SAIVEERA ACADEMY'S GUIDE

VOL -I

(2022-2023 EDITION)

It includes

- ✓ Complete Book Back Answers
- ✓ Knowledge Based Questions
- ✓ Knowledge Based One Marks
- ✓ Additional Book Inside Questions
- ✓ Evaluate Yourself Answers

6- SOLID STATE

Points To Overlook

- **Types of solids :** (i) Crystalline solids (ii)Amorphous solids.
- **Crystalline solid :** Solid in which its constituents (atoms, ions or molecules), have an orderly arrangement extending over a long range.
- **Amorphous solids :** In Greek, amorphous means no form , the constituents are randomly arranged.
- **Isotropy :** Having identical values of physical properties such as refractive index, electrical conductance etc., in all directions
- **Anisotropy :** Different values of physical properties when measured along different directions
- **Ionic solids:** The constituents are cations and anions which are bound together by strong electrostatic attractive forces. Examples: NaCl
- **Covalent solids:** The constituents (atoms) are bound together in a three dimensional network entirely by covalent bonds. **Examples:** Diamond, silicon carbide etc.
- **Molecular solids :** Constituents are neutral molecules which are held together by weak van der Waals forces.
    1) **Non-polar molecular solids :** Constituent molecules are held together by weak dispersion forces or London forces **Examples:** Naphthalene, anthracene etc.,
    2) **Polar molecular solids :** T he constituents are molecules formed by polar covalent bonds. They are held together by relatively strong dipole-dipole interactions.. **Examples :** solid CO_2 , solid NH_3 etc.
    3) **Hydrogen bonded molecular solids :** The constituents are held together by hydrogen bonds.. **Examples:** solid ice (H_2O), glucose, urea etc.,
    4) **Metallic solids :** Lattice points are occupied by positive metal ions and a cloud of electrons pervades the space. Example : Cu,Fe,Zn, Ag ,Au, Cu- Zn etc.
- **Crystal lattice :** The regular arrangement of these species throughout the crystal
- **Characteristic parameters of unit cell :** Three edge lengths or lattice constants a ,b and c and the angle between the edges α, β and γ
- Seven primitive crystal systems : Cubic, tetragonal, orthorhombic, hexagonal, monoclinic, triclinic and rhombohedral.
- Simple cubic unit cell : Each corner is occupied by an identical atoms or ions or molecules. And they touch along the edges of the cube, do not touch diagonally. The coordination number of each atom is 6.
- **Body centered cubic unit cell :** Each corner is occupied by an identical particle and in addition to that one atom occupies the body centre. Coordination number is 8.

- **Face centered cubic unit cell :** Identical atoms lie at each corner as well as in the centre of each face. Coordination number is 2.
- **Schottky defect :** Missing of equal number of cations and anions from the crystal lattice.
- **Frenkel defect** : Dislocation of ions from its crystal lattice. The ion which is missing from the lattice point occupies an interstitial position.
- **Metal excess defect :** Presence of more number of metal ions as compared to anions.
- **Metal deficiency defect** : Presence of less number of cations than the anions.
- **Impurity defect** : Adding impurity ions which are in different valance state from that of host, vacancies are created in the crystal lattice of the host .
- **Packing fraction** :
  - ✓ Simple cubic : 52.31 %
  - ✓ Body centered cubic : 68 %
  - ✓ Face centered cubic : 74 %
- **Vacancy percentage**
  - ✓ Simple cubic : 47.69 %
  - ✓ Body centered cubic : 32 %
  - ✓ Face centered cubic : 26 %

Unit cell	Edge length	Interfacial angles
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$
Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90°, \beta \neq 90$
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$

Textual Questions

1. Graphite and diamond are

a) Covalent and molecular crystals b) ionic and covalent crystals

c) both covalent crystals d) both molecular crystals

Ans : c) both covalent crystals

2. An ionic compound A_xB_y crystallizes in fcc type crystal structure with B ions at the centre of each face and A ion occupying entre of the cube. the correct formula of A_xB_y is

a) AB b) AB_3 c) A_3B d) A_8B_6

Ans : b) AB_3

3. The ratio of close packed atoms to tetrahedral hole in cubic packing is

a) 1:1 b) 1:2 c) 2:1 d) 1:4

Ans : b) 1:2

4. Solid CO_2 is an example of

a) Covalent solid b) metallic solid c) molecular solid d) ionic solid

Ans : c) molecular solid

5. Assertion : monoclinic sulphur is an example of monoclinic crystal system

Reason: for a monoclinic system, a≠b≠c and $\alpha = \gamma = 90°, \beta \neq 0$

a) Both assertion and reason are true and reason is the correct explanation of assertion.

b) Both assertion and reason are true but reason is not the correct explanation of assertion.

c) Assertion is true but reason is false.

d) Both assertion and reason are false.

Ans : a) Both assertion and reason are true and reason is the correct explanation of assertion.

6. In calcium fluoride, having the flourite structure the coordination number of Ca^{2+} ion and F^- Ion are

a) 4 and 2 b) 6 and 6 c) 8 and 4 d) 4 and 8

Ans : c) 8 and 4

7. The number of unit cells in 8 gm of an element X (atomic mass 40) which crystallizes in bcc pattern is (NA is the Avogadro number)

a) 6.023×10^{23} b) 6.023×10^{22} c) 60.23×10^{23} d) $\left(\frac{6.023 \times 10^{23}}{8 \times 40}\right)$

Ans : b) 6.023×10^{22}

8. In a solid atom M occupies ccp lattice and $\left(\frac{1}{3}\right)$ of tetrahedral voids are occupied by atom N. find the formula of solid formed by M and N.

a) MN b) M_3N c) MN_3 d) M_3N_2

Ans : d) M_3N_2

9.The ionic radii of A^+ and B^- are $0.98X10^{-10}$ m and $1.81 X 10^{-10}$ m. the coordination number of each ion in AB is

a) 8 b) 2 c) 6 d) 4

Ans : c) 6

10.CsCl has bcc arrangement, its unit cell edge length is 400pm, its inter atomic distance is

a) 400pm b) 800pm c) $\sqrt{3} \times 100$pm d) $\left(\frac{\sqrt{3}}{2}\right) \times 400$pm

Ans : d) $\left(\frac{\sqrt{3}}{2}\right) \times 400$pm

11. A solid compound XY has NaCl structure. if the radius of the cation is 100pm , the radius of the anion will be

a) $\left(\frac{100}{0.414}\right)$ b) $\left(\frac{0.732}{100}\right)$ c) 100×0.414 d) $\left(\frac{0.414}{100}\right)$

Ans : a) $\left(\frac{100}{0.414}\right)$

12. The vacant space in bcc lattice unit cell is

a) 48% b) 23% c) 32% d) 26%

Ans : c) 32%

13. The radius of an atom is 300pm, if it crystallizes in a face centered cubic lattice, the length of the edge of the unit cell is

a) 488.5pm b) 848.5pm c) 884.5pm d) 484.5pm

Ans : b) 848.5pm

14. The fraction of total volume occupied by the atoms in a simple cubic is

a) $\left(\frac{\pi}{4\sqrt{2}}\right)$ b) $\left(\frac{\pi}{6}\right)$ c) $\left(\frac{\pi}{4}\right)$ d) $\left(\frac{\pi}{3\sqrt{2}}\right)$

Ans : b) $\left(\frac{\pi}{6}\right)$

15. The yellow colour in NaCl crystal is due to

a) excitation of electrons in F centers b) reflection of light from Cl^- ion on the surface

c) refraction of light from Na^+ ion d) all of the above

Ans : a) excitation of electrons in F centers

16. if 'a' stands for the edge length of the cubic system ; sc , bcc, and fcc. Then the ratio of radii of spheres in these systems will be respectively.

a) $\left(\frac{1}{2}a : \frac{\sqrt{3}}{2}a : \frac{\sqrt{2}}{2}a\right)$ b) $\left(\sqrt{1}a : \sqrt{3}a : \sqrt{2}a\right)$

c) $\left(\frac{1}{2}a : \frac{\sqrt{3}}{4}a : \frac{1}{2\sqrt{2}}a\right)$ d) $\left(\frac{1}{2}a : \sqrt{3}a : \frac{1}{\sqrt{2}}a\right)$

Ans : c) $\left(\frac{1}{2}a : \frac{\sqrt{3}}{4}a : \frac{1}{2\sqrt{2}}a\right)$

17. if 'a' is the length of the side of the cube, the distance between the body centered atom and one corner atom in the cube will be

a) $\left(\frac{2}{\sqrt{3}}\right)a$ b) $\left(\frac{4}{\sqrt{3}}\right)a$ c) $\left(\frac{\sqrt{3}}{4}\right)a$ d$\left(\frac{\sqrt{3}}{2}\right)a$

Ans : d$\left(\frac{\sqrt{3}}{2}\right)a$

18. Potassium has a bcc structure with nearest neighbor distance 4.52 A° . its atomic weight is 39. its density will be

a) 915 kg m^{-3} b) 2142 kg m^{-3} c) 452 kg m^{-3} d) 390 kg m^{-3}

Ans : a) 915 kg m^{-3}

19. Schottky defect in a crystal is observed when

a) unequal number of anions and anions are missing from the lattice

b) equal number of anions and anions are missing from the lattice

c) an ion leaves its normal site and occupies an interstitial site

d) no ion is missing from its lattice.

Ans : b) equal number of anions and anions are missing from the lattice

20. The cation leaves its normal position in the crystal and moves to some interstitial position, the defect in the crystal is known as

a) Schottky defect b) F center

c) Frenkel defect d) non-stoichiometric defect

Ans : c) Frenkel defect

21. Assertion: due to Frenkel defect, density of the crystalline solid decreases.

Reason : in Frenkel defect cation and anion leaves the crystal.

a) Both assertion and reason are true and reason is the correct explanation of assertion.

b) Both assertion and reason are true but reason is not the correct explanation of assertion.

c) Assertion is true but reason is false.

d) Both assertion and reason are false

d) Both assertion and reason are false

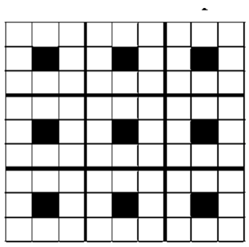
Ans : d) Both assertion and reason are false

22. The crystal with a metal deficiency defect is

a) NaCl b) FeO c) ZnO d) KCl

Ans : b) FeO

23. A two dimensional solid pattern formed by two different atoms X and Y is shown below. The black and white squares represent atoms X and Y respectively. the simplest formula for the compound based on the unit cell from the pattern is



a) XY_8 b) X_4Y_9

c) XY_2 d) XY_4

Ans : a) XY_8

Additional Questions

1.An example for metal deficiency defect is

a) NaCl b) AgCl c) FeO d) CsCl

Ans : c) FeO

2. An ion leaves its regular site and occupies a position in the space between the lattice sites. This defect is called as

a) Schottky defect b) Frenkel defect c) impurity defect d) vacancy defect

Ans : b) Frenkel defect

3. In a simple cubic cell, each point on a corner is shared by

a) one unit cell b) two unit cells c) eight unit cells d) four unit cells

Ans : c) eight unit cells

4.In Bragg's equation 'n' represent

a) number of moles b) Avogadro number

c) quantum number d) order of diffraction

Ans : d) order of diffraction

5.The Bragg's equation is

a) $\lambda = 2d \sin\theta$ b) $nd = 2\lambda \sin\theta$ c) $2\lambda = nd \sin\theta$ d) $n\lambda = 2d \sin\theta$

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

6.The co-ordination number of ZnS is

a) 3 b) 4 c) 6 d) 8

Ans : b) 4

7. The co-ordination number of B_2O_3 is

a) 3 b) 4 c) 6 d) 8

Ans : a) 3

8. The co-ordination number of NaCl is

a) 3 b) 4 c) 6 d) 8

Ans : c) 6

9. The co-ordination number of CsCl is

a) 3 b) 4 c) 6 d) 8

Ans : d) 8

10.The crystal structure of CsCl is

a) simple cube b) face-centred cube

c) body-centred cube d) edge-centred cube

Ans : c) body-centred cube

11.A regular three dimensional arrangement of identical points in space is called

a) Unit cell b) Space lattice c) Primitive d) Crystallography

Ans : a) Unit cell

12. An example for Frenkel defect is

a) NaCl b) AgBr c) CsCl d) FeS

Ans : b) AgBr

13.The solids which are good conductors of electricity and heat are

a) Ionic solids b) Molecular solids c) Metallic solids d) Covalent solids

Ans : c) Metallic solids

14.The solid in which its constituents have an orderly arrangement extending over a long range

a) Ionic solid b) Molecular solids c) Crystalline solids d) Amorpous solids

Ans : c) Crystalline solids

15. The Coordination number of each atom in Simple Cubic , Face centered cubic , Body centered cubic are

a) 6 , 2 , 8 b)2 , 6 , 8 c)2 , 6 , 2 d)6 , 2 , 6

Ans : a) 6 , 2 , 8

16. Percentage of Schottky defect in VO(Vanadium Mono oxide) crystal :

a)14 % b)15% c)16% d)18%

Ans : a)14 %

17. Which one is Non Stoichiometric defect ;

a) Metal excess effect b) Frenkel defect

c) Metal deficiency defect d)Both a and c

Ans : d)Both a and c

18. Percentage of free space (vacant) in Simple cubic , Body centered , Face centered cubic unit cell (Cubic close packing) are

a) 47.69 % , 32 % , 26 % b) 47.69 % , 30 % , 26 %

c) 48.69 % , 32 % , 26 % d) 47.69 % , 32 % , 28 %

Ans : a) 47.69 % , 32 % , 26 %

19. In AAA type each sphere is arranged in contact with ----------- of its neighbours

a) six b) four c) two d) none of these

Ans : b)four

20.In ABAB… type each sphere is arranged in contact with ----------- of its neighbours

a)six b)four c) two d)none of these

Ans : a)six

21.Three atoms P , Q , R crystallize in a cubic solid lattice having P atoms at corners , Q atom at body centre , R atom at face centre .Identify the formula of the compound

a) PQR b) PQR_2 c) PQ_2R d) PQR_3

Ans : d)PQR_3

22.The general formula of an ionic compound which crystallines in body-centred cubic structure is

a) AB b) AB_2 c) A_2B d) AB_3

Ans : a) AB

23.What is the arrangements of layers in a cubic close packing of spheres?

a) AB AB AB… b) ABC ABC ABC…

c) AAAAA… d) None of these

Ans : a) AB AB AB…

24. What is the arrangements of layers in a hexagonal close packing of atom?

a) AB AB AB… b) ABC ABC ABC… c) AAAAA… d) None of these

Ans : b) ABC ABC ABC…

24. If $\left(\frac{r_C^+}{r_A^-}\right)$ is 0.225 – 0.414, the coordination number is

a) 3 b) 4 c) 6 d) 8

Ans : b) 4

25. In which crystal system $a \neq b \neq c$, $\alpha = \beta = \gamma = 90^\circ$

a) tetragonal b) orthorhombic c) rhombohedral d) hexagonal

Ans : b) orthorhombic

26. In both hcp and ccp arrangements, the coordination number of each sphere is

a) 8 b) 4 c) 12 d) 6

Ans : c) 12

27. The coordination number of an octahedral void is

a) 4 b) 6 c) 2 d) 8

Ans : b) 6

28. The coordination number of an tetrahedral void is

a) 4 b) 6 c) 2 d) 8

Ans : a) 4

29. Naphthalene and Anthracene are

a) Non polar molecular crystals b) Polar molecular crystals

c) Metallic crystals d) Ionic crystals

Ans : a) Non polar molecular crystals

30. Glucose is an example for

a) ionic crystals b) hydrogen bonded molecular crystal

c) polar molecular crystals d) non – polar molecular crystals

b) hydrogen bonded molecular crystals

31.The crystal with metal excess defect is

a) ZnO b) FeO c) AgBr d) FeS

a) ZnO

32. A unit cell that contains only one lattice point is called

a) Non – primitive unit cell b) Primitive unit cell

c) Face centred cubic unit cell d) Body centred cubic unit cell

Ans : c) Face centred cubic unit cell

33. In which crystal system $a = b \neq c, \alpha = \beta = \gamma = 90^\circ$

a) hexagonal b) tetragonal c) rhombohedral d) orthorhombic

Ans : b) tetragonal

34.Which one of the following is an amorphous solid?

a) glass b) SiO_2 c) NaCl d) Na

Ans : a) glass

35. Which one of the following is an example for atomic solids?

a) Frozen elements of group 18 b) Group 17 elements

c) Inner-transition elements d) Chalcogens

Ans : a) Frozen elements of group 18

36. Which one of the following is a covalent crystal?

a) Glass b) Diamond c) Anthracene d) Glucose

Ans : b) Diamond

37. Molecular solids contains neutral molecules held together by

a) strong cohesive forces b) weak vanderwals forces

c) weak ionic forces d) strong electrostatic forces

Ans : b) weak vanderwals forces

35. Silicon carbide is an example of

a) ionic solid b) covalent solid

c) polar molecular solid d) non – polar molecular solid

Ans : b) covalent solid

36. Solid NH_3 solid CO_2 are examples of

a) covalent solids b) polar molecular solids

c) molecular solids d) ionic solids

Ans : c) molecular solids

37. Each atom in the corner of the cubic unit cell is shared by how many unit cell?

a) 8 b) 6 c) 1 d) 12

Ans : a) 8

38.Which one of the following metal shows non – stoichiometric defect?

a) FeO b) AgBr c) ZnO d) Both a and c

Ans : d) Both a and c

39. Which is the coordination number of each atom in a simple cubic unit cell?

a) 8 b) 6 c) 12 d) 4

Ans : b) 6

40. The number of atoms belongs to bcc unit cell is

a) 2 b) 4 c) 6 d) 12

Ans : a) 2

41. The number of atoms belongs to fcc unit cell is

a) 2 b) 4 c) 6 d) 8

Ans : b) 4

42. The atoms the face centre is being shared by _______ unit cells.

a) 4 b) 8 c) 2 d) 6

Ans : c) 2

43. The coordination number of zinc sulphide is

a) 3 b) 4 c) 6 d) 8

Ans : b) 4

44. The coordination number of CsCl is

a) 3 b) 4 c) 6 d) 8

Ans : d) 8

45. Metal excess defect is possible in

a)AgCl b) AgBr c) KCl d)FeS

Ans : c) KCl

Textual Questions

Answer the following questions

1.Define unit cell.

- ✓ A basic repeating structural unit of a crystalline solid in a three dimensional pattern is called a unit cell.
- ✓ A unit cell is characterised by the three edge lengths or lattice constants a ,b and c and the angle between the edges α, β and γ

2. Give any three characteristics of ionic crystals

1) They have high melting points.
2) They does not conduct electricity, because the ions are fixed in their lattice positions.
3) They conduct electricity in molten state (or) when dissolved in water because, the ions are free to move in the molten state or solution.
4) They are hard as only strong external force can change the relative positions of ions.

3. Differentiate crystalline solids and amorphous solids

Crystalline Solids	Amorphous solids
Long range orderly arrangement of constituents.	Short range, random arrangement of constituents.
Definite shape	Irregular shape
Anisotropic in nature	Isotropic in nature
They are true solids	They are considered as pseudo solids (or) super cooled liquids
Definite Heat of fusion	Heat of fusion is not definite
They have sharp melting points.	Gradually soften over a range of temperature and so can be moulded
Examples: NaCl , diamond,	**Examples:** Plastics, glass

4. Classify the following solids

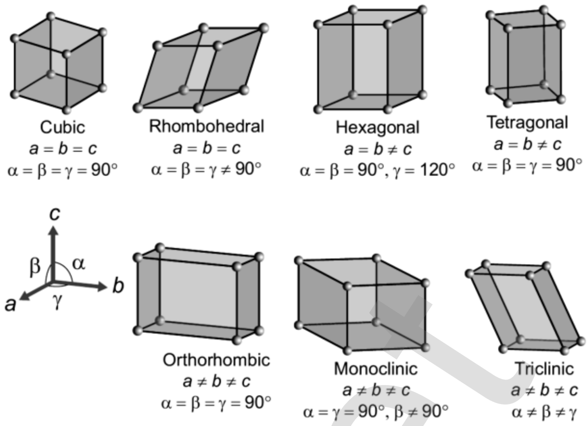
(*a*) P_4 (*b*) Brass (*c*) Diamond (*d*) NaCl (*e*) Iodine

(*a*) P_4 - Molecular solid
(*b*) Brass – Metallic solid
(*c*) Diamond – Covalent solid
(*d*) NaCl – Ionic solid
(*e*) Iodine – Molecular solid

5. Explain briefly seven types of unit cell.

There are seven primitive crystal systems

1) Cubic - NaCl
2) Tetragonal - TiO_2
3) Orthorhombic - BaSO4
4) Hexagonal - ZnO
5) Monoclinic - $PbCrO_4$
6) Triclinic - H_3BO_3
7) Rhombohedral - HgS



6.Distinguish between hexagonal close packing and cubic close packing

Hexagonal Close packing	Cubic Close packing
'ABA' arrangement	**'ABC' arrangement**
The spheres of the third layer is exactly aligned as first layer	The spheres of the third layer is not aligned with those of either the first or second layer.
The hexagonal close packing is based on hexagonal unit cells with sides of equal length	The cubic close packing is based on the face centered cubic unit cell.
Tetrahedral voids of the second layer are covered by the sphere of the third layer	Octahedral voids of the second layer are covered by the sphere of the third layer
The unit cell of hexagonal close packing has 6 spheres.	The unit cell of cubic close packing has 4 spheres
This type is found in metals like **Mg, Zn.**	This type is found in metals like **Cu, Ag.**

7.Distinguish tetrahedral and octahedral voids.

Tetrahedral Void	Octahedral Void
When a sphere of second layer (b) is above the void (x) of the first layer (a), tetrahedral void is formed.	When the voids (y) in the first layer (a) are partially covered by the spheres of layer (b), octahedral void (a)
If the number of close packed spheres be 'n' then, the number of tetrahedral voids generated is equal to 2n.	If the number of close packed spheres be 'n' then, the number of octahedral voids generated is equal to n

This constitutes four spheres , three on the lower (a) and one in the upper layer (b).	This constitutes six spheres the lower layer (a) and three in the upper layer (b)
When the centers of these four sphere sare joined, a tetrahedron is formed	When the centers of these six spheres are joined, an octahedron is formed.
The coordination number is 4.	The coordination number is **6.**

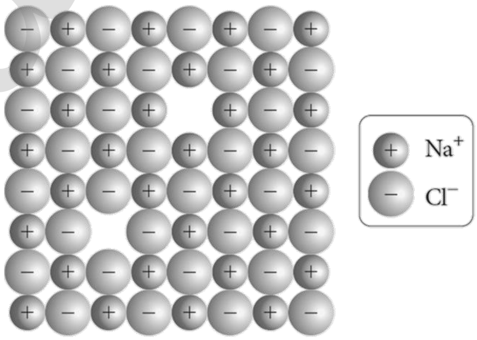
8. What are point defects?

- ✓ If the deviation in the perfect crystal occurs due to missing atoms , displaced atoms or extra atoms the imperfection is called as point defect.
- ✓ It occurs due to imperfect packing during the original crystallisation or they may arise from thermal vibrations of atoms at elevated temperature.

Types : Stoichiometric , Non stoichiometric , Impurity defect

9. Explain Schottky defect

- ✓ Schottky defect arises due to **the missing of equal number of cations and anions** from the crystal lattice.



- ✓ This effect **does not change the stoichiometry** of the crystal.
- ✓ Ionic solids in which the **cation and anion are of almost of similar size** show schottky defect. **Example: NaCl.**
- ✓ Presence of large number of schottky defects in a crystal **lowers its density.**
- ✓ Example: vanadium monoxide (VO).Theoretical density is **6.5 g cm^{-3},** but the actual Experimental density is **5.6 g cm^{-3}**.
- ✓ Approximately **14% Schottky defect** in VO crystal.

10. Write short note on metal excess and metal deficiency defect with an example

Metal excess defect

- ✓ It arises due to the **presence of more number of metal ions** as compared to anions.
- ✓ Alkali metal halides **NaCl, KCl** show this type of defect.
- ✓ The electrical neutrality of the crystal can be maintained by the presence of anionic vacancies equal to the excess metal ions (or) by the presence of extra cation and electron present in interstitial position.

Example : ZnO is colourless at room temperature. When it is heated, it becomes yellow in colour. On heating, it loses oxygen and thereby forming free Zn^{2+} ions. The excess Zn^{2+} ions move to interstitial sites and the electrons also occupy the interstitial positions.

Metal deficiency defect

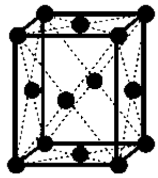
- ✓ It arises arises due to the presence of less number of cations than the anions.
- ✓ This defect is observed in a crystal in which, the cations have variable oxidation states.

Example : In FeO crystal, some of the Fe^{2+} ions are missing from the crystal lattice. To maintain the electrical neutrality, twice the number of other Fe^{2+} ions in the crystal is oxidized to Fe^{3+} ions. In such cases, overall number of Fe^{2+} and Fe^{3+} ions is less than the O^{2-} ions.

11.Calculate the number of atoms in a fcc unit cell.

In a face centered cubic unit cell, identical atoms lie at each corner as well as in the centre of each face.

$N_c = 8$ (Number of atoms in corners) $N_f = 6$ (Number of atoms in face)



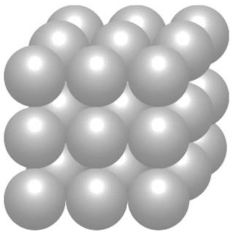
Number of unit cell in fcc $= \frac{N_c}{8} + \frac{N_f}{2}$

$= \frac{8}{8} + \frac{6}{2}$

$= 1 + 3 = 4$

12.Explain AAAA and ABABA and ABCABC type of three dimensional packing with the help of neat diagram.

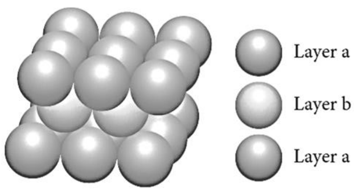
(i) AAAA type



- ✓ It can be obtained by repeating the AAAA type two dimensional arrangements in three dimensions.
- ✓ Spheres in one layer sitting directly on the top of those in the previous layer so that all layers are identical.
- ✓ All spheres of different layers of crystal are perfectly aligned horizontally and also vertically, so that any unit cell of such arrangement as simple cubic structure .
- ✓ In simple cubic packing, each sphere is in contact with 6 neighbouring spheres - Four in its own layer, one above and one below and hence the coordination number of the sphere in simple cubic arrangement is 6.

(ii) ABAB.. Type

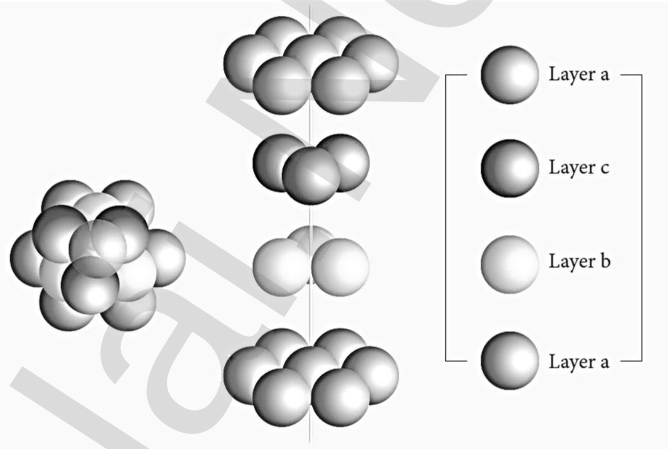
- ✓ In this arrangement, the spheres in the first layer (A type) are slightly separated and the second layer is formed by arranging the spheres in the depressions between the spheres in layer A .
- ✓ The third layer is a repeat of the first.
- ✓ This pattern ABABAB is repeated throughout the crystal.
- ✓ In this arrangement, each sphere has a coordination number of 8, four neighbors in the layer above and four in the layer below.



Body Certered Cubic (BCC)

(iii) ABCABC type arrangement

- ✓ In this arrangement, the first layer is formed by arranging the spheres as in the case of two dimensional ABAB arrangements.
- ✓ The spheres of second row fit into the depression of first row. This is layer 'a'.
- ✓ The second layer is formed by placing the spheres in the depressions of the first layer. This is layer 'b'.
- ✓ There are two types of voids x and y.
- ✓ Wherever a sphere of second layer (b) is above the void (x) of the first layer (a), a tetrahedral void is formed. This constitutes four spheres – three in the lower (a) and one in the upper layer (b). When the centers of these four spheres are joined, a tetrahedron is formed.
- ✓ At the same time, the voids (y) in the first layer (a) are partially covered by the spheres of layer (b), now such a void in (a) is called a octahedral void.



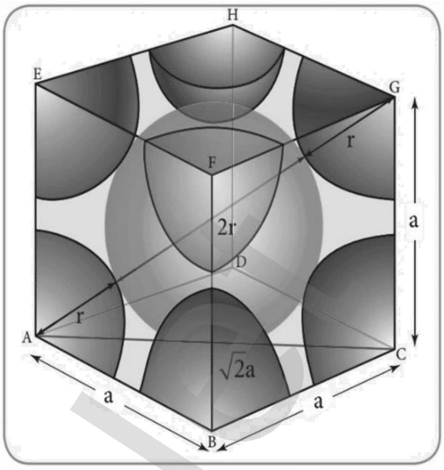
- ✓ The third layer may be placed over the second layer in such a way that all the spheres of the third layer fit in octahedral voids. This arrangement of the third layer is different from other two layers (a) and (b), and hence, the third layer is designated (c). If the stacking of layers is continued in abcabcabc… pattern, then the arrangement is called cubic close packed (ccp) structure.
- ✓ In ccp arrangements, the coordination number of each sphere is 12 – six neighbouring spheres in its own layer, three spheres in the layer above and three sphere in the layer below.

13.Why ionic crystals are hard and brittle?

- ✓ Only strong forces can change the relative position of its constituent ions , so they are hard
- ✓ In ionic compounds the ions are rigidly held in a lattice because the positive and negative ions are strongly attracted to each other and difficult to separate.
- ✓ But the brittleness of a compound is how easy it is to shift the position of atoms or ions in a lattice

14.Calculate the percentage efficiency of packing in case of body centered cubic crystal

The spheres are touching along the leading diagonal of the cube



In ΔABC

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

$AC = \sqrt{AB^2 + BC^2}$

$AC = \sqrt{a^2 + a^2} = \sqrt{2a^2} = \sqrt{2}a$

In ΔACG

$AG^2 = AC^2 + CG^2$

$AC = \sqrt{AC^2 + CG^2}$

$AC = \sqrt{(\sqrt{2}a)^2 + a^2} = \sqrt{3a^2} = \sqrt{3}a$

$\sqrt{3}a = 4r$

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

Volume of the sphere with radius 'r' $= \frac{4}{3}\pi r^3$

$= \frac{4}{3}\pi\left(\frac{\sqrt{3}a}{4}\right)^3$

$= \frac{\sqrt{3}}{16}\pi a^3$

Number of spheres belong to a unit cell in bcc arrangement is equal to two and hence the total volume of all spheres

$= 2 \times \frac{\sqrt{3}}{16}\pi a^3 = \frac{\sqrt{3}\pi a^3}{8}$

Packing fraction $= \frac{\text{Total volume occupied by sphere in a unit cell}}{\text{volume of unit cell}} \times 100$

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

$= \sqrt{3} \times 3.14 \times 12.5 = 1.732 \times 3.14 \times 12.5 = \mathbf{68}\%$

68 % of the available volume is occupied. The available space is used more efficiently than in simple cubic packing.

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

The two dimensional coordination number of a molecule in square close packed layer is **4**

16. Experiment shows that Nickel oxide has the formula $Ni_{0.96}O_{1.00}$. What fraction of Nickel exists as of Ni^{2+} and Ni^{3+} ions?

Given **$Ni_{0.96}O_{1.00}$**

Ratio of Ni : O = 96:100

So, if there are 100 atoms of oxygen then 98 atoms of Ni

Let number of atoms of $Ni^{2+} = x$

Then number of atoms of $Ni^{3+} = 0.96 - x$

Total number of cation $= 2x + 3(0.96 - x)$

$= 2x + 2.88 - 3x$

$= (-x) + 2.88$

Number of anions $O^{2-} = (-2) \times 1 = -2$

Number of cations = Number of anions

$(-x) + 2.88 = 2$

x= 0.88

Fraction of Ni^{2+} = (atom of Ni^{2+} / total number of atoms of Ni)

$= \left(\frac{0.88}{0.96}\right)$

= 0.9166

% of Ni in Ni^{2+} = 91.66%

Fraction of Ni^{3+} = (atom of Ni^{3+} / total number of atoms of Ni)

$= (\left(\frac{8}{96}\right))$

= 0.083

% of Ni in Ni^{3+} = 8.33%

17. What is meant by the term "coordination number"? What is the coordination number of atoms in a bcc structure?

- ✓ The number of nearest neighbour that surrounding a particle in a crystal is called coordination number.
- ✓ The coordination number of atoms in a bcc structure is 8**.**

18.. Aluminium crystallizes in a cubic close packed structure. Its metallic radius is 125pm. Calculate the edge length of unit cell.

let 'a' is the edge of the cube and 'r' is the radius of atom.

Given : r = 125 pm

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

Sub the **value of 'r'** we get,

a = 2 x 1.414 x125 pm

= 354 pm (approximately

19.If NaCl is doped with 10^{-2} mol percentage of strontium chloride, what is the concentration of cation vacancy?

Given : Concentration of $SrCl_2 = 10^{-2}$mole%

Concentration is in percentage so that take total 100 mole of solution

Number of moles of NaCl =100 – moles of $SrCl_2$

Moles of $SrCl_2$ is very negligible as compare to total moles.

Number of moles of NaCl = 100

1 mole of NaCl is dopped with $SrCl_2 = \frac{10^{-2}}{100}$ moles

$= 10^{-4}$mole of $SrCl_2$

cation vacancies per mole of NaCl $= 10^{-4}$mole

1 mole $= 6.023 \times 10^{23}$ particles

So, cation vacancies per mole of NaCl $= 10^{-4} \times 6.023 \times 10^{23}$

$= 6.023 \times 10^{19}$vacancies

20.KF crystallizes in fcc structure like sodium chloride. Calculate the distance between K^+ and F^- in KF. (Given: density of KF is 2.48 g cm^{-3})

Given : $\rho = 2.48$ g cm^{-3}

Since it is face centered number of unit cell = 4 , Molar mass of KF = 58.8 g mol^{-1}

$$a^3 = \frac{nM}{\rho N_A}$$

$$= \frac{4 \times 58.8}{2.48 \times 6.023 \times 10^{23}}$$

$$a^3 = 1.57 \times 10^{-22} \text{ cm}^3$$

V = (Edge length)^3 $= a^3$

Edge length $= \sqrt{V} = \sqrt{1.57 \times 10^{-22}} = 538$ pm

$$d = \frac{a}{\sqrt{2}}$$

$$d = \frac{538}{1.414}$$

$$d = 380.12 \text{ pm}$$

21.An atom crystallizes in fcc crystal lattice and has a density of 10 gcm^{-3} with unit cell edge length of 100pm. calculate the number of atoms present in 1 g of crystal.

Given : ρ = 10 gcm^{-3} a = 100 pm Mass = 1 g

No of atoms in fcc unit cell = 4

Volume of unit cell $a^3 = (100 \times 10^{-10} \text{ cm})^3 = 10^{-24}\text{cm}^3$

Number of atoms in 1g of crystal $= \frac{Z \times M}{\rho a^3} = \frac{4 \times 1}{10 \times 10^{-24}} = 4 \times 10^{23}$atoms

22. Atoms X and Y form bcc crystalline structure. Atom X is present at the corners of the cube and Y

is at the center of the cube. What is the formula of the compound?

The atom at the corner makes a contribution of $\frac{1}{8}$ to the unit cell (X)

The atom at the center makes a contribution of 1 to the unit cell (Y)

Thus, number of atoms X per unit cell = Number of atoms × Contribution per unit cell

$= 8$ (at the corners) $\times \frac{1}{8}$ atoms per unit cell

$= 1$

Thus, number of atoms X per unit cell = Number of atoms × contribution per unit cell

$= 1$ (at the body centre) $\times 1$

$= 1$

Thus, the formula of the given compound is XY.

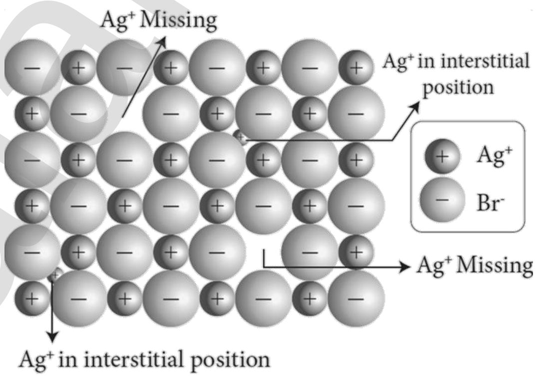
23. Sodium metal crystallizes in bcc structure with the edge length of the unit cell 4.3×10^{-8} cm. calculate the radius of sodium atom.

Given : a = 4.3×10^{-8} *cm*.

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

$= \frac{\sqrt{3}}{4} \times 4.3 \times 10^{-8}$ cm.

$= 1.786 \times 10^{-8}$ cm



24. Write a note on Frenkel defect.

- ✓ Frenkel defect arises due to the dislocation of ions from its crystal lattice.
- ✓ The ion which is missing from the lattice point occupies an interstitial position. This defect is shown by ionic solids in which cation and anion differ in size.
- ✓ Unlike Schottky defect, this defect does not affect the density of the crystal.
- ✓ For example AgBr, in this case, small Ag^+ ion leaves its normal site and occupies an interstitial position as shown in the figure.

Evaluate yourself

1. An element has a face centered cubic unit cell with a length of 352.4 pm along an edge. The density of the element is 8.9 gcm^{-3}. How many atoms are present in 100 g of an element?

Given : a = 352.4 pm , n = 4 (face centered cubic) , $\rho = 8.9 gcm^{-3}$, $N_A = 6.023 \times 10^{23}$

$$M = \frac{\rho a^3 N_A}{n}$$

$$= \frac{8.9 \times (352.4 \times 10^{-12})^3 \times 6.023 \times 10^{23}}{4}$$

$$= 586.47 \times 10^{-1} = 58.65 g$$

58.65 g of the element contains 6.023×10^{23} atom

100g of the element will contain $= \frac{6.023\times10^{23}\times100}{58.65}$ atoms

$= 1.026 \times 10^{22}$ atoms

2.Determine the density of CsCl which crystallizes in a bcc type structure with an edge length 412.1 pm.

Given : M = 168.5 , n = 2 , a = 412.1×10^{-12} , $N_A = 6.023 \times 10^{23}$

$\rho = \frac{nM}{a^3 N_A}$

$\rho = \frac{2\times168.5}{(412.1\times10^{-12})^3\times6.023\times10^{23}}$

$= 0.779 \times 10$

$= 7.99 = 8 gcm^{-3}$

3.A face centered cubic solid of an element (atomic mass 60) has a cube edge of 4Å . Calculate its density.

Given : $\boldsymbol{a = 4Å = 4 \times 10^{-10}}$, M = 60 , n = 4 (face centered cubic)

$\rho = \frac{nM}{a^3 N_A}$

$= \frac{4\times60}{(4\times10^{-10})^3\times6.023\times10^{23}}$

$= 0.6626 \times 10 = 6.626\ gcm^{-3}$

Additional Questions

Short Answers

1.What are General characteristics of solids

- ✓ Solids have definite volume and shape.
- ✓ Solids are rigid and incompressible
- ✓ Solids have strong cohesive forces.
- ✓ Solids have short inter atomic, ionic or molecular distances.
- ✓ Their constituents (atoms , ions or molecules) have fixed positions and can only oscillate about their mean positions

2.What are two types of solids based on the arrangement of their constituents.

(i) Crystalline solids

(ii) Amorphous solids.

3.Define isotropy and anisotropy

Isotropy means uniformity in all directions. In solid state isotropy means having identical values of physical properties such as refractive index, electrical conductance etc., in all directions,

Anisotropy means having different values of physical properties when measured along different directions.

4.Define Crystal lattice

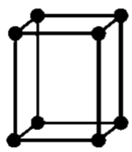
The regular arrangement of these species throughout the crystal is called a crystal lattice.

5.What are two types of unit cells?

- ✓ A unit cell that contains only one lattice point is called a primitive unit cell, which is made up from the lattice points at each of the corners.
- ✓ In non-primitive unit cells, there are additional lattice points, either on a face of the unit cell or with in the unit cell.

6.Calculate the Number of atoms in a simple and body centered cubic unit cell

Simple cubic unit cell



In the simple cubic unit cell, each corner is occupied by an identical atoms or ions or molecules. The coordination number of each atom is 6.

Each atom in the corner of the cubic unit cell is shared by 8 neighbouring unit cells

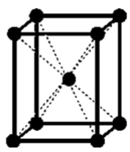
N_c – Number of atoms in corners = 8

Number of atoms in a simple cubic unit cell = $N_c/8$

= 8/8

= 1

Body centered cubic unit cell. (BCC)



In a body centered cubic unit cell, each corner is occupied by an identical particle and in addition to that one atom occupies the body centre.

Those atoms which occupy the corners is surrounded by eight nearest neighbours and coordination number is 8. An atom present at the body centre belongs to only to a particular unit cell i.e unshared by other unit cell.

N_c – Number of atoms in corners = 8 N_b = 1

Number of atoms in a body centered cubic unit cell = $N_c/8$ + N_b / 1

= 8/8 + 1/1

= 1+1 = 2

7.What is Stoichiometric defects in ionic solid:

This defect is also called intrinsic (or) thermodynamic defect. In stoichiometric ionic crystals, a vacancy of one ion must always be associated with either by the absence of another oppositely charged ion (or) the presence of same charged ion in the interstitial position so as to maintain the electrical neutrality

8.Explain about impurity defect

- ✓ A general method of introducing defects in ionic solids is by adding impurity ions.
- ✓ If the impurity ions are in different valance state from that of host, vacancies are created in the crystal lattice of the host.
- ✓ For example, addition of $CdCl_2$ to silver chloride yields solid solutions where the divalent cation Cd^{2+} occupies the position of Ag+.
- ✓ This will disturb the electrical neutrality of the crystal.
- ✓ In order to maintain the same, proportional number of Ag^+ ions leaves the lattice.
- ✓ This produces a cation vacancy in the lattice, such kind of crystal defects are called impurity defects.

9.What is Bragg's equation?

The inter planar distance (d) between two successive planes of atoms can be calculated using the following equation form the X-Ray diffraction data

$$\mathbf{n\lambda = 2d\sin\theta}$$

λ – the wavelength of X-ray used for diffraction.

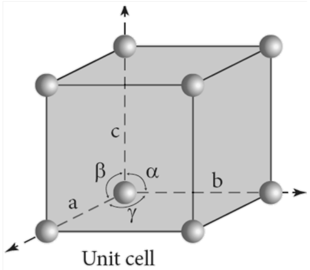
θ – The angle of diffraction

n – Order of difrraction

10.What are characteristic parameters of a unit cell?

Three edge lengths or lattice constants - a ,b and c

angle between the edges - α, β and γ

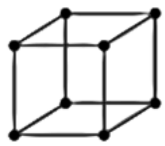


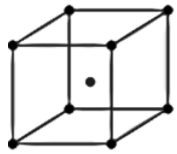
Unit cell

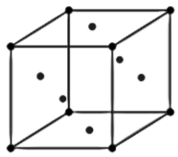
11.What is meant by packing efficiency ? How it is measured?

- ✓ There is some free space between the spheres of a single layer and the spheres of successive layers.
- ✓ The percentage of total volume occupied by these constituent spheres gives the packing efficiency of an arrangement. For example in simple cubic arrangement
- ✓ Packing fraction $= \frac{\text{Total volume occupied by sphere in a unit cell}}{\text{volume of unit cell}} \times 100$

12.Sketch the a) Simple cubic b) Body-centered cubic c) Face centered cubic lattices

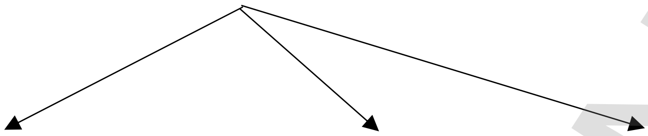

Simple cubic


Body centered cubic


Face centered cubic

13.How will you classify point defects

Point defects



Stoichiometric defect	Non stoichiometric defect	Impurity defect
(i) Shocttky defect	(i) Metall Excess defect	
(ii) Frenkel defect	(ii) Metal deficiency defect	

14.How will you classify crystal defects?

1) Point defects
2) Line defects
3) Interfacial defects
4) Volume defects

15. What is Piezoelectric crystals ?

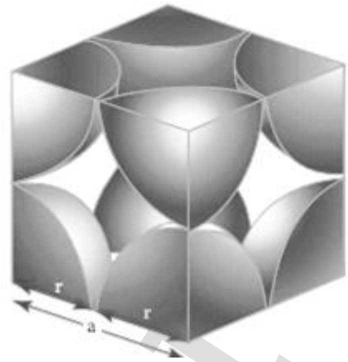
- ✓ Piezoelectricity is the appearance of an electrical potential across the sides of a crystal when you subject it to mechanical stress.
- ✓ The word piezoelectricity means electricity resulting from pressure and latent heat.
- ✓ Even the inverse is possible which is known as inverse piezoelectric effect.

Long Answers

1.Calculate packing efficiency of simple cubic unit cell

$$\text{Packing fraction} = \frac{\text{Total volume occupied by sphere in a unit cell}}{\text{volume of unit cell}} \times 100 \text{........(1)}$$

Consider a cube with an edge length 'a'



Volume of the cube with edge length a $= a^3$……….**(2)**

r- radius of the sphere

From the figure $a = 2r$ which implies $r = \frac{a}{2}$

Volume of the sphere with radius 'r'$= \frac{4}{3}\pi r^3$

$$= \frac{4}{3}\pi\left(\frac{a}{2}\right)^3$$

$$= \frac{\pi a^3}{6} \quad \text{……..(3)}$$

In a simple cubic arrangement, number of spheres belongs to a unit cell is equal to one

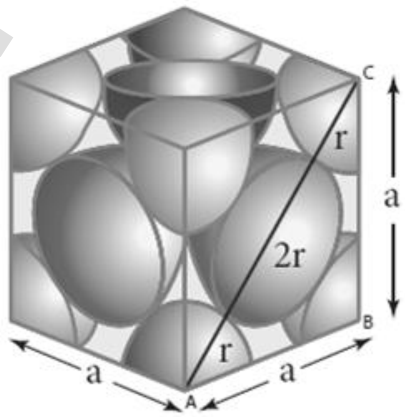
Total volume occupied by sphere in a sc unit cell $= 1 \times \frac{\pi a^3}{6} = \frac{\pi a^3}{6}$……**(4)**

Dividing (4) by (2)

Packing fraction $= \frac{\frac{\pi a^3}{6}}{a^3} \times 100 = 52.13\%$

only 52.31% of the available volume is occupied by the spheres in simple cubic packing, making inefficient use of available space and hence minimizing the attractive forces.

2.Calculate packing efficiency of fcc unit cell



From the figure

AC = 4r

$4r = a\sqrt{2}$

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

In ΔABC

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

$AC = \sqrt{AB^2 + BC^2}$

$AC = \sqrt{a^2 + a^2} = \sqrt{2a^2} = \sqrt{2}a$

Volume of the sphere with radius 'r'$= \frac{4}{3}\pi r^3$

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

$$= \frac{\sqrt{2}}{24}\pi a^3$$

Number of spheres belong to a unit cell in fcc arrangement is equal to 4 and hence the total volume of all spheres

$$= 4 \times \frac{\sqrt{2}}{24}\pi a^3 = \frac{\sqrt{2}\pi a^3}{6}$$

Packing fraction $= \frac{\text{Total volume occupied by sphere in a unit cell}}{\text{volume of unit cell}} \times 100$

$$= \frac{\left(\frac{\sqrt{2}\pi a^3}{6}\right)}{(a)^3} \times 100$$

$$= \frac{1.414 \times 3.14 \times 100}{6} = 74\%$$

74 % of the available volume is occupied. The available space is used more efficiently than in simple cubic packing.

3.How is radius ration is useful in determination of structure of an ionic compound?

- ✓ The structure of an ionic compound depends upon the stoichiometry and the size of the ions.
- ✓ Generally in ionic crystals the bigger anions are present in the close packed arrangements and the cations occupy the voids.
- ✓ The ratio of radius of cation and anion $\frac{r_C^+}{r_A^-}$ plays an important role in determining the structure.

$\left(\frac{r_C^+}{r_A^-}\right)$	Coordination number	Structure	Example
0.155– 0.225	3	Trigonal planar	B_2O_3
0.225 – 0.414	4	Tetrahedral	ZnS
0.414 – 0.732	6	Octahedral	NaCl
0.732 – 1.0	8	Cubic	CsCl

4.How will you derive the formula of density of a unit cell

By Using the edge length of a unit cell, we can calculate the density _() of the crystal by considering a cubic unit cell as follows.

Density of the cell $\rho = \frac{\text{Mass of the unit cell}}{\text{volume of unit cell}}$

Mass of the unit cell $= \left\{ \begin{matrix} \text{total number of atoms belongs} \\ \text{to that unit cell} \end{matrix} \right\} \times$ mass of one atom**…….(1)**

Mass of one atom $= \frac{\text{molar mass (gmol}^{-1})}{\text{Avagardo number (mol}^{-1})}$

$m = \frac{M}{N_A}$**………(2)**

Sub (2) in (1)

Mass of the unit cell$= n \times \frac{M}{N_A}$

For a cubic unit cell, all the edge lengths are equal i.e , a=b=c

Volume of the unit cell $= a^3$

$$\rho = \frac{n \times M}{a^3 N_A}$$

5.Explain about classification of solids

Ionic Solids

- ✓ The structural units of an ionic crystal are cations and anions.
- ✓ They are bound together by strong electrostatic attractive forces.
- ✓ To maximize the attractive force, cations are surrounded by as many anions as possible and vice versa.
- ✓ Ionic crystals possess definite crystal structure

Example : NaCl

Covalent solids:

- ✓ In covalent solids, the constituents (atoms) are bound together in a three dimensional network entirely by covalent bonds.
- ✓ Such covalent network crystals are very hard, and have high melting point. They are usually poor thermal and electrical conductors.

Examples: Diamond, silicon carbide

Molecular solids

- ✓ In molecular solids, the constituents are neutral molecules.
- ✓ They are held together by weak van der Waals forces. Generally molecular solids are soft and they do not conduct electricity.
- ✓ These molecular solids are further classified into three types.

(i) Non-polar molecular solids

In non polar molecular solids constituent molecules are held together by weak dispersion forces or London forces

Examples: Naphthalene, anthracene etc.,

(ii) Polar molecular solids

Thee constituents are molecules formed by polar covalent bonds. They are held together by relatively strong dipole-dipole interactions. They have higher melting points than the non-polar molecular solids.

Examples : Solid CO_2 , solid NH_3 etc.

(iii) Hydrogen bonded molecular solids

The constituents are held together by hydrogen bonds. They are generally soft solids under room temperature.

Examples: Solid ice (H_2O), glucose, urea etc**.,**

iv)Metallic solids

In metallic solids, the lattice points are occupied by positive metal ions and a cloud of electrons pervades the space. They are hard, and have high melting point. Metallic solids possess excellent electrical and thermal conductivity. They possess bright lustre. Examples: Metals and metal alloys belong to this type of solids,

Example : Cu,Fe,Zn, Ag ,Au, Cu-Zn etc.

6.Classification of solids

Classification of solids

Amorphous solids eg. Glass

Crystalline solids

(i) Ionic crystals Ex.NaCl

(ii) Covalent crystals Ex: Diamond, SiO_2

(iii) Molecular crystals Ex: naphthalene, anthracene, glucose

(iv)Metallic crystals Ex: All metallic elements (Na, Mg,Cu,Au,Ag etc..)

(v) Atomic solids - ex: frozen elements of Group 18