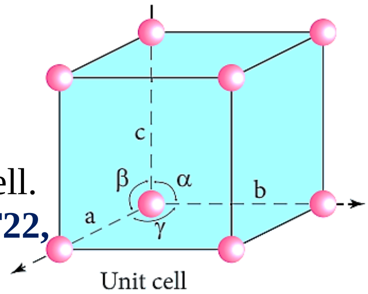
UNIT – 6 – SOLID STATE

II. Answer the following questions:

1. Define unit cell. [AUG-21, FRT,JUL-22, QY-23]

A basic repeating structural unit of a crystalline solid is called a unit cell.



Unit cell

2. Give any three characteristics of ionic crystals. [PTA1,QY,FRT22, FUT23]

- Ionic solids have high melting points.
- These solids do not conduct electricity, because the ions are fixed in their lattice positions.
- They do conduct electricity in molten state (or) when dissolved in water because the ions are free to move in the molten state or solution.

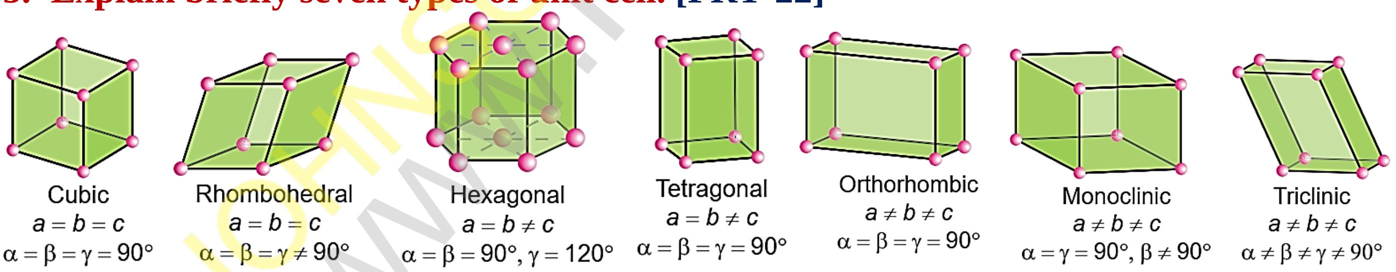
3. Differentiate crystalline solids & amorphous solids.[PTA1,HY,MAY,FMT-22, FUT,HY,SRT-23]

S. NO.	CRYSTALLINE SOLIDS	AMORPHOUS SOLIDS
1	Long range orderly arrangement of constituents	Short range, random arrangement of constituents
2	Definite shape	Irregular shape
3	Generally crystalline solids are anisotropic in nature	They are isotropic like liquids
4	They are true solids	They are considered as pseudo solids (or) super cooled liquids
5	Definite Heat of fusion	Heat of fusion is not definite
6	They have sharp melting points	Gradually soften over a range of temperature and so can be moulded
7	Examples: NaCl, diamond etc.,	Examples: Rubber, plastics, glass etc

4. Classify the following solids. P_4, Brass Diamond NaCI iodine

P_4 – Molecular solid, Brass – Metallic solid, Diamond – Covalent solid, NaCl – Ionic solid, Iodine – Molecular solid

5. Explain briefly seven types of unit cell. [FRT-22]



Cubic – NaCl, **Tetragonal** – TiO_2, **Orthorhombic** – $BaSO_4$, **Hexagonal** – ZnO, **Monoclinic** – $PbCrO_4$, **Triclinic** – H_3BO_3, **Rhombohedral** – Cinnabar Cubic

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 are exactly aligned with those of the first layer	The spheres of the third layer are not aligned with those of the first layer 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.

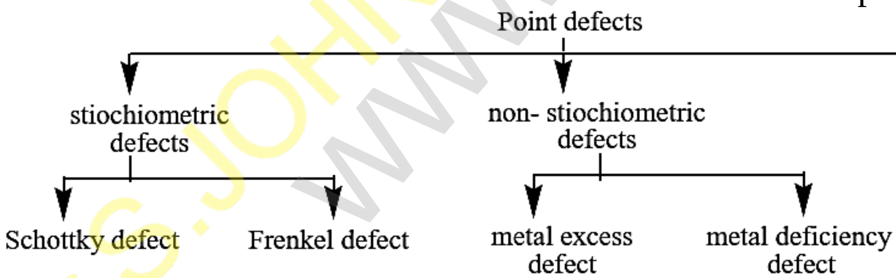
Tetrahedral voids of the second layer may be covered by the spheres of the third layer	Third layer may be placed above the second layer in a manner such that its sphere cover the octahedral voids
The unit cell of hexagonal close packing has 6 spheres	The unit cell of cubic close packing has 4 spheres
This type is found in metals like Mg, Zn	This type is found in metals like Cu, Ag

7. Distinguish tetrahedral and octahedral voids. [HY-22, QY-23]

TETRAHEDRAL VOID	OCTAHEDRAL VOID
A single triangular void in a crystal is surrounded by four (4) spheres and is called a tetrahedral void	A double triangular void like c is surrounded by six(6) spheres and is called an octahedral void
A sphere of second layer is above the void of the first layer, a tetrahedral void is formed	The voids in the first layer are partially covered by the spheres of layer now such a void is called an octahedral void
This constitutes four spheres, three in the lower and one in upper layer. When the centres of these four spheres are joined a tetrahedron is formed	This constitutes six spheres, three in the lower layer and three in the upper layer. When the centers of these six spheres are joined an octahedron is formed
The radius of the sphere which can be accommodated in an octahedral hole without disturbing the structure should not exceed 0.414 times that of the structure forming sphere	The sphere which can be placed in a tetrahedral hole without disturbing the close-packed structure should not have a radius larger than 0.225 times the radius of the sphere-forming the structure
Radius of an tetrahedral void rR = 0.225	Radius of a octahedral void rR = 0.414
The coordination number is 4.	The coordination number is 6.

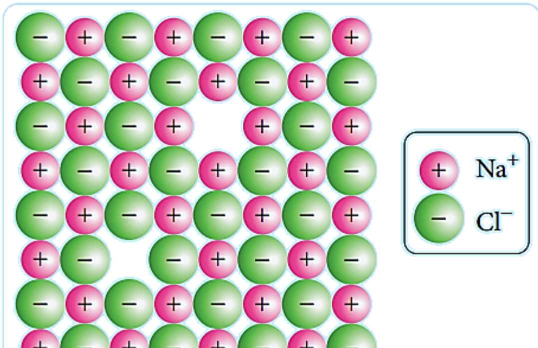
8. What are point defects? (OR) How are point defects classified? [FRT-22, FUT-23]

- If the deviation occurs due to missing atoms, displaced atoms or extra atoms the imperfection is named as a point defect.
- Such defects arise due to imperfect packing during the original crystallisation or they may arise from thermal vibrations of atoms at elevated temperatures.



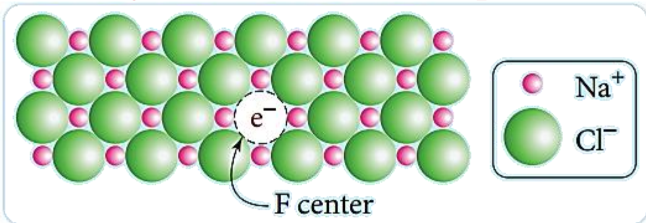
9. Explain Schottky defect. [GMQ, QY-19, SEP-20, FRT-22, FUT,QY-23, SRT-24]

- The schottky defect arises due to the missing of an 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 similar size show Schottky defect. Example: NaCl.
- Presence of large number of schottky defects in crystal, lowers its density.



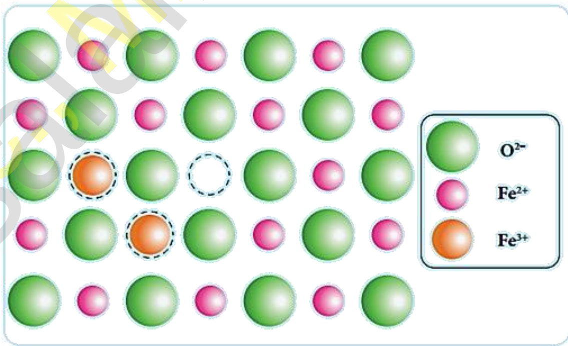
10. Write short note on metal excess and metal deficiency defect with an example.

Metal excess defect:



- Metal excess defect 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.
- For example, when NaCl crystals are heated in the presence of sodium vapour, Na^+ ions are formed and are deposited on the surface of the crystal.
- Chloride ions (Cl^-) diffuse to the surface from the lattice point and combines with Na^+ ion.
- The electron lost by the sodium vapour diffuse into the crystal lattice and occupies the vacancy created by the Cl^- ions.
- Such anionic vacancies which are occupied by unpaired electrons are called F centers.
- Hence, the formula of NaCl which contains excess Na^+ ions can be written as $Na_{1+x}Cl$.

Metal deficiency defect:



- Metal deficiency defect 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.
- For example, in FeO crystal, some of the Fe^{2+} ions are missing from the crystal lattice.
- To maintain electrical neutrality, twice the number of other Fe^{2+} ions in the crystal is oxidized to Fe^{3+} ions.
- In such cases, the overall number of Fe^{2+} and Fe^{3+} ions is less than the O^{2-} ions.
- It was experimentally found that the general formula of ferrous oxide is Fe_xO, where x ranges from 0.93 to 0.98.

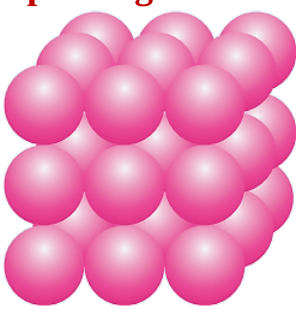
11. Calculate the number of atoms in a fcc unit cell. [HY-19, FMT,FRT-22]

- The atoms in the face centre is being shared by two unit cells each atom in the face centers makes (1/2) contribution to the unit cell.

  ∴ Number of atoms in a fcc unit cell $= \frac{N_c}{8} + \frac{N_f}{2} = \frac{8}{8} + \frac{6}{2} = 1 + 3 = 4.$

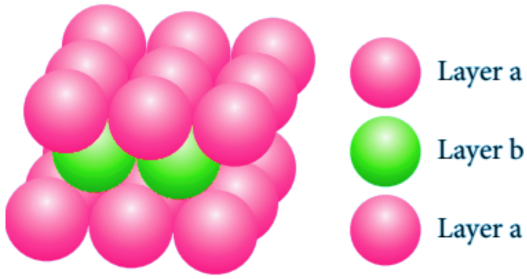
12. Explain AAAA and ABABA and ABCABC type of three-dimensional packing with the help of a neat diagram.

AAAA type of three-dimensional packing



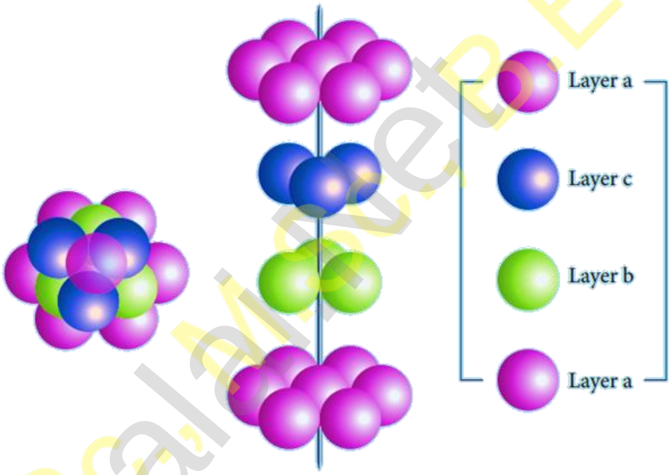
- This type of three-dimensional packing arrangement.
- This can be obtained by repeating the AAAA type two dimensional arrangements in three dimensions.
- Spheres in one layer sitting directly on the top of those in the previous layer so that all layers are identical.
- All spheres of different layers of crystal are perfectly aligned horizontally and also vertically
- Each spheres is in contact with 6 neighbouring spheres – four in its own layer, one above and one below it.
- Hence the coordination number of the sphere in simple cubic arrangement is 6.

ABABA type of three-dimensional packing:



- This is body centred cubic 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.
- Each sphere has a coordination number of 8, four neighbours in the layer above and four in the layer below.

ABCABC type of three-dimensional packing:



- This is face centred cubic arrangement.
- The first layer is formed by arranging the spheres as in the case of two dimensional ABAB arrangements.
- This is layer A. Second layer is formed by placing the spheres in the depressions of the first layer. This is layer B.
- There are two voids x and y.
- If void y in the first layer (A) are partially covered by the spheres of layer (B), it is an octahedral void.
- The third layer (C) may be placed over the second layer (B) in such a way that all the spheres of the third layer fit in octahedral voids.
- This third layer (C) is different from the other two layers (A) and (B).
- This is called cubic closed packed (ccp) structure.
- The coordination number is 12. Voids – The empty spaces between the three-dimensional layers are known as voids. There are two types of common voids possible. They are tetrahedral and octahedral voids.

13. Why ionic crystals are hard and brittle?

- Ionic crystalline are hard because 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.
- The electrostatic repulsion can be enough to split or disorient completely the lattice infrastructure. Thus imparts the brittle character.

14. Calculate the percentage efficiency of packing in the case of a body-centered cubic crystal. Packing efficiency. [QY-19, FRT-24]

In body-centered cubic arrangement the spheres are touching along the leading diagonal of the cube as shown in the,

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

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

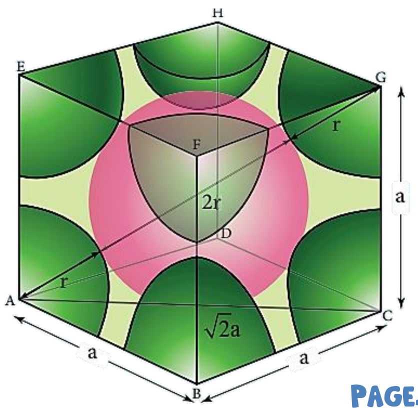
$$AG = \sqrt{AC^2 + CG^2}$$

$$AG = \sqrt{\left(\sqrt{2}a\right)^2 + a^2}$$

$$AG = \sqrt{2a^2 + a^2} = \sqrt{3a^2}$$

$$AG = \sqrt{3}\ a$$

i.e., $\sqrt{3}a = 4r$



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

∴ Volume of the sphere with radius 'r'

$$= \frac{4}{3}\pi r^3$$

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

$$= \frac{\sqrt{3}}{16}\pi a^3 \qquad ...(1)$$

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

$$= 2 \times \left(\frac{\sqrt{3}\,\pi\, a^3}{16}\right) = \frac{\sqrt{3}\,\pi\, a^3}{8}$$

Dividing (2) by (3)

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

$$= \frac{\sqrt{3}\,\pi}{8} \times 100$$

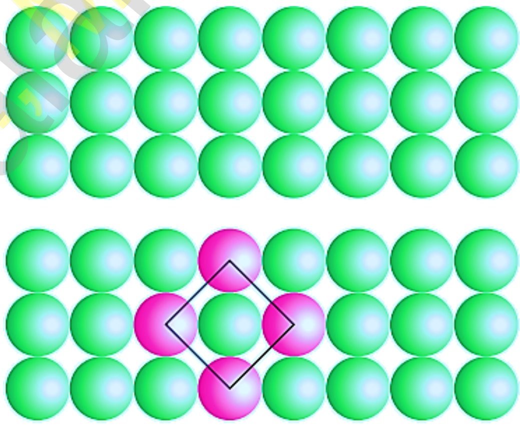
$$= \sqrt{3}\,\pi \times 12.5$$

$$= 1.732 \times 3.14 \times 12.5$$

$$= 68\ \%$$

i.e., 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?



- Linear arrangement of spheres in one direction is repeated in two dimension
- i.e., more number of rows can be generated identical to the one dimensional arrangement such that all spheres of different rows align vertically as well as horizontally as shown in the figure.
- If we denote the first row as A type arrangement, then the above mentioned packing is called AAA type, because all rows are identical as the first one.
- In this arrangement each sphere is in contact with four of its neighbours.
- Thus the two dimentional co-ordination number is 4.
- If the centres of these 4 immediate neighbouring spheres are joined, a square is formed. Hence this packing is called square close packed layer.

16. What is meant by the term "coordination number"? What is the coordination number of atoms in a bcc structure? [AUG-21]

- The number of nearest neighbours that surrounding a particle in a crystal is called the coordination number of that particle.
- Coordination number of atoms in a bcc structure is 8

17. An element has bcc structure with a cell edge of 288 pm. the density of the element is 7.2 gcm^{-3}. How many atoms are present in 208g of the element.

Unit cell (a) = 288pm. The density of the element (ρ) = 7.2gcm^{-3}. For the Bec structure (n) = 2

$$\rho = \frac{nM}{a^3 N_A} = 7.2\text{gcm}^{-3} = \frac{2M}{(288\times10^{-10}cm)^3\times(6.023\times10^{23}mol^{-1})}$$

$$7.2\text{gcm}^{-3} = \frac{2M}{(2.38\times10^{-23}cm^3)\times(6.023\times10^{23}mol^{-1})} = \frac{2M}{14.33cm^3mol^{-1}}$$

7.2g = 0.140M mol

$$M = \frac{7.2g}{0.140\ mol} = 51.42\text{g mol}^{-1}$$

By mole concept, 51.42 g of the element contains 6.023 x 10^{23} atom

208 g of the element will contain = $6.023\times10^{23}\times(208/51.42)$ atoms
= 24.17×10^{23} atoms (or) 2.417×10^{24} atoms

18. Aluminium crystallizes in a cubic close packed structure. Its metallic radius is 125pm. Calculate the edge length of unit cell. [FMT-22]

Given, Radius (r) = 125 pm, Edge length of unit cell (a) = ?

Since aluminium crystallizes in Face centered cubic $a = 2\sqrt{2} \times r$
$= 2 \times 1.414 \times 125 = 353.5$
a = 353.5 pm

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

We know that two Na^{+} ions are replaced by each of the Sr^{2+} ions while $SrCl_2$, is doped with NaCl. But in this case, only one lattice point is occupied by each of the Sr^{2+} ions and produce one cation vacancy.

Here 10^{-2} mole of $SrCl_2$, is doped with 100 moles of NaCl. Thus, cation vacancies produced by NaCl = 10^{-2} mol. Since, 100 moles of NaCl produces cation vacancies after doping = 10^{-2} mol. Therefore,

1 mole of NaCl will produce
cation vacancies after doping = $10^{-2}/100$ moles of $SrCl_2$
= 10^{-4} moles of $SrCl_2$

Total cationic vacancies, = 10^{-4} x Avogadro's number
= $10^{-4} \times 6.023 \times 10^{23}$
= 6.023×10^{19} vacancies

So, that the concentration of cation vacancies created by $SrCl_2$ is 6.023×10^{19} per mol of NaCl.

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})

For fcc structure n = 4; ρ = 2.48 g cm^{-3}; for KF, M=39+19= 58g mol^{-1}; $N_A = 6.023 \times 10^{23}$; **a = ?**

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

$$a^3 = \frac{4 \times 58}{2.48 \times 6.023 \times 10^{23}} = 0.1553 \times 10^{-21}\ cm^3$$

$a = 0.5375 \times 10^{-7}$ cm = 5.375×10^{-8} cm = 537.5 pm

$$\text{Distance between K+ and F-} = \frac{a}{\sqrt{2}} = \frac{537.5}{1.414} = 380.12\ pm$$

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

Density = 10 g cm^{-3}; Unit cell edge length, a = 100pm = 100×10^{-10} cm; Avogadro number, $N_A = 6.023 \times 10^{23}$; No. of atoms per unit cell, n = 4 (for fcc)

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

$M = 10 \times (100 \times 10^{-10})^3 \times (6.023 \times 10^{23}) / 4$

$M = 1.506$ g mol^{-1}

No. of atoms in 1g = ?

$$\text{No. of mole} = \frac{Weight}{molar\ mass} = \frac{1}{1.506} = 0.664$$

∴No. of atoms = No. of mole x N_A
$0.664 \times 6.023 \times 10^{23} = 4 \times 10^{23}$ 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 centre of the cube. What is the formula of the compound?

Atoms X and Y form bcc crystalline structure. Atom X is present at the corners of the cube Atom Y is present at the centre of the cube. No of atoms of X in the unit cell = Nc/8 = 8/8 = 1

No of atoms of Y in the unit cell = Nb / 1 = 1 / 1 = 1

Ratio of atoms X : Y = 1 : 1 Hence formula of the compound = XY.

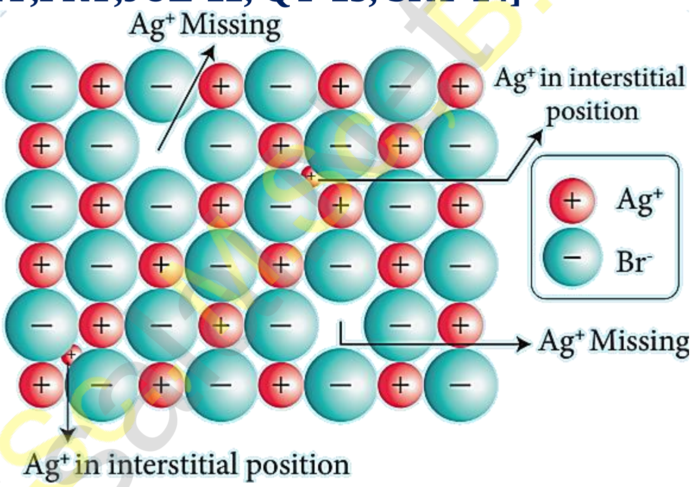
23. Na metal crystallizes in bcc structure with the edge length of the unit cell 4.3x10^{-8} cm. Calculate the radius of sodium atom. [QY-19]

Edge length of the unit cell (a) = 4.3 x 10^{-8}cm; Radius of sodium atom **(r) = ?**

For bcc structure, r = 3√4a = 3√4 (4.3 x 10^{-8}cm) = 1.86 x 10^{-8} cm = 1.86Å

24. Write a note on Frenkel defect. [MAR-20, HY,FRT,JUL-22, QY-23, SRT-24]

- 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 casc, small Ag ion leaves its normal site and occupies an interstitial position as shown in the figure.



Evaluate Yourself

25. 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?

Mass = 100g; Density = 8.9 g cm^{-3}; Edge length = 352.4pm = 352.4 x 10^{-10}cm; N_A = 6.023x10^{23}

$$\rho = \frac{nM}{a^3 N_A} \qquad 8.9cm^{-3} = \frac{4 \times M}{(6.023 \times 10^{23} \times (352.4 \times 10^{-10})^3}$$

M = 58.6g/mole Moles of element = $\frac{Mass\ of\ element}{Molar\ mass\ of\ element} = \frac{100g}{58.6g/mol}$ = 1.7 moles.

As, 1 mol contains 6.023x10^{23} number of atoms. So, 1.7 mole contains, = 1.7 x 6.023 x 10^{23} = 10.24 x 10^{23} no. of atoms

Since each Fcc cube contains 4 atoms, therefore total number of atoms in 100 g of element is 10.24 x 10^{23} atoms

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

Molar mass of CsCl = 168.5 g /mol; No. of atoms in per unit cell for bcc (CsCl) n = 1;
Edge length (a) = 412.1 pm; Density **(ρ) = ?**

$$\rho = \frac{nM}{a^3 N_A} = \frac{1 \times 168.5 g\ mol^{-1}}{(412.1 \times 10^{-10} cm)^3 \times (6.023 \times 10^{23} mol^{-1})} = \frac{168.5 g\ cm^{-3}}{6.998 \times 10^{-23} \times 6.023 \times 10^{23}}$$

$$= \frac{168.5}{42.148} g\,cm^{-3}$$

$$\rho = 3.997\ g\ cm^{-3}$$

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

For FCC n = 4; Edge length (a) = 4Å = 4 x 10^{-8}cm; Mass (M) = 60 g mol^{-1}; Density **ρ = ?**

$$\rho = \frac{nM}{a^3 N_A} = \frac{4\times 60\text{g mol}^{-1}}{(4\times10^{-8}\text{cm})^3\times(6.023\times10^{23}\text{mol}^{-1})} = \frac{240\text{ g mol}^{-1}}{6.4\times10^{-23}\text{cm}^3\times6.023\times10^{23}\text{mol}^{-1}} = \frac{240}{38.54}\text{g cm}^{-3}$$

ρ = 6.227 g cm^{-3}

GOVERNMENT EXAM QUESTION PAPER

1. State Bragg's law. (OR) Explain Bragg's Equation. [QY-23]

The fundamental equation that gives a simple relation between the wavelength of the X-rays, the interplanar distance in the crystal and the angle of reflection is known as Bragg's equation.

$$n\lambda = 2d\sin\Theta$$

where **n** is the order of reflection; **λ** is the wavelength of X-rays; **d** is the interplanar distance in the crystal; **Θ** is the angle of reflection

2. Define packing efficiency. [JUL-22]

The percentage of total volume occupied by these constituent spheres gives the packing efficiency of an arrangement. Let us calculate the packing efficiency in simple cubic arrangement

$$\left\{\begin{array}{l}\text{Packing fraction}\\ \text{(or) efficiency}\end{array}\right\} = \frac{\left\{\begin{array}{l}\text{Total volume occupied by}\\ \text{spheres in a unit cell}\end{array}\right\}}{\text{Volume of the unit cell}}\times100$$

3. If the no. of close packed sphere is 6, calculate the number of Octahedral voids and Tetrahedral voids generated. [MAR-20]

If the number of close packed sphere is 6. So, Octahedral voids is **6** & Tetrahedral voids is **12**

4. Distinguish between Isotropy and Anisotropy in solids. [SEP-20, FRT-22, FRT-24]

S.No.	Isotropy	Anisotropy
1	Isotropy means uniformity in all directions	Anisotropy is the property which depends on the direction of measurement.
2	In solid state isotropy means having identical values of physical properties such as refractive index, electrical conductance etc., in all directions	Crystalline solids are anisotropic and they show different values of physical properties when measured along different directions

5. Define covalent solids. [MAY-22]

In covalent solids, the constituents (atoms) are bound together in a three dimensional network entirely by covalent bonds. Examples: Diamond, silicon carbide etc.

6. What is metal deficiency defect? Give example. [FRT-22, HY-23]

Metal deficiency defect 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: O^{2-}, Fe^{2+}, Fe^{3+}

7. ZnO is colourless at room temperature, but it turns yellow colour on heating. Why? [FRT-22]

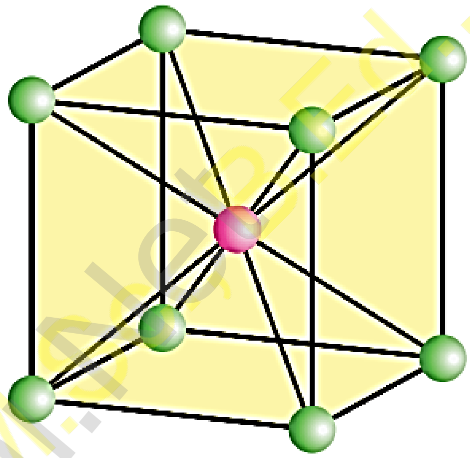
ZnO is colourless at room temperature. When it is heated, it becomes yellow in colour. On heating, it loses oxygen and thereby forming free Zn^{2+} ions. The excess Zn^{2+} ions move to interstitial sites and the electrons also occupy the interstitial positions.

8. Classify molecular crystals with an example for each type. [QY-19]

- Non-polar molecular crystals **Eg:** Naphthalene, Anthracene
- Polar molecular crystals solid **Eg:** Solid CO_2, Solid NH_3
- Hydrogen bonded molecular crystals **Eg:** H_2O, glucose, urea.

9. Barium has a body centred cubic unit cell with a length of 508pm along an angle. What is the density of barium in gcm^{-3}? (M = 137.3 $gmol^{-1}$) [HY-19, FUT,QY-23]

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



In this case,

n=2 ; M=137.3 $gmol^{-1}$; a = 508pm= 5.08×10^{-8}cm

$$\rho = \frac{2 \text{ atoms} \times 137.3 \text{ g mol}^{-1}}{(5.08\times10^{-8}\text{ cm})^3 (6.023\times10^{23}\text{ atoms mol}^{-1})}$$

$$\rho = \frac{2\times137.3}{(5.08)^3\times10^{-24}\times6.023\times10^{23}} \text{ g cm}^{-3}$$

$$\rho = 3.5 \text{ g cm}^{-3}$$

10. Classify the following into covalent, molecular, ionic and metallic solids. [AUG-21]
(i) Diamond, (ii) Brass, (iii) NaCl, (iv) Naphthalene, (v) Glucose, (vi) SiO_2

(i) Diamond - Covalent Network Solid
(ii) Brass - Metallic Solid
(iii) NaCl - Ionic Solid
(iv) Naphthalene - Molecular Solid
(v) Glucose - Covalent (Molecular) Solid
(vi) SiO_2 - Covalent Network Solid

11. Imperfection in solids play an important role in various processes. Justify. [FRT-22]

Imperfection in solids play an important role in various processes. For example, a process called doping leads to a crystal imperfection and it increases the electrical conductivity of a semiconductor material such as silicon. The ability of ferromagnetic material such as iron, nickel etc., to be magnetized and demagnetized depends on the presence of imperfections.

12. The composition of a sample of Wurtzite is $Fe_{0.93}O_{1.00}$. [QY-19]

The number of Fe^{2+} ions in the crystal be x, The number of Fe^{3+} ions in the crystal be y

Total number of Fe^{2+} and Fe^{3+} ions is $x + y$

Given that $x + y$ = 0.93

Total charges = 0

$x(2+) + (0.93 - x)(3+) - 2 = 2x + 2.97 - 3x - 2 = 0$

$x = 0.79$

Percentage of Fe^{3+} $= \left(\frac{(0.93-0.79)}{(0.93)}\right)\times 100$

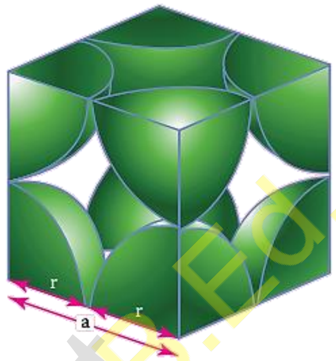
= 15.05%

13. Classify the following allotropic form of sulphur as crystalline and amorphous:
(a) α sulphur (b) β sulphur (c) γ sulphur (d) Colloidal suphur [HY-19]

(a) α sulphur - Crystalline form (b) β sulphur - Crystalline form
(c) γ sulphur - Amorphous form (d) Colloidal suphur - Amorphous form

14. Calculate the percentage of packing efficiency in simple cubic crystal. [FRT,FMT-22, APR-24]

$$\left\{\begin{array}{l}\text{Packing fraction}\\ \text{(or) efficiency}\end{array}\right\} = \frac{\left\{\begin{array}{l}\text{Total volume occupied by}\\ \text{spheres in a unit cell}\end{array}\right\}}{\text{Volume of the unit cell}} \times 100$$



Let us consider a cube with an edge length 'a' as shown in figure.

Volume of the cube with edge length a is = a × a × a = a^3

Let 'r' is the radius of the sphere. From the figure, a=2r ⇒ r = a/2

∴ Volume of the sphere with radius 'r'

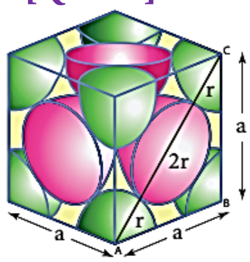
$$= \frac{4}{3}\pi r^3 \quad = \frac{4}{3}\pi\left(\frac{a}{2}\right)^3 = \frac{4}{3}\pi\left(\frac{a^3}{8}\right) \quad = \frac{\pi a^3}{6}$$

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

∴ Total volume occupied by the spheres in sc unit cell = 1 x $\left(\frac{\pi a^3}{6}\right)$

$$\text{Packing fraction} = \frac{\left(\frac{\pi a^3}{6}\right)}{(a^3)} \times 100 = \frac{100\pi}{6} = \mathbf{52.38\%}$$

15. Calculate the percentage efficiency of packing in case of face centred cubic crystal. [QY-23]



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 is

$$= \frac{4}{3}\pi\left(\frac{\sqrt{2}a}{4}\right)^3 = \frac{4}{3}\pi\left(\frac{2\sqrt{2}a^3}{64}\right)$$

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

Total number of spheres belongs to a single fcc unit cell is 4

∴ the volume of all spheres in a fcc unit cell $= 4\times\left(\frac{\sqrt{2}\,\pi a^3}{24}\right) = \left(\frac{\sqrt{2}\,\pi a^3}{6}\right)$

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

$$= \frac{\sqrt{2}\,\pi}{6} \times 100$$

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

= 74%

16. What are the properties of Metallic Solids? [FMT-22]

Metallic solid are hard, and have high melting point. Metallic solids possess excellent electrical and thermal conductivity. They possess bright lustre.

17. Calculate the number of atoms per unit cell in SC, BCC and FCC lattice. [FUT-23]

Number of atoms in a sc unit cell = $\frac{N_c}{8} = \frac{8}{8} = 1.$

Number of atoms in a bcc unit cell = $\frac{N_c}{8} + \frac{N_b}{1} = \frac{8}{8} + \frac{1}{1} = 1 + 1 = 2.$

Number of atoms in a fcc unit cell = $\frac{N_c}{8} + \frac{N_f}{2} = \frac{8}{8} + \frac{6}{2} = 1 + 3 = 4.$