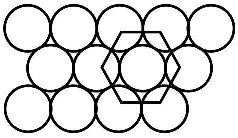
Solid State

SOLUTIONS

EXERCISE - O

1. **Ans. (A)**
Crystalline solids are anisotropic.
2. **Ans. (C)**
Glass are super cooled liquid and Refractive index is same in all the directions.
3. **Ans. (D)**
orthorhombic geometry ($a \neq b \neq c$, $\alpha = \beta = \gamma = 90°$)
4. **Ans. (C)**
Orthorhombic crystal system has all four types i.e. primitive, body-centred, face-centred and end-centred.
5. **Ans. (B)**
Triclinic is the most unsymmetrical crystal system.
6. **Ans. (D)**
There are 3 body centred unit cells in all 14 types of Bravais lattice.
7. **Ans. (C)**
Iron has metallic bond.
8. **Ans. (D)**
Ionic crystals does not exhibit directional character.
9. **Ans. (C)**
Unit cell
10. **Ans. (C)**
Rubber, Solid cake left after distillation of coal tar
11. **Ans. (D)**
(A) → P, Q ; (B) → P, S ; (C) → P,R ; (D) → P
12. **Ans. (B)**
Relation between edge length (a) and radius of atom (r) in simple cubic unit cell is $a = 2r$
13. **Ans. (C)**
Packing efficiency of simple cubic unit cell is 0.52
14. **Ans. (D)**
Second coordination number of atom in simple cubic unit cell is 12.
(Distance of 2^{nd} nearest neighbour = $a\sqrt{2}$.)
15. **Ans. (B)**
Percentage of space is vacant in simple cubic unit cell = 100 – 52 = 48 %
16. **Ans. (C)**
Third coordination number of atom in simple cubic unit cell is 8.
(Distance of 3^{rd} nearest neighbour = $a\sqrt{3}$.)

17. Ans. (C)



$z = 1 + 6 \times \frac{1}{3} = 3$

$$\text{P.f.} = \frac{\text{area of occupied by 3 atoms}}{\text{area of hexagonal}}$$

$$= \frac{3\times\pi r^2}{6\times\frac{\sqrt{3}}{4}a^2} = \frac{3\times\pi r^2}{6\times\frac{\sqrt{3}}{4}\times(2r)^2}$$

$$= \frac{\pi}{2\sqrt{3}}$$

18. Ans. (D)

$$\Rightarrow \quad \text{P.f.} = \frac{2\pi r^2}{a^2}, \ a = \frac{4r}{\sqrt{2}}$$

$$\text{P.f.} = \frac{2\pi r^2}{\left(\frac{4r}{\sqrt{2}}\right)^2} = 78.5\ \%$$

19. Ans. (B)

Volume of the square packing = $a^2 \times \frac{a}{2}$

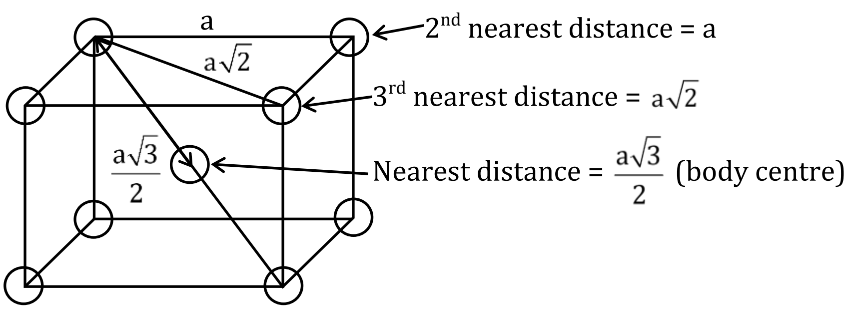
$$\therefore \text{Percentage of vacant space} = \frac{\left(a^2\times\frac{a}{2}\right) - 4\times\frac{4}{3}\pi r^3}{\left(a^2\times\frac{a}{2}\right)}\times 100 \ \ (\therefore 4r = a)$$

$$= 100\left(1 - \frac{\pi}{6}\right).$$

20. Ans. (B)

Number of atom at second nearest neighbour in BCC crystal -

$8 \times 3 \times \frac{1}{4} = 6$ (Which are body center of equidistant cubes)



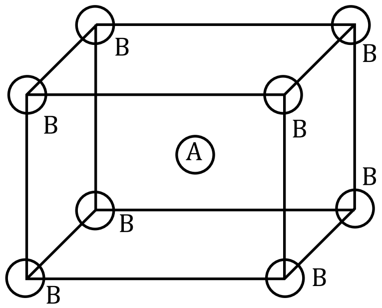
21. Ans. (A)

For BCC : $4r = \sqrt{3}a$

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

$= \frac{\sqrt{3} \times 351}{4} \approx 152$ pm

22. Ans. (A)



B atoms at corner $\Rightarrow 8 \times \frac{1}{8} = 1$

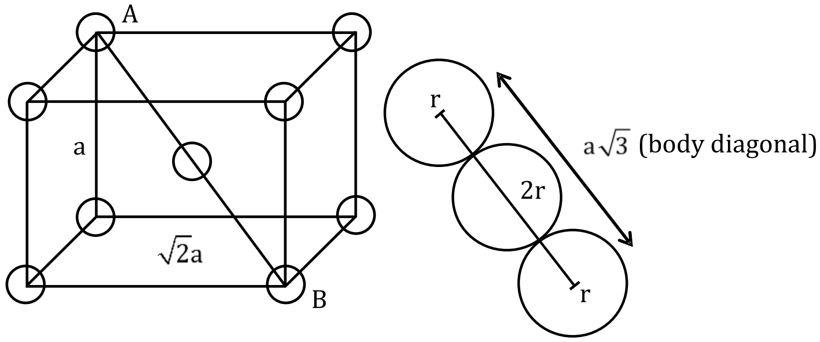
An atom at body centre $\Rightarrow 1 \times 1 = 1$

Simplest formula is AB

23. Ans. (C)

For BCC, Body centre atom $\rightarrow$ 1

Corner atom $\rightarrow$ 8



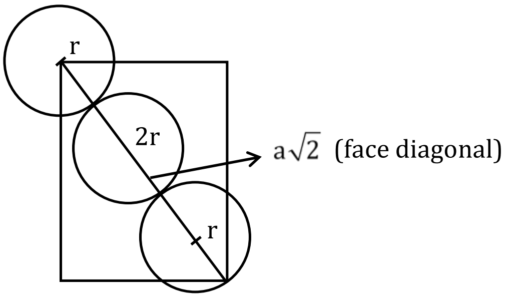
$AB = \sqrt{a^2 + (\sqrt{2}a)^2}$

$4r = \sqrt{3}a$

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

for FCC, face center atom $\rightarrow$ 6

corner atom $\rightarrow$ 8

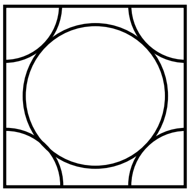


AB = $\sqrt{a^2+a^2}$

4r = $\sqrt{2}a$

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

24. **Ans. (D)**



(z) = Effective atoms = $\frac{1}{4} \times 4 + 1 = 2$

% Area = $\frac{\text{area covered}}{\text{Total area}} \times 100$

% area = $\frac{z\pi r^2}{a^2} \times 100$ $(\because \sqrt{2}a = 4r \;\&\; z = 2)$

% area = $\frac{2\pi\left(\frac{\sqrt{2}a}{4}\right)^2}{a^2} \times 100$

= 78.5 %

25. **Ans. (B)**

SCC $\rightarrow$ 6

FCC $\rightarrow$ 12

BCC $\rightarrow$ 8

26. **Ans. (D)**

SCC $\Rightarrow$ two nearest neighbours $\Rightarrow$ a = 2r (along the edge)

BCC $\Rightarrow \frac{\sqrt{3}a}{2}$ = 2r (along the body diagonal)

FCC $\Rightarrow \frac{\sqrt{2}a}{2}$ = 2r (along the face diagonal)

r $\Rightarrow$ same in all cases

27. **Ans. (A)**

For FCC $\Rightarrow \sqrt{2}a = 4r$

$a = 2\sqrt{2}r$

$z = 4$

For FCC $\Rightarrow a = 2r$

$z = 1$

$$\frac{d_{fcc}}{d_{sCc}} = \frac{\dfrac{Z_1 \times M}{N_A \times (2\sqrt{2}r)^3}}{\dfrac{Z_1 \times M}{N_A \times (2r)^3}}$$

$$= \frac{z_1}{z_2} \times \frac{(2r)^3}{(2\sqrt{2}r)^3}$$

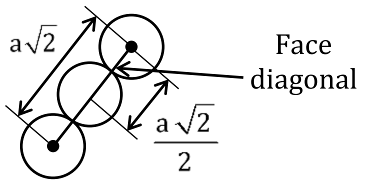
$$= \frac{z_1}{z_2} \times \frac{8r^3}{16\sqrt{2}r^3}$$

$$= \frac{4}{1} \times \frac{1}{2\sqrt{2}}$$

$$= \sqrt{2} : 1$$

28. Ans. (C)

In FCC atoms touches each other along face diagonal. So, distance between nearest neighbor = $\frac{a\sqrt{2}}{2}$



29. Ans. (A)

12 $\rightarrow$ co-ordination number is 12 for HCP.

30. Ans. (C)

HCP has ABABAB ... type packing

31. Ans. (C)

A B B A A B B A

Repeating layer

32. Ans. (D)

Number of A ions = $3 \times 1 + 12 \times \frac{1}{6} + 2 \times \frac{1}{2} = 6$

Number of B ions = $\frac{2}{3} \times 6 = 4$

$\therefore$ simplest formula of compound is A_3B_2.

33. Ans. (A)

Helium is the only noble gas that doesn't crystallise in the CCP structure.

34. Ans. (A)

HCP has ABAB close packing & CCP has ABCABC close packing.

35. Ans. (C)

The arrangement of sphere is shown by body diagonal plane of FCC.

36. Ans. (C)

for tetrahedral void $\Rightarrow \left(\dfrac{r^{\oplus}}{r^{\ominus}}\right) = 0.225$

$r_{TV}^{\oplus} = 0.225\ r^{\ominus}$

For octahedral void $\Rightarrow \left(\dfrac{r^{\oplus}}{r^{\ominus}}\right) = 0.414$

$r_{TV}^{\oplus} = 0.414\ r^{\ominus}$

37. Ans. (A)

FCC $\Rightarrow a = 362$ pm

$\Rightarrow \sqrt{2}a = 4\ r_{cu}$

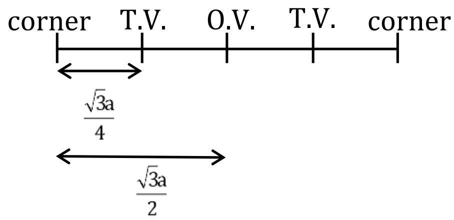
$r_{cu} = \dfrac{\sqrt{2}a}{4} = \sqrt{2} \times \dfrac{362}{4}$

Largest void in FCC is octahedral void

$\dfrac{r_{atom}}{r_{cu}} = 0.414$

$r_{atom} = \sqrt{2} \times \dfrac{362}{4} \times 414 = 53$ pm

38. Ans. (D)



Shortest distance between T.V and O.V

$= \dfrac{\sqrt{3}a}{2} - \dfrac{\sqrt{3}a}{4} = \dfrac{\sqrt{3}a}{4}$

39. Ans. (A)

$A = 4 \Rightarrow$ T.V. = 8, O.V. = 4

$\Rightarrow B = \dfrac{1}{4} \times 8 = 2,\ C = \dfrac{1}{2} \times 4 = 2$

$A_4 B_2 C_2$

$\Rightarrow A_2 BC$

40. Ans. (B)

For ABC ABC

Distance between 2 nearest (successive) tetrahedral voids

$\Rightarrow x = \frac{a}{2}$

Distance between 2 nearest (successive) octahedral voids

$\Rightarrow y = \frac{a}{\sqrt{2}}$

$\Rightarrow \frac{y\sqrt{2}}{x} = 2$

41. **Ans. (C)**

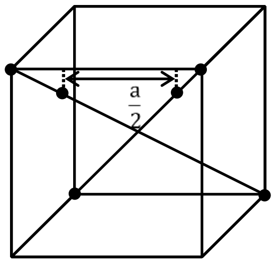
AB AB $\Rightarrow$ HCP

$\Rightarrow \frac{C}{2} = 10\frac{\sqrt{2}}{\sqrt{3}}$ pm

$\Rightarrow \frac{C}{2} = 2R\sqrt{\frac{2}{3}} = 10\frac{\sqrt{2}}{\sqrt{3}} \Rightarrow 2R = 10 \Rightarrow R = 5$ pm

$\Rightarrow$ O.V. $\Rightarrow \frac{r}{R} = 0.414 \Rightarrow r = 0.414 \times R = r = 2.07$ pm

42. **Ans. (C)**



43. **Ans. (A)**

MgS $\Rightarrow \frac{r_{Mg^{2\oplus}}}{r_{s^{2\ominus}}} = \frac{0.65}{1.84} = 0.353$, so $Mg^{2\oplus}$ ion occupy TV hence C.N. of $Mg^{2\oplus}$ is 4

MgO $\Rightarrow \frac{r_{Mg^{2\oplus}}}{r_{o^{2\ominus}}} = \frac{0.65}{1.40} = 0.464$, so $Mg^{2\oplus}$ ion occupy OV hence C.N. of $Mg^{2\oplus}$ is 6

CsCl $\Rightarrow \frac{r_{Cs^{\oplus}}}{r_{Cl^{\ominus}}} = \frac{1.69}{1.81} = 0.933$, so $Cs^{\oplus}$ ion occupy cubical void hence C.N. of $Cs^{\oplus}$ is 8

$\Rightarrow$ CN = 8

44. **Ans. (C)**

$\frac{r_{A^{\oplus}}}{r_{B^{\ominus}}} = \frac{88}{200} = 0.44$, so $A^{\oplus}$ occupy OV hence C.N. of $A^{\oplus}$ is 6.

45. **Ans. (B)**

$A^{\oplus}$ occupy T.V

Radius ration for T.V. = $\frac{r^{\oplus}}{r^{\ominus}} = 0.225$

$\frac{22.5}{r^{\ominus}} = 0.225$

$r^{\ominus} = 100$ pm

46. **Ans. (C)**

Each small cube will contain one tetrahedral void at centre of minicube & $\frac{1}{2}$ octahedral void ($\frac{1}{8}$ part OV at 4 corner).

47. **Ans. (D)**

In BCC and SC irregular (distorted) octahedral voids are formed.

48. **Ans. (D)**

e.g. CsCl, AgBr, NaCl, KCl etc.

49. **Ans. (B)**

Equal number of cations and anions are missing.

50. **Ans. (C)**

(A) Schottky defect ⇒ density decreases

(B) Frenkel defect ⇒ density remains same

(C) Interstitial impurities defects ⇒ density increases

51. **Ans. (D)**

Due to missing anions, $e^{\ominus}$ occupy vacant space, which is known as F-centre.

52. **Ans. (A)**

In Frenkel defect constituent particles leave its position and acquire interstitial sites. In this density of crystal does not changes.

53. **Ans. (C)**

Because of the Frenkel defect, the density of ionic solids does not change.

54. **Ans. (C)**

AgBr has Frankel defects (Silver Bromide = AgBr).

55. **Ans. (A)**

Schottky defect

56. **Ans. (D)**

Metal excess defect because of excess cation

57. **Ans. (B)**

Frenkel defect is due to silver ion is displaced from its lattice position to as interstitial position.

58. **Ans. (B)**

Their electrical conductivity is due to the motion of ions only.

59. **Ans. (B)**

Conductivity increases due to displacement of ions from its interstitial site.

60. **Ans. (A)**

$$d_{FCC} = \frac{4\times M}{N_A \times \left(3.5\times10^{-10}\right)^3}$$

$$d_{BCC} = \frac{2\times M}{N_A \times \left(3\times10^{-10}\right)^3}$$

$$\frac{d_{Fcc}}{d_{Bcc}} = \frac{4}{2}\times\left(\frac{3}{3.5}\right)^3 = 1.259$$

61. Ans. (D)

$$\left.\begin{array}{r} Z_A = 8\times\frac{1}{8}+4\times\frac{1}{2}=3 \\ Z_B = 1+12\times\frac{1}{4}=4 \end{array}\right] \Rightarrow A_3B_4$$

62. Ans. (A)

AB_3

A atoms occupy each corner of the cube $\Rightarrow \frac{1}{8} \times 8 = 1$

B atoms occupy the centre of each face of the cube $\Rightarrow \frac{1}{2} \times 6 = 3$

$\Rightarrow AB_3$

63. Ans. (B)

ZnS

64. Ans. (B)

n-type, germanium and silicon belong to group 14 of the periodic table and have four $e^{\ominus}$ in valance shell when doped with a group 15 element like P or as which contains five valences $e^{\ominus}$, these delocalised $e^{\ominus}$ increase the conductivity of doped silicon with $e^{\ominus}$ rich impurity called as n-type.

65. Ans. (A)

p-type and n-type

66. Ans. (C)

In the range of 10^{-9} to 10^{2} ohm^{-1} cm^{-1n}.

67. Ans. (C)

Semiconductors

68. Ans. (B)

$5e^{\ominus}$ are in the valence shell of group-15

69. Ans. (A)

Trivalent impurity

70. Ans. (A)

MnO_2 is anti-ferromagnetic in nature. Compound MnO_2 will behave as antiferromagnetic upto a critical temperature.

71. Ans. (ABC)

Bond strength depends on the overlapping.
Entropy of an amorphous solid is higher than that of a crystalline solid.
Amorphous solids do not have definite volume.

72. Ans. (ACD)

(A) The edge length is equal to $\frac{4R}{\sqrt{3}}$.

(C) The edge length is equal to $\frac{2d}{\sqrt{3}}$, where d= nearest neighbour distance (d = 2r).

(D) Shortest distance between next nearest neighbour atoms is $\frac{4R}{\sqrt{3}}$.

73. **Ans. (A,B,C,D)**

74. **Ans. (A,B,C,D)**

$$d_{FCC} = \frac{4M}{N_A a^3} = \frac{4M}{N_A\left(\frac{4R}{\sqrt{2}}\right)^3}$$

$$d_{hcp} = \frac{6M}{N_A 24\sqrt{2}r^3}$$

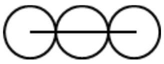
Both are same.

75. **Ans. (A,B,C,D)**

(A) 1^{st} nearest atom = 6

2^{nd} nearest atom = 6

$\frac{6}{6} = 1$

(B)  $a = 4r$

$Z = 8 \times \frac{1}{8} + 12 \times \frac{1}{4} = 4$

$$\%P.E. = \frac{2\times\frac{4}{3}\pi r^3}{a^3} = \frac{4\times\frac{4}{3}\pi r^3}{64r^3} \times 100 = 26\%$$

(C) FCC $\Rightarrow$ ABC type

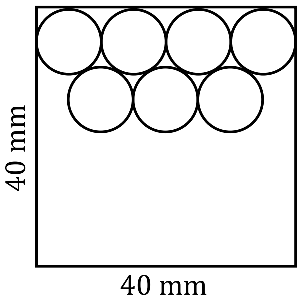
HCP $\Rightarrow$ ABAB type

(D) $x = 2,\ x^3 = 8$

EXERCISE - S

1. **Ans. (18)**

For maximum packing efficiency in 2D, hexagonal arrangement will be used.



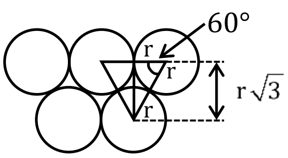
Side of square (a) = 40 mm

Here a = 8r

Radius of Marble = 5 mm

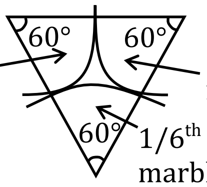
Area of Marble = $pr^2 = p(5\text{ mm})^2$

There will be some gaps left over while keeping the marbles



Total half of marble covers area of an equilateral triangle of side (2r).

$\Rightarrow = \frac{\sqrt{3}}{4}(2r)^2 = \sqrt{3}r^2$



Area covered by 1 marble = $2\sqrt{3}r^2$

Total area to be covered = $a^2 = (8r)^2$

No. of marbles = $\frac{(8r)^2}{2\sqrt{3}r^2} = \frac{32}{\sqrt{3}}$ = 18.47

Hence, we can at maximum put centre of 18 marbles in the given area.

2. **Ans. (500)**

For simple cubic unit cell

2r = a, r = radius of atom X

If Radius of the largest atom that can be placed = R

$\Rightarrow$ 2R = 366 pm

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

$a + 366 = a\sqrt{3}$

$366 = a\left(\sqrt{3}-1\right)$

$a = \frac{366}{0.732}$ = 500 pm

$= 5 \times 10^{-8}$ cm

$d = \frac{Z \times m}{a^3 \times N_A}$ Given $N_A = 6 \times 10^{23}$

$= \frac{1 \times 125}{125 \times 10^{-24} \times 6 \times 10^{23}}$

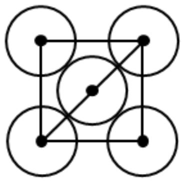
$= \frac{10}{6}$

$d = \frac{5}{3}$ g/cm^3

$\therefore$ correct answer is $\frac{5}{3} \times 300 = 500$.

3. **Ans. (438, 219)**

Nearest neighbour distance would be $\Rightarrow \frac{a}{\sqrt{2}} = \frac{438\sqrt{2}}{\sqrt{2}}$ = 438 pm



The radius of xenon atoms = $4r = \sqrt{2}a$

$r = \frac{a}{2\sqrt{2}} = \frac{438\sqrt{2}}{2\sqrt{2}}$ = 219 pm

4. Ans. (5.83)

$r = \sqrt{2}\,\text{Å} \Rightarrow 1.41 \times 10^{-8}$ cm

$\sqrt{2}a = 4r \Rightarrow a = \dfrac{4\times\sqrt{2}}{\sqrt{2}} = 4\text{Å} = 4\times10^{-8}$ cm

z = 4 for FCC

$d = \dfrac{z\times m}{N_A \times a^3} = \dfrac{4\times56}{6\times10^{23}\times\left(4\times10^{-8}\right)^3}$

$d = 5.83$ g/cm^3

5. Ans. (0.293)

$\because$ For FCC, $\sqrt{2}a = 4r$

Distance not covered = a – 2r

$\Rightarrow$ Fraction uncovered = $\dfrac{a-2r}{a}$

For FCC $\Rightarrow$ a = $\dfrac{2\sqrt{2}r - r}{2\sqrt{2}r}$ = 0.293

6. Ans. (910)

Given : $\dfrac{\sqrt{3}a}{2} = 260\sqrt{3}$ pm

$\Rightarrow$ a = $\dfrac{2\times260\times\sqrt{3}}{\sqrt{3}}$ = 2 × 260 pm

= 520 pm

= 520 × 10^{-12} m

$d = \dfrac{M\times z}{N_A \times a^3} = \dfrac{39\times2}{6\times10^{23}\times\left(520\times10^{-12}\right)^3}$ (For BCC, z = 2)

$d = \dfrac{39\times2\times10^{30}}{6\times10^{23}\times(5.2)^3} = \dfrac{78\times10^{7}\times0.007}{6}$

= 0.091 × 10^7 = 910 × 10^3 g/m^3

= 910 kg/m^3

7. Ans. (5)

Distance between two consecutive layers of hcp unit cell = $\dfrac{2r\sqrt{2}}{\sqrt{3}}$ = 1.6Å

r = 1Å = 10^{-8} cm

volume of hexagonal prism = $24\sqrt{2}r^3$

= $24\sqrt{2}\times10^{-24}$ cm^3

density = $\dfrac{z\times\dfrac{M}{N_A}}{\text{Volume of unit cell}} = \dfrac{6\times12}{6\times10^{23}\times24\sqrt{2}\times10^{-24}}$

= $\dfrac{5}{\sqrt{2}}$ g/cm^3

$\therefore$ the correct answer is $\dfrac{5}{\sqrt{2}} \times \sqrt{2} = 5$

8. Ans. (17)

HCP $\Rightarrow$ z = 6, TV = 12

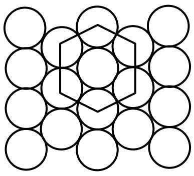
M = 48 g

$\Rightarrow$ 48 g of A has N_A atoms

$\Rightarrow 24 \times 10^{-6}$ g A = $\frac{6\times10^{23}}{48} \times 24 \times 10^{-6} = 3 \times 10^{17}$ atoms

Total THV in 24×10^{-6} g of A = $2 \times 3 \times 10^{17} = 6 \times 10^{17}$

9. Ans. (0.604)



$Z = 12 \times \frac{1}{6} + 2 \times \frac{1}{2} = 3$

Package fraction = $\frac{\text{volume of sphere}}{\text{Base area} \times L}$

$$= \frac{3\times\frac{4}{3}\pi r^3}{6\times\frac{\sqrt{3}}{4}\times(2r)^2\times 2r} \qquad (L = 2r)$$

$$= \frac{\pi}{3\sqrt{3}} = 0.604$$

10. Ans. (2)

$\frac{r_{void}}{R_{atom}} = 0.732 \Rightarrow R_{atom} = \frac{183}{0.732} \Rightarrow 250\text{pm}$

Also, $r + R = \frac{\sqrt{3}a}{2} \Rightarrow 183 + 250 = \frac{\sqrt{3}a}{2}$

a = 500 pm

$x = \frac{1\times125}{(500\times10^{-10})^3\times6\times10^{23}} = \frac{10}{6}\frac{\text{gm}}{\text{cm}^3}$

Value of $\frac{6x}{5} \Rightarrow 6\times\frac{10}{6}\times\frac{1}{5} = 2$

11. Ans. (5)

As there are four lattice points per unit cell, total no. of atoms in the unit cell is 8

Density in gm/cm^3 = $\frac{Z\times M}{a^3\times N_A} = x$

$= \frac{8\times12}{(3.6\times10^{-8})^3\times6\times10^{23}}\ \frac{\text{gm}}{\text{cm}^3}$

= 3.43 gm/cm^3

value of 1.458x = 5

12. Ans. (8)

Given $\frac{\sqrt{3}a_{BCC}}{2} = \frac{a_{FCC}}{\sqrt{2}} \Rightarrow \frac{a_{FCC}}{a_{BCC}} = \sqrt{\frac{3}{2}}$

Also $\frac{\rho_{Fcc}}{\rho_{Bcc}} = \frac{\frac{4 \times M}{a_{FCC}^3 \times N_A}}{\frac{2 \times M}{a_{BCC}^3 \times N_A}} \Rightarrow \left(\frac{a_{BCC}}{a_{FCC}}\right)^3 \times \frac{4}{2}$

$\Rightarrow \frac{x}{1} = \frac{2}{3}\sqrt{\frac{2}{3}} \times 2 = \frac{4\sqrt{2}}{3\sqrt{3}}$

Value of $3\sqrt{6}x = 3\sqrt{6} \times \frac{4}{3}\sqrt{\frac{2}{3}} = 8$

13. Ans. (60%, +4)

O^{-2} is forming CCP = four O^{-2} ions per unit cell

Effective number of Ti ions per unit cell = 2

Molecular formula = TiO_2

with +4 oxidation state of Ti

% by mass of Ti = $\frac{48}{48+32} \times 100 \Rightarrow 60\%$

14. Ans. (5×10^{24})

Density = $7.2 \frac{gm}{Cm^3} = \frac{(1+2) \times M}{2.4 \times 10^{-24} \times 6 \times 10^{23}}$

$\Rightarrow$ M = 34.56

No. of atoms = $\frac{288}{34.56} \times 6 \times 10^{23} \Rightarrow 5 \times 10^{24}$

15. Ans. (0.72 or 0.73)

Let Radius of atom forming lattice = R

Radius of void = r

$P.F. = \frac{1 \times \frac{4}{3}\pi R^3 + 1 + \frac{4}{3}\pi r^3}{(2R)^3}$, Also $\frac{r}{R} = 0.732$

$= \frac{4\pi}{24}[1 + (0.732)^3] \Rightarrow \frac{3.14}{6} \times 1.39 = 0.727$

16. Ans. (4)

Each lattice point has one H_2O molecule

Density = $\frac{16}{17.5}\frac{gm}{cm^3} = \frac{Z \times 18}{a \times a \times b \times 6 \times 10^{23}}$

$\frac{16}{17.5} = \frac{Z \times 18}{5 \times 5 \times 3.5\sqrt{3} \times 10^{-24} \times 6 \times 10^{23}}$

Z = 4

17. Ans. [(i) FCC (ii) 0.116 g/cc]

(i) Density observed = $\frac{Z \times (112+32)}{(5.87 \times 10^{-8})^3 \times 6 \times 10^{23}}$

$Z_{obs} = 3.9019 \simeq 4.$

(ii) Difference in Z per unit cell due to defect

$= 4 - 3.9019 = 0.0980.$

Density of Schottky defects $= \dfrac{0.0980 \times 144}{(5.87 \times 10^{-8})^3 \times 6 \times 10^{23}}$ = 0.116 gm/cm³

18. Ans. [(a) 1.14, (b) 1.20]

(a) $\dfrac{a_{KCl}}{a_{NaCl}} = \dfrac{r_{K^{\oplus}} + r_{Cl^{\ominus}}}{r_{Na^{\oplus}} + r_{Cl^{\ominus}}} = \dfrac{\dfrac{r_{K^{\oplus}}}{r_{Cl^{\ominus}}} + 1}{\dfrac{r_{Na^{\oplus}}}{r_{Cl^{\ominus}}} + 1}$ ...(1)

Given, $\dfrac{r_{Na^{\oplus}}}{r_{Cl^{\ominus}}} = 0.5, \ \dfrac{r_{Na^{\oplus}}}{r_{K^{\oplus}}} = 0.7$

or $\dfrac{r_{K^{\oplus}}}{r_{Cl^{\ominus}}} = \dfrac{5}{7}$

From eq. (1) $\dfrac{a_{KCl}}{a_{NaCl}} = \dfrac{\dfrac{5}{7} + 1}{0.5 + 1} = 1.14$

(b) $\dfrac{\rho_{NaCl}}{\rho_{KCl}} = \dfrac{\dfrac{4 \times 58.5}{(a_{NaCl})^3 \times N_A}}{\dfrac{4 \times 74.5}{(a_{KCl})^3 \times N_A}} = \left(\dfrac{a_{KCl}}{a_{NaCl}}\right)^9 \times \dfrac{58.5}{74.5}$

$\Rightarrow (1.143)^3 \times \dfrac{58.5}{74.5}$

$\Rightarrow 1.5 \times \dfrac{58.5}{74.5} \Rightarrow 1.2$

19. Ans. [(a) MnF_3, (b) 6, (c) 4.02Å]

Mn^{+3} ions per unit cell = 1 (corners)

F^- at edge centres = $12 \times \dfrac{1}{4} = 3$

(a) Formula is MF_3

(b) C.N. of Mn^{+3} ion = 6 surrounded by $6F^-$ ions

(c) $a = 2\,(r_{Mn^{+3}} + r_{F^{\ominus}}) = 2\,[0.65 + 1.36] = 4.02$ Å

20. Ans. [(a) 4.5 Å, (b) 5.2 Å, (c) 8, (d) 6, (e) 0.929 g/cm³]

(a) a = 5.2 A°

Distance between nearest neigbhours = $\dfrac{\sqrt{3}a}{2} = \dfrac{1.732 \times 5.2}{2} = 4.5$Å

(b) Next nearest neighbour is at edge length, a = 5.2 Å

(c) Nearest neighbours = C.N. = 8

(d) Next nearest neighbours = 6

(e) Density = $\dfrac{2\times39}{(5.2\times10^{-8})^3\times6\times10^{23}}\Rightarrow0.929\dfrac{\text{gm}}{\text{cm}^3}$

21. **Ans. (96%)**

Theoretical density = $\dfrac{Z\times M}{a^3\times N_A}=\dfrac{4\times24\times10^{-3}}{(4\times10^{-10}\text{m})^3\times6\times10^{23}}$

$= 2.5 \times 10^3$ kg/m^3

Observed density = 2.4×10^3 kg/m^3

% occupancy = $\dfrac{\text{Observed density}}{\text{Theoretical density}}\times100\Rightarrow\dfrac{2.4\times10^3}{2.5\times10^3}\times100\Rightarrow96\%$

22. **Ans. (4)**

Given $\dfrac{a}{\sqrt{2}}=250\sqrt{2}\Rightarrow a=500\text{pm}$

Density = $\dfrac{4\times75}{(5\times10^{-8})^3\times6\times10^{23}}$

= 4 gm/cm^3

23. **Ans. (Mg_2SiO_4, Fe_2SiO_4, 57.14%)**

O^{-2} = 4 ion per unit cell

Si^{+4} = $\dfrac{1}{4}\times4=1$ per unit cell

Divalent ions = $\dfrac{1}{4}\times8=2$

Forsterite: Mg_2SiO_4

Fayalite: Fe_2SiO_4

Average density of olivine (1 mole) = 3.5 gm/cm^3

Olivine (1 mole)

Fe_2SiO_4 Mg_2SiO_4
x   1−x

$$\frac{4x+3(1-x)}{1}=3.5$$

x = 0.5 = mole fraction of Fe_2SiO_4 [M = Molar mass]

Mass % of Fe_2SiO_4 = $\dfrac{0.5\times M_{Fe_2SiO_4}}{0.5\times M_{Fe_2SiO_4}+0.5\times M_{Mg_2SiO_4}}\times100$

$$=\frac{0.5\times204}{0.5\times204+0.5\times140}\times140\Rightarrow57.14\,\%$$

EXERCISE - JEE (Advanced) PYQ

1. **Ans. (D)**

1. A will occupy 8 corners of cubic unit cell and Face centre of unit cell
2. Total contribution of A = 4
3. B occupy octahedral voids; so total contribution = 4

Now we are removing all face centred atoms along one axis.

Contribution from A remaining $8 \times \frac{1}{8}$ (corner) + $4 \times \frac{1}{2}$ (face centre) = 3

2. **Ans. (A)**

In hexagonal closed packing, each atom has 12 neighbouring atoms, hence it has a coordination number 12.

3. **Ans. (A)**

A atoms occupy each corner of the cube A = $8 \times \frac{1}{8} = 1$

B atoms occupy the centre of each face of the cube B = $\frac{1}{2}\times 6 = 3$

Formula $\rightarrow AB_3$

4. **Ans. (5)**

(A : B :: 1 : 1) Structure of AB rock salt.

$r^{\oplus} + r^{\ominus} = Y^{1/3}$

Edge length of unit cell (a) = $2(r^{\oplus} + r^{\ominus})$

$= 2Y^{1/3}$ nm

$\therefore$ density of AB = $\dfrac{z \times \text{ formula Mass}}{a^3 \times N_A}$

$$= \frac{4 \times 6.023 \times Y \times 10^{-3}}{6.023 \times 10^{23} \times \left(2Y^{1/3} \times 10^{-9}\right)^3}$$

$= 5\ kg/m^3$

5. **Ans. (117.1)**

Radius of atom in interstitial sites = r_1

Radius of atom of FCC = r_2

$\frac{r_1}{r_2} = 0.225$ (T.V.)

$\frac{r_1}{r_2} = 0.414$ (O.V.)

$4r_2 = \sqrt{2}a$

$r_2 = \frac{\sqrt{2}}{4}a$

$2r_1 = 2 \times 0.414\ r_2$

a = 400 pm

$2r_1 = 2 \times 0.414 \times \frac{\sqrt{2}}{4}$ (400)

$2r_1 = 117.1$ pm

d = 117.1 pm

6. **Ans. (B)**

ZnS structure, $S^{2\ominus}$ are in FCC sites and $Zn^{2\oplus}$ are in alternate tetrahedral voids.

7. **Ans. (216)**

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

$$Z = \frac{2 \times 6.022 \times 10^{23} \times (5)^3 \times \left(10^{-8}\right)^3}{75} = 2$$

For BCC $\Rightarrow$ $4r = \sqrt{3}a$

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

$$= \frac{\sqrt{3}}{4} \times 5$$

= 2.165 Å

$= 2.165 \times 10^{-10}$ m

= 216 pm

8. **Ans. (A)**

A $\rightarrow$ P, S; B $\rightarrow$ P, Q; C $\rightarrow$ Q ; D $\rightarrow$ Q, R

9. **Ans. (B)**

No. of atoms per unit cell (HCP)

$$= 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3$$

= 6

10. **Ans. (A)**

Volume = area of base × height

Area of base = $6\sqrt{3} \times r^2$

Height of unit cell = $\sqrt{\frac{2}{3}}\ 4r$

Volume = $6\sqrt{3} \times r^2 \times \sqrt{\frac{2}{3}} 4r$

$$= 24\sqrt{2}r^3$$

11. **Ans. (D)**

Packing efficiency in (HCP) is $\Rightarrow$ 74%

% empty space $\Rightarrow$ 100 – 74 = 26%

12. **Ans. (B,C)**

(B) Frenkel defect is a dislocation defect

(C) Trapping of an electron in the lattice leads to the formation of F-center.

13. Ans. (D)

$4r = \sqrt{2}a$

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

total area = $8\,r^2$

Number of circle inside the square is $1 + 4\left(\frac{1}{4}\right) = 2$

Area of spheres = $2 \times \pi r^2$

P.F. = $\frac{\text{Total area of circle}}{\text{Total area}}$

$= \frac{2\pi r^2}{8r^2} = \frac{\pi}{4} = 0.785$

PE = 78.5%

14. Ans. (8)

A truncated octahedron is a solid shape that has 6 square faces and 8 hexagonal faces.

15. Ans. (B)

$M = 4 \times \frac{1}{4} + 1 = 2$

$X = 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

M_2X_4

$EF = MX_2$

16. Ans. (A)

For octahedral void :

$\frac{r_{A^{\oplus}}}{r_{X^{\ominus}}} = 0.414$

$r_{A^{\oplus}} = 0.414 \times r_{X^{\ominus}}$

$= 0.414 \times 250 = 103.5$ pm

17. Ans. (B, C, D)

(A) incorrect

(B) 74%

(C) No. of O.V. =4

No. of T.V. = 8

(D) $4r = \sqrt{2}a$

$a = 2\sqrt{2}r$

18. Ans. (2)

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

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

$$= \frac{8\times\left(4\times10^{-8}\right)^3\times6\times10^{23}}{4} = \frac{8\times4\times4\times4\times10^{-24}\times6\times10^{23}}{4}$$

= 76.8 g/mol

No. of atoms present in crystal = $\frac{W}{M}\times N_A = \frac{256}{76.8}\times N_A$

$$= \frac{256}{76.8}\times6\times10^{23}$$

No. of atoms = 2×10^{24}

= $N \times 10^{24}$

N = 2

19. Ans. (3)

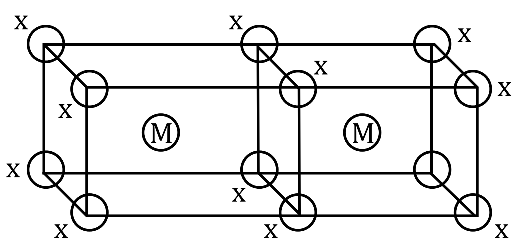
Cation ($M^{\oplus}$) = FCC = 4

anion ($X^{\ominus}$) = OV = 4

	$M^{\oplus}$ 4	$X^{\ominus}$ 4
(i)	4	$4 - 12 \times \frac{1}{4} = 1$
(ii)	$4 - 6 \times \frac{1}{2} = 1$	$1 + 6 \times \frac{1}{2} = 4$
(iii)	$1 - 8 \times \frac{1}{8} = 0$	4
(iv)	0 + 1 = 1	4 – 1 = 3

Ratio of $\frac{X^{\ominus}}{M^{\oplus}} = \frac{3}{1} = 3$

20. Ans. (A,C)



It is the case of BCC where X are at corners and M in cubic voids.

(A) The empirical formula of compound is MX.

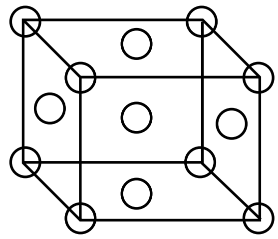
(B) X and M both have same coordination number equal to 8

(C) $\frac{M-X\text{ bond length}}{a} = \frac{\sqrt{3}a}{2\times a} = \frac{1.732}{2} = 0.866$

(D) $\frac{r_M}{r_X} = 0.732$ (ideally)

21. **Ans. (B)**

$$\% \text{ P.F.} = \frac{1\times\frac{4}{3}\pi r_Y^3 + 3\times\frac{4}{3}\pi r_X^3 \times 100}{a^3}$$



also, $r_X + r_Y = \frac{a}{\sqrt{2}}$

$$= \frac{\frac{4}{3}\pi r_Y^3 + 3\times\frac{4}{3}\pi r_X^3}{[\sqrt{2}(r_X+r_Y)]^3}\times 100 \qquad ...(2)$$

from eq. (1) and (2)

% P.F. = 0.63

22. **Ans. (B)**

Atom 'X' occupies FCC lattice points as well as alternate tetrahedral voids of the same lattice

$\Rightarrow \frac{1}{4}$th distance of body diagonal

$$= \frac{\sqrt{3}a}{4} = 2r_X$$

$$\Rightarrow a = \frac{8r_X}{\sqrt{3}}$$

Number of atoms of X per unit cell

= 4 + 4 = 8

(FCC lattice points) (Alternate tetrahedral voids)

$$\% \text{ packing efficiency} = \frac{\text{Volume occupied by X}}{\text{Volume of cubic unit cell}}\times 100$$

$$= \frac{8\times\frac{4}{3}\pi(r_X)^3}{a^3}\times 100$$

$$= \frac{8\times\frac{4}{3}\pi(r_X)^3}{\left(\frac{8r_X}{\sqrt{3}}\right)^3}\times 100$$

$$= \left(8\times\frac{4}{3}\times\pi\times\frac{1}{8^3}\times 3\sqrt{3}\right)\times 100$$

$$= \frac{\sqrt{3}\pi}{16}\times 100$$

= 34%

Hence, option (B) is the most appropriate option

JEE (Advanced) Practice Paper

1. **Ans. (C)**

It is formed by four spheres the centres of which form a regular tetrahedron.

2. **Ans. (A)**

In CsCl unit cell,

Number of $Cs^{\oplus}$ = 1(body centre)

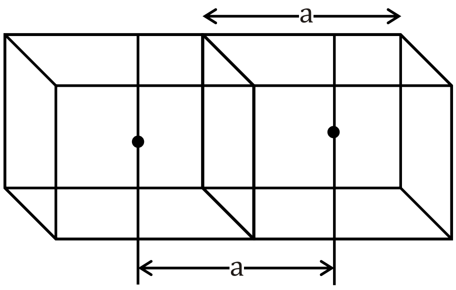
Number of $Cl^{\ominus}$ = $8\times\frac{1}{8}=1$ (At corners)

3. Ans. (C)

(A) Two adjacent face centres touches each other ain FCC

(B) No. of nearest $Na^{\oplus}$ ions of another $Na^{\oplus}$ in Na_2O is 6.

(C)



(D) Density may increase also if replaced ions have more molar mass.

4. Ans. (D)

r = 1.42

$\sqrt{2}a = 4r = 5.68$

a = 4.017 A° = 4.017×10^{-8} cm

z = 4

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

$$= \frac{4 \times 56}{6.023 \times 10^{23} \times \left(4.017 \times 10^{-8}\right)^3}$$

d = 5.74 g/cm^3

5. Ans. (D)

(I) In an anti-fluorite structure, anions form FCC lattice and cations occupy all tetrahedral voids.

(II) Radius Ratio = $\frac{0.2}{0.95}$ = 0.21

Which lies between 0.155 to 0.225 and so, it has coordination number of 3.

(III) Frenkel defect is a defect which is created when an ion leaves its appropriate site in the lattice and occupies an interstitial site.

(IV) The density of crystal may increase or decrease due to substitutional impurity defect.

6. Ans. (D)

Since 5×10^{24} atoms weigh $\rightarrow$ 200 gm

Therefore 6×10^{23} atoms weigh (M) $\rightarrow \frac{200}{5 \times 10^{24}} \times 6 \times 10^{23}$

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

$$d = \frac{4 \times 200 \times 6 \times 10^{23}}{6 \times 10^{23} \times 5 \times 10^{24} \times \left(2 \times 10^{-8}\right)^3}$$

= 20 g/cm^3

7. Ans. (A,C)

(A) In a body centred cubic,

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

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

(B) Coordination number is 8.

(C) 2R = d = nearest neighbouring distance $\Rightarrow$ a = $\frac{2d}{\sqrt{3}}$

(D) $a^2 = \frac{16R^2}{3}$

8. **Ans. (A, B, D)**

(A) Distance between nearest octahedral void and tetrahedral void is $\frac{\sqrt{3}a}{4}$

(B) Distance between two nearest octahedral void is $\frac{a}{\sqrt{2}}$

(C) Distance between nearest tetrahedral void is $\frac{a}{2}$

(D) Distance between layer A and B is $2r\sqrt{\frac{2}{3}}$

9. **Ans. (B)**

$$d = \frac{Z \times M}{N_A \times a^3} = \frac{4 \times 300}{\left(10^{-7}\right)^3 \times 6 \times 10^{23}}$$

$$= \frac{4 \times 300}{10^{-21} \times 6 \times 10^{23}}$$

$= 2\ g/cm^3$

Observed density = 2 g/cm^3

Since density remain same, Frenkel defect is present.

10. **Ans. (A,C)**

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

$$\text{Volume} = \frac{4 \times 207}{6.022 \times 10^{23} \times 11.34}$$

$= 1.213 \times 10^{-22}\ cm^3$

For FCC, we have $4r = a\sqrt{2}$

$$r = \frac{4.95 \times 10^{-8} \times \sqrt{2}}{4}$$

= 175 pm

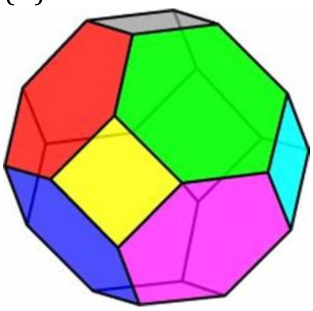
11. **Ans. (A,B,C,D)**

(A) CsCl mainly shows Schottky defect

(B) ZnS mainly shows Frenkel defect

(C) NaCl unit cell contain $4Na^{\oplus}$ and $4Cl^{\ominus}$

(D) Truncated octahedron has 24 corners.



12. Ans. (A,B,D)

(A) Can show Schottky defect

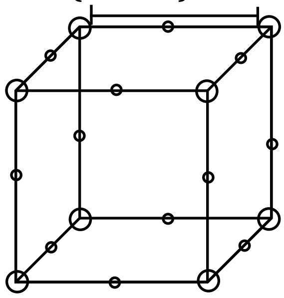
(B) Hexagonal unit cell parameters

$a = b \neq c, \alpha = \beta = 90°, \gamma = 120°$

(C) Compound showing Frenkel defect has less $\frac{r^{\oplus}}{r^{\ominus}}$ ratio

(D) $Na^{\oplus}$ present at every octahedral void of lattice formed by another ion present at FCC lattice points.

13. Ans. (A,B,C,D)



(A) Mn ion contribution = $8 \times \frac{1}{8} = 1$

$F^{\ominus}$ ion contribution = $12 \times \frac{1}{4} = 3$

(B) $Mn^{3\oplus}$ at corner of the cube which touch 6 nearest $F^{\ominus}$ ion along edges.

(C) Edge length $\Rightarrow a = 2r^{\oplus} + 2r^{\ominus}$

$= 2(0.65 + 1.36)$

$a = 4.02$ Å

(D) density = $\frac{Z \times M}{N_A \times a^3}$

$= \frac{4 \times 112 \text{ g/mol}}{(4 \times 10^{-8})^3 \times 6 \times 10^{23} \text{mol}^{-1}}$

$= 2.86 \text{ g/cm}^3$

14. Ans. (B,C)

According to structure of NaCl.

Here A will occupy 8 corners and 6 face centred of cubic unit cell = $8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

B occupies octahedral voids = $1 + 12 \times \frac{1}{4} = 4$

If all the atoms lying along one of the face-centred axes are removed than 1 body centered atom (B) and 2 face centered atom are removed.

Than

A remains $8 \times \frac{1}{8} + 4 \times \frac{1}{2} = 3$

B remains = $0 + 12 \times \frac{1}{4} = 3$

Formula $\Rightarrow A_3B_3 \Rightarrow 3AB, Z = 3$

$a = 2(r_A + r_B) = 2(1.4 + 2.8) = 8.4$ Å

(B) density = $\dfrac{Z \times M}{a^3 \times N_A}$

$= \dfrac{3(40+60)}{(8.4)^3 \times 6 \times 10^{23}}$

$= 0.85\ g/cm^3$

(C) P.F. = $\dfrac{3 \times \frac{4}{3}\pi r_A^3 + 3 \times \frac{4}{3}\pi r_B^3}{a^3}$

$= \dfrac{3 \times \frac{4}{3}\pi(1.4)^3 + 3 \times \frac{4}{3}\pi(2.8)^3}{(8.4)^3} = 0.52$

15. **Ans. (B)**

A $\rightarrow$ P, Q; B $\rightarrow$ P, S; C $\rightarrow$ P, R; D $\rightarrow$ P

16. **Ans. (A)**

A $\rightarrow$ q; B $\rightarrow$ s; C $\rightarrow$ p; D $\rightarrow$ t; E $\rightarrow$ r

17. **Ans. (B)**

% of lattice which is vacant in BCC pattern = 32%

$\Rightarrow$ 5 (0.32 × 64) = nRT

$\Rightarrow$ n = 2 moles

No. of O_2 molecules = $2 \times 6 \times 10^{23} \Rightarrow 1.2 \times 10^{24}$

18. **Ans. (D)**

% increase in density = $\dfrac{\Delta\ \text{mass}}{\text{Initial mass}} \times 100$

$\Rightarrow \dfrac{2 \times 32}{2 \times 64} \times 100 \Rightarrow 50\%$

19. **Ans. (9)**

Primitive cubic arrangement = x

BCC arrangement = y

FCC arrangement = z

x = 6, y = 8, z = 12

$\dfrac{x \times z}{y} = \dfrac{6 \times 12}{8} = 9$

20. **Ans. (1.32)**

$a = 2r^{\oplus} + 2r^{\ominus}$

$r^{\oplus} = \dfrac{a - 2r^{\ominus}}{2}$

$= \dfrac{6.28 - 2 \times 1.82}{2}$

= 1.32 Å