Solid States

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1 One Mark Questions

1.1 What are the types of particles in each of the main classes of crystalline solids?

- Ionic Solids - **Cations and Anions**
- Covalent Network Solids - **Atoms**
- Molecular Solids - **Monoatomic and Polyatomic Molecules**
- Metallic Solids - **Metallic ions in sea of electron**

1.2 Which of the three types of packing used by metals makes the most efficient use of space and which makes the least efficient use of space?

Out of three types of packing fcc (or ccp or hcp) lattice makes the most efficient use of space while simple cubic lattice makes the least efficient use of space.

1.3 What is the unit cell?

The smallest repeating structural unit of crystalline solid is called as unit cell of that solid.

1.4 How does the electrical conductivity of semiconductor changes with temperature? Why?

1. The electrical conductivity of semiconductor increases with increasing temperature.
2. This is because number of electrons with sufficient energy so as to get promoted to the conduction band increases as temperature rises. Thus, at higher temperatures, there are more mobile electrons in the conduction band and more vacancies in the valence band than at lower temperature.

1.5 Solid is hard, brittle and electrically nonconductor. It melt conducts electrically. What type of solid is it?

Type of solid is - **Ionic Solid**

1.6 Mention two properties that are common to both hcp and ccp lattices. Give one property to both hcp and ccp crystal lattices.

Properties common to both hcp and cpp lattice are the same coordination number **12** and the same parking efficiency **74 percent**

2 2 and 3 Marks Question

2.1 What are the valence band and conduction band?

1. **Conduction Band** -
   The highest energy band formed by interactions of the outermost energy levels of closely spaced atoms in solids is called the conduction band.
   The conduction band may be partially occupied or vacant. Electrons in the conduction band are mobile and delocalized over the entire solid. They conduct electricity when an electrical potential is applied.

2. **Valence Band** - The bands having lower energy than conduction band is the valence band.
   The electrons in valence band are not free to move because they are tightly bound to respective nuclei.

2.2 Distinguish between ionic solids and molecular solids

Ionic Solids	**Molecular Solids**
Charged ions (cations and anions	Monoatomic and polyatomic molecules
Held by electrostatic force of attraction between oppositely charged ions	Held by intermolecular forces of attractions such as London forces, dipole-dipole forces and hydrogen force
Hard and Brittle	Soft
High melting points	Low Melting Points
Non-conductors of electricity in solid state. Good conductor when melted or dissolved in water	Poor conductors of electricity.
e.g. NaCl,etc.	Ice, Benzoic Acid, etc.

2.3 How are the spheres arranged in first layer of simple cubic close-packed structures? How are the successive layers of spheres placed above this layer?

Simple cubic closed packed structures are obtained by stacking two- dimensional square close-packed layers.
So, the spheres in the first layer are placed adjacent to one another to form the two dimensional square close packing (i.e.AAAA type arrangement). All the spheres of lower layers. This results in perfect horizontal and vertical alignment between the spheres of various layers.

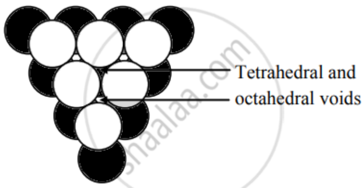
2.4 What are the consequences of Schottky defect?

Consequences of Schottky defect

1. As the number of ions decreases, mass decreases. However, the volume remains unchanged. Hence, the density of a substance decreases.
2. The number of missing cations and anions is equal. Hence, the electrical neutrality of the compound is preserved.

2.5 How are the tetrahedral and octahedral voids formed?

1. Two dimensional hexagonal close-packed layer has triangular voids which is formed by three spheres.
2. When a triangular voids of the first layer are covered by spheres of the next layer, tetrahedral voids are formed. A tetrahedral voids are formed. A tetrahedral void is surrounded by four spheres.
3. The overlapping triangular voids from the two layers together form an octahedral void. An octahedral void is surrounded by six spheres.
4. Thus, the depression in which spheres of the second layer are tetrahedral voids while the depression in which no sphere rests are octahederal voids.

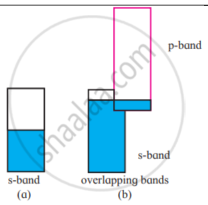
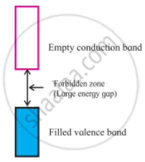
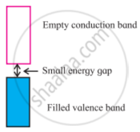


Tetrahedral and octahedral voids

2.6 Third layer of spheres is added to the second layer so as to form the hcp or ccp structure. What is the difference between the addition of the third layer to form these closed packed structures?

In cpp structure, the spheres of the third layer are not aligned with those of the first layer or second layer. Hence, the third is called as 'C' layer. The spheres of the fourth layer get aligned with the spheres of the first layer. Hence the fourth layer is called 'A' layer resulting in patterns of layer called 'ABCABC...'

2.7 Distinguish with the help of diagrams metal conductors, insulators and semiconductors from each other.

Metal Conductors	Insulators	Semiconductors
Metals are good conductors of electricity	Insulators are conductors of electricity	Semiconductors have conductivity that is intermediate between conductors and insulators
In metal conductors, the conduction band is partially filled and there is no band gap or there is overlapping between the valence band or there is overlapping between valence band and conduction band	In insulators, the valence band and conduction band in insulators are separated by large energy gap called forbidden zone.	In semiconductors, the valence band is completely filled with electrons, and the conduction band is empty. However, the energy gap between the two bands is smaller than that in an insulator.
		

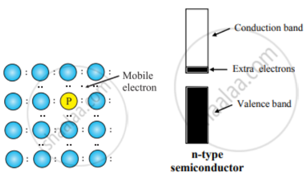
2.8 What are the n-type semiconductors? Why is the conductivity of doped n-type semiconductor higher than that of pure semiconductor? Explain with diagram.

1. An extrinsic semiconductor, which is obtained by adding group 15 element to an intrinsic semiconductor which belongs to group 14, is called as n-type semiconductor.
   e.g Silicon doped with phosphorus.

2. n-type semiconductor contains an increased number of electrons in the conduction band.

3. Consider the doping of Si with phosphorus. Si has a crystal structure in which each Si atom is linked tetrahedrally to four other Si atoms. When a small quantity of phosphorus is added to pure Si, the P atoms occupy some vacant sites in the lattice in place of Si atoms. The overall crystal structure of Si remains unchanged. Four of the five valence electrons of P are utilized in bonding the closest to four Si atoms. Thus, P has one extra electron than needed for bonding. Therefore, Si doped with P has more number of electrons in the conduction band than those in conduction band in pure Si. Thus, the conductivity of Si-doped with P is higher than that of pure Si. The electrons of the conduction band move under the influence of an applied potential and conduct electricity.

P atom occupying regular site of Si atom

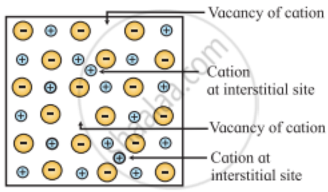


2.9 Explain with diagram, Frenkel defect. What are the conditions for its formation? What is its effects on density and electrical neutrality of the crystal?

- **Frenkel defect:**

  1. Frankel defect arises when an ion of an ionic compound is missing from its regular lattice sites and occupies an inters ilia position between lattice points. The cations are usually smaller than anions. Therefore, the cations occupy inters ilia sites.
  2. The smaller cation is displaced from its normal site to interstitial space. Therefore, it creates a vacancy defect as it's original position and an interstitial defect at its new location in the same crystal. Frenkel defect can regarded as the combination of vacancy defect and interstitial defect.
  3. This defect is found in ionic crystals like Zns, AgCl, AgBr, Agl.

Frenkel defect



- **Conditions for the formation of Frenkel Defect:**

  1. Frenkel defect occurs in ionic compounds with large difference between sizes of cation and anion.
  2. The ions of ionic compounds must be having low concentration number.

- **Consequences of Frenke Defect:**

  1. As no ions are missing from the crystal lattice as a whole, the density of solid and its chemical properties remain unchanged.
  2. The crystal as a whole remains electrically neutral because the equation numbers of cations and anions are present.

2.10 What is the impurity defect? What are its types? Explain the formation of vacancies through aliovalent impurity with example.

1. Impurity defect arises when a foreign atoms, that is atoms different from the host atoms, are present in the crystal lattice.
2. There are two kinds of impurity defects : Substitutions and Interstitial impurity defects.
3. Formation of vacancy through aliovalent impurity:
   Vacancies are created by the addition of the impurities of aliovalent ions (that is, ions with oxidation state different from host of ions) to an ionic solids.

e.g. Consider a small amount of $SrCl^2$ impurity added to NaCl during it crystallization. The added Sr^{+2} ions (O.S. = +2) occupy some of the regular sites of Na^+ host ions (O.S = +1). In order to maintain electrical neutrality, every Sr^{+2} ion removes two Na+ ions. One of the vacant lattice sites created by the removal of two Na^+ ions is occupied by one Sr^{2+} ion. The other site of Na^+ ion remains vacant as show in figure.