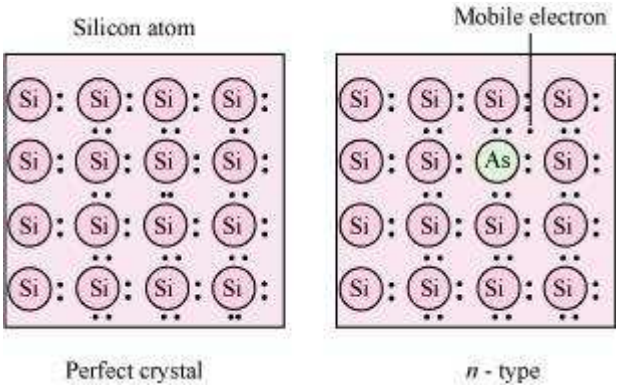
The two main types of semiconductors are:

**(i)** *n*-type semiconductor

**(ii)** *p*-type semiconductor

***n*-type semiconductor:** The semiconductor whose increased conductivity is a result of negatively-charged electrons is called an *n*-type semiconductor. When the crystal of a group 14 element such as Si or Ge is doped with a group 15 element such as P or As, an *n*-type semiconductor is generated.

Si and Ge have four valence electrons each. In their crystals, each atom forms four covalent bonds. On the other hand, P and As contain five valence electrons each. When Si or Ge is doped with P or As, the latter occupies some of the lattice sites in the crystal. Four out of five electrons are used in the formation of four covalent bonds with four neighbouring Si or Ge atoms. The remaining fifth electron becomes delocalised and increases the conductivity of the doped Si or Ge.




***p*-type semiconductor:** The semiconductor whose increased in conductivity is a result of electron hole is called a *p*-type semiconductor. When a crystal of group 14 elements such as Si or Ge is doped with a group 13 element such as B, Al, or Ga (which contains only three valence electrons), a *p*-type of semiconductor is generated.

When a crystal of Si is doped with B, the three electrons of B are used in the formation of three covalent bonds and an electron hole is created. An electron from the neighbouring atom can come and fill this electron hole, but in doing so, it would leave an electron hole at its original position. The process appears as if the electron hole has moved in the direction opposite to that of the electron that filled it. Therefore, when an



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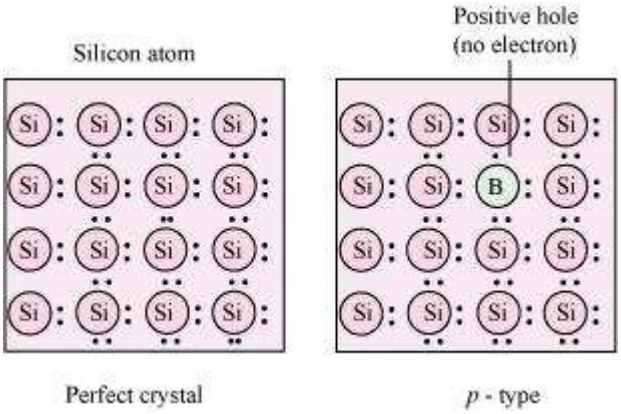
electric field is applied, electrons will move toward the positively-charged plate through electron holes. However, it will appear as if the electron holes are positively-charged and are moving toward the negatively- charged plate.




**Question 1.18:**

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?

Answer

In the cuprous oxide ($Cu_2O$) prepared in the laboratory, copper to oxygen ratio is slightly less than 2:1. This means that the number of $Cu^+$ ions is slightly less than twice the number of $O^{2-}$ ions. This is because some $Cu^+$ ions have been replaced by $Cu^{2+}$ ions. Every $Cu^{2+}$ ion replaces two $Cu^+$ ions, thereby creating holes. As a result, the substance conducts electricity with the help of these positive holes. Hence, the substance is a *p*-type semiconductor.

**Question 1.19:**

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 the ferric oxide.

Answer

Let the number of oxide ($O^{2-}$) ions be *x*.

So, number of octahedral voids = *x*



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

So, number of ferric ($Fe^{3+}$) ions $= \frac{2}{3}x$

Therefore, ratio of the number of $Fe^{3+}$ ions to the number of $O^{2-}$ ions,

$Fe^{3+} : O^{2-}$ $= \frac{2}{3}x : x$

$= \frac{2}{3} : 1$

= 2 : 3

Hence, the formula of the ferric oxide is $Fe_2O_3$.

**Question 1.20:**

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

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

Answer

**(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 be an *n*-type semiconductor.

**Question 1.21:**

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

Answer

For a face-centred unit cell:

$a = 2\sqrt{2}r$

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

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

= 0.407 nm

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



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**Question 1.22:**

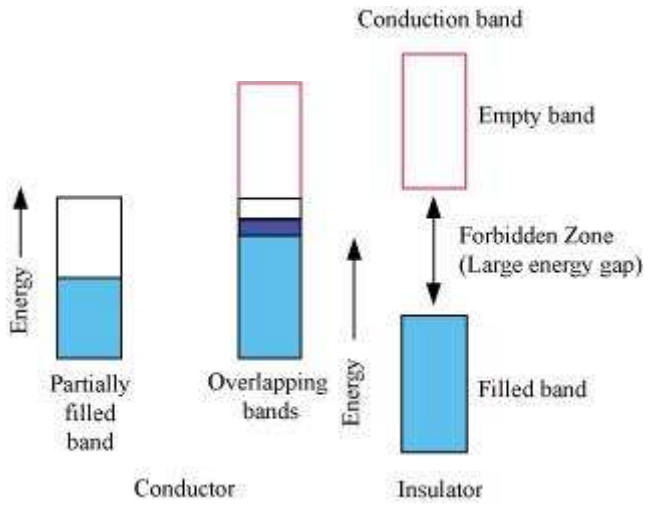
In terms of band theory, what is the difference

**(i)** Between a conductor and an insulator

**(ii)** Between a conductor and a semiconductor

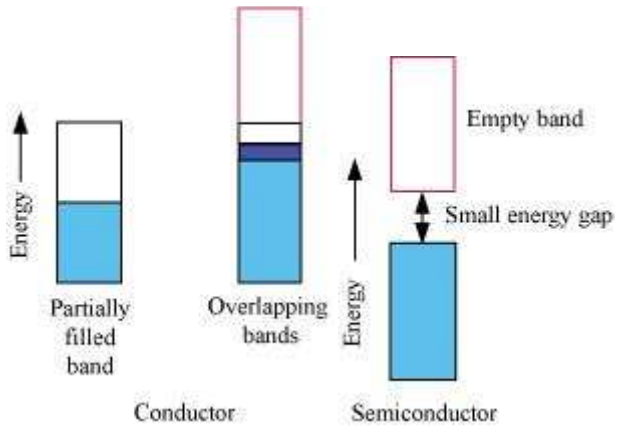
Answer

**(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 between the valence band and the conduction band.

**(ii)** In the case of a conductor, the valence band is partially-filled or it overlaps with a higher energy, unoccupied conduction band. So, the electrons can flow easily under an applied electric field.



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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.

**Question 1.23:**

Explain the following terms with suitable examples:

**(i)** Schottky defect

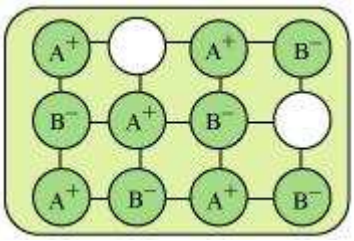
**(ii)** Frenkel defect

**(iii)** Interstitials and

**(iv)** F-centres

Answer

**(i) Schottky defect:** Schottky defect is basically a vacancy defect shown by ionic solids. In this defect, an equal number of cations and anions are missing to maintain electrical neutrality. It decreases the density of a substance. Significant number of Schottky defects is present in ionic solids. For example, in NaCl, there are approximately $10^6$ Schottky pairs per $cm^3$ at room temperature. Ionic substances containing similar-sized cations and anions show this type of defect. For example: NaCl, KCl, CsCl, AgBr, etc.




**(ii) Frenkel defect:** Ionic solids containing large differences in the sizes of ions show this type of defect. When the smaller ion (usually cation) is dislocated from its normal site to an interstitial site, Frenkel defect is created. It creates a vacancy defect as well as an interstitial defect. Frenkel defect is also known as dislocation defect. Ionic solids such as AgCl, AgBr, AgI, and ZnS show this type of defect.



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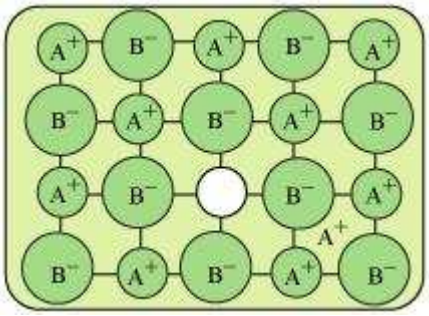
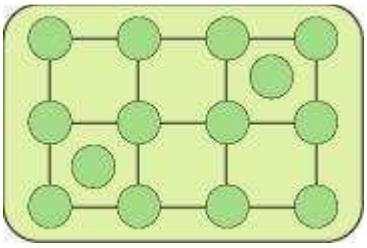
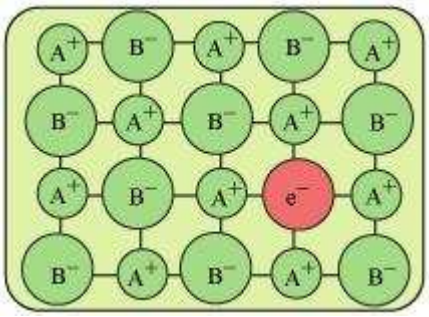



**(iii) Interstitials:** Interstitial defect is shown by non-ionic solids. This type of defect is created when some constituent particles (atoms or molecules) occupy an interstitial site of the crystal. The density of a substance increases because of this defect.



**(iv) 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. For example, 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 from the crystal to its surface and combine with Na atoms, forming NaCl. During this process, the Na atoms on the surface of the crystal lose electrons. These released electrons diffuse into the crystal and occupy the vacant anionic sites, creating F-centres.




**Question 1.24:**

Aluminium crystallises in a cubic close-packed structure. Its metallic radius is 125 pm.



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

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

Answer

**(i)** For cubic close-packed structure:

$a = 2\sqrt{2}r$

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

= 353.55 pm

= 354 pm (approximately)

**(ii)** Volume of one unit cell = $(354 \text{ pm})^3$

= $4.4 \times 10^7$ $pm^3$

= $4.4 \times 10^7 \times 10^{-30}$ $cm^3$

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

Therefore, number of unit cells in 1.00 $cm^3$ = $\frac{1.00 \text{ cm}^3}{4.4 \times 10^{-23} \text{ cm}^3}$

= $2.27 \times 10^{22}$

**Question 1.25:**

If NaCl is doped with $10^{-3}$ mol % of $SrCl_2$, what is the concentration of cation vacancies?

Answer

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 $\frac{10^{-3}}{100}$ mol of $SrCl_2$

= $10^{-5}$ mol of $SrCl_2$

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

$\therefore$ Concentration of the cation vacancies

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

$= 6.022 \times 10^{18} \text{ mol}^{-1}$

Hence, the concentration of cation vacancies created by $SrCl_2$ is $6.022 \times 10^8$ per mol of NaCl.



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**Question 1.26:**

Explain the following with suitable examples:

**(i)** Ferromagnetism

**(ii)**Paramagnetism

**(iii)**Ferrimagnetism

**(iv)**Antiferromagnetism

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

Answer

**(i) Ferromagnetism:** The substances that are strongly attracted by a magnetic field are called ferromagnetic substances. Ferromagnetic substances can be permanently magnetised even in the absence of a magnetic field. Some examples of ferromagnetic substances are iron, cobalt, nickel, gadolinium, and $CrO_2$.

In solid state, the metal ions of ferromagnetic substances are grouped together into small regions called domains and each domain acts as a tiny magnet. In an un-magnetised piece of a ferromagnetic substance, the domains are randomly-oriented and so, their magnetic moments get cancelled. However, when the substance is placed in a magnetic field, all the domains get oriented in the direction of the magnetic field. As a result, a strong magnetic effect is produced. This ordering of domains persists even after the removal of the magnetic field. Thus, the ferromagnetic substance becomes a permanent magnet.

**Schematic alignment of magnetic moments in ferromagnetic substances**

**(ii) Paramagnetism:** The substances that are attracted by a magnetic field are called paramagnetic substances. Some examples of paramagnetic substances are $O_2$, $Cu^{2t}$, $Fe^{3t}$, and $Cr^{3t}$.

Paramagnetic substances get magnetised in a magnetic field in the same direction, but lose magnetism when the magnetic field is removed. To undergo paramagnetism, a substance must have one or more unpaired electrons. This is because the unpaired electrons are attracted by a magnetic field, thereby causing paramagnetism.



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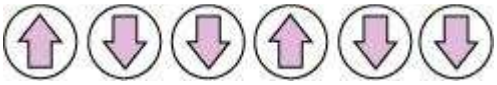
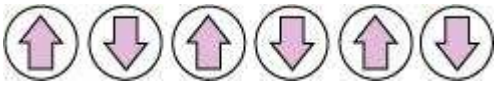
**(iii) Ferrimagnetism:** The substances in which the magnetic moments of the domains are aligned in parallel and anti-parallel directions, in unequal numbers, are said to have ferrimagnetism. Examples include $Fe_3O_4$ (magnetite), ferrites such as $MgFe_2O_4$ and $ZnFe_2O_4$.

Ferrimagnetic substances are weakly attracted by a magnetic field as compared to ferromagnetic substances. On heating, these substances become paramagnetic.



**Schematic alignment of magnetic moments in ferrimagnetic substances**

**(iv) Antiferromagnetism:** Antiferromagnetic substanceshave domain structures similar to ferromagnetic substances, but are oppositely-oriented. The oppositely-oriented domains cancel out each other's magnetic moments.



**Schematic alignment of magnetic moments in antiferromagnetic substances**

**(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 group15 elements. These compounds are prepared to stimulate average valence of four as in Ge or Si. Indium (III) antimonide (IrSb), aluminium phosphide (AlP), and gallium arsenide (GaAS) are typical compounds of groups 13-15. GaAs semiconductors have a very fast response time and have revolutionised the designing of semiconductor devices. Examples of group 12-16 compounds include zinc sulphide (ZnS), cadmium sulphide (CdS), cadmium selenide (CdSe), and mercury (II) telluride (HgTe). The bonds in these compounds are not perfectly covalent. The ionic character of the bonds depends on the electronegativities of the two elements.



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**Text**

**Question 1.1:**

Why are solids rigid?

Answer

The intermolecular forces of attraction that are present in solids are very strong. The constituent particles of solids cannot move from their positions i.e., they have fixed positions. However, they can oscillate about their mean positions. This is the reason solids are rigid.

**Question 1.2:**

Why do solids have a definite volume?

Answer

The intermolecular forces of attraction that are present in solids are very strong. The constituent particles of solids have fixed positions i.e., they are rigid. Hence, solids have a definite volume.

**Question 1.3:**

Classify the following as amorphous or crystalline solids:



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Polyurethane, naphthalene, benzoic acid, teflon, potassium nitrate, cellophane, polyvinyl chloride, fibre glass, copper.

Answer

**Amorphous solids**

Polyurethane, teflon, cellophane, polyvinyl chloride, fibre glass

**Crystalline solids**

Naphthalene, benzoic acid, potassium nitrate, copper

**Question 1.4:**

Why is glass considered a super cooled liquid?

Answer

Similar to liquids, glass has a tendency to flow, though very slowly. Therefore, glass is considered as a super cooled liquid. This is the reason that glass windows and doors are slightly thicker at the bottom than at the top.

**Question 1.5:**

Refractive index of a solid is observed to have the same value along all directions. Comment on the nature of this solid. Would it show cleavage property?

Answer

An isotropic solid has the same value of physical properties when measured along different directions. Therefore, the given solid, having the same value of refractive index along all directions, is isotropic in nature. Hence, the solid is an amorphous solid.

When an amorphous solid is cut with a sharp edged tool, it cuts into two pieces with irregular surfaces.

**Question 1.6:**

Classify the following solids in different categories based on the nature of intermolecular forces operating in them:

Potassium sulphate, tin, benzene, urea, ammonia, water, zinc sulphide, graphite, rubidium, argon, silicon carbide.

Answer

Potassium sulphate → Ionic solid



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Tin → Metallic solid

Benzene → Molecular (non-polar) solid

Urea → Polar molecular solid

Ammonia → Polar molecular solid

Water → Hydrogen bonded molecular solid

Zinc sulphide → Ionic solid

Graphite → Covalent or network solid

Rubidium → Metallic solid

Argon → Non-polar molecular solid

Silicon carbide → Covalent or network solid

**Question 1.7:**

Solid A is a very hard electrical insulator in solid as well as in molten state and melts at extremely high temperature. What type of solid is it?

Answer

The given properties are the properties of a covalent or network solid. Therefore, the given solid is a covalent or network solid. Examples of such solids include diamond (C) and quartz ($SiO_2$).

**Question 1.8:**

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

Answer

In ionic compounds, electricity is conducted by ions. In solid state, ions are held together by strong electrostatic forces and are not free to move about within the solid. Hence, ionic solids do not conduct electricity in solid state. However, in molten state or in solution form, the ions are free to move and can conduct electricity.

**Question 1.9:**

What type of solids are electrical conductors, malleable and ductile?

Answer

Metallic solids are electrical conductors, malleable, and ductile.



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**Question 1.10:**

Give the significance of a 'lattice point'.

Answer

The significance of a lattice point is that each lattice point represents one constituent particle of a solid which may be an atom, a molecule (group of atom), or an ion.

**Question 1.11:**

Name the parameters that characterize a unit cell.

Answer

The six parameters that characterise a unit cell are as follows.

**(i)** Its dimensions along the three edges, *a*, *b*, and *c*

These edges may or may not be equal.

**(ii)** Angles between the edges

These are the angle ∝ (between edges *b* and *c*), β (between edges *a* and *c*), and γ (between edges *a* and *b*).

**Question 1.12:**

Distinguish between

**(i)**Hexagonal and monoclinic unit cells

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

Answer

**(i) Hexagonal unit cell**

For a hexagonal unit cell,

$a = b \neq c$

and $\alpha = \beta = 90°$

$\gamma = 120°$

**Monoclinic unit cell**

For a monoclinic cell,

$a \neq b \neq c$

and $\alpha = \gamma = 90°$

$\beta \neq 90°$

**(ii) Face-centred unit cell**



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In a face-centred unit cell, the constituent particles are present at the corners and one at the centre of each face.

**End-centred unit cell**

An end-centred unit cell contains particles at the corners and one at the centre of any two opposite faces.

**Question 1.13:**

Explain how much portion of an atom located at **(i)** corner and **(ii)** body-centre of a cubic unit cell is part of its neighbouring unit cell.

Answer

**(i)**An atom located at the corner of a cubic unit cell is shared by eight adjacent unit cells.

Therefore, $\frac{1}{8}$th portion of the atom is shared by one unit cell.

**(ii)**An atom located at the body centre of a cubic unit cell is not shared by its neighbouring unit cell. Therefore, the atom belongs only to the unit cell in which it is present i.e., its contribution to the unit cell is 1.

**Question 1.14:**

What is the two dimensional coordination number of a molecule in square close packed layer?

Answer

In square close-packed layer, a molecule is in contact with four of its neighbours. Therefore, the two-dimensional coordination number of a molecule in square close-packed layer is 4.

**Question 1.15:**

A compound forms *hexagonal close-packed* structure. What is the total number of voids in 0.5 mol of it? How many of these are tetrahedral voids?

Answer

Number of close-packed particles = $0.5 \times 6.022 \times 10^{23} = 3.011 \times 10^{23}$

Therefore, number of octahedral voids = $3.011 \times 10^{23}$



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And, number of tetrahedral voids = $2 \times 3.011 \times 10^{23} = 6.022 \times 10^{23}$

Therefore, total number of voids = $3.011 \times 10^{23} + 6.022 \times 10^{23} = 9.033 \times 10^{23}$

**Question 1.16:**

A compound is formed by two elements M and N. The element N forms *ccp* and atoms of M occupy 1/3rd of tetrahedral voids. What is the formula of the compound?

Answer

The *ccp* lattice is formed by the atoms of the element N.

Here, the number of tetrahedral voids generated is equal to twice the number of atoms of the element N.

According to the question, the atoms of element M occupy $\frac{1}{3}$rd of the tetrahedral voids.

Therefore, the number of atoms of M is equal to $2 \times \frac{1}{3} = \frac{2}{3}$rd of the number of atoms of N.

Therefore, ratio of the number of atoms of M to that of N is M: N $= \frac{2}{3} : 1$

$= 2:3$

Thus, the formula of the compound is $M_2 N_3$.

**Question 1.17:**

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

Answer

Hexagonal close-packed lattice has the highest packing efficiency of 74%. The packing efficiencies of simple cubic and body-centred cubic lattices are 52.4% and 68% respectively.

**Question 1.18:**

An element with molar mass $2.7 \times 10^{-2}$ kg $mol^{-1}$ forms a cubic unit cell with edge length 405 pm. If its density is 2.7 × 103 kg $m^{-3}$, what is the nature of the cubic unit cell?

Answer



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It is given that density of the element, $d = 2.7 \times 10^3$ kg $m^{-3}$

Molar mass, M = $2.7 \times 10^{-2}$ kg $mol^{-1}$

Edge length, $a$ = 405 pm = $405 \times 10^{-12}$ m

= $4.05 \times 10^{-10}$ m

It is known that, Avogadro's number, $N_A = 6.022 \times 1023$ $mol^{-1}$

Applying the relation,

$$d = \frac{z, M}{a^3 \cdot N_A}$$

$$z = \frac{d \cdot a^3 N_A}{M}$$

$$= \frac{2.7 \times 10^3 \text{ kg m}^{-3} \times \left(4.05 \times 10^{-10} \text{ m}\right)^3 \times 6.022 \times 10^{23} \text{ mol}^{-1}}{2.7 \times 10^{-2} \text{ kg mol}^{-1}}$$

$$= 4.004$$

$$= 4$$

This implies that four atoms of the element are present per unit cell. Hence, the unit cell is face-centred cubic (*fcc*) or cubic close-packed (*ccp*).

**Question 1.19:**

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

Answer

When a solid is heated, vacancy defect can arise. A solid crystal is said to have vacancy defect when some of the lattice sites are vacant.

Vacancy defect leads to a decrease in the density of the solid.

**Question 1.20:**

What type of stoichiometric defect is shown by:

**(i)** ZnS **(ii)** AgBr

Answer

**(i)** ZnS shows Frenkel defect.

**(ii)** AgBr shows Frenkel defect as well as Schottky defect.



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**Question 1.21:**

Explain how vacancies are introduced in an ionic solid when a cation of higher valence is added as an impurity in it.

Answer

When a cation of higher valence is added to an ionic solid as an impurity to it, the cation of higher valence replaces more than one cation of lower valence so as to keep the crystal electrically neutral. As a result, some sites become vacant. For example, when $Sr^{2+}$ is added to NaCl, each $Sr^{2+}$ ion replaces two $Na^{+}$ ions. However, one $Sr^{2+}$ ion occupies the site of one $Na^{+}$ ion and the other site remains vacant. Hence, vacancies are introduced.

**Question 1.22:**

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

Answer

The colour develops because of the presence of electrons in the anionic sites. These electrons absorb energy from the visible part of radiation and get excited.

For example, when crystals of NaCl are heated in an atmosphere of sodium vapours, the sodium atoms get deposited on the surface of the crystal and the chloride ions from the crystal diffuse to the surface to form NaCl with the deposited Na atoms. During this process, the Na atoms on the surface lose electrons to form $Na^{+}$ ions and the released electrons diffuse into the crystal to occupy the vacant anionic sites. These electrons get excited by absorbing energy from the visible light and impart yellow colour to the crystals.

**Question 1.23:**

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?

Answer

An *n*-type semiconductor conducts because of the presence of extra electrons. Therefore, a group 14 element can be converted to *n*-type semiconductor by doping it with a group 15 element.



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**Question 1.24:**

What type of substances would make better permanent magnets, ferromagnetic or ferrimagnetic. Justify your answer.

Answer

Ferromagnetic substances would make better permanent magnets.

In solid state, the metal ions of ferromagnetic substances are grouped together into small regions. These regions are called domains and each domain acts as a tiny magnet. In an unmagnetised piece of a ferromagnetic substance, the domains are randomly oriented. As a result, the magnetic moments of the domains get cancelled. However, 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.

The ordering of the domains persists even after the removal of the magnetic field. Thus, the ferromagnetic substance becomes a permanent magnet.



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# CHAPTER-1 SOLID STATE

**KEY CONCEPTS** **4 MARKS CHAPTER**

**As we know that matter exists in different physical states under different conditions of temperature and pressure. For example solid state, liquid gases plasma and BEC etc. Now we will study about different aspects of solid state.**

**Introduction:**

1. The state of matter whose M.P is above room temp is solid state. Solids have definite shape and volume, having high density and constituent particles are held strongly.
2. Based on arrangement of particles types of solid :

   1: Crystalline 2: Amorphous
3. Crystalline solids have regular arrangement of constituent particles throughout, melting point is sharp, Anisotropic in nature and give clear cut cleavage.
4. Amorphous solids have no regular arrangement, no sharp M.P, isotropic in nature they do not exhibit cleavage property.
5. Amorphous silica is used in photovoltaic cells.(Applications of amorphous solid)
6. Space lattice is the regular 3D, arrangement of constituent particles in the crystalline solid. It shows how the constituting particles (atoms, molecules etc.) are arranged.
7. Smallest repeating unit in a space lattice is called unit cell.
8. There are 4 types of unit cells, 7 crystal systems and 14 bravais lattices.
9. Types of unit cell No. of atoms per unit cell

i. Simple cubic unit cell 8*1/8=1

ii. FCC (Face centered cubic) 8*1/8+6*1/2=4

iii. BCC (Body centered cubic) 8*1/8+1*1=2

10. Hexagonal close packing and cubic close packing have equal efficiency i.e 74%
11. Packing efficiency =volume occupied by spheres (Particles)/volume of unit cell *100
12. For simple cubic unit cell the p.f.=$1*4/3 *\pi r^3/8*r^3 *100$ =52.4
13. The packing efficiency in **fcc** =$4*4/3 *\pi r^3/16*2^{1/2} r^3 *100$ =74

14. The packing efficiency in **bcc** $=2*4/3*\pi r^3/64*3^{3/2} r^3*100 = 68$

15. The packing efficiency in **hcp =74**

16. Packing efficiency in bcc arrangement in 68% and simple cubic unit cell is 52.4%

17. Unoccupied spaces in solids are called interstitial voids or interstitial sites.

18. Two important interstitial voids are (I). Tetrahedral void and (II). Octahedral void.

19. Radius ratio is the ratio of radius of void to the radius of sphere.

    a. For tetrahedral void radius ratio=0.225

       For octahedral void radius ratio=0.414

20. No. of tetrahedral void=2*N (N=No. of particles)

21. No. of octahedral void=N

22. Formula of a compound depends upon arrangement of constituent of particles.

23. Density of unit cell

$$\text{Density} = \frac{ZxM}{a^3xNA}$$

D=density, M=Molar mass, a=side of unit cell, NA=6.022 $x10^{23}$

24. The relationship between edge length and radius of atom and interatomic or interionic distance for different types of unit is different as given below

    a. Simple cubic unit cell a=2R

    b. F C C $a=4R/\sqrt{2}$

    c. B C C $a=4R/\sqrt{3}$

25. Interatomic distance=2R

26. Interionic distance= Rc+Ra (Rc=Radius of cation, Ra=Radius of anion)

27. Imperfection is the irregularity in the arrangement of constituent particles.

28. Point defect or Atomic defect-> it is the deviation from ideal arrangement of constituent atom. Point defects are two types (a) Vacancy defect (b) Interstitial defect

29. Vacancy defect lowers the density and

30. Interstitial defect increases the density of crystal.

31. Point defects in the ionic crystal may be classified as:

a. Stoichiometric defect (Ratio of cation and anion is same).

b. Non Stoichiometric defect (disturb the ratio).

c. Impurity defects (due to presence of some impurity ions at the lattice sites)

32. Schottky defect lowers the density of crystal it arises due to missing of equal no. of cations of anions from lattice sites e.g. Nacl.

33. Frenkel defectis the combination of vacancy and interstitial defects. Cations leave their actual lattice sites and come to occupy the interstitial space density remains the same eg. Agcl.

34. Non stoichiometric defect

    a. Metal excess defect due to anion vacancy.

    b. Metal excess due to presence of interstitial cation.

    c. Metal deficiency due to absence of cation.

SHORT ANSWER QUESTION (2)

Q1. What do you mean by paramagnetic substance?

Ans: - Attracted by magnetic field field and these substances are made of atoms or ions with unpaired electrons.

Q2. Which substance exhibit schottky and Frenkel both defects.

Ans: - AgBr

Q3. Name a salt which is added to Agcl so as to produce cation vacancies.

Ans:-$CdCl_2$

Q4. Why is Frenkel defects not found in pure Alkali metal halide?

Ans: - Due to larger size of Alkali metal ion.

Q5. What is the use of amorphous silica?

Ans. Used in Photovoltaic cell.

Q6. Analysis shows that a metal oxide has the empirical formula $M_{0.98}O_{1.00}$ Calculate the percentage of $M^{2+}$ and $M^{3+}$ ions in the crystal.

Ans: - Let the $M^{2+}$ ion in the crystal be x and $M^{3+}$ =0.98-x

Since total charge on the compound must be zero

2x + 3(0.98-x) -200=0

X=0.88

%of $M^{2+}$ 0.88/0.96*100=91.67

% of $M3^{+}$ =100-91.91.67=8.33

Q7. What is the co-ordination no. of cation in Antifluorite structure?

Ans: - 4

Q8. What is the Co.No? of cation and anion in Caesium Chloride.

Ans: 8 and 8

Q9. What is F centre?

Ans:- It is the anion vacancy which contains unpaired electron in non-stoichiometric compound containing excess of metal ion.

Q10. What makes Alkali metal halides sometimes coloured, which are otherwise colourless?

## Very Short Answers(1 marks) :

**1. How does amorphous silica differ from quartz?**

In amorphous silica, $SiO_4$ tetrahedral are randomly joined to each other whereas in quartz they are linked in a regular manner.

**2. Which point defect lowers the density of a crystal?**

Schottky defect.

**3. Why glass is called supper cooled liquids?**

It has tendency to flow like liquid.

**4. Some of the very old glass objects appear slightly milky instead of being transparent why?**

Due to crystallization.

**5. What is anisotropy?**

Physical properties show different values when measured along different in crystalline solids.

**6. What is the coordination number of atoms?**

**a) in fcc structure b) in bcc structure**

a) 12 b) 8

**7. How many lattice points are there in one cell of -**

**a) fcc b) bcc c) simple cubic**

a) 14 b) 9 c) 8

**8. What are the co-ordination numbers of octahedral voids and tetrahedral voids?**

6 and 4 respectively.

**9. Why is common salt sometimes yellow instead of being of being pure white?**

Due to the presence of electrons in some lattice sites in place of anions these sites act as F-centers. These electrons when excited impart color to the crystal.

**10. A compound is formed by three elements X , Y. The element Y forms ccp and atoms of X occupy all octahedral voids and half the tetrahedral void. What is formula of the compound?**

| | | |
|---|---|---|
| The particle that is present in CCP/BCC/HCP array | | |
| take that 100 | | Particles |
| Then octahedral void = 100 | | - |
| Tetrahedral void = | 200 | - |

| | |
|---|---|
| Y = 100 | particles |
| Octahedral void = 100 | 100 (all) (X) |
| Tetrahedral void =200 | 100(Half) (X) |
| Total X = 200 | |
| Total Y = 100 | Formula $X_{200}Y_{100}$ |

**<u>HOTS Very Short Answers</u>:**

1. **Define F- centers.**
2. **What type of stoichiometric defect is shown by**
   a. **Zns**
   b. **AgBr**
3. **What are the differences between frenkel and schottky defect?**
4. **Define the following terms with suitable examples**
   - **Ferromagnetism**
   - **Paramagnetism**
   - **Ferrimagnetism**
   - **12-16 and 13-15 group compound**
5. **In terms of band theory what is the difference**
   - **Between conductor and an insulator**
   - **Between a conductor and a semi-conductor**

**<u>Short Answers (2 Marks) HOTS</u>**

1. **Explain how electrical neutrality is maintained in compounds showing Frenkel and Schottky defect.**

   In compound showing Frenkel defect, ions just get displaced within the lattice. While in compounds showing Schottky defect, equal number of anions and Cations are removed from the lattice. Thus, electrical neutrality is maintained in both cases.

2. An element with density 11.2g $cm^{-3}$ forms a fcc lattice with edge length of 4x $10^{-8}$ cm. Calculate the atomic mass of the element.

Ans. $d = ZM/a^3 NA$

For Fcc ,Z = 4 , a = 4x $10^{-8}$ cm ,

$M = d \times a^3 \times NA/Z = 11.2 \times (4 \times 10^{-8})^3 \times 6.022 \times 10^{23} / 4 = 108 g/mol$ CBSE - 2014

3. **Calculate the number of atoms in a cubic unit cell having one atom on each corner and two atoms on each body diagonal.**
8 corner *1/8 atom per unit cell = 1atom
There are four body diagonals in a cubic unit cell and each has two body centre atoms.
So **4*2=8 atoms** therefore total number of atoms per unit cell =1+8=9

4. **Gold crystallizes in an FCC unit cell. What is the length of a side of the cell(r=0.144nm)**

r=0.144nm

$a=2x\sqrt{2}r$

=2x1.414x0.144nm

=0.407nm

5. **Classify each of the following as either a p-type or n-type semi-conductor.**
**a) Ge doped with In**

**b) B doped with Si**

(a) Ge is group 14 elements and In is group 13 element. Therefore, an electron deficit hole is created. Thus semi-conductor is p-type.

(b) Since B is of group 13 element and Si is group 14 element, there will be a free electron, thus it is n-type semi-conductor.

6. **In terms of band theory what is the difference between a conductor, an insulator and a semi-conductor?**

The energy gap between the valence band and conduction band in an insulator is very large while in a conductor, the energy gap is very small or there is overlapping between valence band and conduction band.

7. **$CdCl_2$ will produce Schottky defect if added to AgCl crystal. Explain**

Two $Ag^+$ ions will be replaced by one $Cd^{2+}$ ion to maintain electrical neutrality. Thus a hole is created at the lattice site for every $Ca^{2+}$ ion introduced.

8. **The electrical conductivity of a metal decreases with rise in temperature while that of a semi-conductor increases. Explain.**

In metals with increase of temperature, the kernels(metal nuclei) start vibrating and thus offer resistance to the flow of electrons. Hence conductivity decreases. In case of semi-conductors, with increase of temperature, more electrons can shift from valence band to conduction band. Hence conductivity increases.

9. **What type of substances would make better permanent magnets, ferromagnetic or paramagnetic, why?**

Ferromagnetic substances make better permanent magnets. This is because the metal ions of a ferromagnetic substance are grouped into small regions called domains. Each domain acts as tiny magnet and get oriented in the direction of magnetic field in which it is placed. This persists even in the absence of magnetic field.

10. **In a crystalline solid, the atoms A and B are arranged as follows:-**
    a. **Atoms A are arranged in ccp array.**
    b. **Atoms B occupy all the octahedral voids and half of the tetrahedral voids. What is the formula of the compound?**

| | | | |
|---|---|---|---|
| A= 100 | | particles | |
| Octahedral void = 100 | | 100 (all) (B) | |
| Tetrahedral void =200 | | 100(Half) (B) | |
| Total B = 200 | | | |
| Total A = 100 | Formula | $A_{100}\ B_{200}$ | $AB_2$ |

11. **In compound atoms of element Y forms ccp lattice and those of element X occupy 2/3$^{rd}$ of tetrahedral voids. What is the formula of the compound?**

| | | | |
|---|---|---|---|
| Y= 100 | | particles | |
| Octahedral void = 100 | | - | |
| Tetrahedral void =200 | | 200x2/3 (**2/3$^{rd}$**) (X) | |
| Total X= 400/3 | | | |
| Total Y = 100 | Formula | $X_{400/3}\ Y_{100}$ | $X_4Y_3$ |

12. Examine the given defective crystal

| | | | | |
|---|---|---|---|---|
| $A^+$ | $B^-$ | $A^+$ | $B^-$ | $A^+$ |
| $B^-$ | | $B^-$ | $A^+$ | |
| $A^+$ | $B^-$ | $A^+$ | | $A^+$ |
| $B^-$ | $A^+$ | $B^-$ | $A^+$ | $B^-$ |

Answer the following questions

i) What type of stoichiometric defect is shown by the crystal? **CBSE -2014**

ii) How is the density of the crystal affected by this defect?

iii) What type of ionic substances show such defect?

Ans: i) Schottky defect ii) density decreases iii) Ionic substances in which cations and anions are of almost similar sizes.

**<u>HOTS Short Answer:</u>**

1. How many lattice points are there in one unit cell of the following lattices?
   - FCC
   - BCC
   - SCC

2. A cubic solid is made of two elements X and Y. Atom Y are at the corners of the cube and X at the body centers. What is the formula of the compound?
3. Silver forms ccp lattice and X –ray studies of its crystal show that the edge length of its unit cell is 408.6 pm. Calculate the density of silver (Atomic wt= 107.9u).
4. A cubic solid is made up of two elements P and Q. Atoms of the Q are present at the corners of the cube and atoms of P at the body centre. What is the formula of the compound? What are the co-ordination number of P and Q.
5. What happens when:-
   - CsCl crystal is heated
   - Pressure is applied on NaCl crystal.

**Short Answers (3 marks):**

1. The density of chromium is 7.2g $cm^{-3}$. If the unit cell is a cubic with length of 289pm, determine the type of unit cell (Atomic mass of Cr=52 u and $N_A$ = $6.022*10^{23}$ atoms $mol^{-1)}$.

   (d)Density = $\frac{ZxM}{a^3xNA}$

   $$Z = \frac{d \times a^3 \times N_A}{M} = \frac{7.2 \times (289 \times 10^{-10})^3 \times 6.022 \times 10^{23}}{52}$$

2. An element crystallizes in FCC structure; 200 g of this element has $4.12x10^{24}$ atoms. If the density of A is 7.2g $cm^{-3}$, calculate the edge length of unit cell.
3. Niobium crystallizes in bcc structure. If its density is 8.55 $cm^{-3}$, calculate atomic radius of [At. Mass of Niobium = 92.9u, $N_A$ = $6.022x10^{23}$ atoms $mol^{-1}$ ].
4. If radius of octahedral void is r and radius of atom in close packing is R, derive the relationship between r and R.
5. Non stoichiometric cuprous oxide can be prepared in the laboratory. In this oxide, copper to oxygen ratio is slightly less than 2:1 can u account for the fact that the substance is a p-type semiconductor?
6. The unit cell of an element of atomic mass 50u has edge length 290pm. Calculate its density the element has bcc structure ($N_A$ $6.02*10^{23}$ atoms $mol^{-1)}$.
7. Calculate the density of silver which crystallizes in face centered cubic form. The distance between nearest metal atoms is 287pm (Ag= 107.87g $mol^{-1}$, $N_A$= $6.022x10^{23}$).
8. What is the distance between $Na^+$ and Cl-ions in NaCl crystal if its density 2.165g $cm^{-3.}$ NaCl crystallizes in FCC lattice.
9. Analysis shows that Nickel oxide has $Fe_{0.98}O_{1.00}$ what fractions of nickel exist as $Fe^{2+}$ ions and $Fe^{3+}$ ions?
10. Find the type of lattice for cube having edge length of 400pm, atomic wt. = 60 and density =6.25g/cc.

**HOTS Short Answer:**

1. Aluminium crystallizes in cubic closed pack structure. Its metallic radius is 125 pm
   - What is the length of the side of the unit cell?
   - How many unit cell are there in 100 $cm^3$ of Aluminium.
2. Classify the following as either p-type or n-type semiconductors.

Ge doped with In

B doped with Si

3. Zinc oxide is white but it turns yellow on heating. Explain.

**Long Answer(5 Marks):**

1. It is face centered cubic lattice A metal has cubic lattice. Edge length of lattice cell is $2A^0$. The density of metal is 2.4g $cm^{-3}$. How many units cell are present in 200g of metal.
2. A metal crystallizes as face centered cubic lattice with edge length of 450pm. Molar mass of metal is 50g $mol^{-1}$. The density of mental is?
3. A compound forms hexagonal close packed structure. What is the total number of voids in 0.5 mol of it? How many of these are tetrahedral voids?
4. Copper Crystallizes into FCC lattice with edge length $3.61*10^{-8}$ cm. Show that calculated density is in agreement with measured value of 8.92g/cc.
5. Niobium crystallizes in bcc structure with density 8.55g/cc, Calculate atomic radius using atomic mass i.e. 93u.

**HOTS Long Answer:**

1. The compound CuCl has FCC structure like ZnS, its density is 3.4g $cm^{-3}$. What is the length of the edge of unit cell?

$$Z = \frac{d \times a^3 \times N_A}{M}, \qquad 4 = \frac{3.4 \times a^3 \times 6.022 \times 10^{23}}{99}$$

2. If NaCl is dropped with $10^{-3}$ mol% $SrCl_2$. What is the concentration of cation valancies?

4. The edge length of the unit cell of mental having molecular weight 75g/mol is $A^0$ which crystallizes into cubic lattice. If the density is $2g/cm^3$ then find the radius of metal atom ($N_A = 6.022*10^{23}$)
5. The density of K Br. Is 2.75 gm $cm^{-3}$. the length of edge of the unit cell is 654 pm. Predict the type of cubic lattice to which unit cell of KBr belongs.
   NA=$6.023*10^{23}$ ; at mass of K=39: Br. = 80
   Ans. Calculate value of z= 4 so it has fcc lattice
6. The radius of an Iron atom is 1.42 $A^0$. It has rock salt structure. Calculate density of unit cell. Ans. 5.74 g $cm^{-3}$
7. Copper crystalline with fcc unit cell. If the radius of copper atom is 127.8 pm. Calculate the density of copper metal. At. Mass of Cu=63.55u NA= $6.02*10^{23}$
   Ans.a=2√2 .r , $a^3=4.723*10^{-23}$, d=8.95 5.74 g $cm^{-3}$

# Chapter- 2 Solutions

**5 Marks Chapter**

**Solubility** - The amount of solute which can be dissolved in 100grm of solvent at particular temp. to make saturated solution.

**Concentration Terms:**