

- Gas state

- Gas laws

Boyle's law : At constant temperature, for a fixed amount of gas the pressure (P) varies inversely with its volume (V).

$$P \propto \frac{1}{V}$$

$$\therefore PV = K \text{ (T, n constant)}$$

$$\text{for two different condition, } P_1 V_1 = P_2 V_2 = K$$

$$\text{with respect to density, } = \frac{d_1}{P_1} = \frac{d_2}{P_2}, \therefore \frac{d_1}{d_2} = \frac{P_1}{P_2}$$

Charle's law : At constant pressure, for a fixed amount of gas. its volume is directly proportional to its absolute temperature.

$$V \propto T \text{ (P, n constant)}$$

$$\therefore \frac{V}{T} = K$$

$$\text{For two different conditions, } \frac{V_1}{T_1} = \frac{V_2}{T_2} = K, \therefore \frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Gay-lussac's law : At constant volume, for a fixed amount of gas. its pressure is directly proportional to its absolute temperature.

$$P \propto T \text{ (v, n constant)}$$

$$\therefore \frac{P}{T} = K$$

$$\text{For two different conditions, } \frac{P_1}{T_1} = \frac{P_2}{T_2} = K, \therefore \frac{P_1}{P_2} = \frac{T_1}{T_2}$$

Avagadro's law : At same temperature and pressure, equal volume of all gases contain equal number of molecules.

$$\therefore V \propto n \text{ (P, T constant)}$$

$$V = kn$$

$$\therefore \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

- STP conditions

Standard Temperature : 273 K or 0°C

Standard Pressure : 1 bar = 1×10^5 pascal

Standard molar volume : 22.71 litre (For ideal gas) 22.4 litre

Standard number of particles : 6.022×10^{23} particles

Combined gas equation :

$$V \propto \frac{1}{P} \text{ (Boyle's law), } V \propto T \text{ (Charle's law)}$$

$$\therefore V \propto \frac{T}{P}$$

$$PV \propto T \quad \therefore PV = KT$$

$$\therefore \frac{PV}{T} = K$$

$$\text{For two different conditions, } \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

● Ideal gas equation

$$V \propto \frac{1}{P} \quad (\text{Boyle's law}), V \propto T \quad (\text{Charles's law}), V \propto n \quad (\text{Avagadro's law})$$

$$\therefore V \propto \frac{nT}{P}$$

$$\therefore PV \propto nT$$

$$\therefore PV = nRT \quad (R = \text{universal gas constant})$$

$$\therefore PV = \frac{mRT}{M} \quad n = \frac{m}{M}$$

$$\therefore P = \frac{m}{V} \frac{RT}{M} \quad d = \frac{m}{V}$$

$$\therefore P = \frac{dRT}{M}$$

● Values of gas constant R

$$R = 0.0821 \text{ litre atm K}^{-1} \text{ mol}^{-1}$$

$$R = 82.1 \text{ ml atm K}^{-1} \text{ mol}^{-1}$$

$$R = 8.314 \times 10^7 \text{ erg K}^{-1} \text{ mol}^{-1}$$

$$R = 1.987 \text{ cal K}^{-1} \text{ mol}^{-1}$$

$$R = 8.314 \text{ joule K}^{-1} \text{ mol}^{-1}$$

$$R = 0.08314 \text{ litre bar K}^{-1} \text{ mol}^{-1}$$

● Compressibility Factor

$$Z = \frac{PV}{nRT}$$

$$(i) \quad \text{For ideal gas, } Z = 1$$

$$(ii) \quad \text{For non ideal gas } Z > 1 \text{ or } Z < 1$$

$$\text{If } Z > 1 \text{ then positive deviation } PV > nRT$$

$$\text{If } Z < 1 \text{ then negative deviation } PV < nRT$$

$$\text{At zero pressure, } Z = 1 \text{ all gases behave as an ideal gas.}$$

● **Pressure and volume for non ideal gas**

(i) Pressure for non ideal gas $P_{\text{ideal}} = P_{\text{real}} + \frac{an^2}{V^2}$

where n = number of moles of gas, V = volume in litre a = Van der waal's constant, which depends on the characteristics of gas. It indicates the measurement of intermolecular attractive forces which is free from effect of temperature and pressure.

(ii) Volume for non ideal gas $V_{\text{ideal}} = V_{\text{real}} - nb$

Where n = number of moles of gas and b = Van der waal's constant

$$\therefore \left(P + \frac{an^2}{V^2} \right) (V - nb) = nRT \quad (\text{Van der waal's equation})$$

● **Various Critical conditions**

(i) Critical Pressure $P_c = \frac{a}{27b^2}$

(ii) Critical Volume, $V_c = 3b$

(iii) Critical Temperature $T_c = \frac{8a}{27Rb}$

(iv) $\frac{P_c V_c}{T_c} = \frac{3}{8} R$

(v) Boyle's Temperature $T_b = \frac{a}{R \times b}$

(vi) Inversion Temperature $T_i = 2T_b = \frac{2a}{Rb}$

Where a and b are Van der waal's constnat and R = universal gas constant.

- At a given temperature, definite quantity of N_2 gas is filled in a 100 ml centainer at 200 millibar pressure. If this gas is filled in a one litre container, what will be its pressure ?
(A) 20 millibar (B) 2000 millibar (C) 200 millibar (D) 100 millibar
- If density of gas at sea level is 2.5 ml/gm, then what would be its density at 0.5 bar pressure ?
(A) 5.0 (B) 2.5 (C) 1.25 (D) 0.5
- At 400 K temperature. A gas has volume 4 litre. What should be the temperature to make volume half ?
(A) -73°C (B) $+73^\circ \text{C}$ (C) -173°C (D) 173°C
- Pressure of N_2 gas filled in a 5 litre closed container at 27°C is 1 bar, what will be its pressure at 77°C ?
(A) 0.117 bar (B) 1.17 bar (C) 11.7 bar (D) 2.7 bar
- Pressure of Cl_2 gas filled in a 5 litre closed container at 400 K temperature is 4 bar. If the pressure is to be made 5 bar. What should be its temperature in $^\circ \text{C}$?
(A) 500 (B) 227 (C) 300 (D) 27

6. At 300 K temperature, pressure of 200 ml N_2 gas is 1.75 bar, what would be the volume of N_2 at STP ?
 (A) 239 ml (B) 139 ml (C) 339 ml (D) 250 ml
7. What will be the pressure of 0.1 mole SO_3 gas filled in a 2 litre container at 300 K temperature ?
 (A) 2.46 bar (B) 1.23 bar (C) 1 bar (D) 2 bar
8. What is the value of gas constant R in calorie $K^{-1} mol^{-1}$ unit ?
 (A) 0.0821 (B) 0.08314 (C) 8.314 (D) 1.987
9. Find the pressure of 10 mole chlorine gas filled in a 2 litre container at 300 K temperature.
 (A) 6.235 (B) 0.6235 (C) 62.35 (D) 6.325
10. How many moles of chlorine gas should be filled in a 500 ml container at 350 K temperature to have pressure of 125 bar ?
 (A) 2.15 (B) 4.30 (C) 0.43 (D) 0.215
11. Find pressure of Neon gas at 400 K temperature, having density of 0.8 gm/litre ? (Atomic Mass of Ne = 20)
 (A) 1.3 (B) 3.10 (C) 3.31 (D) 1.33
12. Find volume of 6.022×10^{21} molecules of O_2 gas at STP ?
 (A) 22.4 litre (B) 0.224 litre (C) 2.24 litre (D) 0.0224 litre
13. If $50^\circ C$ temperature of N_2 gas is made $100^\circ C$ its volume becomes.
 (A) twice (B) more than twice (C) less than twice (D) remains same
14. What will be the compressibility factor (Z) for He gas ?
 (A) 1 (B) >1 (C) <1 (D) zero
15. Which gas at low pressure shows positive deviation ?
 (A) He (B) CO_2 (C) CH_4 (D) N_2
16. Which of the following is the true for real gas equation ?
 (A) $\left(P + \frac{aV^2}{n^2}\right)(V - nb) = RT$ (B) $\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$
 (C) $\left(P + \frac{aV^2}{n^2}\right)(V + nb) = RT$ (D) $\left(P + \frac{an^2}{V^2}\right)(V - nb) = RT$
17. If a gas kept at 1 bar pressure has its volume decreased and made $\frac{1}{4}$, then its pressure becomes ?
 (A) 1 times (B) 2 times (C) 4 times (D) $\frac{1}{4}$ times
18. If density of a gas at 300 K temperature and 1 bar pressure is d, then at what temperature will its density become 0.75 ?
 (A) $20^\circ C$ (B) $30^\circ C$ (C) 400 K (D) 300 K

19. At 303 K temperature, on increasing pressure on He gas its volume becomes half. At what temperature should the gas be heated to make the volume double than its original volume ?
 (A) 303 K (B) 606 K (C) 1212 K (D) 30° C
20. What will be the volume occupied by 14 g N₂ and 36 gm O₃ at identical temperature and pressure ?
 (A) 2V_{N₂} = 3V_{O₃} (B) 3V_{N₂} = 2V_{O₃} (C) 3V_{N₂} = 4V_{O₃} (D) 4V_{N₂} = 3V_{O₃}
21. N₂ gas stored in a 10 litre closed container at 4 bar pressure. There is a leakage in the container, by the time the leakage is repaired the pressure of left out N₂ in container is 2.36 bar at 27° C temperature, then find amount of N₂ gas leaked ?
 (A) 18.7 gm (B) 0.67 gm (C) 52.6 gm (D) 10.0 gm
22. Calculate density of CH₄ gas at 27° C temperature and 2 bar pressure (Molecular Mass of CH₄ = 16).
 (A) 0.13 g/L (B) 0.26 g/L (C) 1.3 g/L (D) 26 g/L
23. What will be the value of compressibility factor (Z) for an ideal gas ?
 (A) Z = 1 (B) Z > 1 (C) Z ≤ 1 (D) Z ≥ 1
24. Methane and Hydrogen gas of identical mass are filled in a closed container at 25° C calculate the pressure of Hydrogen gas in the container.
 (A) $\frac{1}{2}$ P (B) $\frac{8}{9}$ P (C) $\frac{1}{9}$ P (D) $\frac{16}{17}$ P

Answers : 1. (A), 2. (C), 3. (A), 4. (B), 5. (B), 6. (A), 7. (B), 8. (D), 9. (C), 10. (A), 11. (D), 12. (B), 13. (B), 14. (B), 15. (A), 16. (B), 17. (C), 18. (C), 19. (C), 20. (B), 21. (A), 22. (C), 23. (A), 24. (B)

Dalton's law of partial pressure : The total pressure exerted by the mixture of non reactive gases is equal to the sum of the partial pressure of individual gases.

$$P_{\text{total}} = P_A + P_B + P_C \dots\dots\dots$$

Partial pressure of a gas Based on mass and volume $P = \frac{nRT}{V} = \frac{WRT}{MV}$

Based on mole fraction and total pressure

$$P_{\text{gas}} = \chi_{\text{gas}} \times P_{\text{Total}} = \frac{n_2}{n_1 + n_2} \times P_{\text{Total}}$$

Based on percentage volume

$$P_{\text{gas}} = \frac{\% \text{ by volume of gas} \times P_{\text{Total}}}{100}$$

When gas is collected over water :

$$P_{\text{Total}} = P_{\text{dry gas}} + P_{\text{H}_2\text{O}} \therefore P_{\text{dry gas}} = P_{\text{Total}} - P_{\text{H}_2\text{O}}$$

Graham's law of gaseous diffusion : Under identical conditions of temperature and pressure. The rate of diffusion for various gases varies inversely to the square root of their densities.

$$r \propto \frac{1}{\sqrt{d}} \quad r = \text{rate of diffusion of gas, } d = \text{density of gas}$$

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

$$\therefore, d \propto M, \frac{d_2}{d_1} = \frac{M_2}{M_1}$$

$$\therefore \frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

$$\text{now } r = \frac{V}{t}$$

$$\therefore \frac{r_1}{r_2} = \frac{V_1/t_1}{V_2/t_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

$$\text{If } V_1 = V_2 \text{ then, } \frac{t_2}{t_1} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

$$\text{If } t_1 = t_2 \text{ then, } \frac{V_1}{V_2} = \sqrt{\frac{d_2}{d_1}} = \sqrt{\frac{M_2}{M_1}}$$

- 25.** If 4 mole Cl_2 , 4 mole N_2 and 2 mole O_2 are filled in a 5 litre container at 27°C then calculate total pressure of the gaseous mixture ?
 (A) 100 bar (B) 50 bar (C) 5 bar (D) 10 bar
- 26.** Total pressure of a gaseous mixture containing 4 mole N_2 , 3 mole Cl_2 and 3 mole O_2 gas at 27°C is 50 bar, then calculate partial pressure of N_2 gas ?
 (A) 20 bar (B) 50 bar (C) 10 bar (D) 15 bar
- 27.** If equal mass of H_2 , N_2 and O_2 gas are filled in a container at a definite temperature, then partial pressure of which gas will be highest ?
 (A) N_2 (B) O_2 (C) H_2 (D) H_2 and N_2
- 28.** If O_2 takes 40 seconds to travel from sun to earth, then how much time will He take for the same ?
 (A) 14.15 seconds (B) 28.30 seconds (C) 20 seconds (D) 40 seconds
- 29.** Which of the following gases will have highest rate of diffusion ?
 (A) CO_2 (B) Cl_2 (C) NO_2 (D) H_2
- 30.** If 50 ml of N_2 gas and 70 ml of unknown gas have same time of diffusion, then calculate the molecular mass of unknown gas.
 (A) 14.3 gm/mole (B) 28 gm/mole (C) 25 gm/mole (D) 18.3 gm/mole
- 31.** At a definite temperature, rate of diffusion of CH_4 gas is twice that of gas X, then calculate Molecular mass of X ?
 (A) 64 (B) 32 (C) 16 (D) 4

32. If volume of a gas is made half by increasing pressure, then how many moles of gas will be present in the container ?
 (A) 2 times (B) Half (C) remain same (D) more than 2 times
33. If O_2 and CH_4 are filled in a container at $25^\circ C$ temperature, then what will be the pressure of O_2 in the container ?
 (A) $\frac{1}{2}$ (B) $\frac{2}{3}$ (C) $\frac{1}{3}$ (D) $\frac{3}{2}$
34. In a long glass tube, from one end of the tube a cotton plug dipped in $NH_{3(aq)}$ and from other end cotton plug dipped in HCl are fixed at the same time, the white fumes of NH_4Cl will be obtained at.
 (A) centre of the tube (B) closer to HCl end (C) closer to NH_3 end (D) in the whole tube
35. Calculate total number of atoms in 50 gm $CaCO_3$?
 (A) 3.011×10^{23} (B) 6.022×10^{23} (C) 12.044×10^{23} (D) 15.055×10^{23}
36. Which of the following compounds contain maximum number of atoms ?
 (A) 20 gm H_2 (B) 44 gm CO_2 (C) 100 gm $CaCO_3$ (D) 28 gm CO
37. Calculate mass of 2.24 litre of H_2 gas at STP.
 (A) 2.24 gm (B) 0.2 gm (C) 1 gm (D) 0.1 gm
38. Calculate volume of 14 gm N_2 gas at STP.
 (A) 22.4 litre (B) 2.24 litre (C) 11.2 litre (D) 1.12 litre
39. If 10 gm H_2 , 12 gm He and 28 gm N_2 are filled in a container at a definite temperature, which gas in the container will have maximum partial pressure ?
 (A) He (B) H_2 (C) N_2 (D) He and H_2 .
40. At 298 K temperature and 760 mm pressure 5 gm of which of the following gases will have minimum volume ?
 (A) HCl (B) HF (C) HBr (D) HI
41. What will be the ratio of rate of diffusion of SO_2 and O_2 ?
 (A) 1:1 (B) 1:2 (C) 2:1 (D) 1:1.414
42. At which temperature a gas can be liquified ?
 (A) greater than its critical temperature (B) at its critical temperature
 (C) less than its critical temperature (D) at any temperature
- (A) B (B) D (C) C (D) A
43. If a hole is made in a container containing 0.5 mole of each H_2 , SO_2 and CH_4 gas, then after some time, what will be the order of their partial pressure ?
 (A) $P_{H_2} > P_{CH_4} > P_{SO_2}$ (B) $P_{SO_2} > P_{CH_4} > P_{H_2}$ (C) $P_{SO_2} > P_{H_2} > P_{CH_4}$ (D) $P_{CH_4} > P_{SO_2} > P_{H_2}$
44. One litre ideal gas is equal to how many moles ?
 (A) PT/R (B) PRT (C) P/RT (D) $\frac{RT}{P}$
45. Critical temperature of gases A, B, C and D are $25^\circ C$, $10^\circ C$, $-80^\circ C$ and $15^\circ C$ respectively. Which of the gases can be liquified easily ?
 (A) B (B) C (C) D (D) A

Answers : 25. (B), 26. (A), 27. (C), 28. (A), 29. (D), 30. (A), 31. (A), 32. (C), 33. (C), 34. (B), 35. (D), 36. (A), 37. (B), 38. (C), 39. (B), 40. (D), 41. (D), 42. (C), 43. (B), 44. (C), 45. (D).

- **Solid States**

- **There are five states of matter known which are as follows :**

Solid, liquid and gas : Which exist at normal temperature and pressure and in these conditions study of properties of this matter is done.

Plasma : It is obtained at high temperature. It is such a state of matter where atoms have electrons free from attraction due to which existence of structure of atom is not possible and so electronic configuration is not formed in such a state quantity of free electron existing increases.

Bose Einstein Condensate (B.E.C.) : It is obtained at very low temperature. A state of matter in which all elements show identical properties and there remains no difference in the property of the element.

Solid substances are available in two forms : crystalline and amorphous forms

- **Difference between crystalline and Amorphous solid**

Property	Crystalline solid	Amorphous solid
(1) Shape	Definite shape and possessing characteristic geometry	Irregular shape
(2) Melting point	Definite and sharp melting point	does not have definite and sharp melting point. Becomes soft gradually during the small temperature range.
(3) Fusion enthalpy	Definite and characteristic fusion enthalpy	Not definite and characteristic fusion enthalpy
(4) Cleavage property	Divides into two parts on cutting with sharp tools like knife. The surface of the new part obtained is plain and soft	Divides in two parts on cutting the crystal with sharp tools like knife but the surface of new part is not as original one. It is irregular.
(5) Nature	True solid	Pseudo solid or super cooled liquids
(6) Order of Arrangement of constituent particle	The order is maintained till a long range	The order is maintained in a short range
(7) Effect of temperature	The graph of $(T \rightarrow t)$ obtained on cooling after heating is not a curvature. The temperature remains definite during crystallization	The graph of $(T \rightarrow t)$ obtained on cooling after heating is a curvature. Temperature range is obtained during crystallisation.
(8) Other properties	Their properties like electrical conductivity, thermal conductivity, mechanical strength and refractive index are different in different directions.	Their properties like electrical conductivity, thermal conductivity, mechanical strength and refractive index are same in all directions.

The classification of solid substances on the basis of intermolecular attraction forces involved in them, can be divided into four classes.

Type of solid		Constituent particles	Attraction forces	Physical nature	Melting point	Electrical conductivity	Exmaple
(1) Molecular solid	(i) Nonpolar	Molecules	Dispersion or london forces	soft	very low	Non conductor	Ar, CCl ₄ , H ₂ , I ₂ , CO ₂ , P ₄ , S ₈
	(ii) Ploar	Molecules	Dipole - Dipole attraction	soft	low	Non conductor	HCl, SO ₂ , NH ₃
	(iii) H-bond possessing	Molecules	H-bond	hard	low	Non conductor	H ₂ O (ice)
(2) Ionic solid		Ions	coulombic or electro-static	hard but brittle	high	Solid state, non conductivity but molten or aqueous solution conductor	NaCl, MgO, ZnS, CaCl ₂
(3) Metallic solid		positive ion in sea of delocalised electrons	Metallic bond	Normally hard, but S-block metals and some others are soft. ductile and Malleable	for some metals high (eg. Os) some metals medium (eg. Ba) some metals low eg. Hg and Ga.	conductors in solid and molten state	Fe Au Na etc.
(4) Covalent or Network solid		Atoms	Covalent bond	Hard	very High	Non condutors	eg. quartz (SiO ₂) Silicon carbide (SiC) Diamond and graphite

- Which type of solids are SO_2 , Ar and H_2O respectively. (At definite temperature and pressure)
 - Non polar Molecular solid, Polar Molecular solid, H-Bond possessing Molecular solid.
 - Polar Molecular solid, Non-Polar Molecular solid, H-Bond possessing Molecular solid
 - Non polar Molecular solid, H-Bond possessing Molecular solid, polar molecular solid
 - H-Bond possessing molecular solid, polar Molecular solid, non polar molecular solid.
- Which of the following is not a property of crystalline solid ?
 - It is a true solid
 - Constituent particles are in an ordered arrangement for a longer period
 - Shape possesses definite and characteristic geometry
 - Their properties like electrical conductivity, thermal conductivity, mechanical strength and refractive index are same in all directions.
- Match the following Group 1 (Type of solid) and Group 2 (example).

Group-1	Group-2	
(A) Molecular solid	(I) SiC	(A) A-II, B-III, C-IV, D-I
(B) Ionic solid	(II) CO_2	(B) A-II, B-IV, C-III, D-I
(C) Metallic solid	(III) CaF_2	(C) A-III, B-I, C-II, D-IV
(D) covalent solid	(IV) Mg	(D) A-I, B-II, C-IV, D-III
- Column (I) (types of solid) and column II (physical properties) Match the columns and select proper choice given below.

Column-1	Column-2	
(A) Molecular solid	(I) Hard but ductile and malleable	(A) A-II, B-III, C-IV, D-I
(B) Ionic solid	(II) Hard	(B) A-III, B-IV, C-I, D-II
(C) Metallic solid	(III) soft	(C) A-III, B-I, C-II, D-IV
(D) covalent solid	(IV) Hard but brittle	(D) A-I, B-II, C-IV, D-III
- Column I (Type of solid), column II (physical properties) and column III (electrical conductivity) Match the columns and select proper choice given below.

Column-1	Column-2	Column-3
(A) Metallic Solid	(I) Hard	(X) Conductor
(B) Covalent Solid	(II) Hard but brittle	(Y) Non Conductor
(C) Non-polar Molecular solid	(III) Soft	(Z) Conductor in solid and Molten state
(D) Ionic solid	(IV) Hard but ductile and malleable	(W) Non conductor in solid state but conductor in molten state

(A) A-II-X, B-I-Z, C-III-X, D-II-W	(B) A-IV-Z, B-I-Y, C-III-Y, D-II-W
(C) A-III-Y, B-I-Y, C-II-Y, D-IV-W	(D) A-II-Z, B-IV-Y, C-III-Y, D-I-Z
- Select the correct option for the given statements : T = True statement, F = False statement
 - Melting point of polar molecular solid is lower than non polar molecular solid
 - In spite of possessing +ve and -ve ions, ionic solid cannot conduct Heat and electricity
 - luster of metal and in some cases colour is due to free electrons in the metal
 - Graphite is a rigid network crystalline solid.

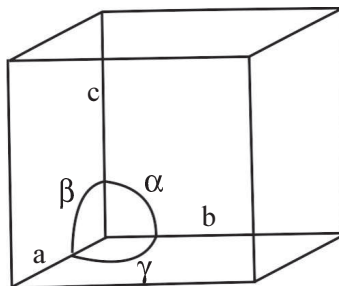
(A) FFTT	(B) TFTF	(C) TFFT	(D) FTTF
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Answers : 1. (B), 2. (D), 3. (A), 4. (B), 5. (B) 6. (D)

Crystal lattice : Ordered arrangement of constituent particles in three dimensional space is called crystal lattice.

Unit cell : Smallest part of the crystal made up of atom, ion or molecule, which is repeated periodically in a three dimensional arrangement to form a crystal. Such smallest part of the crystal is called unit cell. Unit cell possesses all the characteristics properties of the crystal and it describes the shape of the crystal.

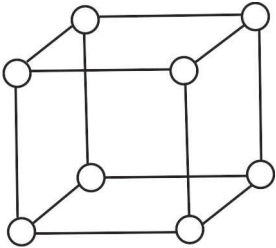
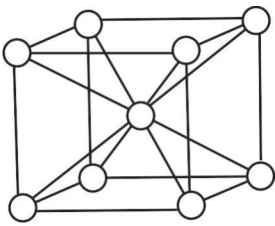
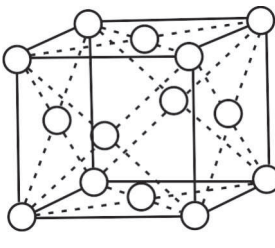
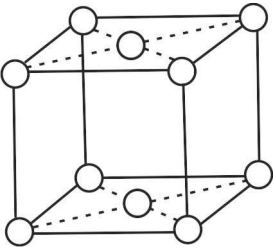
A unit cell can be described by 6 parameters : It has three edges a, b, c and the angles between the edges α , β and γ .



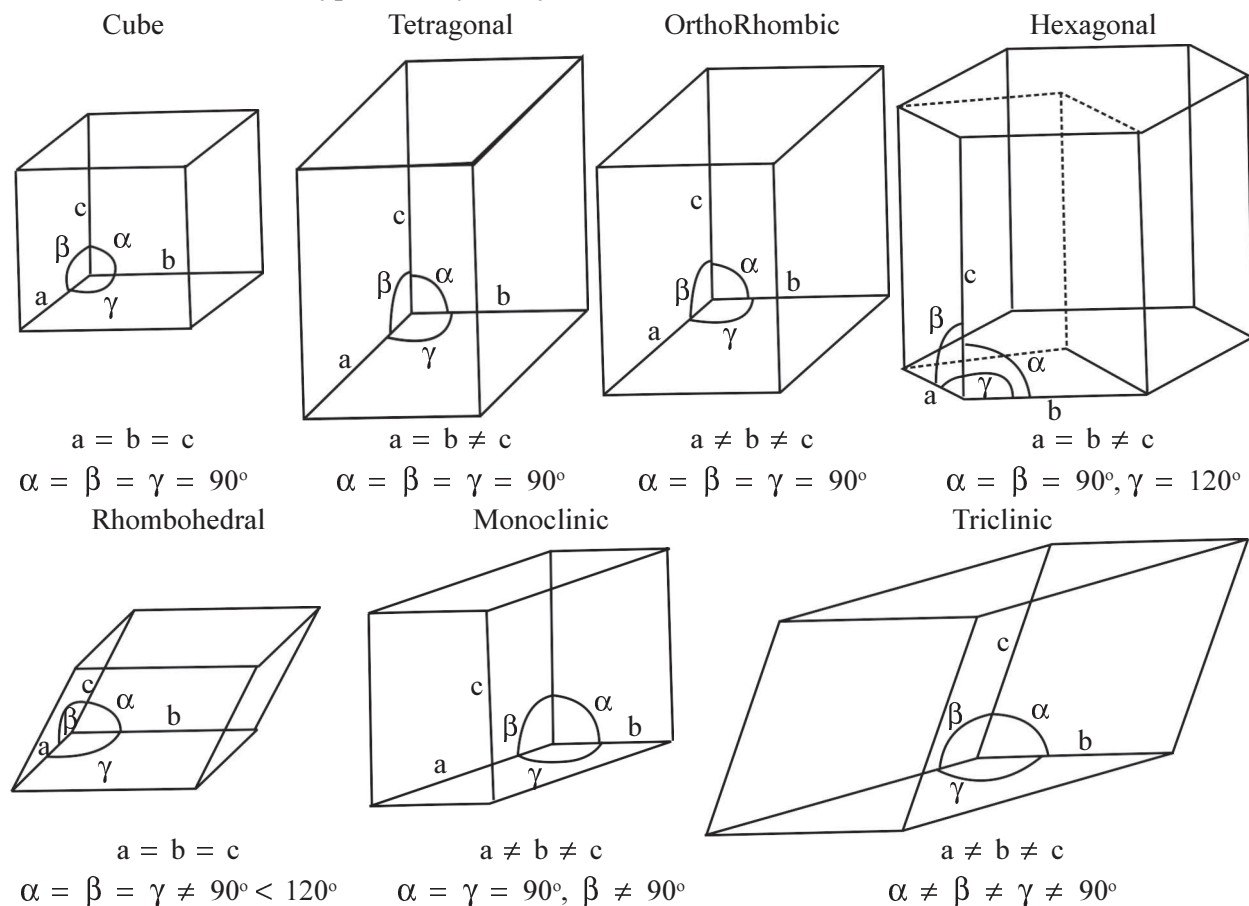
Lattice site and number of lattice site in a unit cell

	Corners	Face centre	Body centre	Edge centre
Number	8	6	1	12
Required constituent particle for the site	$\frac{1}{8}$	$\frac{1}{2}$	1	$\frac{1}{4}$
Total number of particle for the sites in unit cell	$\frac{1}{8} \times 8 = 1$	$\frac{1}{2} \times 6 = 3$	$1 \times 1 = 1$	$\frac{1}{4} \times 12 = 3$

Types of unit cell

Primitive unit cell Where constituent particles are arranged at the corners of the unit cell only.	Centered unit cell Where one or more constituent particles are arranged at other places in addition to the sites of the corner.		
	Body centred unit cell : constituent particles are arranged at corners and Body centre of a unit cell. 	Face centred unit cell : Constituent particles are arranged at corners and face centres of a unit cell. 	End centred unit cell : In such a unit cell one constituent particle is present at the centre of any two opposite faces besides the ones present at its corners. 

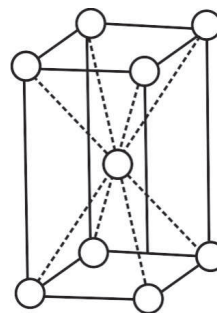
● There are in all seven types of Crystal system



● Seven Primitive unit cells and deviation possible as centred unit in Them

Sr.	Crystal System	Possible variation (Bravice lattice)	Axial distance or distance of edge	Axis angle	Example
(1)	Cube	Primitive, Body centred, Face centred	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	NaCl, Cu, ZnS Ag
(2)	Tetragonal	Primitive, Body centred	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	white tin, SnO_2 , TiO_2 , CaSO_4
(3)	Ortho Rhombic	Primitive, Body centred, Face centred, End centred	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Rhombic S KNO_3 , BaSO_4
(4)	Hexagonal	Primitive	$a = b \neq c$	$\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$	graphite, ZnO, CdS
(5)	Rhombohedral or Trigonal	Primitive	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	calcite, (CaCO_3) , Cinnabar (HgS)
(6)	Monodinic	Primitive, End centred	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ$, $\beta \neq 90^\circ$	Monoclinic S Na_2SO_4 , $10\text{H}_2\text{O}$
(7)	Triclinic	Primitive	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	$\text{K}_2\text{Cr}_2\text{O}_7$, H_3BO_3 $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

7. Body centred unit cell (Bravice lattice or possible variation) is observed in which type of crystal system ?
 (A) Rhombohedral (B) Tetragonal (C) Triclinic (D) Monoclinic
8. Which type of unit cell (Bravice lattice or possible variation) are found in Monoclinic crystal system ?
 (A) Body centred (B) End centred (C) Face centred (D) Mentioned all
9. Calcite (CaCO_3) is an example of which type of crystal system ?
 (A) Rhombohedral (B) Tetragonal (C) Orthorhombic (D) Triclinic
10. Crystal system unit cell has edges $a \neq b \neq c$ and angle between edges $\alpha \neq \beta \neq \gamma \neq 90^\circ$.
 (A) Triclinic (B) Monoclinic (C) Orthorhombic (D) Tetragonal
11. Crystal unit cell has edges $a = b \neq c$ and angle between edges $\alpha = \beta = 90^\circ, \gamma = 120^\circ$
 (A) KNO_3 (B) $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (C) graphite (D) HgS
12. Crystal unit cell has edges $a = b = c$ and angle between edges $\alpha = \beta = \gamma \neq 90^\circ$ is not less than 120° .
 (A) Cinnabar (B) CaSO_4 (C) CaCO_3 (calcite) (D) Mentioned all three
13. Which of the following parameters are true for Tetragonal unit cell ?
 (A) $a = b = c$ and $\alpha = \beta = \gamma \neq 90^\circ$ (B) $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$
 (C) $a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$ (D) $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90^\circ$
14. Which of the following parameters are true for Triclinic unit cell ?
 (A) $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$ (B) $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$
 (C) $a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$ (D) $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90^\circ$
15. Which parameters are possible for face centred unit cell ?
 (A) $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90^\circ$ (B) $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$
 (C) $a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$ (D) $a = b = c$ and $\alpha = \beta = \gamma \neq 90^\circ$
16. Which parameters are true for unit cell of $\text{NaSO}_4 \cdot 10\text{H}_2\text{O}$?
 (A) $a \neq b \neq c$ and $\alpha = \gamma = 90^\circ, \beta \neq 90^\circ$ (B) $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$
 (C) $a = b \neq c$ and $\alpha = \beta = \gamma = 90^\circ$ (D) $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90^\circ$
17. For the given unit cell which option is true ?
 (A) Cube and body centred
 (B) Cube and primitive
 (C) Tetragonal and body centred
 (D) Orthorhombic and Body centred



18. Each corner of a unit cell in a crystal is associated jointly with other unit cells in contact with it. Considering all such corners of a unit cell. How many other unit cells are in contact with it ?

(A) 18 (B) 14 (C) 16 (D) 26

19. Column I (Type of unit cell) Column (II) (Sides and angles) If correctly matched, which is the right option ?

Column-1

Column-2

- | | | |
|----------------|--|---|
| (A) Cube | (I) $a \neq b \neq c, \alpha \neq \beta \neq \gamma \neq 90^\circ$ | (A) (A)-(IV), (B)-(II), (C)-(III), (D)-(I) |
| (B) Tetragonal | (II) $a = b = c, \alpha = \beta = \gamma \neq 90^\circ$ | (B) (A)-(II), (B)-(I), (C)-(III), (D)-(VI) |
| (C) Trigonal | (III) $a = b \neq c, \alpha = \beta = \gamma = 90^\circ$ | (C) (A)-(IV), (B)-(III), (C)-(II), (D)-(I) |
| (D) Triclinic | (IV) $a = b = c, \alpha = \beta = \gamma = 90^\circ$ | (D) (A)-(II), (B)-(IV), (C)-(III), (D)-(I)s |

20. Column (I) (Type of unit cell) Column (II) (examples) If correctly matched, which is the right option ?

Column-1

Column-2

- | | | |
|------------------|---|--|
| (A) Orthorhombic | (I) ZnO | (A) (A)-(IV), (B)-(II), (C)-(III), (D)-(I) |
| (B) Monoclinic | (II) BaSO_4 | (B) (A)-(II), (B)-(IV), (C)-(I), (D)-(III) |
| (C) Hexagonal | (III) H_3BO_3 | (C) (A)-(IV), (B)-(III), (C)-(II), (D)-(I) |
| (D) Triclinic | (IV) $\text{Na}_2\text{SO}_4, 10\text{H}_2\text{O}$ | (D) (A)-(II), (B)-(IV), (C)-(III), (D)-(I) |

Answers : 7. (B), 8. (B), 9. (A), 10. (A), 11. (C), 12. (B), 13. (C), 14. (D), 15. (B), 16. (A), 17. (C), 18. (D), 19. (C), 20. (B)

● **Total number of atoms per unit cell**

Serial No.	Type of unit cell	Number of atoms on the corner	Number of atoms on the face	Number of atoms in body centre	Total atoms (Z)
(1)	Primitive	$\frac{1}{8} \times 8 = 1$	0	0	1
(2)	Face centred	$\frac{1}{8} \times 8 = 1$	$\frac{1}{2} \times 6 = 3$	0	4
(3)	Body centred	$\frac{1}{8} \times 8 = 1$	0	1	2

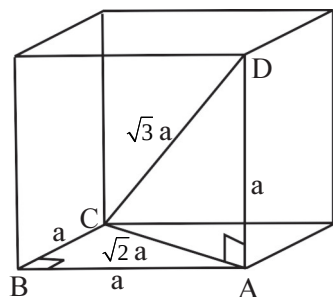
● **Total number of atoms in end centred orthorhombic unit cell**

$$\left(\frac{1}{8} \times 8 \text{ corners} = 1\right) + \left(\frac{1}{2} \times 2 \text{ (pair of opposite sides)} = 1\right) = 2$$

● **Total number of atoms in end centred monoclinic unit cell**

$$\left(\text{Total number of atoms including 8 corner is } 1\right) + \left(\frac{1}{2} \times 2 \text{ (pair of opposite side)} = 1\right) = 2$$

● For a simple cube unit all



edge length $a = b = c$ and $\alpha = \beta = \gamma = 90^\circ$

Any face diagonal = right angle $\triangle ABC$ where length of hypotenuse $\overline{AC}$

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

and body diagonal = right angle $\triangle DAC$, where length of hypotenuse $\overline{CD}$

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

● Packing efficiency in a cube's crystal

number of atoms in a unit cell = Z

Volume of a constituent particle (volume of sphere) = $v = \frac{4 \times \pi r^3}{3}$, Volume of unit cell = $V = a^3$

$\therefore$ Packing efficiency of a cubic crystal (packing efficiency of a unit cell)

$$= \frac{100 \times Z \times v}{V} = \frac{100 \times Z \times \left(\frac{4 \times \pi r^3}{3} \right)}{a^3} = \frac{100 \times Z \times 4 \times \pi r^3}{3 \times a^3}$$

● Packing efficiency of a simple cubic crystal

Here constituent particles are arranged only at the corners.

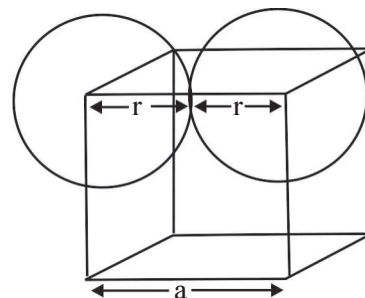
The particles touch each other along the edges.

$\therefore a = 2r$, where r = radius of each particle

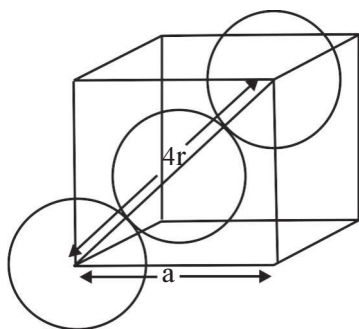
Number of atoms in a simple cube $Z = 1$

$$\text{Packing efficiency} = \frac{100 \times Z \times 4 \times \pi r^3}{3 \times a^3} = \frac{100 \times 1 \times 4 \times 3.14 \times r^3}{3 \times (2r)^3} = \frac{314}{6}$$

$$= 52.33 \approx 52 \% (52.36 \%)$$



● Packing efficiency in a face centred unit cell



Here constituent particles are arranged at the eight corners and the centres of each face. These particles touch each other on the face diagonal.

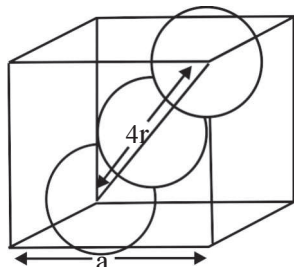
$\therefore 4r = \sqrt{2} \cdot a \therefore a = 2\sqrt{2} \cdot r$ where r = radius of the particle
number of atoms in the unit cell $Z = 4$

$$\therefore \text{Packing efficiency} = \frac{100 \times Z \times 4 \times \pi r^3}{3 \times a^3} = \frac{100 \times 4 \times 4 \times 3.14 \times r^3}{3 \times (2\sqrt{2}r)^3}$$

$$= \frac{314}{3\sqrt{2}} = 74.0 \%$$

● Packing efficiency in a body centred unit cell

Here constituent particles are arranged at the eight corners and the centre of the body. These particles touch each other on the body diagonal.



$$\therefore 4r = \sqrt{3} \cdot a \therefore a = \frac{4r}{\sqrt{3}} \text{ where } r = \text{radius of the particle}$$

Number of atoms in unit cell $Z = 2$

$$\begin{aligned} \therefore \text{Packing efficiency} &= \frac{100 \times Z \times 4 \times \pi r^3}{3 \times a^3} \\ &= \frac{100 \times 2 \times 4 \times 3.14 \times r^3}{3 \times \left(\frac{4r}{\sqrt{3}}\right)^3} = \frac{314 \times \sqrt{3}}{8} = 67.98 \approx 68\% \end{aligned}$$

● Number of atoms in Hexagonal close pack unit cell and its packing efficiency

Height (c) of Hexagonal close pack unit cell and volume (V) of unit cell can be calculated as follows :

Centre of spheres P, Q, R, and S in contact with each other form equilateral Tetrahedron.

ΔPQR is an equilateral triangle and $PQ = QR = RP = 2r$. In equilateral triangle ΔPQR , $\overline{PX}$ is the median and height and G is the centroid.

In right angle ΔPQX $m\angle PQR = 60^\circ$

$$\therefore PX = PQ \sin 60^\circ = 2r \frac{\sqrt{3}}{2} = \sqrt{3} \cdot r$$

$$PG = \frac{2PX}{3} = \frac{2\sqrt{3} \cdot r}{3} = \frac{2r}{\sqrt{3}}$$

In right angle ΔSGP $SG^2 + PG^2 = SP^2$

$$\therefore SG^2 = SP^2 - PG^2 = 4r^2 - \left[\frac{2r}{\sqrt{3}}\right]^2 = 4r^2 - \frac{4r^2}{3} = \frac{8r^2}{3} \therefore SG = \frac{2\sqrt{2} \cdot r}{\sqrt{3}}$$

$$\text{Now, Height of Hexagonal close pack unit cell is } C = MS = 2SG = 2 \times \frac{2\sqrt{2} \cdot r}{\sqrt{3}} = 4 \cdot \frac{\sqrt{2}}{\sqrt{3}} \cdot r$$

OR

$$\text{In } \Delta XRY, XY = c, XR = YR = 2r \text{ and } m\angle XRY = 109^\circ 28' = \cos^{-1}\left(-\frac{1}{3}\right)$$

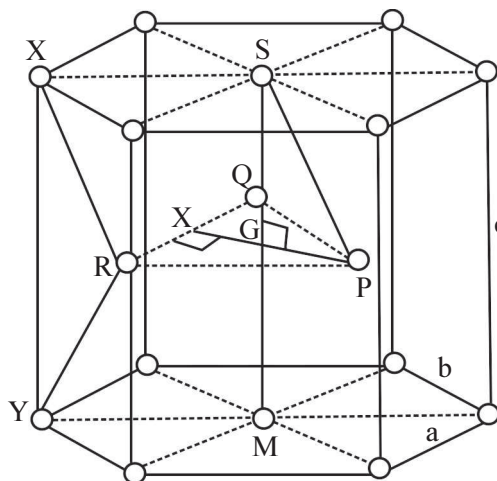
$$\text{By the laws of cosine, } \cos(m\angle XRY) = \frac{XR^2 + YR^2 - XY^2}{2 \cdot XR \cdot YR} \therefore \cos\left(\cos^{-1}\left(-\frac{1}{3}\right)\right) = \frac{XR^2 + YR^2 - XY^2}{2 \cdot XR \cdot YR}$$

$$\therefore -\frac{1}{3} = \frac{4r^2 + 4r^2 - c^2}{2 \times 2r \times 2r} \therefore -8 \cdot r^2 = 24r^2 - 3c^2 \therefore 3c^2 = 32r^2 \therefore c^2 = \frac{32r^2}{3}$$

$$\therefore c = 4\sqrt{\frac{2}{3}} r$$

Now, base of a Hexagonal close pack unit cell is a regular Hexagon, whose surface area

$$= 6 \times \text{area of equilateral triangle } \Delta PQR = 6 \times \sqrt{3} r^2$$



volume of Hexagonal close pack unit cell = Surface area of regular Hexagon $\times$ Height of Hexagonal close pack unit cell

$$V = 6 \times \sqrt{3} r^2 \times 4 \sqrt{\frac{2}{3}} \cdot r = 24\sqrt{2} \cdot r^3$$

In a Hexagonal close pack unit cell, it gets the share of $\frac{1}{6}$ th part of atoms present in its 12 corners and gets $\frac{1}{2}$ atom (s and M) present in the centre of Hexagon at the top and bottom. The three atoms P, Q and R present in centre of the body are not shared by other unit cells.

$$\therefore \text{Number of atoms in a unit cell of Hexagonal close pack } Z = \left(12 \times \frac{1}{6}\right) + \left(2 \times \frac{1}{2}\right) + 3 = 6$$

$$\begin{aligned} \text{Packing efficiency of Hexagonal close pack unit cell} &= \frac{100 \times Z \times \left(\frac{4}{3} \pi r^3\right)}{V} = \frac{100 \times 6 \times \left(\frac{4 \times 3.14 \times r^3}{3}\right)}{24\sqrt{2}r^3} \\ &= \frac{314}{3\sqrt{2}} = 74\% \end{aligned}$$

- **Density of a solid crystal substance :** $d = \frac{Z \times M}{N \times V}$ Z = number of atoms in unit cell,
 M = Molecular/atomic mass
 $N = 6.022 \times 10^{23}$, V = volume of unit cell

For a simple cube ($a = b = c$) density $d = \frac{Z \times M}{N \times a^3}$

- **Volume of unit cell of any solid crystal substance**

$$V = abc \left[1 - \cos^2 \alpha - \cos^2 \beta - \cos^2 \gamma + 2 \cos \alpha \cdot \cos \beta \cdot \cos \gamma \right]^{\frac{1}{2}}$$

- **Volume of Hexagonal close pack unit cell**

Type of unit cell	Relation between 'a' & r	Length of a Face diagonal ($\sqrt{2}a$)	Length of a body diagonal ($\sqrt{3}a$)	Surface area of face (a^2)	Total surface area ($6a^2$)	volume of unit cell (a^3)
(1) Primitive	$a = 2r$	$2\sqrt{2}r$	$2\sqrt{3}r$	$4r^2$	$24r^2$	$8r^3$
(2) Face centred	$\sqrt{2}a = 4r$	$4r$	$2\sqrt{6}r$	$8r^2$	$48r^2$	$16\sqrt{2}r^3$
(3) Body centred	$\sqrt{3}a = 4r$	$4\sqrt{\frac{2}{3}}r$	$4r$	$\frac{16r^2}{3}$	$32r^2$	$\frac{64r^3}{3\sqrt{3}}$

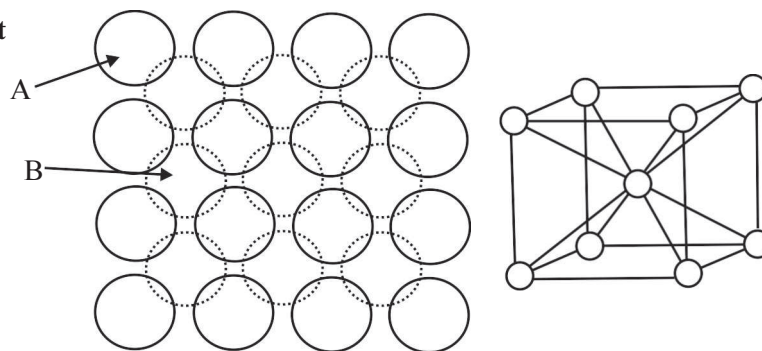
- The atomic radius of Ag is 144 pm. If a crystal is made up of only Ag atom, then what is the edge length of its unit cell ?
 (A) 288.24 pm (B) 407.35 pm (C) 576.4 pm (D) 432 pm
- What is the packing efficiency of ccp or fcc unit cell ?
 (A) $\frac{50\sqrt{3}\pi}{2} \%$ (B) $\frac{25\sqrt{2}\pi}{3} \%$ (C) $\frac{50\sqrt{2}\pi}{3} \%$ (D) $\frac{25\sqrt{3}\pi}{2} \%$

23. If in a given unit cell of ccp or fcc, radius of constituent particle is 'r', then what is the length of a face diagonal ?
 (A) 2r (B) $2\sqrt{2}r$ (C) 4r (D) $\sqrt{2}r$
24. In a bcc unit cell, If radius of constituent particle is 'r', then what is the length of any one body diagonal. (What is the distance between opposite corners of a unit cell ?)
 (A) 2r (B) $4\sqrt{2}r$ (C) 4r (D) $3\sqrt{6}r$
25. What is the ratio of atomic radius r to edge length (l) in a fcc or ccp unit cell ?
 (A) 0.433 (B) 0.3535 (C) 2.83 (D) 2.309
26. If the ratio of atomic radius r to edge length (l) is 0.433, then what will be its packing efficiency ?
 (A) 52.36 % (B) 36.52 % (C) 68 % (D) 74 %
27. Which of the following will be the atomic radius of a solid crystal having fcc structure with a density 19.3 gm/cm^3 and atomic mass 197 gm/mole ?
 (A) 110 pm (B) 174 pm (C) 195 pm (D) 144 pm
28. How many atoms will be present in 208 gm of an element having bcc unit cell whose density is 7.2 gm/cm^3 , having edge length 208 pm ?
 (A) 1.208×10^{23} (B) 4.216×10^{24} (C) 2.418×10^{24} (D) 1.208×10^{24}
29. Calculate density of Cu metal having atomic mass of 63.1 gm/mole with an edge length of 360.8 pm.
 (A) 8.92 gm/cm^3 (B) 4.46 gm/cm^3 (C) 6.44 gm/cm^3 (D) 9.82 gm/cm^3
30. Density of a metal having fcc unit cell is 10.5 gm/cm^3 If the atomic radius is 144.44 pm, then calculate its atomic mass ?
 (A) 197 gm/mole (B) 63.5 gm/mole (C) 107.9 gm/mole (D) 56 gm/mole
31. Edge length of Al unit cell is 405 pm, its density is 2.7 gm/cm^3 . The unit cell of Al is (Atomic mass of Al = 27 gm/mole).
 (A) Body centred (B) End centred (C) Primitive (D) Face centred
32. Diamond has fcc structure, where each carbon is attached to four other carbon atom, having C–C bond length 154.48 pm, calculate the edge length of its unit cell ?
 (A) 356.75 pm (B) 178.38 pm (C) 437.0 pm (D) 308.96 pm
33. Diamond has fcc structure, where each carbon is attached to four other carbon atoms. How many atoms are present in one such unit cell ?
 (A) 4 (B) 8 (C) 6 (D) 12
34. What will be the volume of a Rhombohedral (Triagonal) unit cell of a crystal with edge length a and $\alpha = \beta = \gamma = 60^\circ$.
 (A) a^3 (B) $\frac{a^3}{2}$ (C) $\frac{\sqrt{3}a^3}{2}$ (D) $\frac{a^3}{\sqrt{2}}$

35. What will be the packing efficiency of diamond, having fcc structure of unit cell in which each carbon is attached to four carbon atoms by covalent bond.
 (A) 74 % (B) 34 % (C) 68 % (D) 56.5 %
36. Atomic radius of a metal having hcp arrangement is r , then according to the prevailing symbolic method. Which of the following is the value of c for its unit cell ?
 (A) $2\sqrt{\frac{2}{3}} \cdot r$ (B) $3\sqrt{\frac{3}{2}} \cdot r$ (C) $4\sqrt{\frac{2}{3}} \cdot r$ (D) $2\sqrt{3} \cdot r$
37. How many % of space of a face diagonal is occupied by spheres (atoms) in a fcc crystal lattice arrangement ?
 (A) 50.25 % (B) 30.44 % (C) 48.24 % (D) 40.82 %
38. In as hcp unit cell, axial distance $a : b : c = \dots\dots\dots$
 (A) $\sqrt{3} : \sqrt{3} : \sqrt{2}$ (B) $\sqrt{2} : \sqrt{2} : \sqrt{3}$ (C) $2\sqrt{3} : \sqrt{3} : \sqrt{5}$ (D) $\sqrt{3} : \sqrt{3} : 2\sqrt{2}$
39. A metal having hcp arrangement has atomic radius $\sqrt{6} \text{ \AA}$. According to prevailing symbol its c for the unit cell is
 (A) $8 \text{ \AA}$ (B) $6 \text{ \AA}$ (C) $5.5 \text{ \AA}$ (D) $7.5 \text{ \AA}$
40. If in a complete Hexagonal close pack arrangement spheres are replaced by cylinder then calculate its packing efficiency ?
 (A) 65.42 % (B) 80.25 % (C) 74 % (D) 90.64 %
41. If r is radius of a sphere column I (unit cell), column II (length of face diagonal of unit cell) and column III (length of body diagonal of unit cell, which option is right, if these columns are correctly matched ?
- | Column-1 | Column-2 | Column-3 | |
|---------------|----------------------------|------------------|--|
| (A) Primitive | (I) $\frac{4\sqrt{6}r}{3}$ | (X) $2\sqrt{6}r$ | (A) (A)-(III)-(Z), (B)-(II)-(X), (C)-(I)-(Y) |
| (B) fcc | (II) $2\sqrt{2}r$ | (Y) $4r$ | (B) (A)-(II)-(Z), (B)-(III)-(X), (C)-(I)-(Y) |
| (C) bcc | (III) $4r$ | (Z) $2\sqrt{3}r$ | (C) (A)-(II)-(X), (B)-(III)-(Z), (C)-(I)-(Y) |
| | | | (D) (A)-(I)-(Z), (B)-(III)-(X), (C)-(II)-(Y) |
42. If a Triagonal crystalline arrangement has edge length a and $\alpha = \beta = \gamma = 60^\circ$ then the length of the longest body diagonal is ?
 (A) $2\sqrt{2}a$ (B) $\sqrt{3}a$ (C) $\sqrt{6}a$ (D) $2\sqrt{3}a$

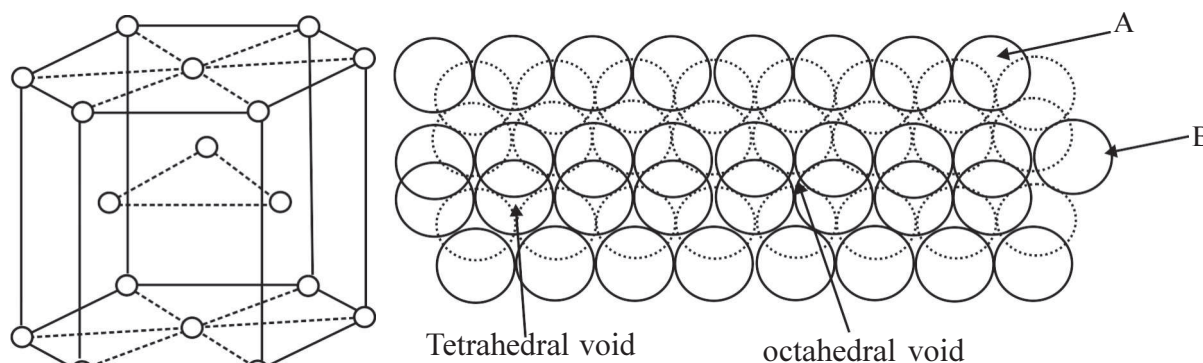
Answers : 21. (B), 22. (C), 23. (C), 24. (C), 25. (B), 26. (C), 27. (D), 28. (C), 29. (A), 30. (C), 31. (D), 32. (A), 33. (B), 34. (D), 35. (B), 36. (C), 37. (D), 38. (D), 39. (A), 40. (D), 41. (B), 42. (C)

● **Body-centred close pack arrangement**



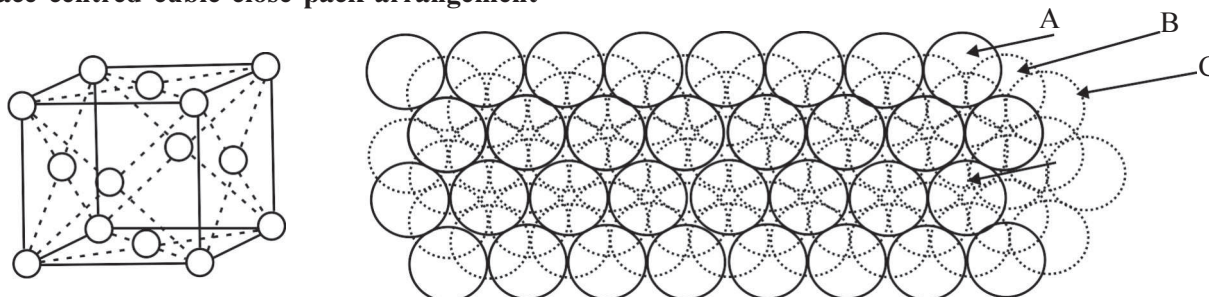
Co-ordination number of constituent particle is = 8

● **Hexagonal close pack arrangement**



Co-ordination number of constituent particle = 12

● **Face centred cubic close pack arrangement**



Co-ordination number of constituent particle is = 12

On crystallization most of the metal produce body centred close pack arrangement, Hexagonal close pack arrangement and face centred cubic close pack arrangement.

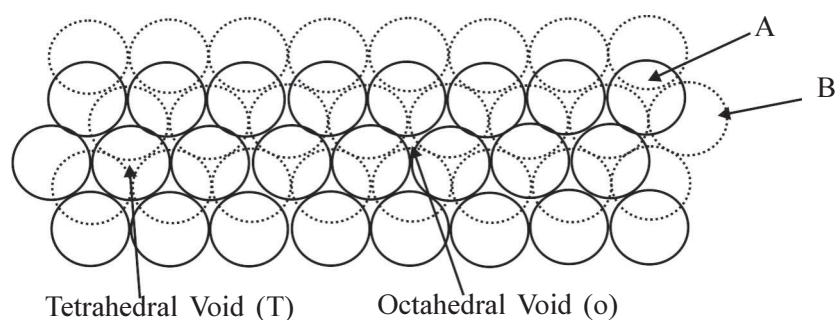
Metals having bcc arrangement : Alkali metal (Li, Na, K, Rb, Cs) Fe, Ba, V, Ra, Cr, Mn....

Metals having fcc arrangement : Sr, Ca, Ni, Cu, Ag, Au, Pt, Pd....

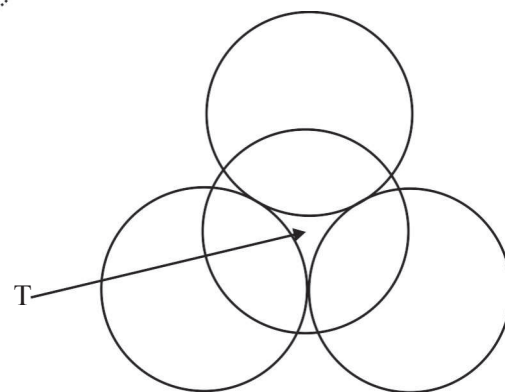
Metals having hcp arrangement : Mg, Sc, Ti, Co, Zn....

In fcc and hcp arrangement constituent particles are arranged very close to each other. Such close pack arrangements are known as closest pack arrangement.

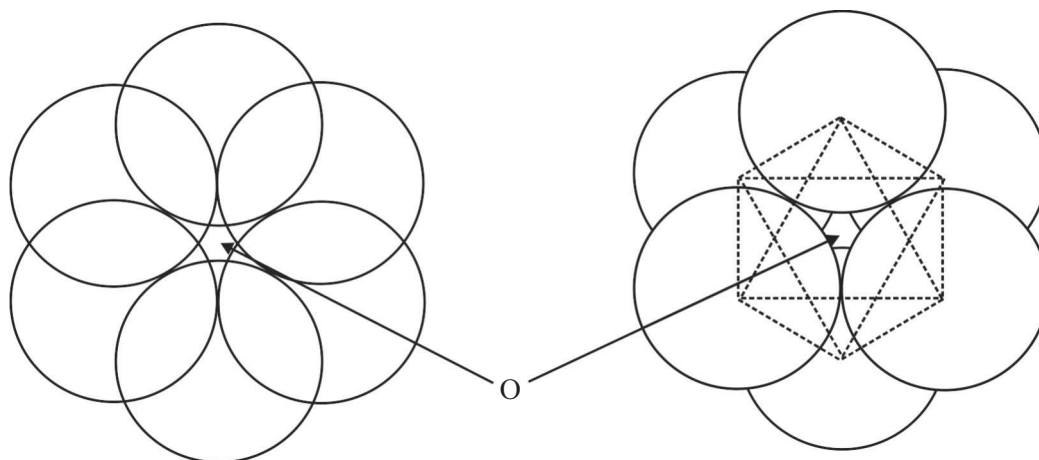
In closest pack arrangement (hcp and fcc) of constituent particles, (sphere) on stacking two consecutive layers, there are two types of voids created : (1) Tetrahedral void and (2) Octahedral void.



(1) Tetrahedral void : When three identical spheres are in mutual contact of each other such that the centres of these spheres create equilateral triangle and fourth identical sphere is placed above or below the void created between them, then the void created by these four identical spheres is called a Tetrahedral void (T)



(2) Octahedral Void : When four identical spheres are in mutual contact of each other such that the centres of these spheres create square planar and two identical spheres are placed above and one below the void created between them, then the void created by these six identical spheres is called an Octahedral void (O)



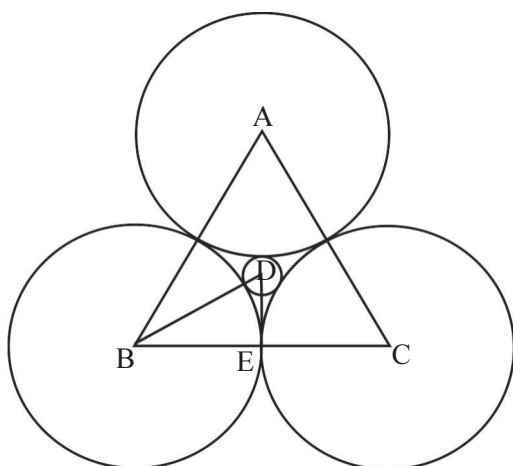
In closest pack arrangement (hcp and fcc) The number of Tetrahedral voids is twice the number of Octahedral voids.

In closest pack arrangement (hcp and fcc) If number of constituent particle is n , then number of octahedral void is n and Tetrahedral void is $= 2n$

Therefore, number of constituent particle : number of octahedral void : number of Tetrahedral void = $1 : 1 : 2$

● **When a cation is arranged in a triangular void created by anion, the co-ordination number of cation becomes 3 and smallest ionic radii ratio ($\frac{r^+}{r^-}$ or $\frac{r}{R}$)**

Radius of a cation = r^+ or r and radius of anion = r^- or R



A, B and C are centres of anions and D the centre of cation arranged in their triangular void. In Right angle $\triangle DEB$ $m\angle DEB = 90^\circ$, $m\angle DBE = 30^\circ$

$$BE = R \text{ and } DB = R + r$$

$$\cos(m\angle DBE) = \cos(30^\circ) = \frac{BE}{DB} \therefore \frac{\sqrt{3}}{2} = \frac{R}{R+r}$$

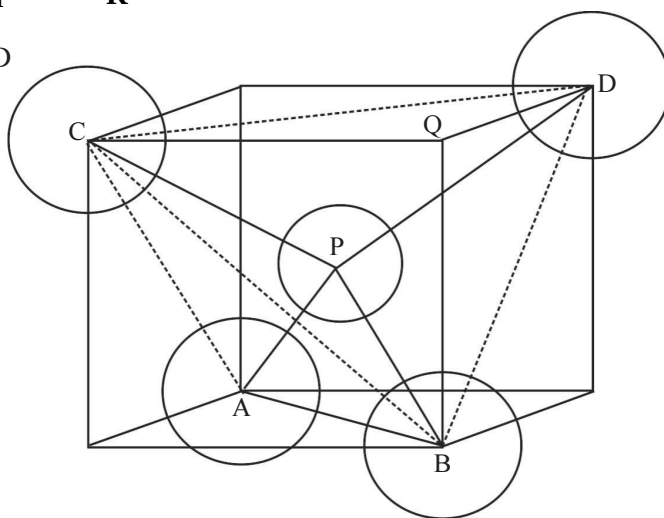
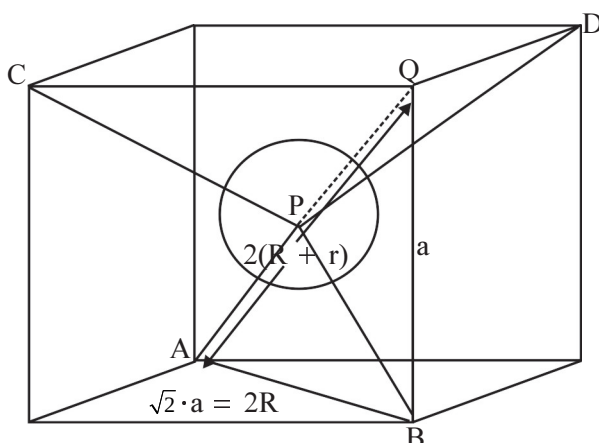
$$\therefore \sqrt{3}R + \sqrt{3}r = 2R$$

$$\therefore \sqrt{3}r = R(2 - \sqrt{3}) \therefore \frac{r}{R} = \frac{2 - \sqrt{3}}{\sqrt{3}}$$

$$= 0.1547 \approx 0.155$$

$$\therefore \text{Smallest ionic radii ratio for triangular void } \frac{r}{R} = 0.155$$

- When a cation is arranged in a tetrahedral void. Created by anion, the co-ordination number is 4 and the smallest ionic radii ratio ($\frac{r^+}{r^-}$ OR $\frac{r}{R}$)



Corners A, B, C and D are centres of anions spheres arranged at corners of tetrahedral voids. P is the centre of cation sphere arranged in tetrahedral void of anions.

$$\text{Cation radius} = r^+ \text{ or } r \text{ and anion radius} = r^- \text{ or } R$$

Edge length in cube unit cell $BQ = a$, length of body diagonal $AQ = \sqrt{3}a = 2(R + r)$ and length of face diagonal

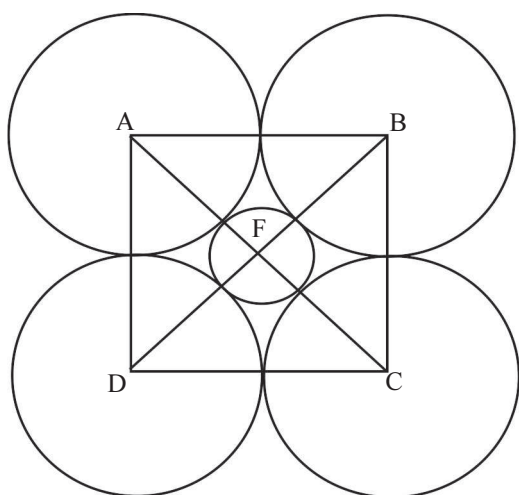
$$AB = \sqrt{2}a = 2R \text{ (as anions touch each other on a face diagonal)}$$

$$\therefore a = \sqrt{2}R \therefore \sqrt{3} \times \sqrt{2}R = 2(R + r) \therefore \sqrt{3}R = \sqrt{2}(R + r) \therefore \sqrt{2}r = (\sqrt{3} - \sqrt{2})R$$

$$\therefore \frac{r}{R} = \frac{\sqrt{3} - \sqrt{2}}{\sqrt{2}} = 0.2249 \approx 0.225 \therefore \text{Ionic radii ratio of tetrahedral void} = \frac{r}{R} = 0.225$$

- Octahedral void produced by anions when is occupied by cation then the co-ordination number is 6 and smallest ionic radii ratio ($\frac{r^+}{r^-}$ or $\frac{r}{R}$)

$$\text{Radius of a cation} = r^+ \text{ or } r \text{ and radius of anion} = r^- \text{ or } R$$



A, B, C and D are centres of sphere of anions. Which are in mutual contact of each other such that centres of spheres are corners of square planar. The cation with centre E occupy the void created by four anion.

Right angle $\triangle BEC$, $m\angle BEC = 90^\circ$ and $\overline{BC}$ is the chord.

$EB = EC = R + r$ and $BC = 2R$

$$\therefore EB^2 + EC^2 = BC^2 \quad \therefore 2(R + r)^2 = (2R)^2$$

$$\therefore R + r = \sqrt{2}R \quad \therefore r = (\sqrt{2} - 1)R$$

$$\therefore \frac{r}{R} = \sqrt{2} - 1 = 1.414 - 1 \quad \therefore \frac{r}{R} = 0.414$$

Ionic radii ratio for octahedral void construction $\frac{r}{R} = 0.414$

Ionic radii ratio $\left(\frac{r^+}{r^-}\right)$	Arrangement of anion	Co-ordination number of cation	example
$0 < \frac{r^+}{r^-} < 0.155$	linear	2	
$0.155 \leq \frac{r^+}{r^-} < 0.225$	planar Triangular	3	B_2CO_3
$0.225 \leq \frac{r^+}{r^-} < 0.414$	Tetrahedral	4	ZnS
$0.414 \leq \frac{r^+}{r^-} < 0.732$	Octahedral	6	NaCl
$0.732 \leq \frac{r^+}{r^-} < 1.0$	cubic	8	CsCl

● Cubic void created by anion (Body centred void created in a primitive cube unit cell) occupied by cation

Co-ordination number of cation is 8 and ionic radii ratio $\left(\frac{r^+}{r^-} \text{ or } \frac{r}{R}\right)$

radius of cation = r^+ and radius of anion = r^- or R

Edge length of unit cell = a , cationic radius = r and anionic radius = R

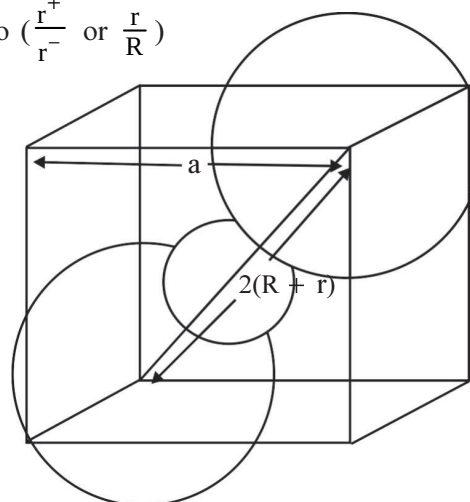
Length of Body diagonal in a unit cell = $\sqrt{3}a$

$$\therefore 2(R + r) = \sqrt{3} \cdot a \text{ and } a = 2R \quad \therefore 2(R + r) = \sqrt{3} (2R)$$

$$\therefore R + r = \sqrt{3} \cdot R \quad \therefore r = (\sqrt{3} - 1)R$$

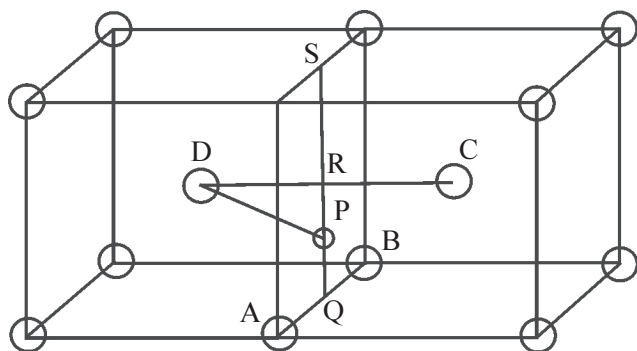
$$\therefore \frac{r}{R} = \sqrt{3} - 1 = 1.732 - 1 \quad \therefore \frac{r}{R} = 0.732$$

$\therefore$ ionic radii ratio for Body centred void $\frac{r}{R} = 0.732$



- The co-ordination number of a cation occupying the void created by bcc arrangement of anion is 4 and smallest ionic radii ratio is $(\frac{r^+}{r^-} \text{ or } \frac{r}{R})$

radius of cation = r^+ or r radius of anion = r^- or R



Shown in the figure are two consecutive unit cell created by bcc arrangement of anions.

A and B are centres of anion spheres arranged in the common corners of two consecutive unit cells and C and D are centre of anion spheres occupying bcc void of consecutive unit cells. P is the centre of cation sphere occupying the void created by the above mentioned anion spheres.

Q and R are mid points of $\overline{AB}$ and $\overline{CD}$ respectively. Mid point of $\overline{QS}$ is also R. Mid point of $\overline{QR}$ is P (Centre of cation occupying void)

edge length of unit cell = $a \therefore AB = CD = QS = a = \frac{4R}{\sqrt{3}}, QR = \frac{a}{2}$

$\therefore$ In a right angle $\triangle DRP$, $DR = QR = \frac{a}{2}$, $PR = \frac{a}{4}$,

$m\angle DRP = 90^\circ$ and $\overline{DP}$ is chords, length of the chord $DP = (R + r)$

$$\therefore DR^2 + PR^2 = DP^2 \therefore \frac{a^2}{4} + \frac{a^2}{16} = (R + r)^2$$

$$\therefore \frac{5a^2}{16} = (R + r)^2 \therefore \frac{16 \times 5R^2}{16 \times 3} = (R + r)^2 \therefore \sqrt{5} R = \sqrt{3} (R + r) \therefore \sqrt{3} r = (\sqrt{5} - \sqrt{3}) R$$

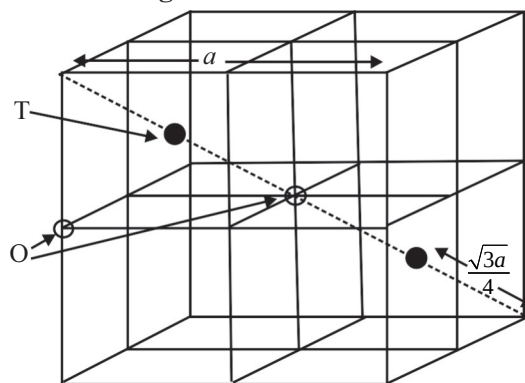
$$\therefore \frac{r}{R} = \frac{\sqrt{5} - \sqrt{3}}{\sqrt{3}} = 0.291 \therefore \text{cation radius occupying void created by bcc arrangement of anion}$$

is r and radius of anion is R and their ratio $\frac{r}{R} = 0.291$

- Position of octahedral void and tetrahedral void in a fcc arrangement.

The position of a Tetrahedral void (T) is at $\frac{1}{4}$ th length

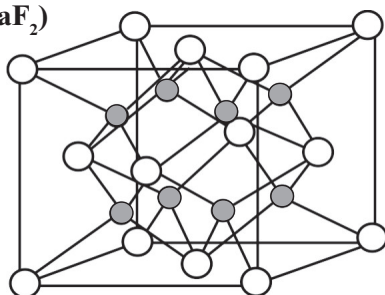
of each body diagonal i.e. $\frac{\sqrt{3} \cdot a}{4}$ of the unit cell. Therefore there are eight tetrahedral voids in each unit cell. There is one octahedral void (O) in the centre of the body of unit cell and $\frac{1}{4}$ th octahedral void in the mid point of each edge line (Total 12 edge lines). Therefore total octahedral voids in a unit cell is $(1 + 12 \times \frac{1}{4} = 4)$



● Anions of element A form fcc or hcp arrangement, the octahedral voids in this arrangement are occupied by cations of element B and Tetrahedral voids are occupied by cations of element C, then the simplest formula of crystal line solid is : BC_2A .

$\therefore$ Number of octahedral voids : Number of Tetrahedral voids : Number of atoms in fcc or hcp = 1 : 2 : 1

● **Flourite (CaF_2)**

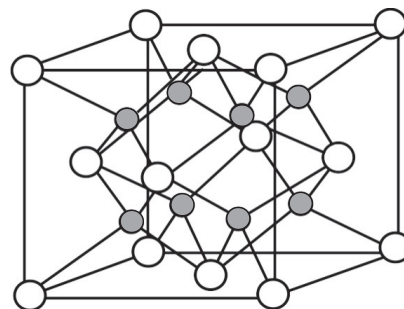


○ = Ca^{2+} having co-ordination number 8 and fcc arrangement
 ● = F^- having co-ordination number 4 and occupying all tetrahedral voids

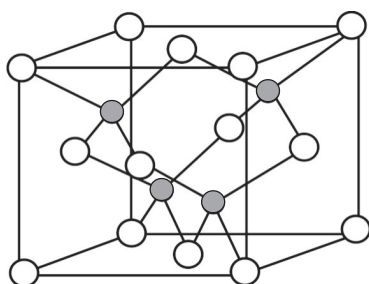
● **Antifluorite arrangement** eg., (Na_2O)

○ = O^{2-} having co-ordination number 8 and fcc arrangement

● = Na^+ having co-ordination number 4 and occupying all tetrahedral void.



● **Sphalerite (ZnS) (Zinc Blende)**

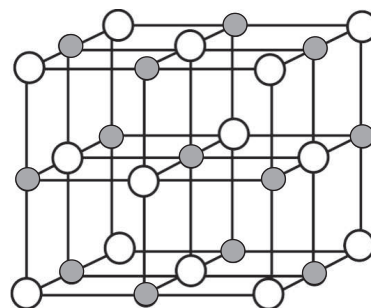


○ = S^{2-} having co-ordination number = 4 and Fcc arrangement
 ● = Zn^{2+} having co-ordination number = 4 occupying alternate tetrahedral voids. i.e. half of the total tetrahedral voids.

● **Rocksalt (NaCl)**

○ = Cl^- having co-ordination number = 6 and fcc arrangement

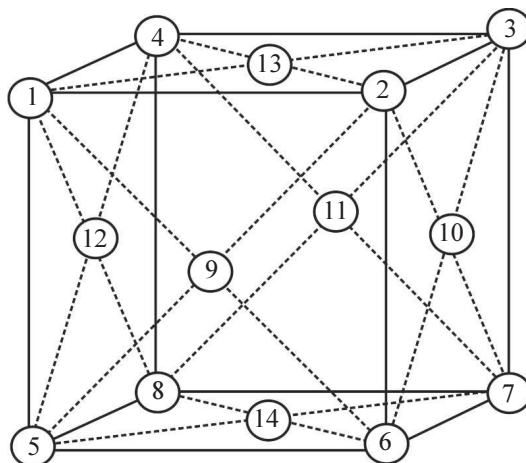
● = Na^+ having co-ordination number = 6 occupying all octahedral voids.



-
43. Oxide ions are arranged in hcp. one fourth of tetrahedral voids are occupied by ions of metal B and one third of octahedral voids are occupied by ions of metal A, then what will be the formula of metal oxide ?
- (A) $\text{A}_3\text{B}_2\text{O}_6$ (B) $\text{A}_2\text{B}_3\text{O}_6$ (C) $\text{A}_2\text{B}_3\text{O}_4$ (D) $\text{A}_3\text{B}_4\text{O}$
44. Oxide ions are arranged in Fcc all octahedral voids are occupied by ions of metal A and one fourth of tetrahedral voids are occupied by ions of metal B, then what will be the formula of metal oxide ?
- (A) AB_2O_2 (B) ABO_2 (C) A_2BO (D) A_2BO_2
45. an oxide compound have oxide ions arranged in fcc. one fourth of its tetrahedral voids are occupied by ions of metal B. One third of octahedral voids are occupied by ions of metal A, then what is the possible oxidation state of ions A & B respectively ?
- (A) +2, +3 (B) +3, +3 (C) +2, +2 (D) +3, +2
-

46. Which of the following statement is correct for an oxide having formula AB_2O_4 and O^{2-} (oxide) ions arranged in ccp ?
- (A) half of the octahedral voids are occupied by ions of metal A and one fourth of tetrahedral voids are occupied by ions of metal B
- (B) one fourth of octahedral voids are occupied by ions of metal A and one fourth of tetrahedral voids are occupied by ions of metal B
- (C) One fourth of octahedral voids are occupied by ions of metal A and half of the tetrahedral voids are occupied by ions of metal B
- (D) half of the octahedral voids are occupied by ions of metal A and half of the tetrahedral voids are occupied by ions of metal B
47. If ions of equal size arranged in bcc have radius R, then what will be the radius of created void in it?
- (A) $\left(\frac{\sqrt{5}}{\sqrt{3}}-1\right)R$ (B) $\left(\frac{\sqrt{3}}{2}-1\right)R$ (C) $(\sqrt{3}-1)R$ (D) R
48. An ionic compound AB_2 has A^{2+} ion forming fcc arrangement and B^- ion occupying all tetrahedral voids. If the edge length of the unit cell is 310 pm. Then calculate the minimum distance between centres of two anions ?
- (A) 134.23 pm (B) 219.24 pm (C) 155 pm (D) 179 pm
49. A solid crystalline oxide with formula A_3BO_3 has oxide ions arranged in ccp while ions of metal A and metal B are occupying tetrahedral void and octahedral void respectively. Calculate percentage space occupied by ions of metal A and B in tetrahedral and Octahedral voids respectively ?
- (A) 50 %, 33.33 % (B) 33.33 %, 12.5 % (C) 25 %, 12.5 % (D) 50 %, 25 %
50. In a primitive simple cube unit cell crystal lattice arrangement. Spheres with radius 180 pm are touching each other along the edges, then calculate the radius of void developed in it ?
- (A) 131.76 pm (B) 74.52 pm (C) 40.5 pm (D) 52.38 pm
51. In a fcc crystal lattice arrangement radius of sphere is 180 pm, then calculate the radius of voids created in it ?
- (A) 131.76 pm (B) 74.52 pm (C) 40.5 pm (D) 52.38 pm
52. An oxide compound has oxide ions forming fcc. The tetrahedral voids are filled by ions of metal B and the octahedral voids are filled by ions of metal A. If all atoms on two body diagonals are removed. What will be the simplest formula of the solid. (Do not consider electrical neutrality of the compound.)
- (A) $A_6B_8O_7$ (B) $A_4B_3O_2$ (C) AB_4O_3 (D) $A_4B_8O_5$

53. In the given figure of fcc arrangement of unit cell, which number spheres are occupying tetrahedral voids ?



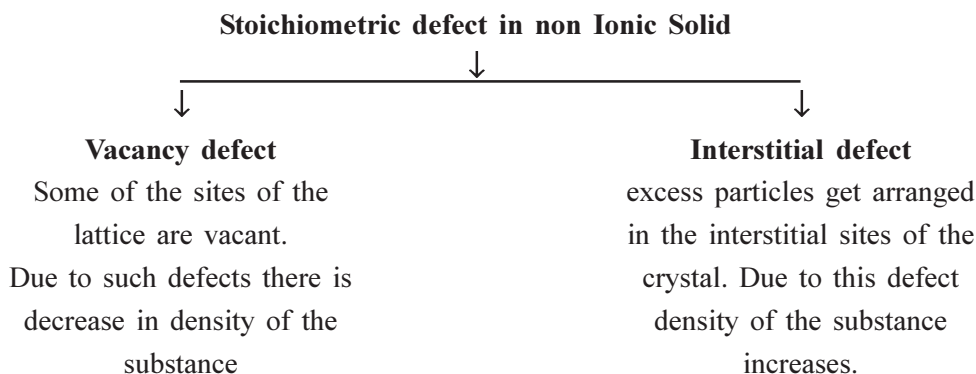
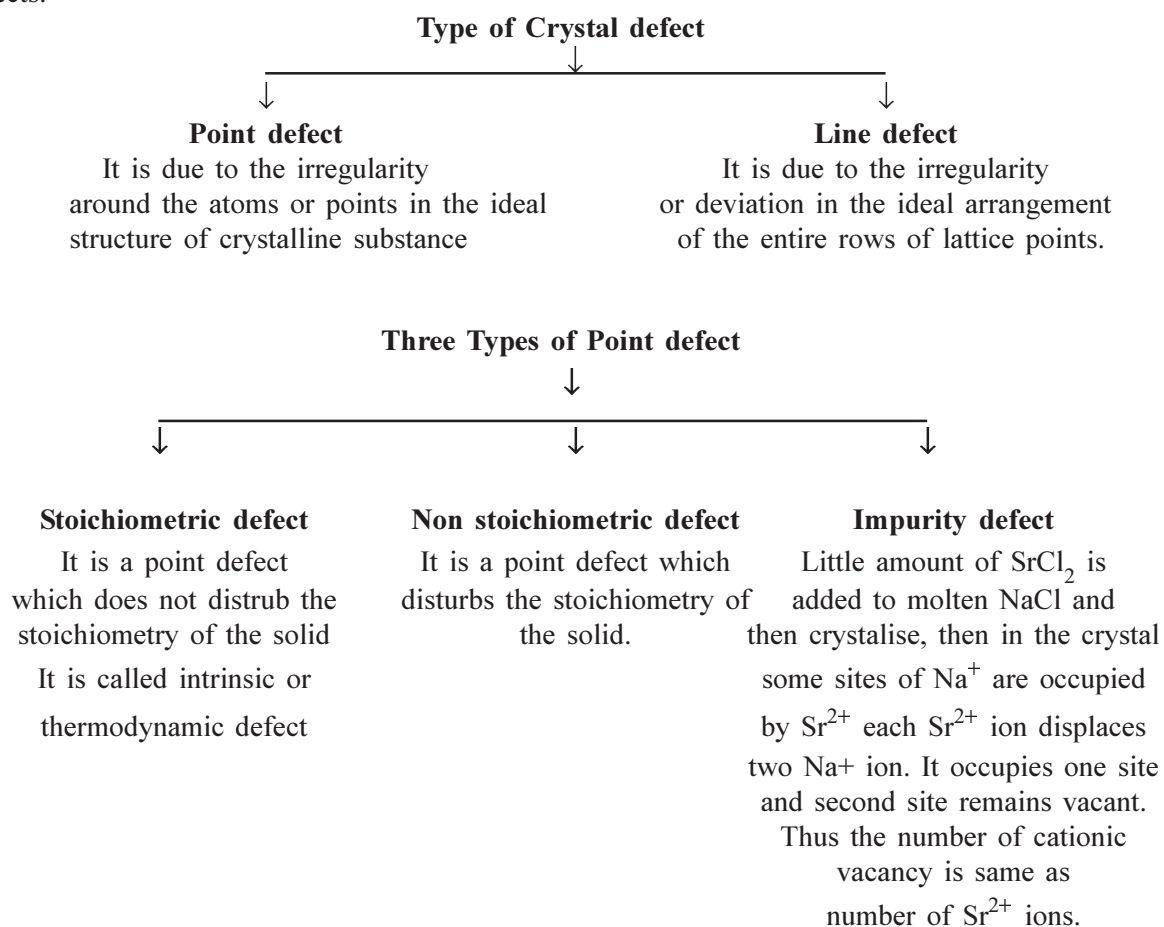
- (A) 1, 13, 11, 12
(B) 3, 10, 13, 2
(C) 8, 11, 12, 14
(D) 6, 10, 9, 11
54. In a trigonal crystalline arrangement If $\alpha = \beta = \gamma = 60^\circ$ Then how many body diagonals will be perpendicular to each other ?
(A) 4 (B) 2 (C) 3 (D) None of them
55. Volume of 10 moles of a metal having fcc arrangement of its atoms is 101.76 cm^3 then calculate the atomic radius of the metal ?
(A) 128 pm (B) 100 pm (C) 162 pm (D) 144 pm
56. An ionic compound has bcc arrangement. In the crystalline arrangement if the distance between cation and anion is 175 pm, then calculate its molar volume (anions are at the corners of the cube and cations in the body centre)
(A) 2.48 cm^3 (B) 0.31 cm^3 (C) 4.96 cm^3 (D) 0.62 cm^3
57. A metal crystallizes into fcc arrangement, then calculate the distance between centres of two tetrahedral voids ?
(A) $2r$ (B) $\sqrt{2} r$ (C) $\frac{\sqrt{3} \cdot r}{2}$ (D) $\sqrt{3} \cdot r$
58. KCl and NaCl have identical crystalline arrangement. If their ionic radii ratio is 0.74 and 0.55 respectively then calculate their edge length ratio ?
(A) 1.3454 (B) 1.1226 (C) 1.5432 (D) 1.4525
59. An ionic compound has antifluorite arrangement (anions form Fcc arrangement and cations occupy tetrahedral voids). In its regular crystalline arrangement if the edge length of its unit cell is 545 pm, then radius of cation and anion respectively is ?
(A) 67.4 pm, 168.585 pm (B) 70.83 pm, 181.511 pm
(C) 60.47 pm, 168.225 pm (D) 72.342 pm, 175.723 pm
60. An ionic compound has antifluorite arrangement (anion form fcc arrangement and cations occupy tetrahedral voids) If $r^+ + r^- = 205 \text{ pm}$, calculate minimum distance between centres of two anions ?
(A) 314.38 pm (B) 228.38 pm (C) 268.25 pm (D) 334.76 pm
61. CsCl crystallizes into bcc crystal lattice arrangement. If edge length of its unit cell is 'a', then which of the following formula is true ?

(A) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \sqrt{3} \cdot a$ (B) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = 3a$ (C) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \frac{3a}{2}$ (D) $r_{\text{Cs}^+} + r_{\text{Cl}^-} = \frac{\sqrt{3} \cdot a}{2}$

62. In a crystalline arrangement of ZnS (wurtzite) Zn^{2+} forms hcp arrangement and S^{2-} ions occupy alternate tetrahedral voids. Ionic radius of Zn^{2+} and S^{2-} is 74 pm and 29.7 pm respectively. Calculate the edge length 'c' of its unit cell. (Note : as per the value given here size of cation is larger than that of anion)
- (A) 349.18 pm (B) 218.42 pm (C) 326.28 pm (D) 276.53 pm

Answers : 43. (B), 44. (D), 45. (D), 46. (B), 47. (A), 48. (C), 49. (A), 50. (A), 51. (D), 52. (A), 53. (C), 54. (C), 55. (D), 56. (C), 57. (B), 58. (B), 59. (A), 60. (D), 61. (D), 62. (D)

Crystal defect : The irregularities in the structure of crystal due to particles is called crystal defects.



Stoichiometric defect in ionic solid

Schottky defect

To maintain electrical neutrality in compounds like Alkali Halides equal number of cation and anion are missing due to this defect density of solid decreases. The cations and anions in ionic solids whose sizes are same or whose co-ordination numbers are high show schottky defect eg. NaCl, KCl, AgBr

Frenkel defect

Smaller cations displace from its general site and arrange in the interstitial site in the middle. There is large difference between the ionic sites of cation and anions that is co-ordination number of cation is low then ionic crystal show such defect eg. AgCl, AgBr, AgI, ZnS. Due to this defect there is no effect on the density of the crystal due to Frenkel defect dielectric constant of the crystal increases and covalent nature of crystal increases.

Non Stoichiometric defect

Metal excess defect due to the vacancy by anion

Alkali Halides like NaCl and KCl show this type of defect. Suppose NaCl is heated in presence of vapour of Na, Sodium deposits on the surface of the crystal. Hence, Cl^- ion diffuse in the layer of the crystal and combine with Na atom and forms NaCl. The e^- released from Na atom diffuse in the crystal and reach the side of anion. Because of this there is increase in Na in the crystal. The anionic sites occupied by unpaired e^- are called F-centres. Hence the crystal of NaCl possesses yellow colour due to such defect LiCl crystal is pink and KCl crystal is violet.

Excess metal defect due to presence of extra cations on the interstitial site

Zinc oxide is a white colour substance at room temperature. It becomes yellow when heated because it loses Oxygen $\text{ZnO} \xrightarrow{\text{heat}} \text{Zn}^{+2} + \frac{1}{2}\text{O}_2 + 2e^-$ Now Zn^{2+} increases in the crystal and so its formula will be Zn_{1+x}O This extra Zn^{2+} ion will be arranged in interstitial site and e^- will be arranged in the neighbouring interstitial site.

Metal deficiency defect

In many solids there are less number of metal atoms seen due to which there is change in their stoichiometry formula. For eg. due to less number of Fe atoms in FeO. Its stoichiometry formula range between $\text{Fe}_{0.93}\text{O}$ to $\text{Fe}_{0.96}\text{O}$ and mostly $\text{Fe}_{0.95}\text{O}$ is seen. In crystal of FeO, some Fe^{2+} ions are found missing and the decrease in positive charge is satisfied by Fe^{3+} ions.

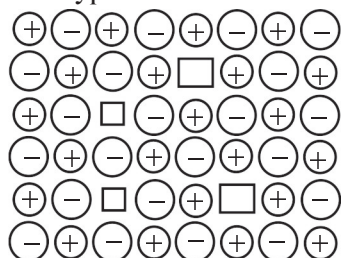
Displacement defect

Sometimes the atoms in the lattice of the crystal are exchanged mutually from their sites to the sites of the other lattice of the crystal and produce displacement defect. For eg. in Cu and Au mixture of metals and Cu and Ag mixture of metals.

● Bragg's equation to calculate distance between two consecutive layers of a crystal having close pack arrangement.

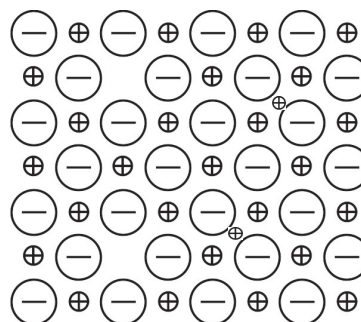
$n\lambda = 2d \sin\theta$, where λ = wave length of the X-ray used, d = distance between two consecutive layers in a crystal, θ = angle of incidence, $n = 1, 2, \dots$

63. Which of the following type of defect is a stoichiometric defect ?
 (A) metal excess defect (B) Schottky defect
 (C) Impurity defect (D) Metal deficiency defect
64. Crystals having show frenkel defect
 (A) large difference in size of cation and anion (B) Higher coordination number of cation
 (C) Almost equal size of cation and anion (D) Size of anion smaller than that of cation
65. Which of the following does not show Schottky defect ?
 (A) KCl (B) AgBr (C) ZnS (D) CsCl
66. are called F-centres (colour centres) ?
 (A) holes created in Schottky defect (B) holes created in Frenkel defect
 (C) unpaired electron occupying anionic site (D) vacant space occupied by impurity
67. Which type of defect is seen in the given figure ?

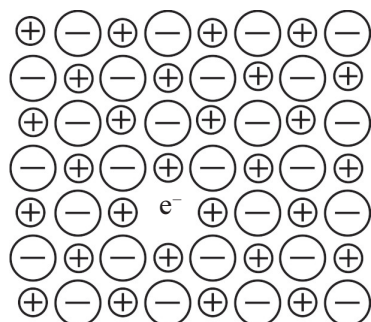


- (A) Frenkel defect (B) Metal excess defect
 (C) Interstitial defect (D) Schottky defect

68. Which type of defect is seen in the given figure ?
 (A) Interstitial defect (B) Frenkel defect
 (C) vacancy defect (D) Schottky defect



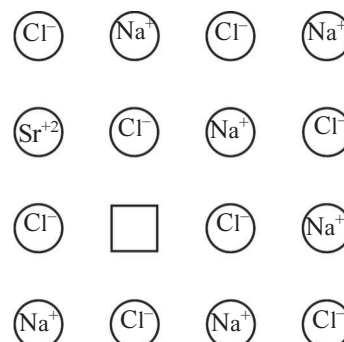
69. Which type of defect is seen in the given figure ?



- (A) Metal excess defect due to vacancy by Anion
 (B) Excess metal defect due to presence of extra cations on the interstitial site
 (C) vacancy defect
 (D) Schottky defect

70. Which type of defect is seen in the given figure ?

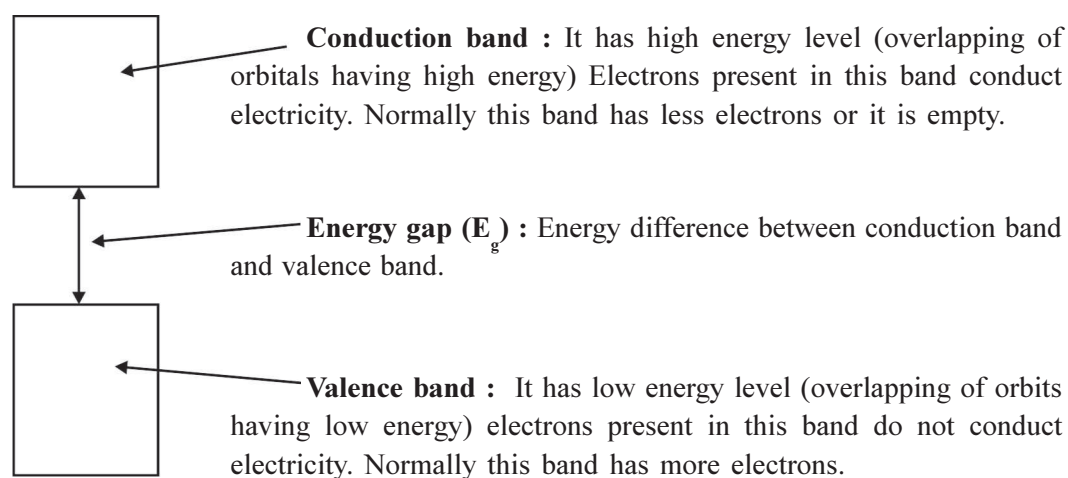
- (A) Metal excess defect due to vacancy by anion.
 (B) impurity defect
 (C) Vacancy defect
 (D) Schottky defect



71. Calculate percentage proportion of Fe^{2+} and Fe^{3+} ions in Fe_xO having metal deficiency defect ?
 (A) 95 %, 5 % (B) 57.5 %, 12.5 % (C) 85 %, 15 % (D) 89.5 %, 10.5 %
72. Based on practical information formula of a metal oxide is $\text{M}_{0.98}\text{O}$. Metal M in its oxide is in M^{2+} and M^{3+} form, then calculate % M^{3+} ion in the oxide ?
 (A) 4.08 % (B) 6.05 % (C) 5.08 % (D) 7.01 %

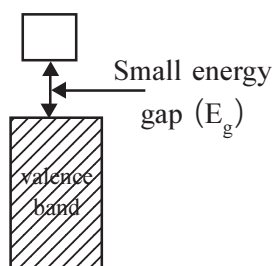
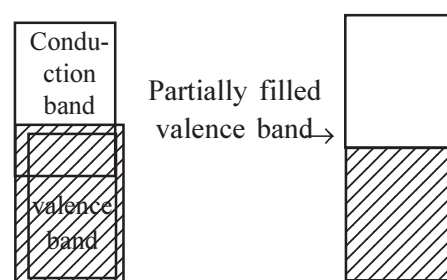
Answers : 63. (B), 64. (A), 65. (C), 66. (C), 67. (D), 68. (B), 69. (A), 70. (B), 71. (D), 72. (A)

Band principle : According to this principle a band is formed due to overlapping of valence orbitals having equal energy in the constituent particles. These bands are of two types valence band and conduction band.



For a substance to conduct electricity it must possess electrons in conduction band. Those substances which have small energy gap (E_g) can allow, electrons to jump from valence band to conduction band easily. Such substances are good conductor of electricity or show high conductivity.

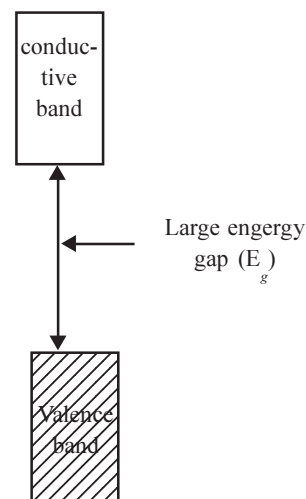
In metals, valence band and conduction band are overlapped or valence band is half filled (incompletely filled) due to which conductivity of metal is high
 (Electrical conductivity of metal ranges from 10^4 to $10^7 \Omega^{-1}\text{m}^{-1}$)



In semi conductors value of energy gap between valence band and conduction band is small due to which if the semi conductors are heated a little, the electrons gain this heat energy and move from valence band to conduction band easily due to this the conductivity of semiconductors increases (or they become electrical conductor)

(Electrical conductivity of semiconductors ranges from 10^{-6} to $10^4 \Omega^{-1}\text{m}^{-1}$)

The value of energy gap (E_g) is very large between valence band and conduction band in a non conductor. The electrons cannot jump from valence band to conduction band easily. Due to which such substances are non conductor of electricity.



(Electrical conductivity of non conductors ranges from 10^{-20} to $10^{-10} \Omega^{-1}\text{m}^{-1}$.)

Semiconductors : They behave as non conductor at normal temperature but on increasing temperature their conductivity increases. eg., Si, Ge....

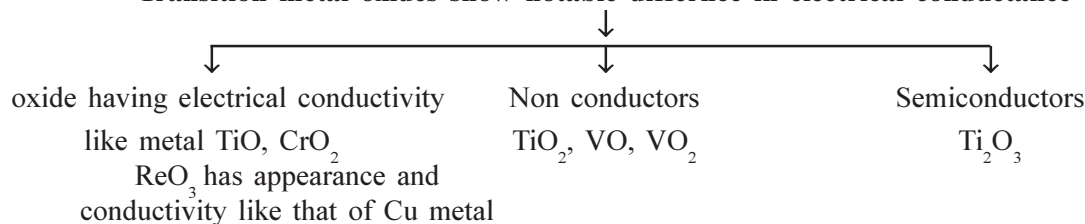
Doping : In semi conductors if any suitable substance in some suitable proportion is added to it as an impurity, its conductance can be increased. This process is called Doping.

N-type (Negative type) semiconductor : In the periodic table elements of Grp 14 (Si, Ge....) have four electrons in this valence orbit and are identified as tetravalent. In them, if Grp 15 element (P, As, Sb, Bi,) whose valence orbit contains five electrons and are identified as pentavalent is added as impurity in suitable proportion then it becomes a semiconductor with more electron and is called n-type (Negative type) semiconductor.

P-type (positive type) semiconductor : In the periodic table elements of Grp 14 (Si, Ge...) have four electrons in their valence orbit and are known as tetra valent. In them, if Grp 13 elements (B, Al, Ga, In) whose valence orbit contains three electrons and are known as trivalent is added as impurity in suitable proportion then it becomes a semiconductor with less electrons and is called p-type (positive type) semiconductors.

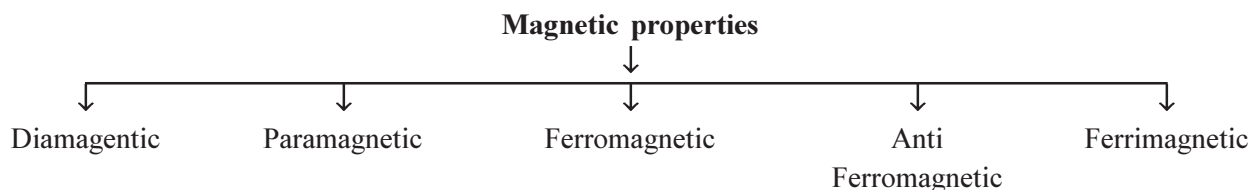
- n-type and p-type semiconductors are very useful in electronic industries.
- Diode is formed by joining n-type and p-type semiconductor
- By combination of semiconductor of the type pnp or npn can be prepared having different properties.
- Semiconductors like gallium arsenide (GaAs) have created a revolution by things having such semiconductors because of their very fast response.

Transition metal oxides show notable difference in electrical conductance



73. Which of the following has appearance and conductivity like Cu ?
 (A) TiO (B) VO_3 (C) CrO_2 (D) ReO_3
74. Cu and Ge are which type of conductors ?
 (A) electrical conductor and non electrical conductor
 (B) Semiconductor and electrical conductor
 (C) electrical conductor and semiconductor
 (D) semiconductor and semiconductor
75. Dopping of which type of element should be added in Ge to produce p-type semiconductors ?
 (A) As (B) P (C) Al (D) Sb

Answers : 73. (D), 74. (C), 75. (C)



Diamagnetic : Those substances which when placed in magnetic field they get weakly repelled by magnetic field and move from stronger area of magnetic field to weaker area of magnetic field.

Substance having all electrons paired are called diamagnetic substance.

Such substance when subjected to magnetic field they will show lesser weight.

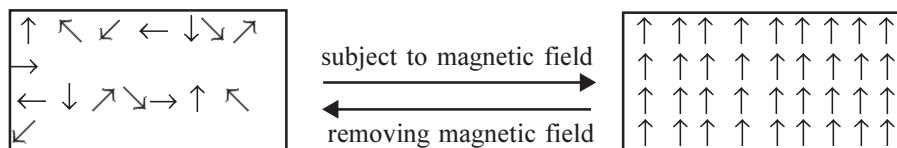
eg. Benzene, TiO_2 , NaCl etc.

Paramagnetic : Those substances which when placed in magnetic field they get attracted by magnetic field and move from weaker area of magnetic field to stronger area of magnetic field are called paramagnetic substance.

Those substances which have one or more unpaired e^- are called paramagnetic substance.

Such substance when subjected to magnetic field they will show more weight.

eg., FeO, Fe^{3+} , Cr^{3+} , Cu^{2+} etc.



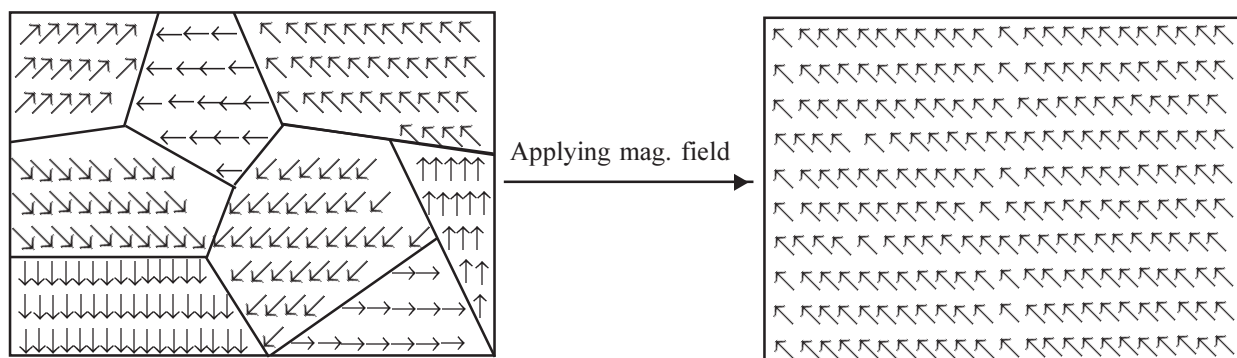
In this substance magnetic moment of unpaired electrons remain non aligned in absence of magnetic field and they do not possess magnetic attraction, but in presence of magnetic field they get aligned in one direction and behave as a magnet and possess magnetic attraction. On removal of magnetic field the magnetic moment again get non aligned and does magnetic attraction.

Ferromagnetic : In certain substances smaller domains and the magnetic moment of their unpaired electron are aligned in one direction, different domains are aligned in different directions. Such that domains and mag. Moment are aligned in opposite direction and net magnetic moment becomes zero and does not possess magnetic attraction.

When magnetic field is subjected to this substance and this magnetic moment and domain get aligned and they possess strong magnetic attraction and it acts as a magnet.

Now even on removal of magnetic field of this substance and their magnetic moment and domain remain aligned. Such substances are permanent magnets and they are called as magnets

eg., Fe, Co, Ni, Gd, CrO_2



Antiferro magnetic : Such substances, when are subjected to magnetic field, the unpaired electron's magnetic moment are arranged in such a manner that magnetic moment value is zero due to which, such substances can not become a magnet.

eg., MnO $\uparrow \downarrow \uparrow \downarrow \uparrow \downarrow$

Ferrimagnetic : In certain substance domains and magnetic moment of unpaired e^- are aligned antiparallel to each other but are in unequal number and so net magnetic moment is not zero.

eg., Magnetite (Fe_3O_4), Ferrites (MgFe_2O_4 and ZnFe_2O_4)

76. Which pair of substances are paramagnetic and diamagnetic respectively ?

- (A) NaCl, N_2 (B) O_2 , Cr^{3+} (C) Co^{3+} , Fe^{3+} (D) Cr^{3+} , H_2O

77. Which pair of substances are ferromagnetic and antiferromagnetic respectively ?

- (A) MgFe_2O_4 , MnO (B) FeO, ZnFe_2O_4 (C) MnO, Fe_3O_4 (D) C_6H_6 , H_2O

78. Connect in a suitable way 4×4 matrix for column-I given crystal column-II given unit cell.

Column-1

Column-2

- | | | |
|------------------|----------------------------------|---|
| (A) cube | (P) Primitive unit cell | (A) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$ |
| (B) orthorhombic | (Q) Face centred Cubic unit cell | (B) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$ |
| (C) Tetragonal | (R) Body centred Cubic unit cell | (C) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$ |
| (D) Monoclinic | (S) End centred Cubic unit cell | (D) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$ |

Answers : 76. (D), 77. (A), 78. (A) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$

(B) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$

(C) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$

(D) $\textcircled{\text{P}}$ $\textcircled{\text{Q}}$ $\textcircled{\text{R}}$ $\textcircled{\text{S}}$