Ectlt 1

chapter 1. THE SOLID STATE

Teacher oriented and students oriented

Solid, Classification of solids based on the arrangement of constituents particles, Classification of Crystalline Solids Based on the Nature of particles, Space Lattice and Unit Cell, Primitive and Non-Primitive Unit Cell, Types of Cubic Unit Cell, Calculation of Number of Particles Per Unit Cell, Determination of Formula of a Compound, Close Packing of Constituent Particles, Types of Voids or Holes or Interstices, Calculation of Number of Voids in a Crystal, Location of T.V. and O.V. in FCC Crystal.The Structures of Important Compounds like NaCl, CsCl, ZnS, CaF_2 and Na_2O etc., Calculation of Packing Fraction and packing efficiency in Cubic System, Derivation of Relation between Radius of Void and the Radius of Sphere, Calculation of density of cubic solids.Imperfections or Defects in Solids, Types of Imperfections or Defects, Schottky Defects, Frenkel Defects, Metal Excess Defects, Metal Deficient Defects, Impurity Defects, Electrical Properties of Solids, Magnetic properties of Solid, Super-Conductors and Superconductivity.

Concept detail

Crystalline Solids: In these solids, there is definite and regular arrangement of the constituent particles.**Amorphous solids**: In these solids, there is indefinite and irregular arrangement of the constituent particles.**Ionic Solids**: In this case, the constituent particles are ions i.e. cation and anion. **Covalent Solids**: In this case, the constituent particles are non-metal atoms. **Metallic Solids**: In this case, the constituent particles are metal atoms. **Molecular Solids**: In this case, the constituent particles are molecules.The three dimensional arrangement of these lattice points is called **space lattice or crystal lattice**. In space lattice, there is smallest portion or part which repeats itself over and again in all directions. It iscalled **unit cell**.

The number of particles per simple cubic unit cell = 1. The total number of particles per body centred cubic (bcc) unit cell = 2. The total number of particles per face centred cubic (fcc) unit cell = 4.

Coordination Number [C.N.]: It is the number of spheres which are touching a given sphere in the close packing arrangement.

Calculation of Number of Voids in a Crystal: If there are "N" spheres in a crystal, then number of O.V. = N while number of T.V. = 2 x N. In simple cubic crystal, there is only one cubic void per unit cell.**Packing fraction**:

$$\text{P.F.} = \frac{\textit{the volume occupied by the spheres per unit cell}}{\textit{the total volume of the unit cell}}$$

P.F. is 0.524, 0.68 and 0.74 in simple cubic, body centred and face centred cubic unit cell respectively.

Relationship between radius of voids and spheres: $r_{t.v.} = 0.414\ R_{sphere}$ and $r_{o.v.} = 0.225\ R_{sphere}$.

Calculation of density of cubic solids: The density of cubic solid, $d = \frac{Z \times M}{a^3 \times N_A}$ g/cm^3.**Schottky Defects**: In this case, the cations and anions are missed from the solid in such a way that solid remains electrically neutral. **Frenkel Defects**: In this case, the cations are missed from their normal positions but are present

in the voids within the solid.**Metal Excess Defects**: Here, the metal atoms or cations are more than those non-metal atom or anions. **Metal Deficient Defects**: Here, the metal atoms or cations are less than those non-metal atoms or anions. **Impurity Defects**: When impurity or some foreign substance is added into a pure substance, then defects produced are known as impurity defects. *The process of adding of foreign substance into a pure substance is called doping*.**Conductors**: In these substances, the electrical conductivity value is greater than $10^{4}\Omega^{-1}$ cm^{-1}.**Insulators**: In these substances, the electrical conductivity value is less than $10^{-6}\Omega^{-1}$ cm^{-1}. **Semi-conductors**: In these substances, the electrical conductivity value is in the range of $10^{-6}\Omega^{-1}$ cm^{-1} to $10^{4}\Omega^{-1}$ cm^{-1}.

Diamagnetic substances: A substance is said to be diamagnetic in nature if it has no unpaired electrons.

Paramagnetic substances: A substance is said to be paramagnetic in nature if it has one or more unpaired electrons.

Ferromagnetic substances: A substance is said to be ferromagnetic in nature if it shows permanent magnetism even in the absence of magnetic field.**Anti-ferromagnetic substances:** The substances which are expected to possess paramagnetism or ferromagnetism on the basis of unpaired electrons but actually they possess zero magnetic moment are called anti ferromagnetic substances.

Ferri-magnetic substances: The substances which are expected to possess large magnetism on the basis of unpaired electrons but actually they have less net magnetic moment are called ferri-magnetic substances.

Super-Conductors and Superconductivity: A substance is said to be superconductor if it offers no resistance to current or electricity and phenomenon is called superconductivity.

Activity

Make cubic and rhombic crystal system to explain the axial length and axial angles.
Draw the structure of NaCl, CsCl, ZnS, CaF_2 and Na_2O.
Make energy bands to explain the electrical properties of conductors, insulators and semi-conductors.

Instant diagnostic questions:

1. What are crystalline and amorphous solids?
2. Define space lattice and unit cell?
3. Define coordination number.
4. What is the number of particles per unit cell in sc, bcc and fcc?What is the packing fraction in case of bcc and fcc lattice?
5. What is the C.N. of Cl^- in NaCl structure?
6. What is the relationship between radius of T.V. and radius of sphere? What are Schottky defect?
7. What are Frenkel defect?
8. What are ferromagnetic and ferrimagnetic substances?

Formative assignment

1. What is the co-ordination number of an octahedral void?
2. What is the number of atoms per unit cell in body centered cubic structure?
3. How many tetrahedral voids are present in 1 mole of compound, AB having ccp arrangement?

4. Distinguish between crystal lattice and unit cell.What is the co-ordination number of Ca^{2+} and F^- ions in the CaF_2 crystal?
5. Niobium crystallizes in body centered structure. If its density is 8.55 g/cm^3, then calculate its atomic radius. Given that atomic weight of Niobium is 93 amu.
6. Prove that radius of tetrahedral void = 0.225 times the radius of sphere.

Level wise questions:

Level 1

1. Define space lattice and unit cell?
2. Define coordination number.
3. Urea has sharp melting point but glass does not. Explain why?What is the packing fraction in case of bcc and fcc lattice?
4. What is the C.N. of Cl^- in NaCl structure?
5. What is the relationship between radius of T.V. and radius of sphere?

Level 2

1. Why are ionic solids conducting in the molten state but not in the solid state?
2. The refractive index of a solid is found to be same in all the direction in it. Identify the nature of solid. Would it show clean cleavage property?
3. Calculate the number of atoms in a cubic based unit cell having each atom on the corner and two atoms on each body diagonal.
4. What are consequences of Schottky and Frenkel defects?
5. Classify each of the following as n-type or p-type semi-conductor: (i) Ge doped with In (ii) Si doped with B.
6. What types of defects are present in the following? (i) ZnS (ii) AgBr

Level 3

1. In fcc arrangement of A and B atoms, the atoms A are present at the corners of the cube while atoms B are present at the face centre of cube. If one atom A is missing from the corner, then what is the formula of the compound?
2. In a crystalline solid, the atoms A and B are arranged as follows: (i) atoms A adopt ccp arrangement. (ii) Atoms B occupy all the octahedral voids and half of the tetrahedral voids. Write the formula of the compound.
3. Calculate the packing fraction in case of face centered cubic structure.
4. Na adopt bcc unit cell having edge length of 429 pm. What is the radius of Na atom and length of the body diagonal?
5. The edge length of NaCl unit cell is 564 pm. What is the density of NaCl in g/cm^3?

Project

Make a model to explain the close packing of particles in solids.
Make a memory frame to remember the structure of important ionic compounds.
Make a memory frame to remember the defects present in solids.