Chapter 1

The Solid State

Solutions

SECTION - A

Objective Type Questions (One option is correct)

1. Metal A crystallize in body centred cubic unit cell having edge length x cm and metal B crystallize in simple cubic unit cell having edge length y cm. If density of unit cell of B is same as of unit cell of A and y = 2x. The value of (M_B/M_A) is (M_B and M_A are molar mass of B and A in g/mol respectively).

(1) 4 (2) 8 (3) 16 (4) 32

Sol. Answer (3)

$$d_A = \frac{2\times M_A}{N_A x^3}$$

$$d_B = \frac{1\times M_B}{N_A y^3}$$

$$\frac{2\times M_A}{N_A x^3} = \frac{M_B}{N_A y^3} \Rightarrow \frac{M_B}{M_A} = 2\left(\frac{y}{x}\right)^3 = 16$$

2. Cubic close packing (CCP) is ABC ABC type packing. The maximum number of atoms present in one plane of this packing which are in contact with one atom are

(1) 6 (2) 8 (3) 10 (4) 12

Sol. Answer (1)

3. Select the correct statement.

(1) $Fe_{0.95}O$ have metal deficiency defect

(2) Schottky defect is non-stoichiometric defect

(3) Density decreases due to Frenkel defect

(4) All of these

Sol. Answer (1)

Fact

4. AB has NaCl type structure. If edge length of crystal lattice is 141 Å. The radius of A^+(approx)

(1) 2.5 Å (2) 20.6 Å (3) 32 Å (4) 28.3 Å

Sol. Answer (2)

$$\frac{r^+}{r^-} = 0.414 \text{ (approx)}$$

$$r_{A^+} + r_{B^-} = 70.5 \text{ Å}$$

$$r_{A^+} = 20.6 \text{ Å}$$

5. Select the incorrect statement.

(1) NaCl is diamagnetic substance

(2) Conductivity of semiconductor increase on increasing the temperature

(3) Diamagnetic substances are weakly attracted by magnetic field

(4) MnO is anti-ferromagnetic substance

Sol. Answer (3)

6. If metal A crystallize in face centred cubic unit cell with edge length x Å and metal B crystallize in simple cubic unit cell with edge length y Å. Density of both unit cell is same and $(M_A/M_B) = 2$, the (x/y) is

[Here $M_A \rightarrow$ Molar mass of A in (g/mol)

$M_B \rightarrow$ Molar mass of B in (g/mol)]

(1) 1 (2) 2 (3) 3 (4) 4

Sol. Answer (2)

$$\text{Density of A} = \frac{4M_A}{N_A x^3}$$

$$\text{Density of B} = \frac{M_B}{N_A y^3}$$

$$\text{If } d_A = d_B \Rightarrow \frac{4M_A}{N_A x^3} = \frac{M_B}{N_A y^3}$$

$$\Rightarrow \quad 4\left(\frac{M_A}{M_B}\right) = \left(\frac{x}{y}\right)^3$$

$$\Rightarrow \quad 8 = \left(\frac{x}{y}\right)^3 \Rightarrow \frac{x}{y} = 2$$

7. Metal M having molar mass 30 (g/mol) and crystallize in cubic lattice with edge length 1 nm. If density of unit cell is 0.2 g/cm^3 the unit cell in which M crystallize (Take $N_A = 6 \times 10^{23}$ mol^{-1})

(1) Primitive unit cell (2) Body-centred unit cell

(3) Face-centred unit cell (4) End-centred unit cell

Sol. Answer (3)

$$d_{(g cm^{-1})} = \frac{Z \times M(g)}{N_A \times a^3(cm)}$$

$$\frac{d \cdot N_A \cdot a^3}{M} = Z$$

$$\Rightarrow \quad \frac{0.2(g/cm^3) \times 6 \times 10^{23} mol^{-1} \times 10^{-21} cm^3}{30\ g/mol} = z$$

$$\Rightarrow \quad \frac{1.2 \times 100}{30} = z \Rightarrow z = 4$$

So unit cell is F.C.C.

8. Metal *P* crystallizes in simple cubic unit cell having edge length of unit cell *X* Å and metal *Q* crystallizes in body centred cubic unit cell having edge length of unit cell is *Y* Å. Find the correct statement.

(1) When $X = Y$, density of unit cell of *Q* is always greater than density of unit cell of *P*

(2) When $X = Y$, density of unit cell of *Q* is equal to density of unit cell of *P* if molar mass of *P* and *Q* is equal

(3) When $X = Y$, density of unit cell of *Q* is equal to density of unit cell of *P* if $M_P = 2M_Q$

[Here $M_P \rightarrow$ Molar mass of *P*(g/mol), $M_Q \rightarrow$ Molar mass of *Q*(g/mol)]

(4) When $X = Y$, density of unit cell of *Q* is always less than density of unit cell of *P*

Sol. Answer (3)

9. Among the following co-ordination number (nearest neighbour) of cation is maximum in

(1) NaCl type structure

(2) CsCl type structure

(3) ZnS type structure

(4) Na_2O (Antifluorite) type structure

Sol. Answer (2)

CN is 8.

10. In an alloy Mn–Si, atoms of Si are at 50% of corners and remaining 50% of corners of cube are occupied by Mn. If Mn also occupies body centre position, fraction of Mn in alloy will be

(1) 0.25 (2) 0.50 (3) 0.75 (4) 0.80

Sol. Answer (3)

$$Mn_{\left(\frac{1}{8}\times 4\right)+1}\ Si_{\left(\frac{1}{8}\times 4\right)} \Rightarrow Mn_{\left(\frac{1}{2}+1\right)}Si_{\frac{1}{2}}$$

$$\Rightarrow MN_{3/2}\ Si_{1/2}$$

$$\Rightarrow Mn_{1.5}\ Si_{0.5}$$

Fraction of Mn = $\frac{1.5}{1.5+0.5} = \frac{1.5}{2.0} = 0.75$

11. Interstitial sites that are formed when three closed packed spheres of one layer is put on three close packed spheres of the second layer, their positions being inverted with respect to each other.

(1) Cubic (2) Octahedral (3) Rhombohedral (4) Tetrahedral

Sol. Answer (2)

 $\rightarrow$ Coordination number = 6 (octahedral void)

12. A sample of Fe_xO contains one Fe(III) for every three Fe(II), then the value of x is

(1) 0.93 (2) 0.96 (3) 0.888 (4) 0.82

Sol. Answer (3)

$$Fe^{2+} \text{ —— } Fe^{3+} \quad \Rightarrow \quad \frac{3}{4}x(+2)+\frac{1}{4}x(+3)=2 \quad \Big| \quad x=\frac{8}{9}$$

$$\frac{3}{4}x \quad \frac{1}{4}x$$

$$\Rightarrow \quad \frac{6x}{4}+\frac{3x}{4}=2$$

$$\Rightarrow \quad \frac{9x}{4}=2$$

13. Metal M crystallize in B.C.C unit cell and density is x g/c.c. Under different condition of pressure and temperature metal M crystallizes in F.C.C unit cell having density y g/c.c. Select the correct statement.

(1) y = x (2) y > x (3) y < x (4) Cannot be predicted

Sol. Answer (2)

$$x=\frac{2\times\text{mass of one metal atom}}{\left(\frac{4r}{\sqrt{3}}\right)^3}$$

$$y=\frac{4\times\text{mass of one metal atom}}{\left(\frac{4r}{\sqrt{2}}\right)^3}$$

$$\frac{x}{y}=\frac{2\times3\sqrt{3}}{4\times2\sqrt{2}}\approx0.92$$

$\therefore$ y > x

14. A solid XY crystallizes in NaCl type structure (X is cation). Some atoms are removed such that crystal remain neutral. The possible case is

(1) All atom along a body diagonal are removed

(2) All atom along a face diagonal are removed

(3) Atom along a line which passes through opposite face centres and body centre are removed

(4) Atom from two corner are removed

Sol. Answer (3)

If atoms along the axis passing through two opposite face centres are removed, crystal will remain neutral.

15. Which of the following pair contain only ferromagnetic substances ?

(1) Benzene and Cu^+ (2) NaCl and Cu^{2+} (3) Fe and Co (4) Cu^+ and Cu^{2+}

Sol. Answer (3)

Iron & cobalt are ferromagnetic substances.

16. An ionic solid A^+B^- crystallizes in rock salt type structure. What is the third nearest neighbour of anion B^- and how many in number ?

(1) A^+, 6 (2) B^-, 12 (3) A^+, 8 (4) B^-, 6

Sol. Answer (3)

Dist. of 1st nearest neighbour (A^+) to corner ion $B^- = \frac{a}{2}$

Dist. of 2nd nearest neighbour (B^-) $= \frac{a}{\sqrt{2}}$

Dist. of 3rd nearest neighbour (A^+) $= \frac{\sqrt{3}}{2}a$

17. Consider the statement :

Statement I : Dislocation defect is shown by ZnS.

Statement II : Due to Schottky defect, density of solid decreases.

Statement III : Interstitial defect increases the density of substance in non ionic solids.

The correct statement(s) is(are)

(1) Only I (2) Only II and III (3) Only I and III (4) I, II and III

Sol. Answer (4)

[All the statements are true]

18. Which of the following is not a property of amorphous solids?

(1) They do not have definite heat of fusion

(2) They are pseudo solids or super cooled liquids

(3) Their physical properties show different values when measured along different directions in the same crystal

(4) Their constituent particles follow short range order

Sol. Answer (3)

Amorphous solids are isotropic in nature.

19. Consider the following examples of solid and attractive forces and select the incorrect one.

(1) CCl_4 – London forces

(2) $H_2O(s)$ – H-bonding

(3) SiO_2 – Covalent bonding

(4) SO_2 – London forces

Sol. Answer (4)

SO_2 – Dipole -Dipole interactions

20. A crystal is made by using particles X, Y and Z. Particle Z forms CCP, X occupies all the tetrahedral voids and Y all the octahedral voids. If all the particles along one of C–3 axis of symmetry are removed, then the formula of the crystal would be

(1) $X_8Y_4Z_5$ (2) X_2YZ (3) $X_5Y_4Z_3$ (4) $X_6Y_3Z_5$

Sol. Answer (1)

C – 3 axis of symmetry is body diagonal.

$\therefore$ Number of particles of X removed = 2

Number of particles of Y removed = 1

Number of particles of Z removed = $\frac{1}{4}$

Formula of crystal = $X_6Y_3Z_{\frac{15}{4}} = X_8Y_4Z_5$

21. An ionic solid FeO crystallizes into a cubic structure and has edge length equal to 5.0 Å. If the density of crystal is 4 g/cm^3, then the relation between formula mass (X) and mass of a unit cell (Y) is

(1) X = Y (2) X = 4Y (3) Y = 2X (4) Y = 4X

Sol. Answer (4)

Density = $\frac{Z\times(56+16)}{N_A\times5\times5\times5\times10^{-24}}$

$\Rightarrow$ Z = 4

$\therefore$ Mass of a unit cell = 4 × formula mass

22. The pink colour of lithium chloride crystal is due to

(1) Frenkel defect

(2) Metal excess defect

(3) Metal deficiency defect

(4) Impurity defect

Sol. Answer (2)

The colour is due to presence of F-centres in crystal.

SECTION - B

Objective Type Questions (More than one options are correct)

1. Which of the following is/are pseudo solid?

(1) KCl (2) $BaCl_2.2H_2O$ (3) Rubber (4) Coke

Sol. Answer (3, 4)

Pseudo solids means behaving like solids but atoms in the solid are having irregular arrangement. Rubber and coke are pseudo solids.

2. What will be the distance between two nearest neighbours in primitive, fcc and bcc unit cell?

(1) For primitive, d = a (2) For fcc, d = 0.707a

(3) For bcc, d = 1.732a (4) For bcc, d = 1.414a

Sol. Answer (1, 2)

Distance between the neighbouring atoms

For primitive $\left(d=\frac{a}{2}\right)$

For FCC $\left(d=\frac{a}{\sqrt{2}}\right)$

For BCC $\left(d=\frac{\sqrt{3}\,a}{2}\right)$

3. Incorrect option(s) about a CCP structure is/are

(1) First and fourth layers are repeated (2) First and third layers are repeated

(3) Second and fourth layers are repeated (4) First, third and sixth layers are repeated

Sol. Answer (2, 3, 4)

Manner of aggregation of layers in ccp can be represented as ABCA……..

So fourth layer repeats.

4. Which of the following is correctly matched?

(1) In HCP unit cell - No. of effective atoms = 6

(2) In ABC ABC type packing - No. of effective atoms = 12

(3) In FCC unit cell - No. of effective atoms = 12

(4) In primitive unit cell - No. of effective atoms = 1

Sol. Answer (1, 4)

For hcp packing the no. of effective atoms is 6 and in primitive unit cell

No. of effective atoms = $8 \times \frac{1}{8} = 1$

5. In the closest packing of atoms

(1) Coordination number of particles placed in of tetrahedral voids is smaller than octahedral voids

(2) Size of tetrahedral void is larger than that of octahedral void

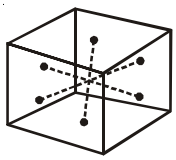
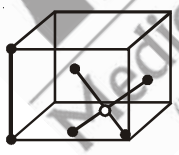
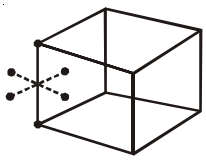
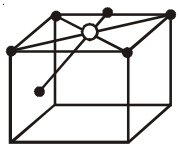
(3) Size of voids depend upon size of atoms and tetrahedral void is smaller than octahedral void

(4) Radius ratio for tetrahedral voids is smaller than octahedral void

Sol. Answer (1, 3, 4)

Tetrahedral voids have coordination number 4 and are smaller than octahedral voids. Size of voids depends upon the size of atom and Radius Ratio. T-voids are smaller than octahedral voids. 0.225 to 0.414 for T-voids and 0.414 to 0.732 for O-voids.

6. Which of the following represent octahedral void?

(1)  (2)  (3)  (4) 

Sol. Answer (1, 3)

Voids are surrounded by six atoms at edge centre & body. So, (1) & (3) are correct answers.

7. For hcp lattice which statements will be correct?

(1) Coordination number of hcp = 12

(2) Volume of unit cell unoccupied = 74%

(3) It contains both tetrahedral and octahedral voids

(4) This is more efficient packing than ccp

Sol. Answer (1, 3)

For Hexagonal packing the coordination number is 12 and contains tetrahedral and octahedral voids.

8. CsCl has bcc structure. If atomic mass of Cs and Cl atom is 133 and 35.5 amu respectively, what would be correct about its unit cell?

(1) Number of formula unit (z) = 1

(2) Number of formula unit (z) = 2

(3) Mass of unit cell = 370 g mol^{-1}

(4) Mass of unit cell = 168.5 g mol^{-1}

Sol. Answer (1, 4)

CsCl has BCC structure

Cs = 133, Cl = 35.5

Cs^+ is present at the centre and 8 Cl^- ions are present at the corners.

$\therefore$ No. of formula unit (z) = 1

Mass of unit cell = 133 + 35.5 = 168.5

$\Rightarrow$ M_w = 133 + 35.5 = 168.5

9. Which of the following statements is/are correct for fluorite structure (CaF_2)?

(1) Ca^{2+} ions are in ccp with fcc unit cell and F^- ions occupy all the tetrahedral voids

(2) Ca^{2+} ion is surrounded by $4F^-$ ions

(3) Mass of one unit cell = mass of $4Ca^{2+}$ + Mass of $4F^-$

(4) C.N. of F^- = 4, C.No. Ca^{2+} = 8

Sol. Answer (1, 4)

In CaF_2 : Ca^{2+} occupies FCC (or ccp) and $F^{\dot{E}}$ are present in tetrahedral voids

$\therefore$ No. of $Ca^{2+} = 8\times\frac{1}{8}+6\times\frac{1}{2}=4$

$F^{\dot{E}}$ = 1 × 8 = 8

$\therefore$ Formula becomes $Ca_4F_8 \Rightarrow CaF_2$

Coordination no. of $F^{\dot{E}}$ = 4

Coordination no. of Ca^{2+} = 8

10. Incorrect option(s) about NaCl structure is/are

(1) Only 50% lattice ponits at corners are shared among more then one unit cells

(2) 100% lattice points at edge centres are shared among more then one unit cells

(3) Only 50% lattice points at face centres are shared among more then one unit cells

(4) No lattice point is present on body diagonal of unit cell

Sol. Answer (1, 3, 4)

11. In which operation(s), the formula of NaCl remains same?

(1) On passing one body-diagonal plane in unit cell and all the ions are removed touching body-diagonal plane

(2) On passing one rectangular plane in unit cell and all the ions are removed touching rectangular plane

(3) On passing tetrad axis in unit-cell and all the ions are removed touching the tetrad axis

(4) On passing body-diagonal line in unit cell and all the ions are removed touching the body-diagonal line

Sol. Answer (1, 2, 3)

Body diagonal touches :

$$\left.\begin{matrix}4 \text{ corners}\\ 2 \text{ face centres}\end{matrix}\right\} \Rightarrow Cl^- \text{ removed} = \frac{4}{8}+\frac{2}{2}$$

$$\left.\begin{matrix}2 \text{ edge centres}\\ \& \text{ 1 body centre}\end{matrix}\right\} \Rightarrow Na^+ \text{ removed} = \frac{2}{4}+1$$

Thus same number of Na^+ and Cl^- are removed

Rectangular plane touches :

$$4 \text{ face-centres} \Rightarrow Cl^- \text{ removed} = \frac{4}{2}$$

$$\left.\begin{matrix}4 \text{ edge centres}\\ 1 \text{ body centre}\end{matrix}\right\} \Rightarrow Na^+ \text{ removed} = \frac{4}{4}+1$$

Thus same number of Na^+ and Cl^- are removed.

Tetrad axis touches ;

$$2 \text{ face centres} \Rightarrow \frac{2}{2} Cl^-$$

& 1 body centre $\Rightarrow$ 1 Na^+

Thus same number of Na^+ and Cl^- are removed.

Body-diagonal touches

$$2 \text{ corners} \Rightarrow Cl^- \text{ removed} = \frac{2}{8}$$

& 1 body centre $\Rightarrow$ Na^+ removed = 1

Thus Na^+ removed $\neq$ Cl^- removed.

12. In an oxide, oxide ions are packed with FCC unit cell in which B^{3+} ion occupy x% of octahedral void and A^{2+} ion occupy y% of tetrahedral void, then what is correct about the unit cell?

(1) Formula is $A_3B_2O_6$ in which x = 50% and y = 12.5%

(2) Formula is $A_2B_4O_6$ in which x = 50% and y = 50%

(3) Formula is AB_2O_4 in which x = 50% and y = 12.5%

(4) Formula is AB_2O_4 in which x = 12.5% and y = 50%

Sol. Answer (3)

In AB_2O_4

O^{2-} present as ccp

$\therefore$ No. of $O^{2-} = 8\times\frac{1}{8}+6\times\frac{1}{2} = 4$

$\therefore$ $4O^{2-}$ are present

8 T-voids and 4 O-voids are present in FCC unit cell

B^{3+} occupy x% of O-voids are occupied, since 2B atoms are present,

we can conclude 50% O-voids are occupied

$\therefore$ X = 50%

A^{2+} ions occupy tetrahedral voids and y% are occupied. Since only one ion is present it means $\frac{1}{8}$ × (T-voids) are present

$\therefore$ y = 12.5%

13. In fluorite structure of AB_2

(1) On subjecting to strong heating it changes to antifluorite structure

(2) Interchanging the position of positive and negative ion changes to antifluorite structure

(3) Coordination number of A = 8 and B = 4

(4) Coordination number of A = 4 and B = 8

Sol. Answer (2, 3)

Fluorite is basically $CaF_2(AB_2)$

Interchanging +ve and –ve ions will give antifluorite structure

Coordination no. of A = 8 and B = 4

14. The density of KBr is 2.75 g/cm^3 and edge length of unit cell is 654 pm (K = 39, Br = 80) then what are the features of this unit cell?

(1) Unit cell is fcc type (2) Number of formula units = 4

(3) Solid has bcc type (4) Number of formula units = 2

Sol. Answer (1, 2)

ρ (KBr) = 2.75 g/cm^3.

a (edge length) = 654 pm

We can apply the equation

$$\rho = \frac{Z \times M_w}{a^3 \times N_A} \quad \therefore \quad Z = \frac{2.75 \times (6.54 \times 10^{-8})^3 \times (6.023 \times 10^{23})}{119}$$

$$\therefore \quad Z = (2.75)\frac{(6.54)^3 \times 6.023 \times 10^{-1}}{119} = 4$$

$\therefore$ It is FCC lattice (unit cell) and no. of formula unit = 4

15. Fe_3O_4 has inverse spinel structure. What is not true about this solid?

(1) Fe^{3+} ions are equally distributed between octahedral and tetrahedral voids

(2) Tetrahedral voids are equally distributed between Fe^{2+} and Fe^{3+} ions

(3) No. of $O^{-2} > Fe^{+3} > Fe^{+2}$

(4) Coordination no. of Fe^{3+} = 8 through out the unit cell

Sol. Answer (2, 4)

Fe_3O_4 has inverse spinel structure

O^{2-} ions forms FCC unit cell

Fe^{3+} occupies $\frac{1}{8}$ (TV) = one Fe^{3+}

Fe^{2+} occupies $\frac{1}{4}$ (OV) = one Fe^{2+}

Fe^{3+} occupies $\frac{1}{4}$ (OV) = one Fe^{3+}

Formula ratio of Fe^{2+}, Fe^{3+}, O^{2-} = 1 : 2 : 4

16. CsCl structure is interchanged into NaCl structure. This can be done because

(1) Temperature is increased (2) Pressure is decreased

(3) Temperature is decreased (4) Presure is increased

Sol. Answer (1, 2)

In CsCl co-ordination number is 8, this can be converted into NaCl structure (CN = 6) by release in packing that can be achieved either by increase of temperature or by decrease in pressure.

17. All spinel structures do not have

(1) CCP array of anions (2) Simple cubic structure

(3) BCC array of anions (4) HCP array of anions

Sol. Answer (2, 3, 4)

In spinel structures anions form ccp in which divalent cation occupy tetrahedral void and trivalent cations occupy octahedral voids.

18. Which of the following defects doesn't disturb stoichiometry of solid?

(1) Schottky defect (2) Metal excess defect

(3) Non-stoichiometric defects (4) Frenkel defect

Sol. Answer (1, 4)

'Schottky' and 'Frenkel' defect doesn't disturb the stoichiometry of the solid.

19. Which of the following is/are true statement(s)?

(1) On rising pressure coordination no. changes from 8 : 8 to 6 : 6

(2) On rising temperature coordination no. changes from 8 : 8 to 6 : 6

(3) Compounds with metal deficiency defect may behave as a p-type semiconductor

(4) Compounds with metal excess defect may behave as a p-type semiconductor

Sol. Answer (2, 3)

On raising temperature coordination no. changes from 8 : 8 to 6 : 6 and compounds with metal deficiency behave as a p-type semiconductor.

20. Which of the following is/are true statements?

(1) In Schottky defect density remains constant

(2) KCl is violet on heating with K-metal vapour because of F-centers

(3) Crystals with defects are better conductor of electricity

(4) Al_2O_3 can show metal deficiency defect

Sol. Answer (2, 3)

KCl is violet. Because of Metal excess defect F-centers are present and because of charge carried in defected crystals, they are better conductor of electricity.

SECTION - C

Linked Comprehension Type Questions

Comprehension-I

NaCl is a AB type of solid. Its crystalline structure is known as rock salt structure in which r_{Na^+} and r_{Cl^-} are 95 and 181 pm respectively, where Cl^- is present at the lattice point of face centered cubic unit cell Na^+ ions are located in void and those compounds which have same crystalline structure also have same coordination system in which Na^+ and Cl^- ions are surrounded by certain number of opposite ions respectively. Under high pressure coordination number changes to 8 : 8 type from 6 : 6 type.

1. On subjecting NaCl under high pressure it changes

(1) From NaCl to CsCl (2) From NaCl to ZnS

(3) NaCl remains NaCl (4) It causes Schottky defect

Sol. Answer (3)

There is no change in composition of NaCl when pressure is applied. Only co-ordination number changes.

2. LiCl adopts rock salt crystalline structure in which edge length is 5.40 Å. What would be the radii of Li^+?

(1) 0.89 Å (2) 2.7 Å (3) 1.78 Å (4) 0.98 Å

Sol. Answer (1)

Since it is a FCC lattice and cations occupy the octahedral voids.

$\therefore \quad 2(R_{Li^+} + R_{Cl^-}) = a$ [Edge length]

$\Rightarrow \quad 2[R_{Li^+} + 1.81] = 5.40 \quad \Rightarrow \quad 2R_{Li^+} + 3.62 = 5.40$

$\therefore \quad 2R_{Li^+} = (5.40) - (3.62) = 1.78$

$\therefore \quad R_{Li^+} = \dfrac{1.78}{2} = 0.89$ Å

3. In rock salt type structure of AB solid, what would be the maximum radius of X^+ that can displace A^+ if radius of B^- is 100 pm?

(1) 41.4 pm (2) 73.2 Å (3) 41.4 Å (4) 73.2 pm

Sol. Answer (4)

For solid AB, $R_{B^-} = 100$ pm

$\dfrac{R_{A^+}}{R_{B^-}} = 0.732 \quad \Rightarrow \quad R_{A^+} = (0.732)(100) = 73.2$ pm

4. If the atomic mass of Li and Cl are 7 and 35.5 amu respectively, then what would be number of LiCl molecule in cube of LiCl with length × height × breadth = 1 × 1 × 1 = 1 cm^3?

(1) Nearly 2.5×10^{22} (2) Nearly 4×10^{20}

(3) Nearly 12×10^{30} (4) Nearly 14×10^{23}

Sol. Answer (1)

In volume (a^3) number of LiCl molecules = 4

$\Rightarrow \quad (5.40 \times 10^{-8})^3 \text{ cm}^3 = 4$

$$1 \text{ cm}^3 = \frac{4}{(5.40)^3 \times 10^{-24}}$$

$\Rightarrow$ 2.5×10^{22} molecules

5. What is the number of second nearest neighbours of Na^+ in NaCl crystal?

(1) 6 (2) 12 (3) 8 (4) 4

Sol. Answer (2)

In a Rock-salt structure number of second nearest neighbours of Na^+ in NaCl crystal is 12.

Comprehension-II

Magnesium and Titanium form a crystalline oxide in which Mg appears at the eight corners, oxygen appears at face centres and titanium appears at the centre of cube. The atomic mass of magnesium, titanium and oxygen is 24, 45.9 and 16 amu respectively. A similar compound is formed by calcium with titanium and oxygen.

1. What would be the formula of substance (oxide)?

(1) Mg_2TiO_3 (2) $MgTiO_3$ (3) $MgTiO_4$ (4) Mg_2TiO_4

Sol. Answer (2)

Mg appears at eight corners.

$\therefore$ Mg numbers will be $8 \times \frac{1}{8} = 1$

'O' appears at centres of faces

$\Rightarrow$ $6 \times \frac{1}{2} = 3$

Ti appears at centre of the cube. $\therefore$ Only one Ti is present at the centre.

Hence formula becomes $MgTiO_3$.

2. What would be the number of nearest neighbours for Ti?

(1) 8 (2) 6 (3) 12 (4) 4

Sol. Answer (2)

Since Titanium is surrounded by six faces, therefore, we can say that there are Six (6) neighbouring atoms.

3. What type of crystalline structure does $MgTiO_3$ have?

(1) Spinel (2) Wurtzite (3) Antifluorite (4) Pervoskite

Sol. Answer (4)

$MgTiO_3$ is a Pervoskite structure.

4. What would be the molar mass of unit cell of $MgTiO_3$?

(1) Nearly 118 g mol^{-1} (2) 236 g mol^{-1} (3) 59 g mol^{-1} (4) None of these

Sol. Answer (1)

Molar mass of $MgTiO_3$ is

$24 + 45.9 + (16 \times 3) = 117.9$ g/mol. $\approx$ 118 g/mol

Comprehension-III

Atoms A, B, C and D are located at corners, face-centres, T-voids and O-voids respectively.

1. If atoms touching one of the body-diagonal plane of symmetry are removed, then formula of compound is

(1) $AB_2C_4D_7$ (2) $AB_4C_8D_7$ (3) $AB_2C_4D_5$ (4) $AB_4C_8D_5$

Sol. Answer (4)

Body diagonal plane touches :

4 corners $\Rightarrow$ removed A = $\frac{4}{8}$

2 face-centres $\Rightarrow$ removed B = $\frac{2}{2}$

4 THVs $\Rightarrow$ removed C = 4

$\& \begin{Bmatrix} 2 \text{ edge centres} \\ 1 \text{ body} - \text{centre} \end{Bmatrix} \Rightarrow \text{removed D} = \frac{2}{4} + 1$

Therefore, compared will become

$A_{1-\frac{1}{2}}\ B_{3-1}\ C_{8-4}\ D_{4-\frac{3}{2}} = AB_4C_8D_5$

2. If atoms touching each of one of the 2-fold, 3-fold and 4-fold axis of symmetry are removed, then formula of compound is

(1) $A_3B_4C_{12}D_{10}$ (2) $A_3B_2C_6D_5$ (3) $A_3B_8C_{24}D_{10}$ (4) $A_3B_6D_3D_5$

Sol. Answer (3)

Two fold axis is along diagonally opposite edge centres so

A removed = 0

D removed = $1+\frac{2}{4}$

3-fold axis is along body diagonal so A removed = $\frac{2}{8}$

3-fold axis passes through opposite face centres, so B removed = $\frac{2}{2}$

Therefore, overall the compound will be

$A_{1-\frac{1}{4}}\ B_{3-1}\ C_8\ D_{4-\frac{3}{2}} = A_{\frac{3}{4}}\ B_2\ C_8\ D_{\frac{5}{2}}$

$\Rightarrow$ $A_3B_8C_{21}D_{10}$

3. If the body-centre is the origin and atoms present in (or touching) first octant are removed, then formula of the compound is

(1) $A_7B_{12}C_{56}D_{18}$ (2) $A_7B_{12}C_{28}D_{20}$ (3) $A_{16}B_7C_{28}D_{20}$ (4) $A_7B_{16}C_{56}D_{18}$

Sol. Answer (1)

A removed = 1/8

B removed = 3/2

C removed = 1

D removed = 7/4

Therefore overall the compound will be $A_{7/8}B_{3/2}C_7D_{9/4}$

i.e., $A_7B_{12}C_{56}D_{18}$

4. If the minimum distances of atoms B, C and D from atom A are x, y and z respectively, then x : y : z is equal to

(1) $2\sqrt{2}:\sqrt{3}:2\sqrt{3}$ (2) $2\sqrt{2}:\sqrt{3}:2$ (3) $2\sqrt{2}:\sqrt{3}:\sqrt{2}$ (4) $2\sqrt{2}:\sqrt{3}:1$

Sol. Answer (2)

$$AB=\frac{a}{\sqrt{2}},\ AC=\frac{a\sqrt{3}}{4},\ AD=\frac{a}{2}$$

$$\therefore \text{ Ratio} = 2\sqrt{2}:\sqrt{3}:2$$

SECTION - D

Matrix-Match Type Questions

1. Match the following.

	Column-I		Column-II
(A)	Orthorhombic	(p)	$a = b = c;\ \alpha = \beta = \gamma = 90^\circ$
(B)	Cubic	(q)	$a \neq b \neq c;\ \alpha = \beta = \gamma = 90^\circ$
(C)	Monoclinic	(r)	$a \neq b \neq c;\ \alpha = \gamma = 90^\circ$ and $\beta \neq 90^\circ$
(D)	Hexagonal	(s)	$a = b \neq c;\ \alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$

Sol. Answer A(q), B(p), C(r), D(s)

2. Match the following.

	Column-I		Column-II
(A)	Al_2O_3	(p)	Co-ordination no. of cation = 4
(B)	NaCl	(q)	Co-ordination no. of anion = 4
(C)	CaF_2	(r)	hcp lattice of anions
(D)	Li_2O	(s)	Co-ordination no. of anion = 6

Sol. Answer A(r), B(s), C(q), D(p)

(A) $AlCl_3$ forms CCP lattice of Cl^-. Octahedral holes are occupied by Al^{3+}. Coordination number of Al^{3+} is 6.

(B) NaCl forms CCP lattice of Cl^- in which all Octahedral holes are occupied by Na^+. Co-ordination number of Na^+ is 6.

(C) CaF_2 form CCP lattice of Ca^{2+} in which all tetrahedral holes are occupied by F^-. C.N of F^- is 4.

(D) Li_2O forms reverse structure of CaF_2.

3. Match the following.

	Column-I		Column-II
(A)	Monoclinic	(p)	Primitive only
(B)	Tetragonal	(q)	Primitive and end centred
(C)	Orthorhombic	(r)	Primitive; face centred; body centred and end centred
(D)	Rhombohedral	(s)	Primitive and body centred

Sol. Answer A(q), B(s), C(r), D(p)

4. Match the following.

	Column-I (Nearest neighbours of Cl^- in NaCl lattice)		Column-II (Number of nearest neighbours)
(A)	1st co-ordination number	(p)	12
(B)	2nd co-ordination number	(q)	24
(C)	3rd co-ordination number	(r)	6
(D)	5th co-ordination number	(s)	8

Sol. Answer A(r), B(p), C(s), D(q)

SECTION - E

Assertion-Reason Type Questions

1. STATEMENT-1 : Schottky type of defect is shown by crystals with high co-ordination numbers.

and

STATEMENT-2 : In Schottky defect, equal number of cations and anions are missing from their lattice sites.

Sol. Answer (2)

In Schottky defect, equal number of positive and negative ions are missing but it does not explain that this defect is shown by crystal's with high coordination number.

2. STATEMENT-1 : Na_2O adopts structure similar to that of CaF_2 but positions of positive and negative ions are reversed.

and

STATEMENT-2 : The structure of Na_2O is also known as antifluorite structure.

Sol. Answer (2)

Statement-1 is correct as both Na_2O and CaF_2 structures are same. Only positive and negative ions are interchanged.

$\therefore$ Statement-2 is correct but not the correct explanation.

3. STATEMENT-1 : Metals are generally good conductors of electricity.

and

STATEMENT-2 : Electrical conductivity of metals is due to Schottky type of defect.

Sol. Answer (3)

Metals are good conductors because of presence of free electrons and electrical conductivity is due to charge carriers, but in Schottky defect positive and negative ions are missing.

4. STATEMENT-1 : Molecular solids have higher melting point than covalent solids.

and

STATEMENT-2 : In molecular solids, the lattice points are occupied by molecules.

Sol. Answer (4)

The covalent forces are stronger than the molecular forces i.e. Melting Point of covalent solids is higher than that of molecular solid.

$\therefore$ Statement-2 is correct as lattice points are occupied by molecules.

5. STATEMENT-1 : Amorphous solids are isotropic.

and

STATEMENT-2 : Amorphous solids show physical properties like mechanical strength, electrical conductivity refractive index etc. same in all directions.

Sol. Answer (1)

Amorphous solids are isotropic as they show physical properties same in all direction.

$\therefore$ Statement (2) is the correct explanation of statement (1).

6. STATEMENT-1 : In NaCl structure, Na^+ ions occupy octahedral holes and Cl^- ions show ccp like packing.

and

STATEMENT-2 : The distance of the nearest neighbours in NaCl structure is $\frac{a}{2}$ where a is the edge length of the cube.

Sol. Answer (2)

Statement (1) is correct & the distance of the nearest neighbours in NaCl structure is $\frac{a}{2}$.

$\therefore$ So, both statements are correct.

7. STATEMENT-1 : For NaCl structure, Cl^- ions occupy corners and face centre and Na^+ ions occupy edge centres and body centre.

and

STATEMENT-2 : The radius ratio of NaCl structure varies from 0.414 to 0.732.

Sol. Answer (3)

Statement (1) is correct as Cl^- occupies corners and face centers and Na^+ occupies octahedral voids but radius ratio of NaCl structure is fixed, and not varies from 0.414 to 0.732.

8. STATEMENT-1 : For a CsCl unit-cell, $r_{Cs^+} + r_{Cl^-} = \frac{\sqrt{3}}{2}a$ where a is edge-length.

and

STATEMENT-2 : CsCl structure has FCC type unit-cell.

Sol. Answer (3)

CsCl is bcc type unit cell.

9. STATEMENT-1 : The coordination number of a cation present in an octahedral void is 6.

and

STATEMENT-2 : Octahedral voids are formed due to overlapping of two trigonal voids of adjacent layers.

Sol. Answer (1)

Statement (2) is correct explanation of Statement (1)

10. STATEMENT-1 : p-type semiconductors are formed due to metal excess defect.

and

STATEMENT-2 : F-centres are created due to metal excess defect.

Sol. Answer (4)

p-type are formed by metal deficient defect.

SECTION - F

Integer Answer Type Questions

1. What are the number of total planes of symmetry in a cube?

Sol. Answer (9)

Fact.

2. How many aluminium ions are present per unit cell of corundum (Al_2O_3)?

Sol. Answer (4)

O^{2-} ions are in HCP

Al^{3+} ions occupy $\frac{2}{3}$ rd octahedral holes.

Hence, $n = \frac{2}{3} \times 6 = 4$

3. Calculate the number of formula units of NaCl per unit cell of NaCl.

Given :

(i) Internuclear distance of adjacent ions = 0.282 nm

(ii) Density of solid NaCl = 2.17×10^3 kg/m^3

Sol. Answer (4)

$$Z = \frac{\rho \times N_0 \times V_{uc}}{M} \qquad \Rightarrow Z = 4$$

4. Solid spheres of diameter 10 cm are arranged in a square packing, with side of the square as 50 cm. If 'n' is the number of spheres whose centre either lie inside or on the side of the square, then find the value of $\sqrt{n}$.

Sol. Answer (6)

Total no. of spheres whose centre either lie inside or on the side of the square are 36.

So, $\sqrt{n} = 6$

5. In a B.C.C. unit-cell of compound AB, A is located at cubical void. Calculate the ratio of 4th C.N. and 3rd C.N. of A.

Sol. Answer (2)

4^{th} C.N. of A will be 24 B on corners of adjacent unit cells on each face.

3^{rd} C.N. of A will be 12.

$\therefore$ ratio = 2

6. Atoms A, B, C and D are present at corners, face centres, body-centre and edge-centres respectively. If atoms touching one of the 2-fold axis, 3-fold axis and 4-fold axis are removed, then total number of atoms remaining per unit cell is $x + \frac{1}{4}$. Find x.

Sol. Answer (5)

Two fold axis is along diagonally opposite edge centres, so

C removed = (1) and D removed = $\frac{2}{4}$

Three fold axis is along body-diagonal, so

A removed = $\frac{2}{8}$

4-fold axis passes through opposite face-centres

So, B removed = $\frac{2}{2}$

Originally the molecule is AB_3CD_3, after removal it will become $A_{1-\frac{1}{4}}B_{3-1}C_{1-1}D_{3-\frac{1}{2}}$

Remaining atoms = $\frac{3}{4}+2+0+\frac{5}{2}=\frac{(3+8+10)}{4}=\frac{21}{4}=\left(5+\frac{1}{4}\right)$

$\therefore$ x = 5

7. In NaCl structure, Na^+ is present at all octahedral voids while chloride (Cl^-) ions form ccp lattice. The formula of unit cell is Na_4Cl_4. If by performing one of the operations mentioned below, formula of the unit cell becomes Na_3Cl_3, then the number of that operation is [Above change takes place by a single operation only]

Operation 1 : All particles along one C_3 - axis are removed.

Operation 2 : All particles along one C_4 - axis are removed.

Operation 3 : Remove all particles along one C_2-axis.

Operation 4 : Remove all atoms along one body diagonal.

Operation 5 : Remove all atoms along one facial diagonal.

Operation 6 : Remove all atoms along two facial diagonal.

(Suppose that if this takes place by operation 6 then you mark '06' as your answer]

Sol. Answer (2)

C_4-axis contains opposite face centre and body centre.

C_4-axis pass through opposite face centres and body centre. If 2 face centre atom and one body centre atom is removed then formula becomes Na_3Cl_3.

8. In CCP, there are 8 tetrahedral sites and all are present completely inside the unit cell. There are 13 octahedral sites out of which 1 is at the body centre and 12 are at edge centres. Like CCP, another packing is HCP, in which the number of tetrahedral sites that are completely inside one unit cell is x. Mark the value of x^2.

[Assume those sites are completely inside the cell that are not shared between unit cells]

Sol. Answer (64)

In H.C.P., 8 T.V are inside the unit cell while 12 are at vertical edges (2 on each vertical edge)

$$\text{T.V.} = 8 + 12 \times \frac{1}{3} = 12$$

One edge in H.C.P. contributes $\frac{1}{3}$.

9. The ionic radii of A^+ and B^- ions are 1.62 Å and 2.8 Å. What is the number of second nearest neighbours of anion?

Sol. Answer (12)

$$\frac{r_+}{r_-} = \frac{1.62}{2.8} = 0.58$$

AB has NaCl type structure.

10. In a crystal of XY, X form CCP lattice and Y are present at all tetrahedral voids. If particles along one of body diagonal are removed, then formula of compound is X_nY_m. The value of (n + m) is

Sol. Answer (13)

X = Corners and Face centre

Y = Tetrahedral voids

If all particles along one body diagonal are removed, it means two corners and two tetraheral particles are removed.

$$X = 3 + \frac{6}{8} = \frac{15}{4}$$

Y = 6

$$X_{\frac{15}{4}}Y_6 \Rightarrow X_5Y_8$$

m + n = 5 + 8 = 13

❑ ❑ ❑