Date :

Name : SOLID STATE

Std. : Roll No. : Subject : Marks :

1. Data :-

Atoms A are at 8 corners, atoms B at the 6 face centres and one atom C at body centre.

To find :-

formula of crystalline compound.

Solution :-

Total no. of atoms of $A = \frac{1}{8} \times 8 = 1$.

Total no. of atoms of $B = \frac{1}{2} \times 6 = 3$.

One atom of C at the body centre.

∴ The unit cell contains one atom of A, three atoms of B and one atom of C.

Hence, the formula of the compound is AB_3C.

Ans:- The formula of the crystalline compound is AB_3C.

2. Data :-

Sodium has bcc structure.

$\therefore$ No. of Na atoms in the unit cell = 2.

Atomic radius, $r_{(Na)} = 186\ pm$

Atomic mass of Na = $23\ g\ mol^{-1}$

Avogadro number = $N_A = 6.022 \times 10^{23}\ mol^{-1}$

To find :-

1. Edge length = $a = ?$
2. Volume of unit cell = $a^3 = ?$
3. Density = ?

Solution :-

1. For bcc structure,

$$r_{(Na)} = \frac{\sqrt{3}}{4} \times a.$$

$$\therefore a = \frac{4}{\sqrt{3}} \times r_{(Na)}$$

$$\therefore a = \frac{4}{\sqrt{3}} \times 186 = 430\ pm.$$

$$\therefore a = 4.3 \times 10^{-8}\ cm.$$

2. Volume of unit cell = a^3

$$= (4.3 \times 10^{-8})^3$$

$$\therefore a^3 = 79.5 \times 10^{-24}\ cm^3$$

3. Mass of 1 Na atom = $\frac{23}{6.022 \times 10^{23}}$

$$= 3.82 \times 10^{-23}\ g.$$

$\therefore$ Mass of 2 Na atoms = $2 \times 3.82 \times 10^{-23}$

$$= 7.64 \times 10^{-23}\ g.$$

3. Data :-

Density of Niobium (Nb) crystal = $8.55\ g\ cm^{-3}$.

Crystalline structure is bcc.

Atomic mass of Nb = $93\ g\ mol^{-1}$

Avogadro number = $N_A = 6.022 \times 10^{23}\ mol^{-1}$.

~~Atomic radius~~

To find :-

Atomic radius of Niobium = ?

Solution :-

In bcc unit cell, there are 8 atoms at 8 corners and 1 atom at the body centre.

$\therefore$ No. of Nb atoms $= \frac{1}{8} \times 8 + 1$

$= 1 + 1 = 2$.

Mass of one Nb atom $= \frac{93}{6.022 \times 10^{23}}$

$= 1.544 \times 10^{-22}\ g$

$\therefore$ Mass of 2 Nb atoms $= 2 \times 1.544 \times 10^{-22}$

$= 3.088 \times 10^{-22}\ g$.

Mass of unit cell = Mass of 2Nb atoms = $3.088 \times 10^{-22}\ g$.

if a is edge length of bcc unit cell,

volume of unit cell = a^3

$$\text{Density} = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$$

$$d = \frac{3.088 \times 10^{-22}}{a^3}$$

$$\therefore a^3 = \frac{3.088 \times 10^{-22}}{d}$$

$$\therefore a^3 = \frac{3.088 \times 10^{-22}}{8.55}$$

$$\therefore a^3 = 0.361 \times 10^{-22} \text{ cm}^3$$

$$\therefore a^3 = 36.1 \times 10^{-24} \text{ cm}^3$$

$$\therefore a = (36.1 \times 10^{-24})^{1/3}$$

$$\therefore \boxed{a = 3.3 \times 10^{-8} \text{ cm}}$$

If r is the radius of 1 Nb atom, then in bcc structure

$$r = \frac{\sqrt{3}}{4} a = \frac{\sqrt{3}}{4} \times 3.3 \times 10^{-8} = 1.43 \times 10^{-8} \text{ cm}.$$

$$= 1.43 \times 10^{-10} \text{ m}$$

$$= 1.43 \times 10^{-10} \times 10^{9} \text{ nm}$$

$$= 0.143 \text{ nm}.$$

$$\therefore \boxed{r = 0.143 \text{ nm}.}$$

4. Data :-

Density of Au = $19.3\ Kg\ dm^{-3}$

Molar mass = $197\ g\ mol^{-1}$

Avogadro constant = $N_A = 6.022 \times 10^{23}\ mol^{-1}$

To find :-

Atomic radius of Au = ?

Solution :-

In fcc unit cell, there are 8 atoms of Au at 8 corners and 6 atoms at 6 face centres.

No. of Au atoms in the unit cell = $\frac{1}{8} \times 8 + \frac{1}{2} \times 6$

$= 4$ atoms.

Mass of 1 Au atom = $\frac{197}{6.022 \times 10^{23}} = 3.271 \times 10^{-22}\ g$.

$\therefore$ Mass of 4 Au atoms = $4 \times 3.271 \times 10^{-22}\ g$

$= 1.308\ g \times 10^{-21}\ g$.

$\therefore$ Mass of unit cell = $1.308 \times 10^{-21}\ g$

$= 1.308 \times 10^{-24}\ Kg$

Density of the unit cell

$= \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$

$\therefore d = \frac{1.308 \times 10^{-21}}{a^3}$

$\therefore a^3 = \frac{1.308 \times 10^{-21}}{d} = \frac{1.308 \times 10^{-24}}{19.3}$

$\therefore a^3 = 6.777 \times 10^{-24}\ dm^3$

$\therefore a^3 = 6.777 \times 10^{-23}\ cm^3$

$\therefore a = (6.777 \times 10^{-23})^{1/3} = (67.77 \times 10^{-24})^{1/3}$

$\therefore a = 4.077 \times 10^{-8}\ cm.$

If r is the radius of Au atom, then for fcc unit cell,

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

$\therefore r = \frac{4.077 \times 10^{-8}}{2\sqrt{2}} = 1.442 \times 10^{-8}\ cm.$

$\therefore \boxed{r = 144.2\ pm.}$

Ans :- Radius of Au atom = 144.2 pm.

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6. Data :-

Type of crystal : fcc

Density of Au = d = 19.4 g cm^{-3}

Edge length = 407.2 pm = 4.072×10^{-8} cm.

No. of Au atoms in fcc unit cell = 4.

To find :-

Avogadro Number = N_A = ?

Solution :-

Mass of Au atom = $\frac{197}{N_A}$ g.

No. of Au atoms in fcc unit cell = Z = 4

$\therefore$ Mass of unit cell = $4 \times \frac{197}{N_A}$

Volume of cubic unit cell = $a^3 = (4.072 \times 10^{-8})^3$

$= 6.75 \times 10^{-23}$

Density of unit cell = d = $\frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$

$$19.4 = \frac{4 \times 197 / N_A}{6.75 \times 10^{-23}}$$

$$\therefore N_A = \frac{4 \times 197}{19.4 \times 6.75 \times 10^{-23}}$$

$\therefore$ $N_A = 6.02 \times 10^{23}\ mol^{-1}$

6. Data :-

Cu crystal has fcc structure.

Edge length of unit cell = $a = 3.8\,\text{Å} = 3.8 \times 10^{-8}$ cm.

To find :-

Radius of copper atom = $r = ?$

Solution :-

In case of fcc structure,

$$r = \frac{a}{2\sqrt{2}} = \frac{3.8 \times 10^{-8}}{2 \times \sqrt{2}} = \frac{3.8 \times 10^{-8}}{2 \times 1.414}$$

$$\boxed{r = 1.343 \times 10^{-8}\ \text{cm}}.$$

Hence radius of copper atom = 1.343×10^{-8} cm

$= 1.343\,\text{Å}$

Ans :- Radius of Cu atom = 1.343×10^{-8} cm = $1.343\,\text{Å}$

7. Data :-

Edge length = $a = 288\ pm = 2.88 \times 10^{-8}\ cm$.

Density of crystal = $d = 7.86\ g\ cm^{-3}$

Avogadro number = $6.022 \times 10^{23}\ mol^{-1}$

Atomic mass of Fe = $56\ g\ mol^{-1}$

To find :-

Type of crystal lattice = ?

Solution :-

Mass of one Fe atom = $\frac{56}{6.022 \times 10^{23}} = 9.3 \times 10^{-23}\ g$.

If there are 2 atoms in the unit cell, then

Mass of unit cell = Mass of 2 atoms = $2 \times 9.3 \times 10^{-23}\ g$

Volume of unit cell = $a^3 = (2.88 \times 10^{-8})^3$

$= 23.88 \times 10^{-24}\ cm^3$

Density of unit cell = $d = \frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$

$$7.86 = \frac{z \times 9.3 \times 10^{-23}}{23.88 \times 10^{-24}}$$

$$\therefore z = \frac{7.86 \times 23.88 \times 10^{-24}}{9.3 \times 10^{-23}} = 2.01$$

$\therefore z \cong 2$.

$\because$ The no. of atoms in the unit cell is 2, the crystal lattice must be of bcc type.

Ans. Type of crystal lattice is bcc.

8. Data :-

Cu Crystalline in fcc structure.

Distance between two neighbouring Cu atoms = 234 pm

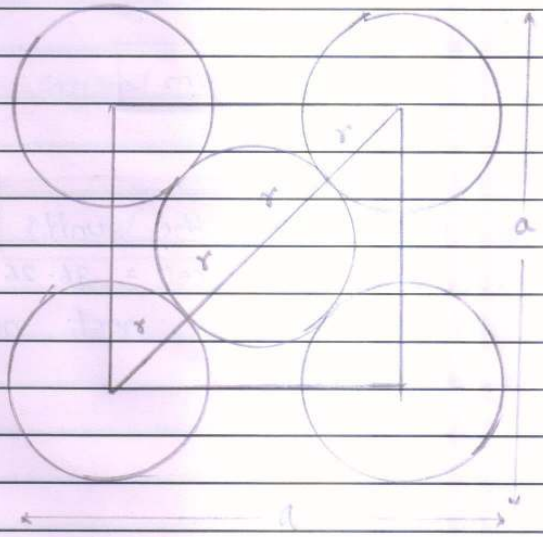
To find :-

1. Edge length = a = ?
2. The volume of unit cell = ?
3. The distance between next neighbouring atom = ?

Solution :-

1. In fcc structure, Cu atoms touch along the face diagonal

$\therefore$ Radius of Cu atom = $\frac{234}{2}$ = 117 pm.



A face to fcc unit cell

length of face diagonal = $4r = 4 \times 117 = 468$ pm.

if a is edge length, then

$$a^2 + a^2 = (468)^2 \quad \therefore 2a^2 = (468)^2$$

$$\therefore a = \frac{468}{\sqrt{2}} = \frac{468}{1.414} = 331 \text{ pm}$$

$$\therefore \boxed{a = 3.31 \times 10^{-8} \text{ cm}.}$$

2. The volume of the unit cell = a^3

$$= (3.31 \times 10^{-8})^3$$

$$= 36.26 \times 10^{-24} \text{ cm}^3.$$

$$\boxed{a^3 = 36.26 \times 10^{-24} \text{ cm}^{-3}}$$

3. The next neighbouring atom will be along the edge length a.

$\therefore$ The distance between next neighbouring atoms

$= a = 331$ pm.

$$\boxed{a = 331 \text{ pm}.}$$

Ans :-

1. Edge length of the unit cell = 331 pm.
2. Volume of unit cell = 36.26×10^{-24} cm^{-3}
3. The distance between next neighbouring atoms = 331 pm.

9. Data :-

Mass of crystal = 2 gram

Type of crystal = fcc

Edge length = a = 100 pm = 100×10^{-12} m = 1×10^{-8} cm.

Density = d = 10 g cm^{-3}

~~No. of atoms~~ = ?

To find :-

No. of atoms = ?

Solution :-

Volume of unit cell = $a^3 = (1 \times 10^{-8})^3$

$= 1 \times 10^{-24}$ cm^3

Mass of unit cell = Density × Volume

$= 10 \times 1 \times 10^{-24}$

$= 1 \times 10^{-23}$ g.

Fcc unit cell contains 4 atoms which weigh 1×10^{-23} g.

$\because$ 1×10^{-23} g crystal contains 4 atoms

$\therefore$ 2 g crystal contains, $\frac{2 \times 4}{1 \times 10^{-23}} = 8 \times 10^{23}$ atoms

No. of atoms = 8×10^{23}.

10. Data :-

Density of crystal = $d = 9.02\ g\ cm^{-3}$

Edge length of unit cell = $a = 4.3\ Å = 4.3 \times 10^{-8}\ cm$

Atomic mass = $89\ g\ mol^{-1}$

To find :-

No. of atoms in unit cell = $z = ?$

Solution :-

Mass of one atom = $\frac{89}{6.022 \times 10^{23}} = 1.48 \times 10^{-22}\ g$.

If there are z atoms in the unit cell, then,

Mass of unit cell = Mass of z atoms = $z \times 1.48 \times 10^{-22}\ g$.

Volume of cubic unit cell = $a^3 = (4.3 \times 10^{-8})^3$

$= 7.95 \times 10^{-23}\ cm^3$

Density of unit cell = $\frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$

$$d = \frac{z \times 1.48 \times 10^{-22}}{7.95 \times 10^{-23}}$$

$$\therefore z = \frac{7.95 \times 10^{-22} \times d}{1.48 \times 10^{-22}} = \frac{7.95 \times 10^{-23} \times 9.02}{1.48 \times 10^{-22}}$$

$$\therefore \boxed{z = 4.84 \cong 5}$$

Ans:- No. of atoms in unit cell = 5.

11. Data :-

Type of crystal lattice of Cu = fcc

Density of crystal = $d = 8.966\ g\ cm^{-3}$

Molar mass of Cu = $M = 63.5\ g\ mol^{-1}$

Avogadro number = $N_A = 6.022 \times 10^{23}\ mol^{-1}$

No. of Cu atoms in face centred unit cell = 4.

To find :-

Volume of Cu unit cell = ?

Solution :-

Mass of one Cu atom

$$= \frac{\text{Molar mass}}{N_A}$$

$$= \frac{63.5}{6.022 \times 10^{23}} = \frac{63.5}{6.022} \times 10^{-23}$$

$$= 1.054 \times 10^{-22}\ g.$$

Mass of unit cell = Mass of 4 Cu atoms

$$= 4 \times 1.054 \times 10^{22}$$

$$= 4.216 \times 10^{-23}\ g.$$

$\because$ Density of Cu = $\frac{\text{Mass of unit cell}}{\text{Volume of unit cell}}$

$\therefore$ Volume of unit cell

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

$$= \frac{4.216 \times 10^{-22}}{8.966}$$

$$= 0.4702 \times 10^{-22}$$

$$= 4.702 \times 10^{-23} \text{ cm}^3$$

Ans:- Volume of unit cell = 4.702×10^{-23} cm^3

12. Data :-

Atomic mass of Al = 27 g mol^{-1}

Mass of Al = 10g

Avogadro Number = N_A = 6.022×10^{23} mol^{-1}

~~Atomber of At atoms~~ = ?

To find :-

No. of Al atoms = ?

No. of unit cells = ?

Solution :-

1 gram atom of Al = 27g Al contains 6.022×10^{23} Al atoms.

$\therefore$ No of Al atoms in 10g = $\frac{10 \times 6.022 \times 10^{23}}{27}$

$= 2.23 \times 10^{23}$

In fcc structure, each unit cell contains 4 Al atoms.

$\therefore$ No. of unit cells = $\frac{2.23 \times 10^{23}}{4}$

$= 5.575 \times 10^{22}$

Ans:- No. of Al atoms = 2.23×10^{23}

No. of unit cells = 5.575×10^{22}.