Chapter 1
Solid State

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1 Marks Questions

1. What are fluids? Give examples.

Ans. Substances which flow are fluids e.g. liquids and gases.

2. Solids are rigid why?

Ans. Rigidity in solids is due to fixed positions of the constituent particles and their oscillations about their mean positions

3. How are solids classified?

Ans. Solids may be classified into two categories – crystalline and amorphous.

4. Why do crystalline solids are anisotropic nature and amorphous solid are isotropic in nature.

Ans. Anisotropy in crystals is due to different arrangement of particles along different directions. Isotropic in amorphous solid is due to its long range order in them and arrangement is irregular along all the directions.

5. Define the term: Crystal lattice

Ans. A regular three dimensional arrangement of points in space is called crystal lattice.

6. What is a unit cell?

Ans. The smallest portion of a crystal lattice which, when, repeated in different directions, generates the entire lattice, is called its unit cell.

7. What are the axial angles and edge length in a cubic crystal system?

Ans. Axial angles, $\alpha = \beta = \gamma = 90^0$ and edge lengths a = b = c.

8. Give one example of each – Tetragonal and hexagonal crystal system.

Ans. Tetragonal crystal system – white tin, SnO_2 .

Hexagonal crystal system – Graphite, ZnO.

9. What is square close packing?

Ans. The close packing of spheres – atoms or ions, in which each sphere is in contact with four of is neighbors, whose centres, if joined, form a square, is called square close packing.

10. What is the coordination number in:-

(a) Square close packing

(b) Hexagonal close packing.

Ans. (a) in square close packing, the coordination no. is 4.

(b) In hexagonal close packing, the coordination no. is 12.

11. Define – (a) void (b) coordination Number

Ans. (a) void – the empty space left between close packed spheres are voids.

(b) Coordination number – the number of spheres or atoms surrounding a single sphere or atom in a crystal is called coordination number.

12. What is the packing efficiency in

Ans. (a) hcp packing efficiency is 74%.

(b) bcc packing efficiency is 68%.

(c) packing efficiency in simple cubic structure is 52.4%.

13. What is the meaning of term 'defect' with reference to crystal

Ans. The defects are irregularities in the arrangement of constituent particles in a crystal.

14. Name the types of point defect.

Ans. point defects are of three types – stoichiometric defect, impurity defect & non – stoichiometric defect.

15. What are F centres?

Ans. F – centre is the position of an anion in an ionic crystal which is occupied by a trapped electron

16. Why do the heating of NaCl in an atmosphere of sodium vapour impact yellow colour ?

Ans. In an atmosphere of sodium vapour the Cl^- diffuses to the surface of the crystal and combine with Na atom to form NaCl. During this process Na atom loses an electron –cl for Na^+. As a result the crystal has an excess of sodium which import yellow colour to the crystal.

17. Give an example which shows both frenkel and Schottky defect.

Ans. AgBr.

18. Define the term – doping.

Ans. Doping – The process of introduction of impurity atoms into an insulator to make it a semiconductor is called doping.

19. What is the meaning of 13 – 15 compounds?

Ans. A semiconductor formed by combination of 13 groups & 15 groups elements is 13 – 15 compound.

20. Name an element which can be added to silicon to give a –

(i) p – type semiconductor

(ii) n – type semiconductor.

Ans. (i) For p – type semiconductor Borom can be added.

(ii) For n – type semiconductor, Phosphorous can be added.

21. What is the difference between ferromagnetic and paramagnetic substances?

Ans. A ferromagnetic substance has permanent magnetic behaviour whereas a paramagnetic substance acts as a magnet only in the presence of an external magnetic field.

2 Marks Questions

1. The window panes of the old buildings are thick at the bottom. Why?

Ans. Glass panes of old buildings are thicker at the bottom than at the top as from is an amorphous solid and flows down very slowly and makes the bottom portion thicker.

2. The stability of a crystal is reflected in the magnitude of its melting point. Explain

Ans. Melting point of a solid gives an idea about the intermolecular forces acting between particles. When these forces are strong, the melting point is higher and when these forces are weak, low melting point is observed. Higher is the melting point, more stable the solid is.

3. Graphite is soft and good conductor of electricity. Explain.

Ans. Graphite is soft and good conductor due to its typical structure here carbon atoms are arranged in different layers and each atom a covalently bonded to three of its neighbouring atoms in the same layer. The fourth electron of each atom is free to move about due to which it conducts electricity. Different layers can slide over the other which makes it a soft solid.

4. Ionic solids are good conductors in molten state and in aqueous solutions but not in solid state. Why?

Ans. In the solid state, the ions in the ionic solids are not free to move about due to their rigid structure & strong electrostatic forces. Therefore they cannot conduct electricity whereas in molten state and aqueous solution, the ions become free to move about and they conduct electricity.

5. Name three types of cubic unit cells?

Ans. (a) Simple cubic

(b) Face – centred cubic

(c) Body centred cubic

6. How many atoms are there in a unit cell of a metal crystallizing in a:

(a) FCC structure

(b) BCC structure

Ans. (a) FCC = 4   (b) BCC = 2

7. What is the contribution of an atom per unit cell if the atom is:

(a) At the corner of the cube.

(b) On the face of the cube.

(c) In the centre of the cube.

Ans. (a) When atom is at the corner of the cube, the contribution is $\frac{1}{8}$ atom.

(b) When the atom is on the face of the cube, its contribution is $\frac{1}{2}$ atom.

(c) If the atom is in the centre of the cube, its contribution is 1 atom.

8. A compound formed by A & B crystallizes in the cubic structure where 'A' are at the corners of the cube and B are at the face centre. What is the formula of the compound?

Ans. Contribution of atom A per unit cell = $\frac{1}{8} \times 8 = 1$ atom

Contribution of atom B per unit cell = $\frac{1}{2} \times 6 = 3$ atom

Ratio of A & B = 1:3   Formula = AB_3.

9. Calculate the no. of atoms in a cubic based unit – cell having one atom on each

corner and two atoms on each body diagonal.

Ans. No. of atoms contributed by 8 corners per unit cell = $\frac{1}{8} \times 8 = 1$ atom.

No. of atoms contributed by one diagonal = 2

No. of diagonal = 4

$\therefore$ Total contribution by diagonal = 4 × 2 = 8

$\therefore$ Total no. of atoms = 8 + 1 = 9 atoms

10. What is the no. of octahedral and tetrahedral voids present in a lattice?

Ans. No. of octahedral voids present in a lattice is equal to the no. of close packed particles and the number of tetrahedral voids is twice the no. of close packed particles.

11. Give the relationship between density and edge length of a cubic crystal.

Ans. Density, d of a cubic cell is given by –

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

Where Z = no. of atoms per unit cell

M = molar mass

N_A = Avogadro number

a = edge length

12. Copper which crystallizes as a face – centred cubic lattice has a density of $8.93\ g/cm^3$ at $20^\circ C$. calculate the length of the unit cell.

Ans. 63.1 u

13. An element crystallizes in BCC structure. The edge of its unit cell is 288 pm. If the density is $7.2\ g/cm^3$, calculate the atomic mass of the element.

Ans. 52 g/ mol

14. The compound CuCl has ZnS structure and the edge length of the unit cell in 500 pm. Calculate the density. (Atomic masses: Cu = 63, Cl = 35.5, Avogadro no = $6.02 \times 10^{23} mol^{-1}$)

Ans. $5.22\ g / cm^3$

15. In a compound, B ions form a close – packed structure & A ions occupy all the tetrahedral voids. What is the formula of the compound?

Ans. Let the no. of B ions = 100

No. of A ions = no. of tetrahedral voids

= 2 $\times$ no. of B = 2 $\times$ 100 = 200

Ratio of A & B = 200 : 100 = 2 : 1

Formula = A_2B .

16. Define two main types of defects.

Ans. Defects are of two types –

Point defects: - Irregularities or deviations from ideal arrangement around a point or on atom in a crystal.

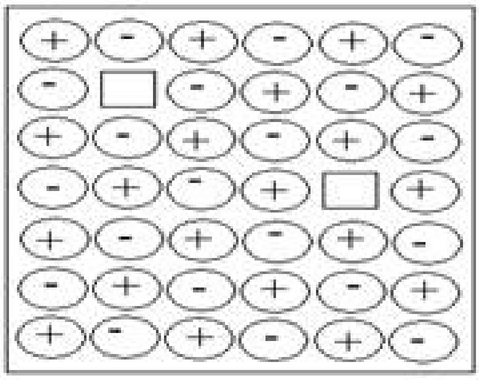
Line defect: - Irregularities or deviation from ideal arrangement in entire row of lattice points.

17. (a) Identify the defect in figure below :

(b) How does it affect the density of crystal?

(c) Give an example of crystal where this defect can be found.

(d) What is its effect on electrical neutrality of crystal?



Ans. (a) Schottky defect.

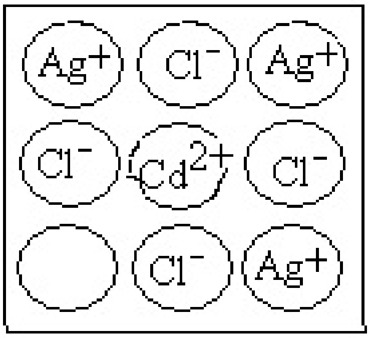
(b) It decreases the density of crystal.

(c) NaCl, KCl

(d) The crystal remains electrically neutral.

18. Which defect is observed in a solid solution of $CdCl_2$ and AgCl? Explain.

Ans. In a solid solution of $CdCl_2$ and AgCl, impurity defect is observed. In the crystal of AgCl, some of the sites of Ag^+ are occupied by Cd^{2+}, each Cd^{2+} replacing two Ag^+. It replaces the site of one ion and other site remains vacant.



19. Excess of lithium makes LiCl crystal pink. Explain.

Ans. When crystals of LiCl are heated in an atmosphere of Li vapour the Lithium atoms are deposited on the surface of crystal. The Cl^- ions diffuse to the surface of crystal & combine with Li atoms to from LiCl which happens by loss of electrons by Li atoms to form Li^+ ions. These released elements diffuse into the crystal & electrons get excited after absorbing light from visible region & emit pink colour.

20. In the fig –

(i)

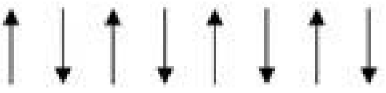


Fig. (i)

(a) Identify the magnetic behaviour of substance.

(b) How are these substances different from diamagnetic substances?

Ans. (a) Antiferromagnetic field.

(b)In Antiferromagnetic substance the domain structure is similar to ferromagnetic substance but the domains are oppositely oriented and cancel out each others magnetic moment whereas in diamagnetic substance all individual electron are paired which cancels the individual magnetic moments.

21. Define the terms – Intrinsic semiconductor and extrinsic semiconductor.

Ans. Intrinsic semiconductor – An insulator which conducts electricity when heated.

Extrinsic semiconductor – An insulator which conducts electricity on addition of an impurity.

22. Classify solids on the basis of their conductivities.

Ans. Solids can be classified into three types on the basis of their conductivities –

Solids	Conductivities
1. Conductor	$10^{4} \, to \, 10^{7} \, \Omega^{-1} m^{-1}$
2. Insulators	$10^{-20} \, to \, 10^{-10} \, \Omega^{-1} m^{-1}$
3. Semi – conductor	$10^{-6} \, to \, 10^{4} \, \Omega^{-1} m^{-1}$

23. Give two examples of each.

(a) Ferromagnetic substances

(b) Ferrimagnetic substances

Ans. (i) Ferromagnetic substances –Fe, Co, Ni, CrO_2, Gadolinium.

(ii) Ferrimagnetic substance – Fe_3O_4, Magnetite and Ferrites.

24. Give two application of p – type and n – type semiconductors.

Ans. Application –

(i) A combination of both p – type and n – type semiconductors is used in diode which is used as rectifiers.

(ii) npn & pnp types of transistors are used as amplifiers.

25. Non-stoichiometric cuprous oxide, Cu_2O can be prepared in laboratory. In this oxide, copper to oxygen ratio is slightly less than 2:1. Can you account for the fact that this substance is a *p*-type semiconductor?

Ans. In the cuprous oxide (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.

26. 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.

Ans. Let the number of oxide (O_{2-}) ions be *x*.

So, number of octahedral voids = *x*

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

So, number of ferric (Fe^{3+}) ions=23x

Therefore, ratio of the number of Fe3+ions to the number of O2− ions, Fe^{3+} Fe3+: O2−=23 x:x

=23:1

= 2 : 3

Hence, the formula of the ferric oxide isFe2O3.

27. 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.

Ans. (i) Ge (a group 14 element) is doped with In (a group 13 element). Therefore, a hole will be created and the semiconductor generated will be a *p*-type semiconductor.

(ii) B (a group 13 element) is doped with Si (a group 14 element). Thus, a hole will be created and the semiconductor generated will be a *p*-type semiconductor.

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

Ans. For a face-centred unit cell:a=$22\sqrt{r}$

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

So, $a = 22\sqrt{\times 0.144}nm$

= 0.407 nm

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

29. In terms of band theory, what is the difference

(i) Between a conductor and an insulator

(ii) Between a conductor and a semiconductor

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

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

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.

30. 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) 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.

31. Explain

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

(ii) Ionic solids are hard and brittle.

Ans. (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.

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

Ans. 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.

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

Ans. 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.

34. Classify the following as amorphous or crystalline solids:

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

Ans. **Amorphous solids:** Polyurethane, teflon, cellophane, polyvinyl chloride, fibre glass

Crystalline solids: Naphthalene, benzoic acid, potassium nitrate, copper

35. (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?

Ans. **(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

3 Marks Questions

1. Differentiate between amorphous and crystalline solids with reference to

(1) Melting point

(2) Cleavage property

(3) Nature

Ans.

Property	Crystalline solids	Amorphous solids
1. Melting point	They have sharp melting point	They have a range of melting point.
2. Cleavage property	They split into pieces of plain and smooth surfaces when cut with a sharp edged tool.	When cut with a sharp edged tool, pieces of irregular surfaces are obtained.
3. Nature	They are true solids.	They are pseudo solids or super cooled liquids.

2. How are crystalline solids classified on the basis of nature of bonding? Explain with examples.

Ans. Classification of crystalline solids.

1. **Molecular solids:** The forces operating between molecules are dispersion or London forces, dipole – dipole interactions, hydrogen bounding e.g. CCl_4, HCl, ice etc.

2. **Ionic solids:**The intermolecular forces are coulomibic or electrostatic forces, e.g. NaCl, MgO etc.

3. **Metallic solids:** The forces operating is metallic bonding e.g. Fe, Cu, Ag etc.

4. **Covalent or network solids:** The attractive forces are covalent bonding e.g. Diamond, Quartz etc.

3. In crystalline solid, anions C are arranged in cubic close – packing, cations A occupy 50% of tetrahedral voids & cations B occupy 50% of octahedral voids. What is the formula of solid?

Ans. Suppose no. of anions, C = 100

Suppose no. of cations, A = $\frac{50}{100} \times$ no. of tetrahedral voids

= $\frac{1}{2}(2 \times C)$

No. of cations, B = $\frac{50}{100} \times$ no. of octahedral voids

$= \frac{1}{2} \times (C)$

= $\frac{1}{2} \times 100 = 50$

Ratio of ions A : B : C = 100 : 50 : 100

= 2 : 1 : 2

Formula = A_2BC_2

4. Which type of ionic substances show?

(a) Schottky defect

(b) Frenkel defect

Ans. (a) Schottky defect – ionic substances in which the cation and anion are of almost similar sizes eg. NaCl, KCl, CrCl.

(b) Feenkel Defect – Ionic substances in which there is large difference in size of ions eg. ZnS, AgCl, AgBr.

5. Aluminium crystallises 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 cm^3 of aluminium?

Ans. (i) For cubic close-packed structure:

$$a = 22\sqrt{r} = 22\sqrt{\times 125}\,pm$$

= 353.55 pm

= 354 pm (approximately)

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

= $4.4\times107pm^3$

=$4.4\times10^7\times 10^{-30}cm^3$

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

Therefore, number of unit cells in 1.00 cm^3 =1.00cm $34.4\times10^{-23}cm^3$

= 2.27×10^{22}

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

Ans. It is given that NaCl is doped with 10^{-3} % of $SrCl_2$.

This means that 100 mol of NaCl is doped with $10-^{3}$mol of $SrCl_2$.

Therefore, 1mol of NaCl is doped with103100mol 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 = $10^{-5} \times 6.022 \times 1023$

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

Hence, the concentration of cation vacancies created by $SrCl_2$ is $6.022 \times 108\, mol$ of NaCl.

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

Ans. It is given that the edge length, $a = 4.077 \times 10^{-8} cm$

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, $NA = 6.022 \times 1023\, mol^{-1}$

Using the relation:

$$d = zMa^3NA$$

$$M = da^3NAz = 10.5 g\, cm^3 \times \left(4.077 \times 10^{-8} cm\right) \times 6.022 \times 1023\, mol^{-14}$$

$$= 107.13\, g\, mol^{-1}$$

Therefore, atomic mass of silver = 107.13 u

8. 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. 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 = $8 \times 18 = 1$

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.

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

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

Atomic mass, M = 93 g mol^{-1}

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

We also know that, $NA = 6.022 \times 1023 \, mol^{-1}$

Applying the relation:

$$d = zMa^3NA$$
$$a^3 = zMdNA$$

$$= 2 \times 93 \, g \, mol^{-1} 18.55 \, g \, cm^{-3} \times 6.022 \times 1023 \, mol^{-1}$$

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

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

For body-centred cubic unit cell:

$$r = 3\sqrt{4}a = 3\sqrt{4} \times 3.306 \times 10^{-8} cm$$

$=1.432\times10^{-8}cm$

$=14.32\times10^{-9}cm$

= 14.32 nm

10. 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.

Ans. 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

$\angle POQ = 90^\circ$

Now, applying Pythagoras theorem, we can write:

$PQ^2 = PO^2 + OQ^2$

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

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

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

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

$\Rightarrow r = 2\sqrt{R} - R$

$\Rightarrow r = (2\sqrt{-1})R$

$\Rightarrow r = 0.414R$

11. Copper crystallises into a fcc lattice with edge length $3.61\times10^{-8}cm$. Show that the calculated density is in agreement with its measured value of 8.92 g cm^3.

Ans. Edge length, $a = 3.61\times10^{-8}cm$

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, $NA = 6.022 \times 1023 mol^{-1}$

Applying the relation:

$d = zMa^3 NA$

$= 4 \times 63.5 g\, mol^{-1}(3.61 \times 10^{-8} cm)3 \times 6.022 \times 1023 mol^{-1}$

$8.97\ g\, cm^{-3}$

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.

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

Ans. 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 mass of one atom of the metal and ‘z’ be the number of atoms in the unit cell.

Now, density of the unit cell =Mass of the unit cell Volume of the unit cell

d=zma3………………………(i)

[Since mass of the unit cell = Number of atoms in the unit $cell \times mass$ of one atom]

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

From equation (*i*), we have:

m=da3z………………………(ii)

Now, mass of one atom of metal (*m*) = Atomic mass (M) Avogadro's number (NA)

Therefore, M = da3NAz………………………(iii)

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

m = d(abc)NAz……………………………(iv)

13. '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?

Ans. 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

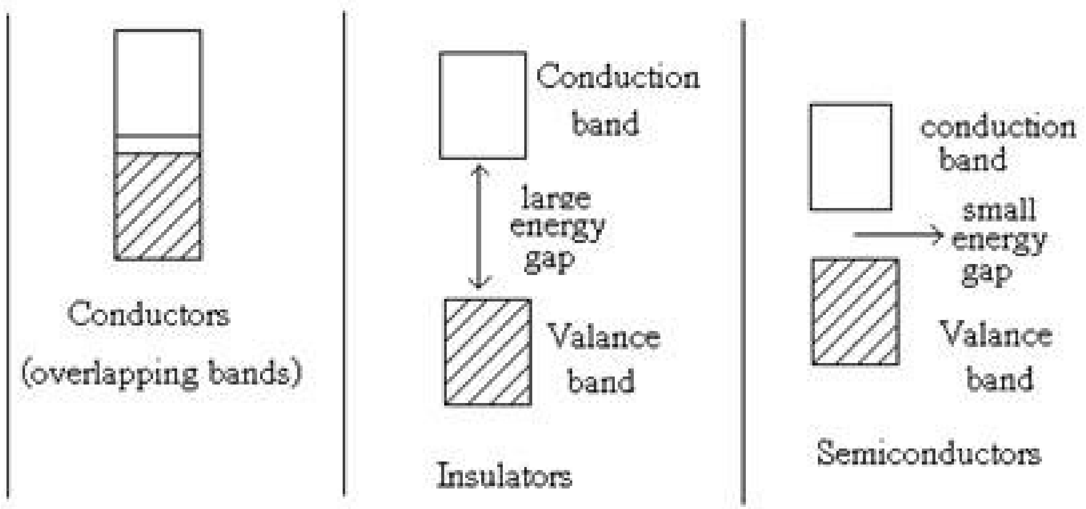
Methane = 89.34 K

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.

5 Marks Questions

1. Explain conduction of electricity on the basis of band theory.

Ans. The conductivity of metals depend upon the no. of valance electrons available per atom. The atomic orbitals of metal atoms form molecular orbitals which are so close in energy to each other as to form a band. If this band is partially filled & overlaps with a higher energy unoccupied, conduction band, then electrons can flow easily under an applied electric field & metal is a conductor. If the gap between filled valance band and conduction band is large, electron cannot jump to it & the substance is an insulator where as if the gap is small & on heating, can be overcome, the substance acts as semiconductor



2. 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?

Ans. 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.

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

Case1: 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.

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.

3. 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).

Ans. (i)Simple cubic

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 = $43\pi r^3$

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

= $43\pi r^3 \, 8r^3 \times 100\%$

= $16\pi \times 100\%$

= $16 \times 227 \times 100\%$ =52.4%

(ii) Body-centred cubic

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:

b2=a2+a2⇒b2=2a2⇒b= $2\sqrt{a}$

Again, from ΔAFD , we have:

c2=a2+b2⇒c2=a2+2a2⇒c2=3a2 (Since b2=2a2)

c= $3\sqrt{a}$

Let the radius of the atom be *r*.

Length of the body diagonal, c= 4π

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

= $a = 4r3\sqrt{}$

r= $3\sqrt{a}4$

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

A body-centred cubic lattice contains 2 atoms.

So, volume of the occupied cubic lattice = $2\pi 43r^3$

$= 83\pi r^3$

Therefore, Packing efficiency = Volume occupied by two spheres in the unit cell Total volume of the unit cell

$= 83\pi r^3(43\sqrt{r})\times 100\%$

$= 83\pi r^3(6433\sqrt{r^3})\times 100\%$

(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:

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

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

$b^2 = 2a^2$

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

4. Analysis shows that nickel oxide has the formulaNi0.98O1.00. What fractions of

nickel exist as Ni^{2+} and Ni^{3+} ions?

Ans. The formula of nickel oxide is Ni0.98O1.00.

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 = $100\times(-2)$

= -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+} =9498

= 0.959

And, fraction of nickel that exists as Ni^{3+} =498

= 0.041

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

= 0.041

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

Ans. Semiconductors are substances having conductance in the intermediate range of 10^–6to10^4ohm^–1m^–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 Geis 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 neighboring 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 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.

6. Explain the following terms with suitable examples:

(i) Schottky defect

(ii) Frenkel defect

(iii) Interstitials and

(iv) F-centres

Ans. (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 106Schottky pairs per cm3at 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.

(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 NaClare 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.

7. Explain the following with suitable examples:

(i) Ferromagnetism

(ii) Paramagnetism

(iii) Ferrimagnetism

(iv) Antiferromagnetism

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

Ans. (i) Ferromagnetism: 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.

(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.