BYJU'S Classes

Solid State

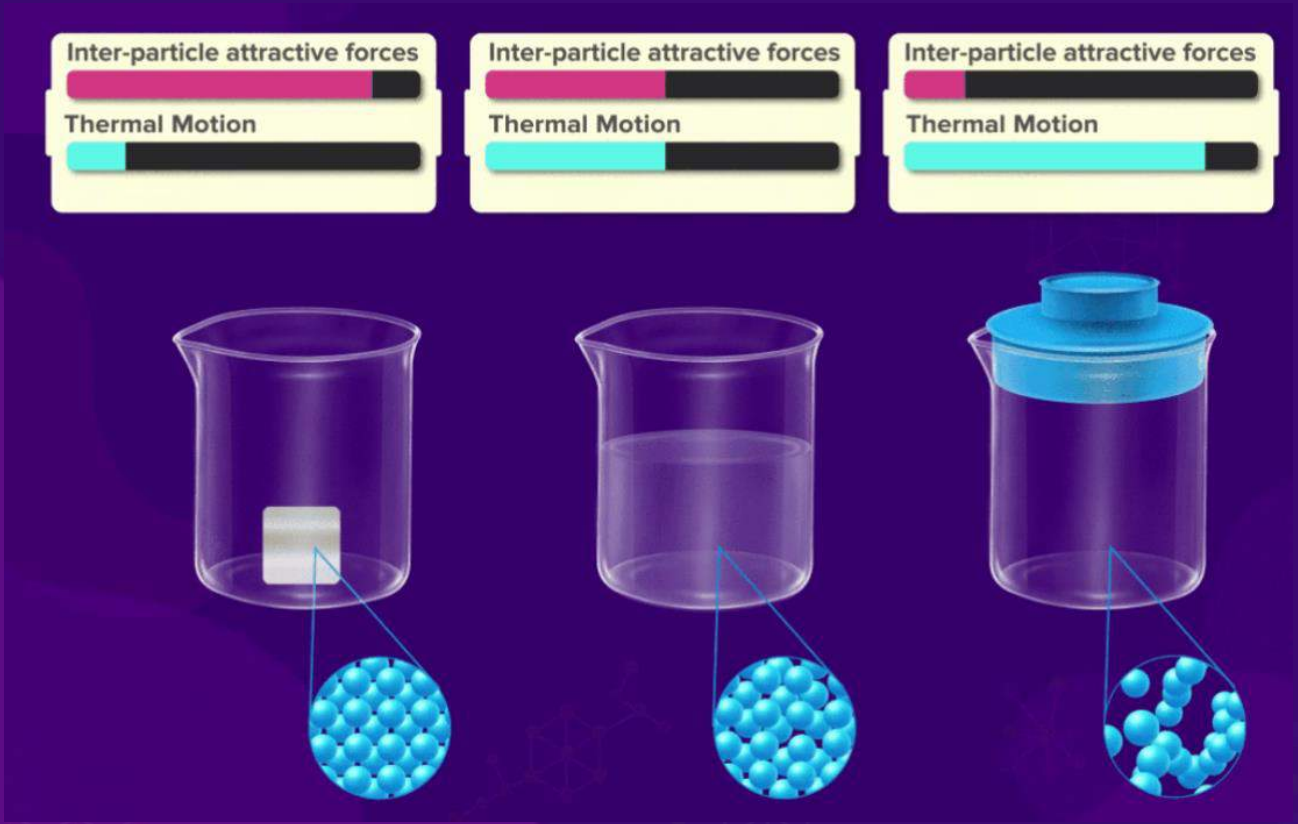
States of Matter

Depends on

(i) Relative motion of particles at a particular temperature, i.e., **thermal motion**.

(ii) Interparticle **attractive** forces

States of Matter



Solid Liquid Gas

Solid

Solid State

Solid state has **strong** interparticle attraction and **negligible** thermal motion of particles.

Solid State

Why Do We Need To Study Solids?

To understand how **different arrangements** of particles results in several types of structures.

And explore why different arrangements of structural units lend **different properties** to solids.

The correlation between structure and properties helps in the **discovery of new solid materials** with desired properties.

Example: **Carbon nanotubes**. It is tougher than steel, lighter than aluminium and have more conductive property than copper.

Solid State

Other examples

High temperature superconductors, magnetic materials, biodegradable polymers for packaging, biocompliant solids for surgical implants, etc.

Such materials may play an expanding role in **future development** of science & society.

Thus, the study of this state becomes **more important** in the present scenario.

Properties of Solids

Properties of Solids

a. Have a **definite mass**, **volume**, and **shape**. usually

b. **Least interparticle distances** in solids as compared to liquids and gases.

c. **Strong** interparticle forces of attraction.

Properties of Solids

d. Particles **cannot flow**.

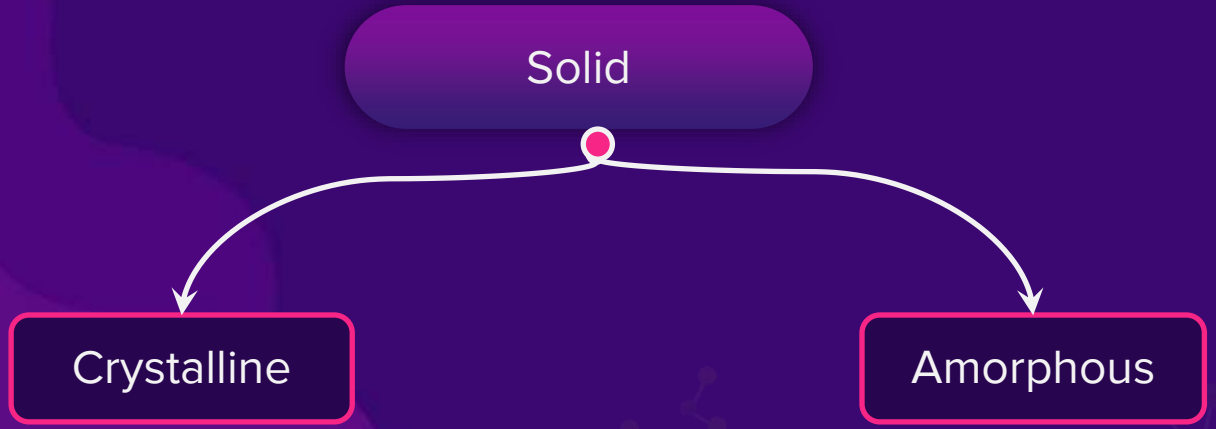
e. Constituting particles have **fixed positions**. They can only oscillate about their **mean position**, i.e., they have **vibrational motions** only.

f. **Rigid** and **incompressible**.

Classification of Solids

Classification of Solids

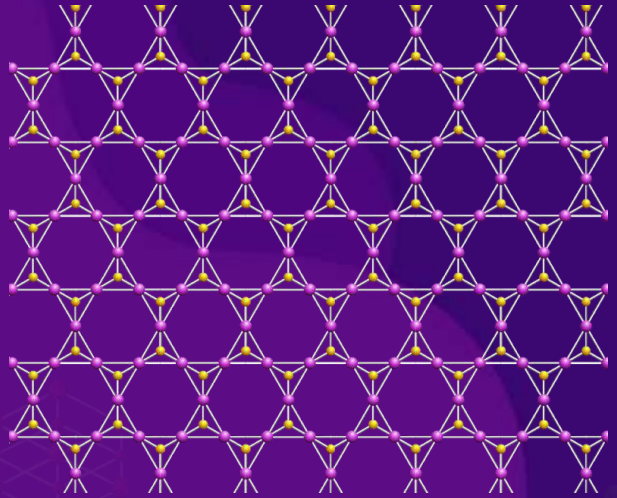
Solids can be classified as **crystalline or amorphous** on the basis of the nature of order present in the arrangement of their constituent particles.



Difference between Crystalline and Amorphous Solids

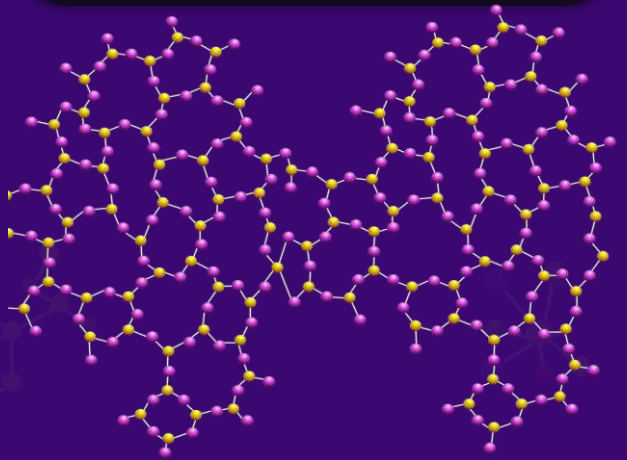
Crystalline Solid

Particle follow a **definite** regular arrangement.



Amorphous Solid

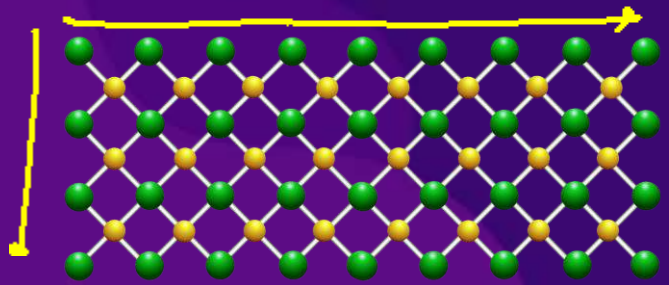
No particular pattern is followed, and particles are **randomly arranged.**



Difference between Crystalline and Amorphous Solids

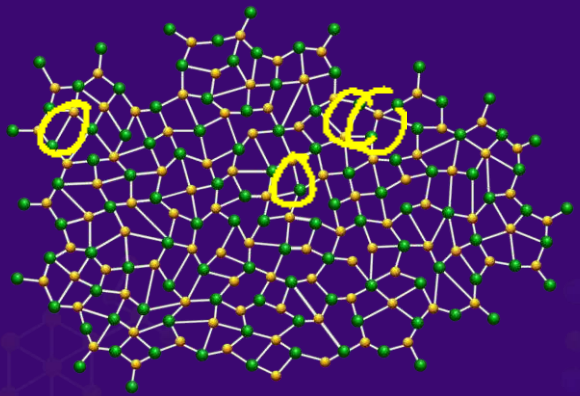
Crystalline Solid

Long-range order in the arrangement.



Amorphous Solid

Short range order in the arrangement.



Difference between Crystalline and Amorphous Solids

Crystalline Solid	Amorphous Solid
Produced by **slow cooling** under controlled condition of liquid. The crystalline structure is also dependent on conditions.	Produced by **rapid cooling** of the liquid.

Polymorphism

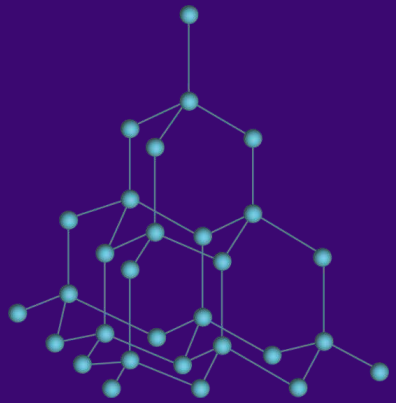
Polymorphism

Different crystalline structure of the **same substance** are called its polymorphic forms.

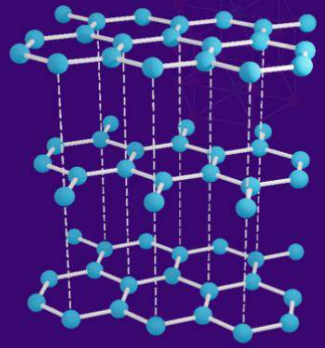
Due to the **difference** in the **arrangement** of the constituent particles, two types of solids **differ in their properties**.

Polymorphism

Diamond



Graphite

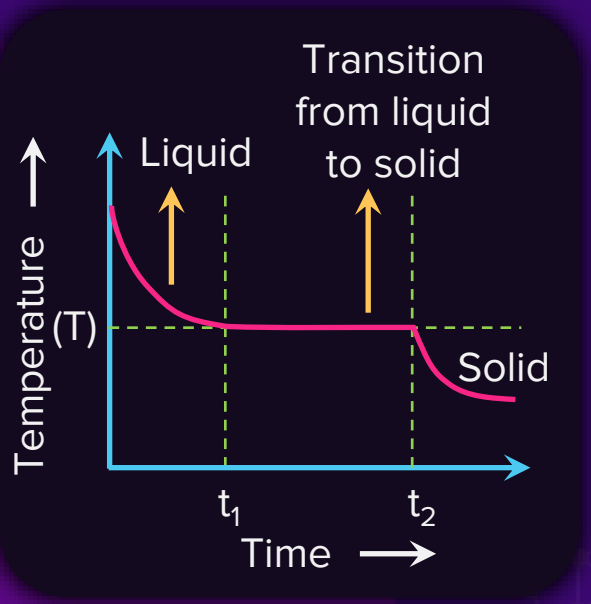


Difference between Crystalline and Amorphous Solids

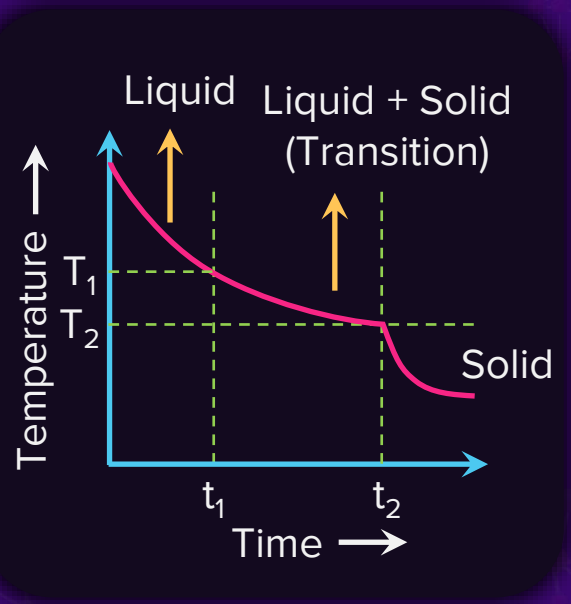
Crystalline Solid	Amorphous Solid
Have a **fixed or sharp** melting point and enthalpy of fusion.	Have a **range of temperature** in which they melts as M.P. and the enthalpy of fusion is not fixed.

Difference between Crystalline and Amorphous Solids

Crystalline Solid



Amorphous Solid



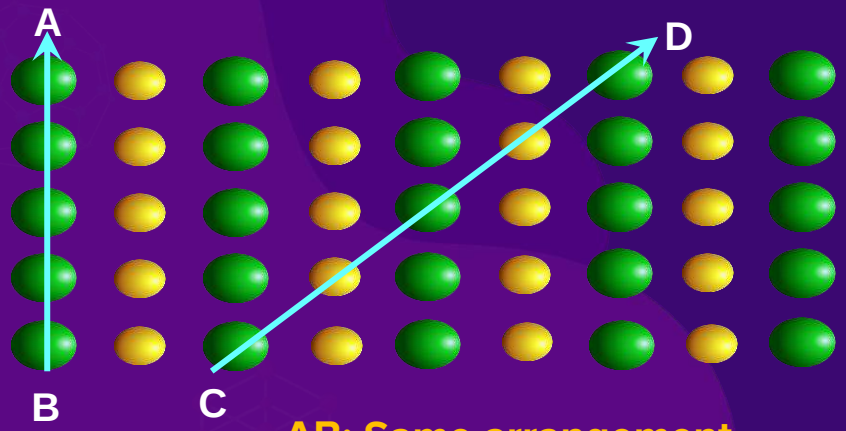
Difference between Crystalline and Amorphous Solids

Crystalline Solid	Amorphous Solid
When **cut** with a sharp edged tool, they split into two pieces and the newly generated surfaces are **plain and smooth**.	When **cut** with a sharp edged tool, they cut into two pieces with **irregular surfaces**.
True solids.	**Pseudo** solids or super-cooled liquids.

Difference between Crystalline and Amorphous Solids

Crystalline Solid

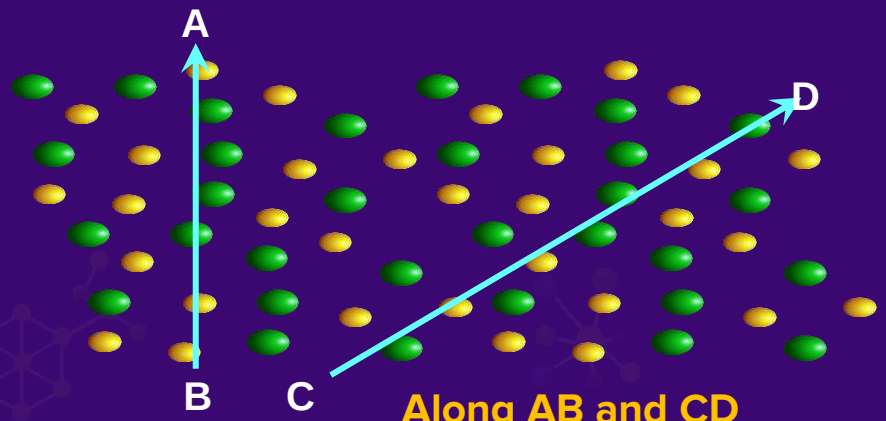
Anisotropic:
Different values of physical properties in **different directions**.



AB: Same arrangement
DC: Different arrangement

Amorphous Solid

Isotropic:
Same values of physical properties in all different directions due to random arrangement of particles



Along AB and CD different arrangement

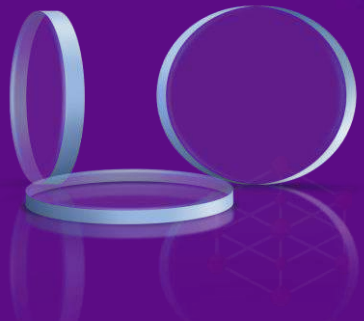
Difference between Crystalline and Amorphous Solids

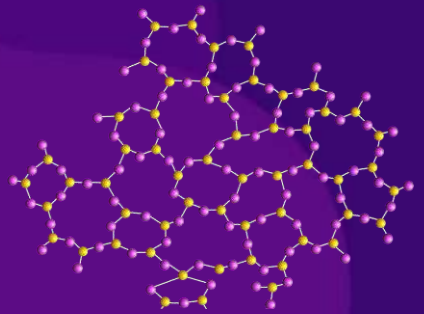
Crystalline Solid

Example:

Ag, Fe, Cu, NaCl, H_2O (s), diamond, quartz, sucrose (sugar)

Quartz Glass: It is a amorphous solid and transparent form of pure silica.



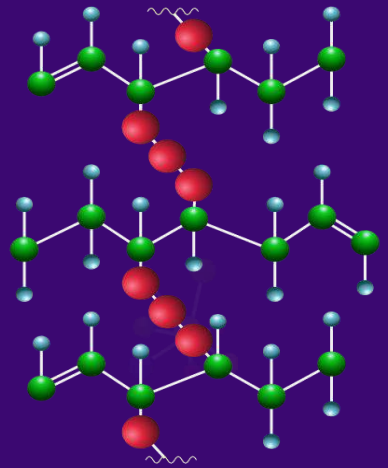


Amorphous Solid

Example:

Glass, plastic, amorphous silica, rubber, starch

Rubber:



Difference between Crystalline and Amorphous Solids

Amorphous Solid

- Amorphous solids have the same structural features as liquids and are conveniently regarded as **extremely viscous liquids**.
- Amorphous solids have a **tendency to flow** (very slowly), hence they are called **pseudo solids** or **super-cooled liquids**.

Polycrystalline Solid

Note:

Solids which apparently **appear amorphous** but **have microcrystalline** structure are called polycrystalline solids.

Metals often occur in polycrystalline conditions.

Individual crystals are randomly oriented so a metallic sample **may appear to be isotropic** even though single crystal is **anisotropic**.

Which one is called pseudo solid or supercooled liquid?

B

a CaF_2

b Glass

c NaCl

d All

Solution

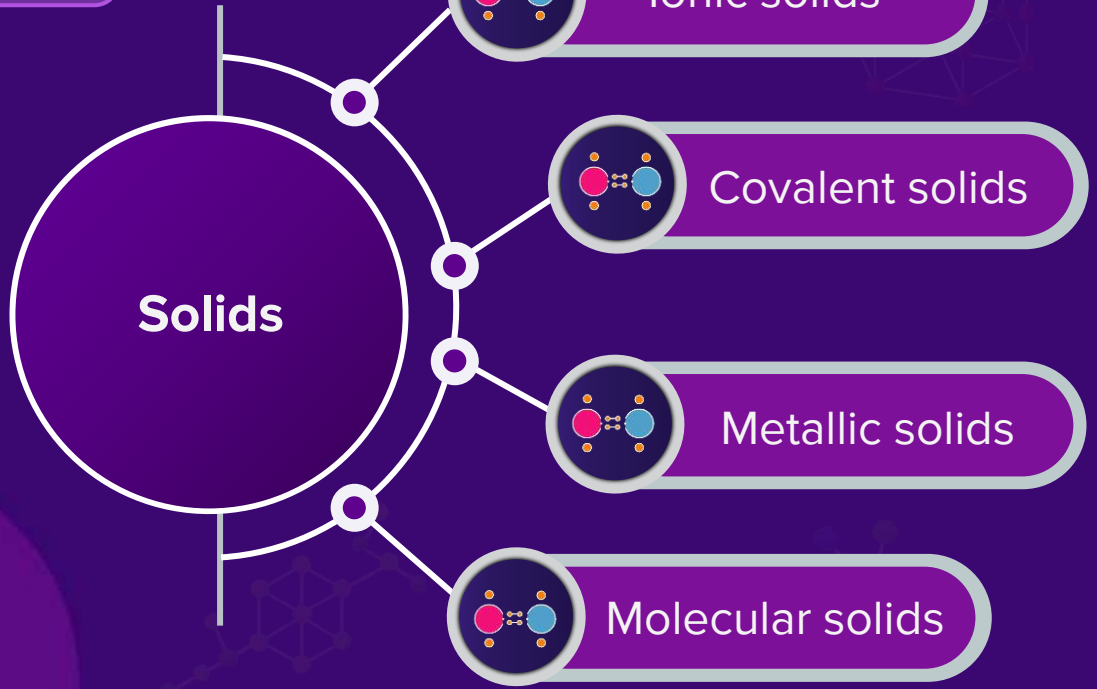
Glass is an amorphous solid which is sometimes called supercooled liquid or pseudo liquid.

Hence, options (b) is the correct answers.

Classification of Crystalline Solids

Classification of Solids

Based on the forces among constituting particles



Ionic Solids

Constituent particles	Ions
Force of interaction	Coulombic (electrostatic)
Physical state	Very hard (brittle)
Melting point	Very high

Electrical conductivity

Solid form → Insulator

Molten & aqueous form → Conducting

Examples

NaCl, ZnS, CsCl

Covalent Solids

Constituent particles	**Atoms** (Non metals)
Force of interaction	**Covalent bond**
Physical state	**Very hard** (Graphite → soft)
Melting point	**Very high**

Covalent Solids

They are also called **giant molecules**

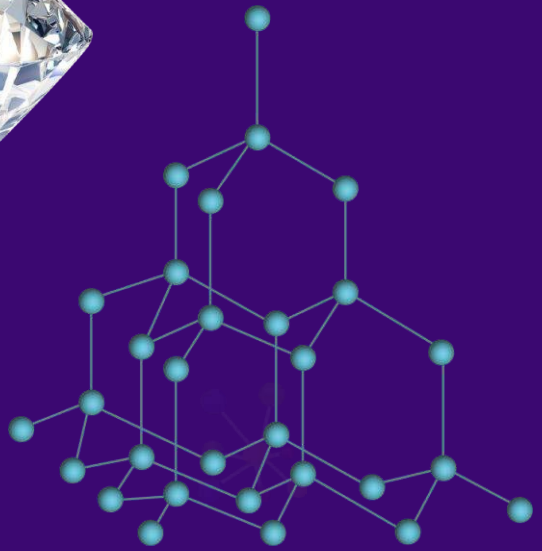
Electrical conductivity

Insulator except graphite

Examples

Diamond, SiC, SiO_2, graphite

Diamond

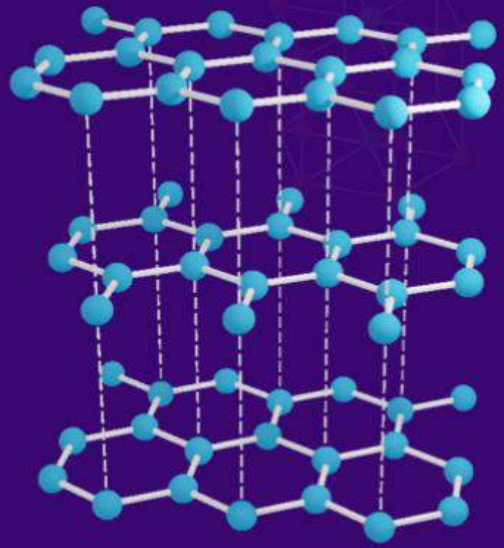


Covalent Solids

Graphite

Graphite belongs to covalent solids, but it is **soft** and a **good conductor** of electricity.

Its exceptional properties are due to its **typical structure**.



Covalent Solids

In graphite, carbon atoms are arranged in different layers and each atom is covalently bonded to three of its neighboring atoms in the same layer. The fourth valence electron of each atom is present between different layers and is free to move about. These free electrons make graphite a good conductor of electricity.

Carbon atoms are **arranged in different layers**

Different layers can **slide** over the other making it a soft solid and a good solid lubricant.

Metallic Solids

Constituent particles	Metal ion at fixed locations in **the sea of delocalised electrons**
Force of interaction	**Metallic bond**
Physical state	**Soft & hard** (depending on metallic bond)
Melting point	**Low to high** (depending on metallic bond)

Metallic Solids

Electrical conductivity

Good conductor in solid and molten state

Thermal conductivity

Good conductor in solid and molten state

Examples

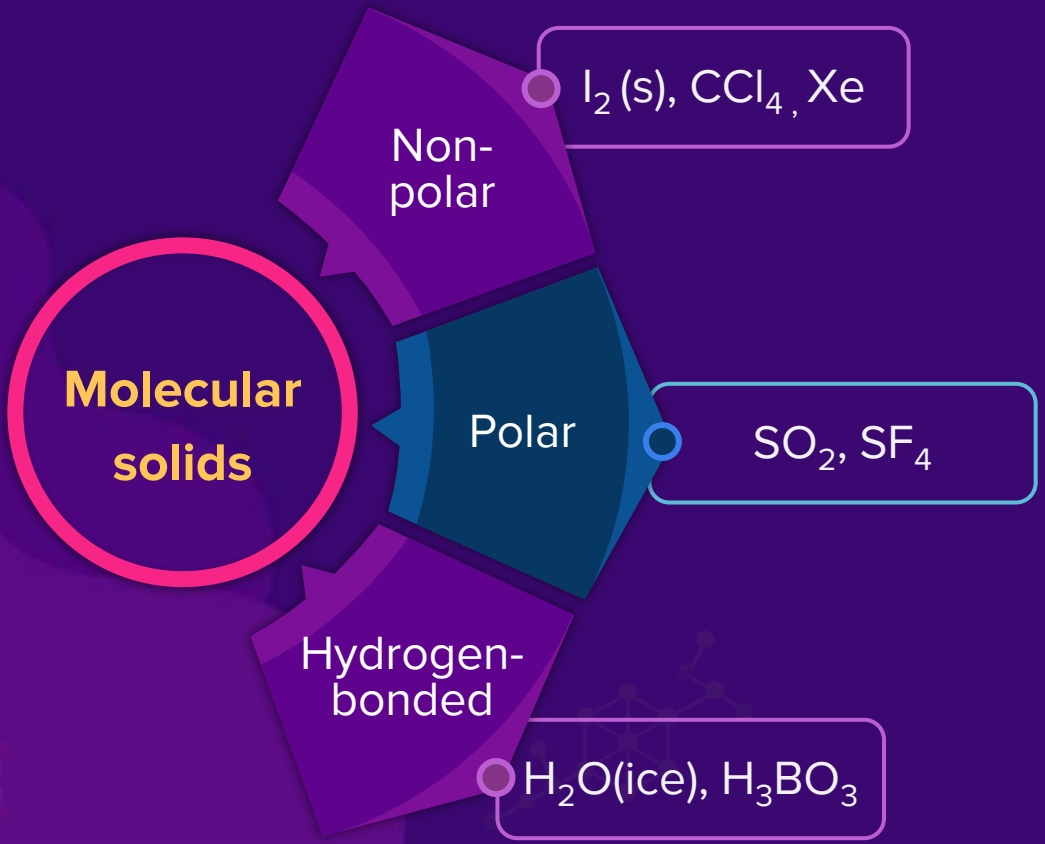
Cu, Al, Zn, Ag

Molecular Solids

Constituent particles → **Molecules**

Type of molecule	Force of interaction
Non-polar	Dispersion force or London forces
Polar	Dipole-dipole
	H-bonding

Molecular Solids



Molecular Solids

Type of molecular solids	Physical state	M.P.
Non-polar	Very soft	Very low
Polar	Soft	Low
H-bonded	Hard	Low

Low

Electrical conductivity

Non-conducting

Examples

I_2, Xe(s), C_6H_6, CCl_4, HCl, H_2O(s), H_3BO_3(s)

Crystals which are good conductor of electricity and heat are known as:

a. Ionic crystals

b. Covalent crystals

c. Metallic crystals

d. Molecular crystal

Solution

Metals conduct heat and electricity.

Hence, option (c) is the correct answer.

Which of the following solids is incorrectly matched with the bonds found between the constituent particles?

Solution

a. H_3BO_3: Polar & H-bond

b. Graphite: Covalent and van der Waals

c. NaCl: Coulombic London forces

d. Metal alloys: Ions-delocalised electrons

Hence, option (c) is the correct answer.

Which of the following is incorrect for ionic crystals?

Solution

a. They possess high melting point and boiling point

b. They are electrolyte

c. Exhibit directional properties of the bond

d. None of these

Hence, option (c) is the correct answer.

For each of the following substances, identify the intermolecular force or forces that predominate. Using your knowledge of the relative strengths of the various forces, rank the substances in order of theirs normal boiling points. Al_2O_3, F_2, H_2O, Br_2, ICl, NaCl. Which of the following is incorrect order?

a $F_2 < Br_2 < ICl$

b $H_2O < NaCl < Al_2O_3$

c $ICl < H_2O$

d $H_2O < ICl$

Solution

- Order of boiling points can be predicted on the basis of intermolecular forces present in them:
- Al_2O_3 is ionic, F_2 has van der waal's forces, H_2O has hydrogen bonding , Br_2 has van der Waal forces, ICl has van der waal forces and NaCl has ionic bond. F_2, H_2O, Br_2, ICl are molecular solids ;
- As size of Br_2 is more than F_2 so its van der waal forces will be more and boiling point of Br_2 will be more than F_2 and ICl and in ICl there is polarity difference I and Cl so its dipole-dipole interactions will be more than Br_2. So , ICl has more boiling point than Br_2 and F_2 so the order is $F_2 < Br_2 <$ ICl and thus **option (a) is correct.**

- H_2O has hydrogen bonding and NaCl and Al_2O_3 are ionic. So , NaCl and Al_2O_3 have much more boiling point than water and out of NaCl and Al_2O_3, electrostatic attraction will be more in Al_2O_3 than NaCl. So , order is
  Al_2O_3 > NaCl > H_2O and thus **option (b) is correct.**
- Out of ICl and H_2O, H_2O has more boiling point than ICl as H_2O has H-bonding which is much stronger than ICl which has van der waal forces thus **option (c) is correct and (d) is wrong.**

Hence, option (d) is the correct answer.

Cation and anion combines in a crystal to form following type of compound.

Solution

Cation and anion combine in a crystal to form the ionic compound.

Hence, option (a) is the correct answer.

a. Ionic

b. Metallic

c. Covalent

d. Dipole-dipole

The existence of a substance in more than one solid modifications is known as:

B

Solution

The existence of a substance in more than one solid modifications is known as polymorphism.

Hence, option (b) is the correct answer.

a. Isomorphism

b. Polymorphism

c. Amorphism

d. Allotropy

Which of the following statement is true for ionic solids?

B

Solution

a

Ionic solids are soluble in non-polar solvent

b

Under the electric field cations and anions acquire translatory motion in opposite directions.

Which of the following statement is true for ionic solids?

B

Solution

c ✗ Structural units have strong electrostatic force of attraction.

d ✗ Structural units have dipole-dipole interactions

Hence, option (a) is the correct answer.

Solids which do not show the same physical properties in different directions are called:

a. Pseudo solids

b. Isotropic solids

c. Polymeric solids

d. Anisotropic solids

Solution

Solids which do not show the same physical properties in different directions are known as anisotropic solids.

Hence, option (d) is the correct answer.

Crystals which are good conductors of electricity and heat are known as:

a. Ionic crystals

b. Covalent crystals

c. Metallic crystals

d. Molecular crystals

Solution

Metallic crystals are good conductors of electricity and heat.

Hence, option (c) is the correct answer.

Assertion: Amorphous solids are isotropic.
Reason: Amorphous solids lack a regular three-dimensional arrangement of atoms.

B

a. If both assertion and reason are correct and reason is the correct explanation of assertion

b. If both assertion and reason are correct, but reason is not the correct explanation of assertion.

c. If assertion is correct but reason is incorrect.

d. If both the assertion and reason are incorrect

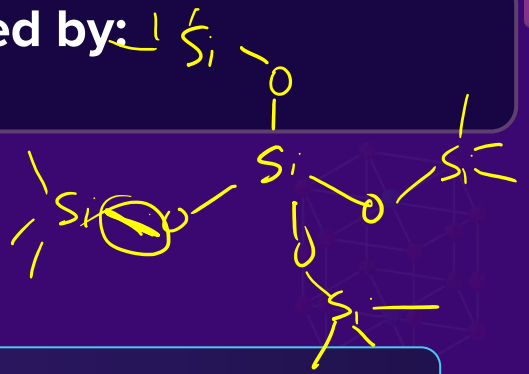
Solution

Assertion is true ; Reason is also true and reason is the correct explanation of assertion.

Amorphous solids are isotropic because the arrangement of particles is different along different directions i.e., (they lack a regular 3D arrangement of particles), the value of the physical properties is found to be the same along each direction. The property remains the same in all directions. This property is known as isotropy.

Hence, option (a) is the correct answer.

Constituent particles in quartz are bounded by:



Solution

Constituent particles in quartz are bounded by covalent bonds.

Hence, option (b) is the correct answer.

a. Electrostatic bonds

b. Covalent bonds

c. van der Waals forces

d. Metallic bonds

Ionic solid are characterised by:

Solution

a. Good conductivity in solid state

b. High vapour pressure

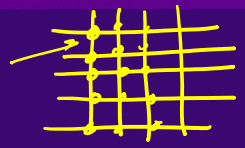
c. Low melting point

d. Solubility in polar solvents

Hence, option (d) is the correct answer.

Internal Arrangement of Particles in a Crystal

Lattice Point



Each constituent particle (molecule, atom, and ions) will be represented by a **dot (.)**

Each dot is called a **lattice point**.

Lattice or Space or Crystal Lattice

The **3-D regular and repeating arrangement** of constituent particles represented by dots in a solid.

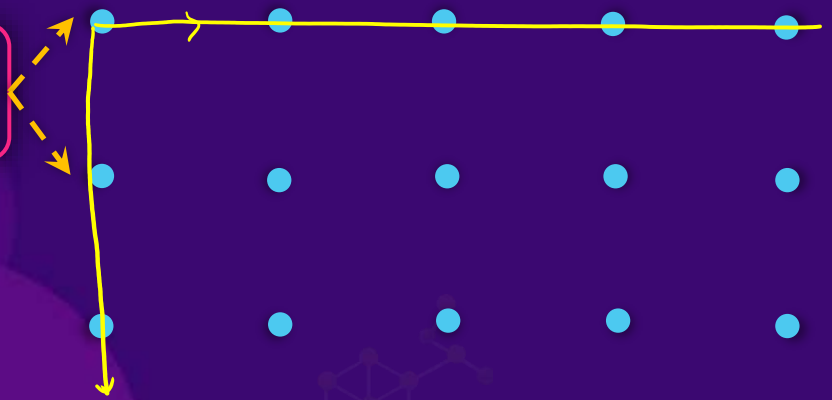
→ atoms/ molecules/ ions

2-D Lattice

In **2-D**

Space lattice

Lattice points

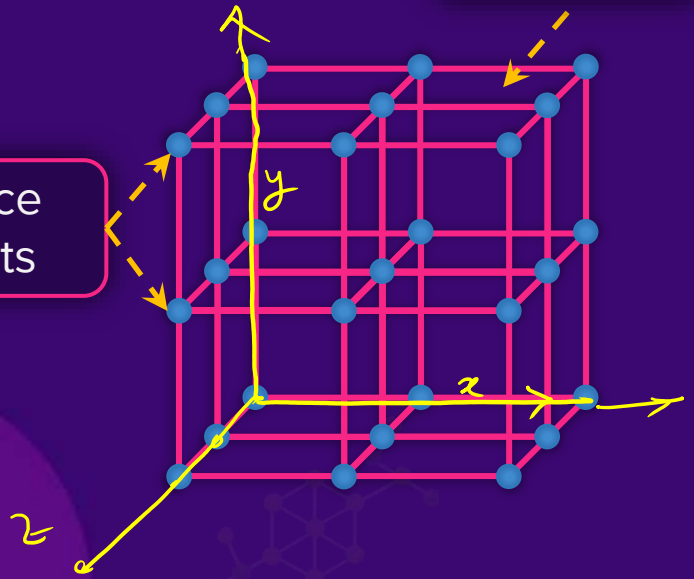


3-D Lattice

In **3-D**

Space lattice

Lattice points



Note

Each lattice point specifies the location of a **structural motif** (or basis), which may be atoms, molecules, or groups of atoms, molecules, or ions.

Crystal structure is the **collection of structural motifs** arranged according to the lattice.

Lattice or Space or Crystal Lattice

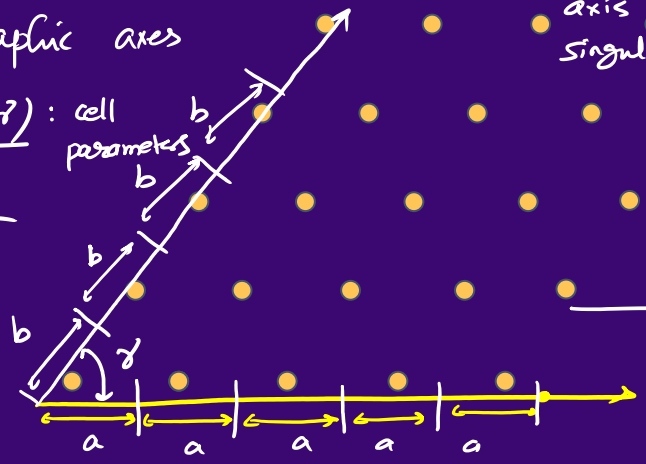
crystallographic axes

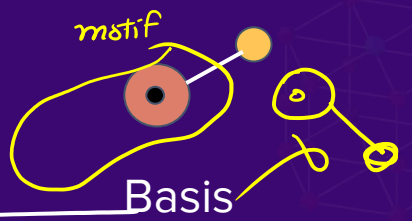
3D : (a, b, c) (α, β, γ) : cell parameters

2D : (a, b) , γ

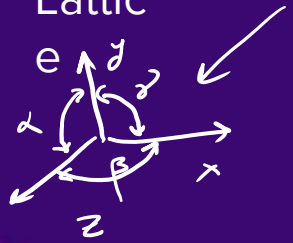
1D : (a)

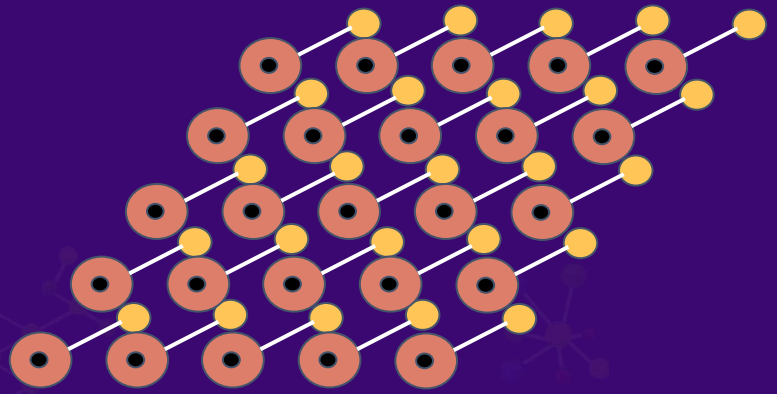
axis singular axes plural





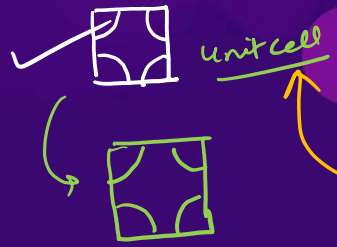
Lattic e

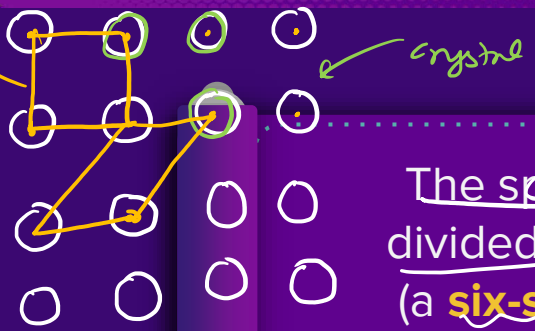




Crystal structure

Unit Cell





The space lattice of a crystal can be divided into **identical parallelepipeds** (a **six-sided** geometrical solid whose faces are all **parallelograms**) by joining the lattice points with straight lines.

Each such parallelepiped is called a **unit cell**.

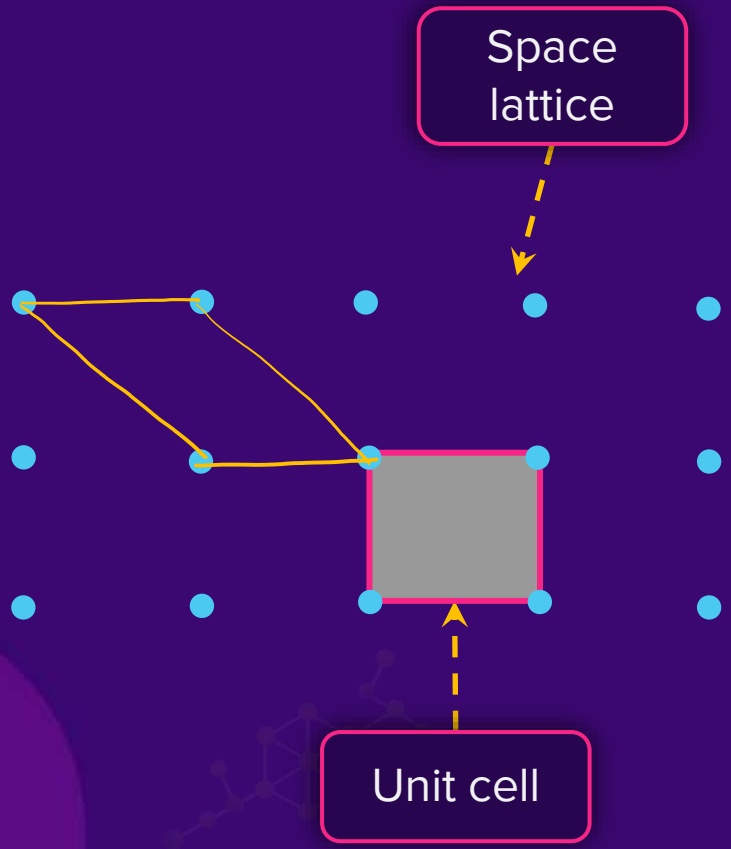
Unit Cell

Unit cell is usually the **smallest portion** of a lattice which, when repeated in different directions, generates the **entire lattice**.

Generally, **the most symmetrical** and **smallest volume** unit cell is selected.

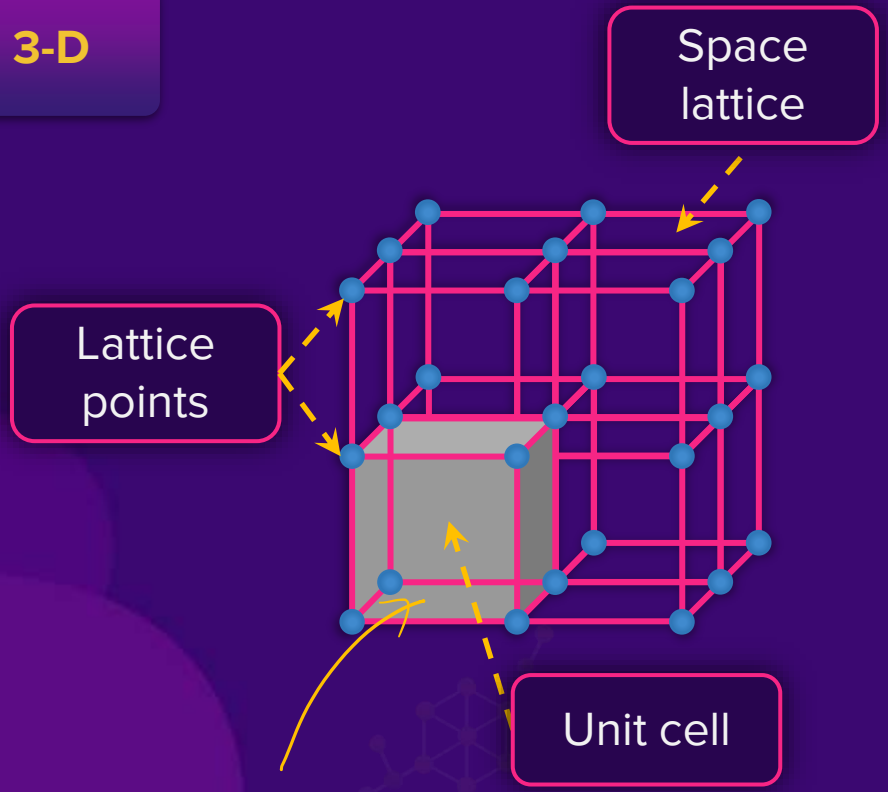
2-D Unit Cell

In **2-D**

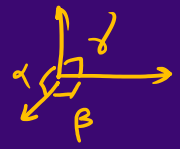


3-D Unit Cell

In **3-D**



Characteristics of Unit Cell



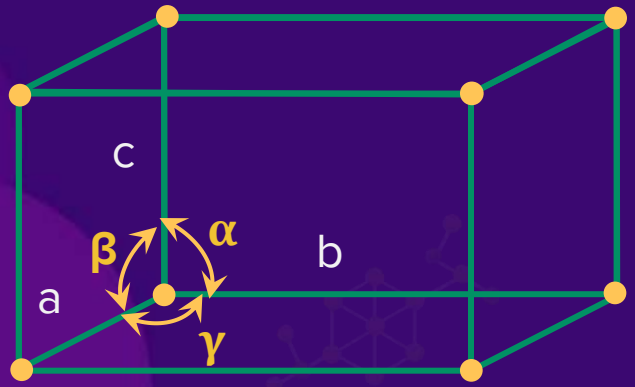
(1) Its dimensions along the **three edges**, a, b, and c may or may not be mutually perpendicular.

(2) Angles between the edges, α (between b and c), β (between a and c), and γ (between a and b).

Characteristics of Unit Cell

(3)

Each unit cell has characteristic relation between **a, b, and c** or **α, β, and γ** that gives rise to **different types** of unit cell.



The smallest repeating pattern which when repeated in three dimensions results in the crystal of the substance is called:

Solution

a Space lattice

b Crystal lattice

c Unit cell

d Coordination number

Hence, option (c) is the correct answer.

Which of the following is a incorrect statement?

Solution

a

Crystal structure is the collection of structural motifs arranged according to the lattice.

True

b

The basis may be a single atom or molecule.

True

Which of the following is a incorrect statement?

Solution

c

A unit cell is a parallel-sided (but not necessarily rectangular) figure from which the entire crystal structure can be constructed by using only translations (not reflections, rotations, or inversions).

d

Space lattice is the smallest portion of a crystal lattice which, when repeated in different directions, generates the entire lattice.

Hence, option (d) is the correct answer.

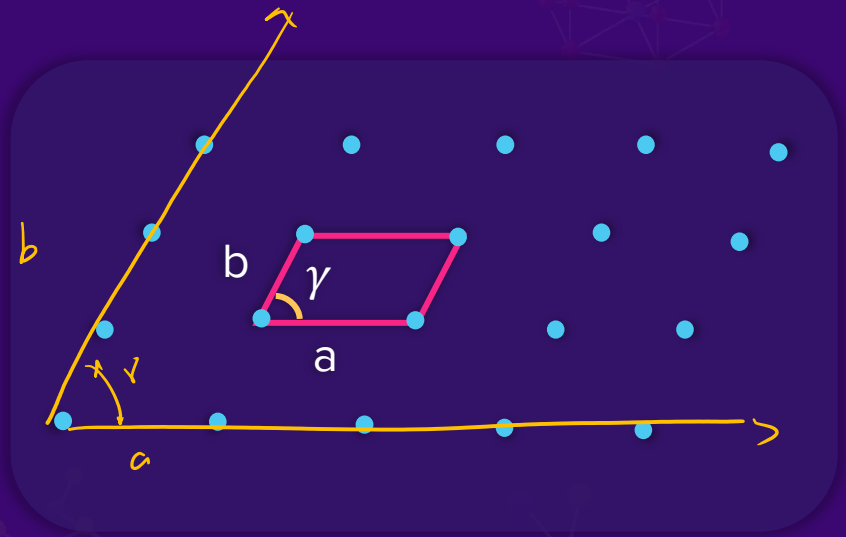
Unit Cells in 2-D

There are **5 types** of unit cells possible in **2-D lattice**.

Unit cells in 2-D is **parallelogram** which is described by **three parameters i.e., a, b, γ**.

a, b, γ

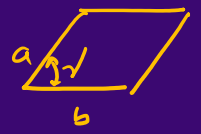
Parallelogram



Unit Cells in 2-D

Unit Cell	a, b	γ
Square	a = b	$\gamma = 90^{o}$
Rectangle	a ≠ b	$\gamma = 90^{o}$
Hexagonal	a = b	$\gamma = 120^{o}$

Unit Cells in 2-D



Unit Cell	a, b	γ
Rhombic	a = b	$\gamma \neq 90^{o}$, $\gamma \neq 60^{o}$ & $\gamma \neq 120^{o}$
Parallelogram	a ≠ b	$\gamma \neq 90^{o}$

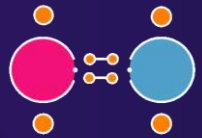
Most symmetrical → **Square unit cell**

3-D Unit Cell

In 3-D lattice to specify any unit cell **6 parameters** are required.

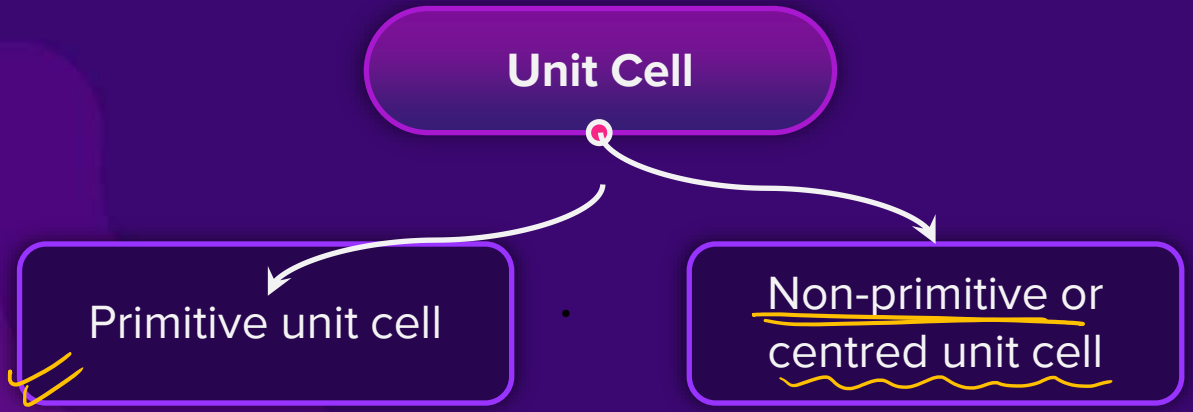
3-edge length (**a, b, c**) and 3-angle between these i.e., **α, β, and γ**.

In 3-D lattice, **14** different types of unit cells are found and these are also known as **Bravais lattice**.



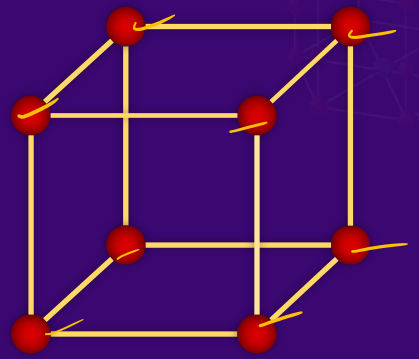
These 14 unit cells are grouped in 7 crystal systems depending upon **7 types** of primitive unit cells.

Unit Cell


Unit Cell
Primitive unit cell
Non-primitive or centred unit cell

Primitive Unit Cell

Unit cell having lattice point only at the **corners**.



Primitive/Simple unit cell

Non-Primitive or Centred Unit Cell

Unit cell having lattice point at **corners** as well as **within** the unit cell.

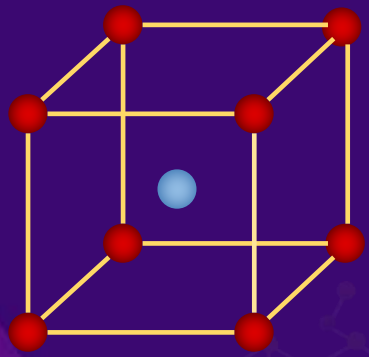
Non-primitive or Centred Unit Cell

- Body-centred (B.C.)
- Face-centred (F.C.)
- End-centred (E.C.)

Non-Primitive or Centred Unit Cell

Body-centred unit cell

It contains one constituent particle (atom, molecule, or ion) at its body centre besides the particles at its corners. In body centred unit cell, the constituent particles are present at the eight corners of the unit cell and also at the centre of the unit cell as shown below.

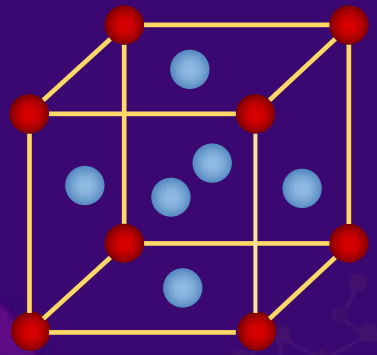


Body-centred unit cell

Non-Primitive or Centred Unit Cell

Face-centred unit cell

Such a unit cell contains one constituent particle present at the centre of each face, besides the ones that at its corners. In face centred unit cell, constituent particles are present at the eight corners of the unit cell and also at the centre of six faces of the unit cell as shown below.

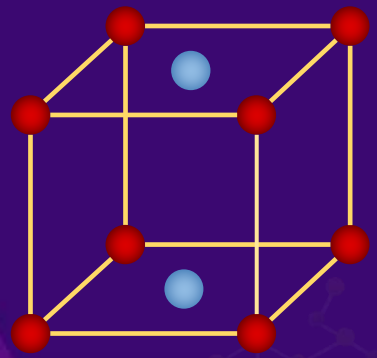


Face-centred unit cell

Non-Primitive or Centred 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. In end centred unit cell, constituent particles are present at the eight corners of the unit cell and also at the centre of any two opposite faces of the unit cell as shown below.



End-centred

In the face-centred unit cell, the lattice points are present at the:

Solution

a Corners and face-centres of the unit cell

b Corners and centre of the unit cell

c Corners and edge-centre of the unit cell

d Body-centre of the unit cell

Hence, option (a) is the correct answer.

Choose the correct statement:

Solution

a. There are 3 types of unit cells possible in 2-D lattice.

b. The most symmetrical unit cell in 2-D lattice is cube

Choose the correct statement:

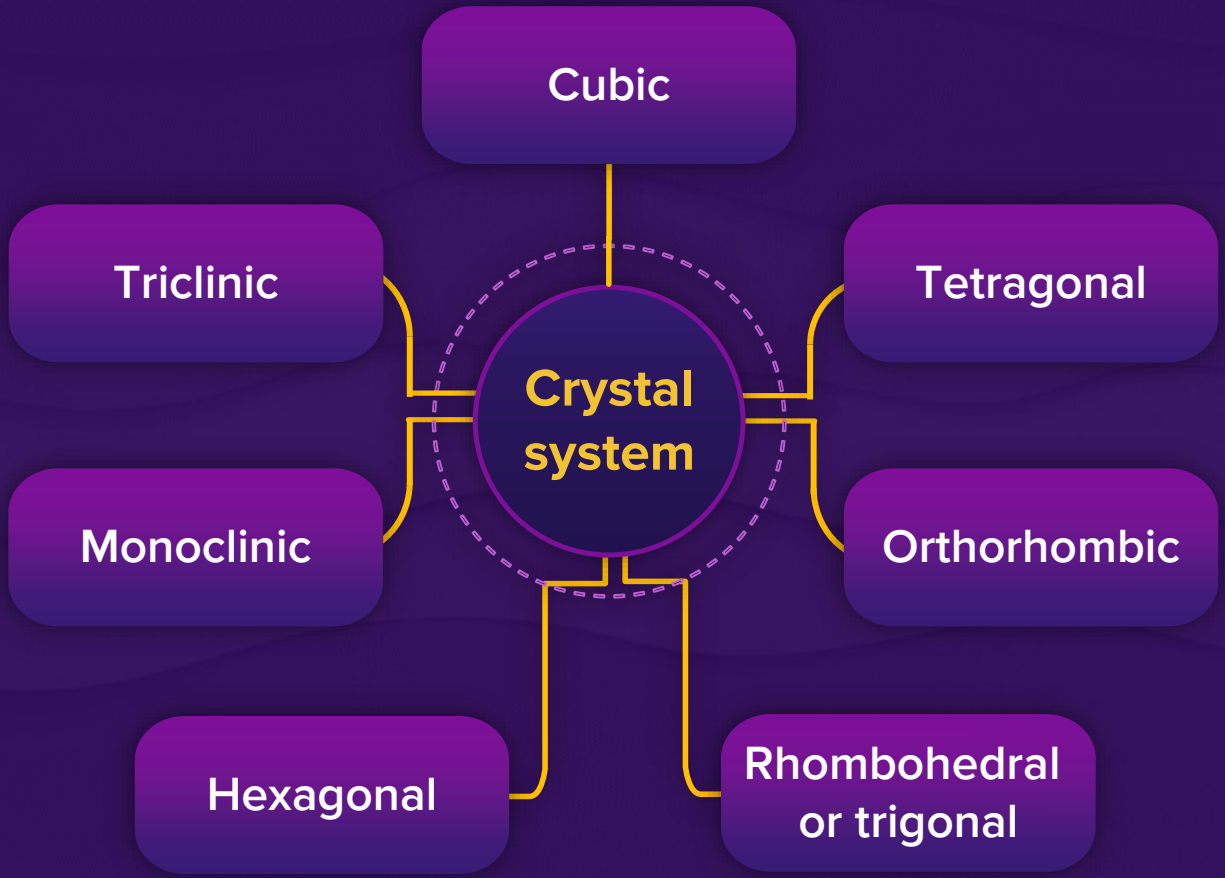
Solution

c In 3-D lattice to specify any unit cell, 6 parameters are required.

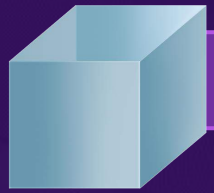
d In 3-D lattice, 12 different types of unit cell are found.

Hence, option (c) is the correct answer.

Crystal System



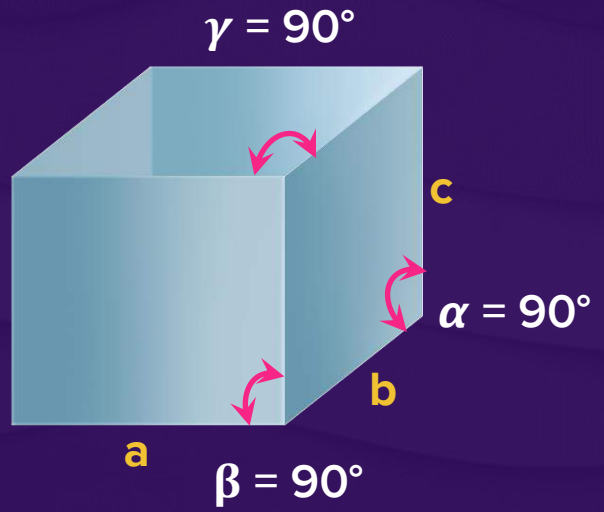
Crystal System



Cubic crystal lattice

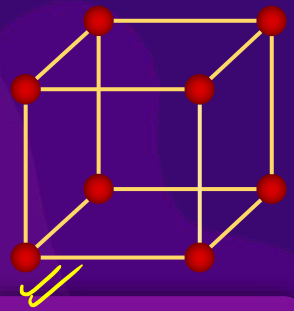
Edge length	Angle
a = b = c	$\alpha = \beta = \gamma = 90°$

Unit cell found	Examples
Primitive, BC, FC	NaCl, ZnS, Cu

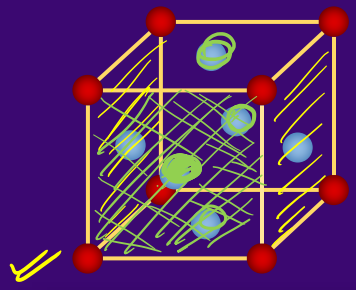


Crystal System

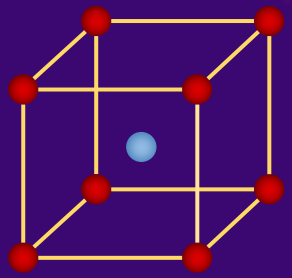
Cubic



Simple cubic

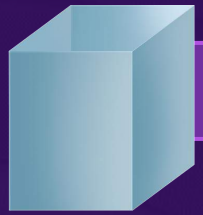


Face-centred cubic



Body-centred cubic

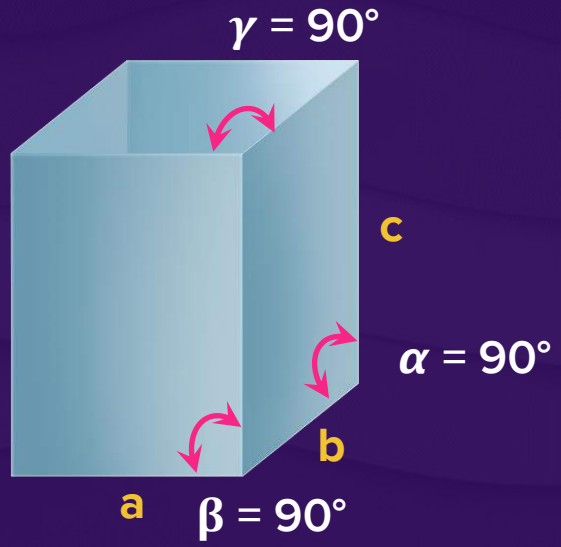
Crystal System



Tetragonal crystal lattice

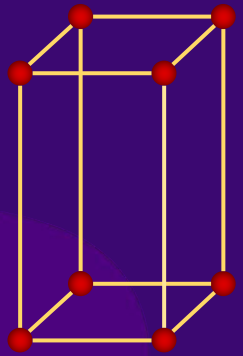
Edge length	Angle
a = b ≠ c	$\alpha = \beta = \gamma = 90^\circ$

Unit cell found	Examples
Primitive, BC	White tin, SnO_2, TiO_2

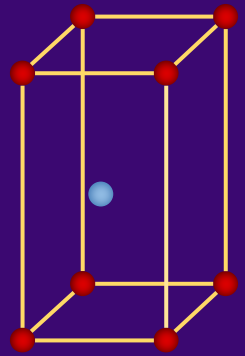


Crystal System

Tetragonal

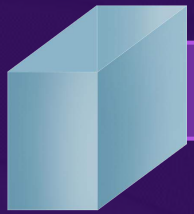


Primitive



Body-centred

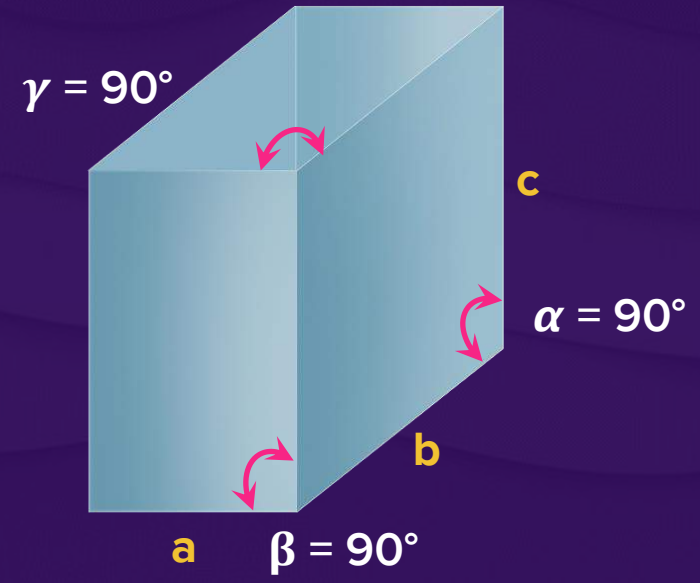
Crystal System



Orthorhombic crystal lattice

Edge length	Angle
$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$

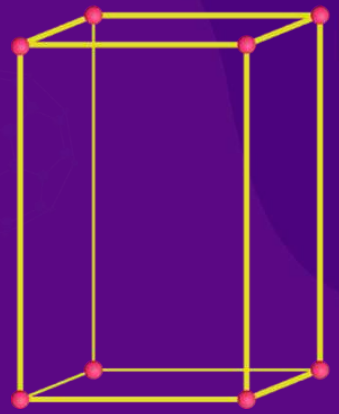
Unit cell found	Examples
Primitive, BC, FC, EC	Rhombic sulphur, KNO_3, $BaSO_4$



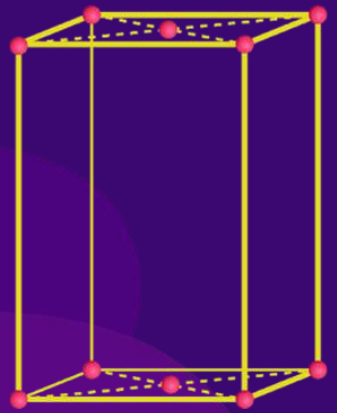
Crystal System

Orthorhombic system

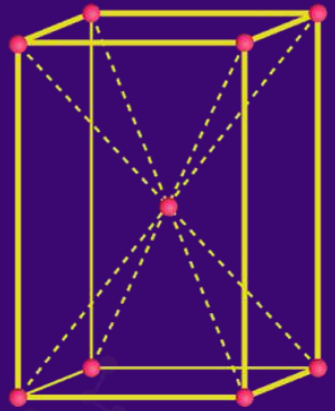
Simple (primitive), end-centred, body-centred, and face-centred unit cells are possible in an orthorhombic crystal system.



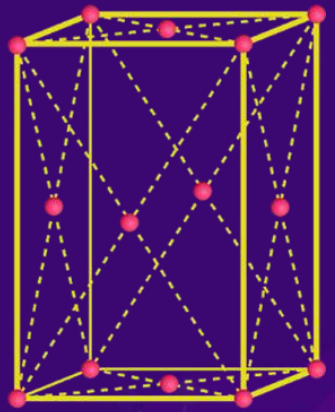
Primitive



End centered



Body centered



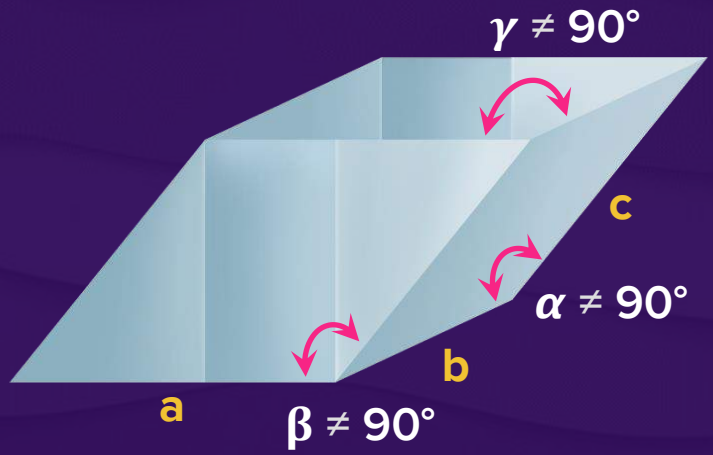
Face centered

Crystal System

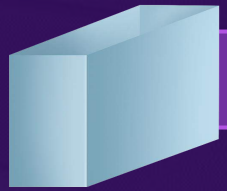
Rhombohedral or Trigonal crystal system

Edge length	Angle
a = b = c	$\alpha = \beta = \gamma \neq 90°$

Unit cell found	Examples
Primitive	Calcite ($CaCO_3$), cinnabar (HgS)



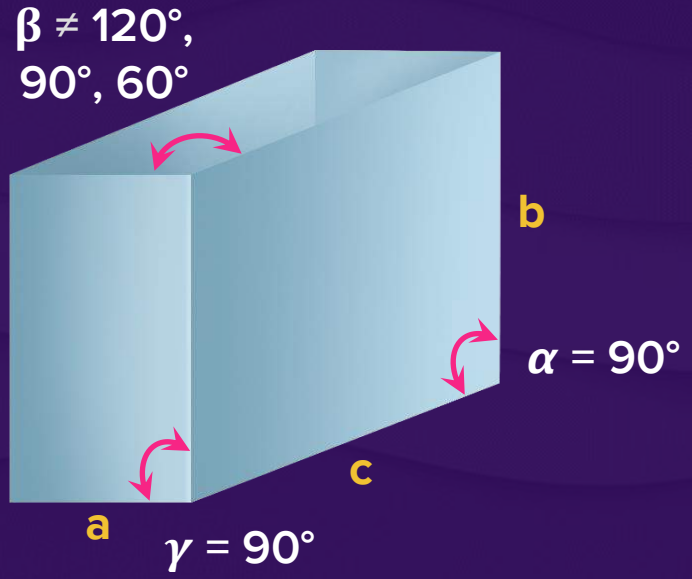
Crystal System



Monoclinic crystal system

Edge length	Angle
$a \neq b \neq c$	$\alpha = \gamma = 90^\circ$ $\beta \neq 120^\circ, 90^\circ, 60^\circ$

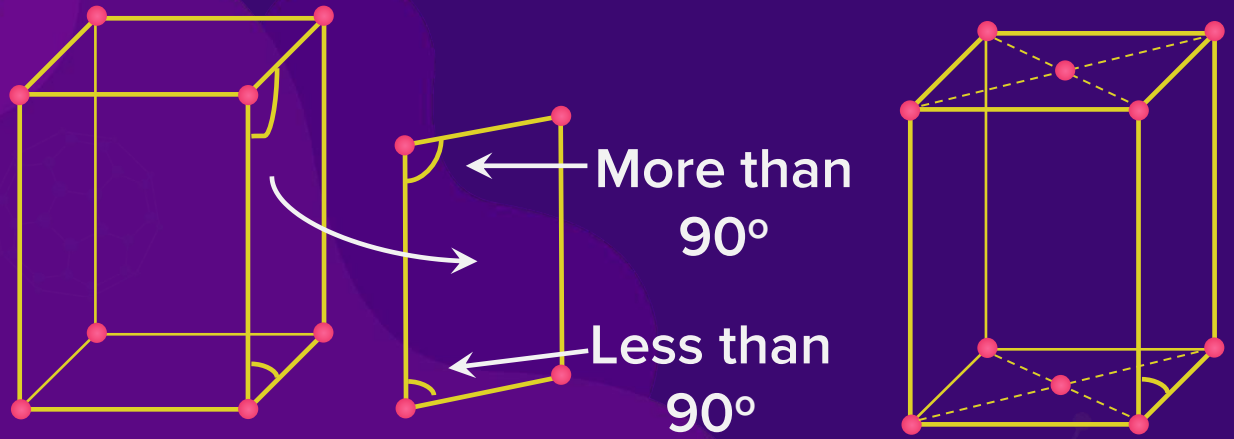
Unit cell found	Examples
Primitive, EC	Monoclinic sulphur, $Na_2SO_4.10H_2O$



Crystal System

Monoclinic system

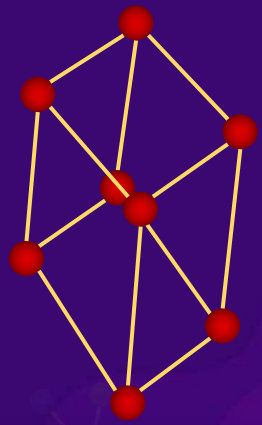
Simple (primitive) and end-centred unit cells are possible in a monoclinic crystal system.



Primitive

End Centered

Rhombohedral or trigonal



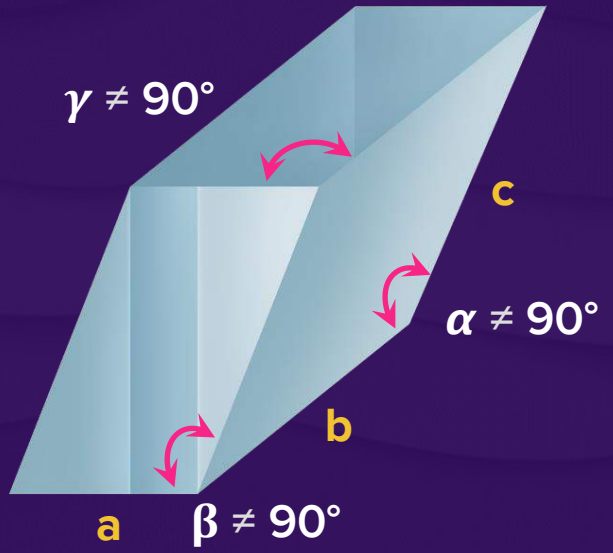
Primitive

Crystal System

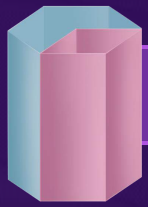
Triclinic crystal system

Edge length	Angle
$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$

Unit cell found	Examples
Primitive	$K_2Cr_2O_7$, $CuSO_4.5H_2O$, H_3BO_3



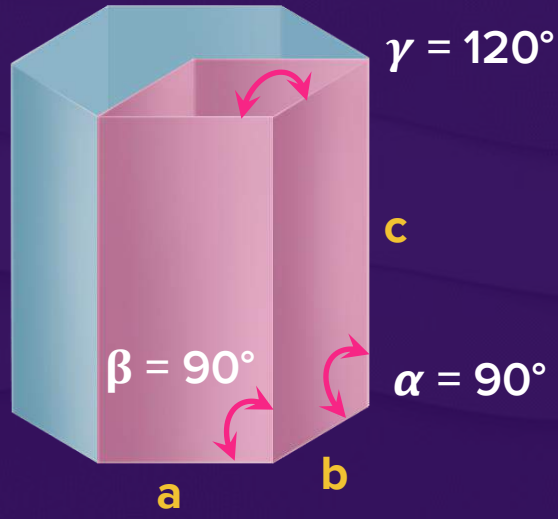
Crystal System



Hexagonal crystal lattice

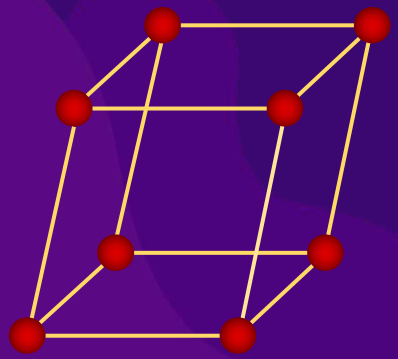
Edge length	Angle
a = b ≠ c	$\alpha = \beta = 90^\circ$ $\gamma = 120^\circ$

Unit cell found	Examples
Primitive	Graphite, ZnO, CdS



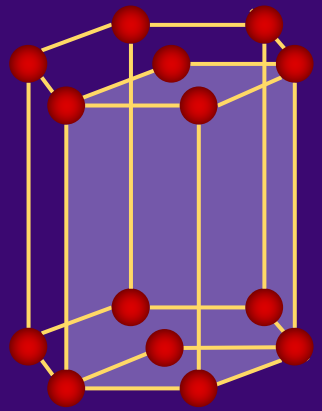
Crystal System

Triclinic



Primitive

Hexagonal



Primitive

Tetragonal crystal system has the following unit cell dimensions:

a. $a = b = c$ and $\alpha = \beta = \gamma = 90°$

b. $a = b \neq c$ and $\alpha = \beta = \gamma = 90°$

c. $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90°$

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

Solution

The tetragonal crystal system has only 2 sides equal and all 3 angles are equal to 90°.

Hence, option (b) is the correct answer.

In the primitive cubic unit cell, the atoms are present at the:

a. Corners of unit cell only

b. Centre of unit cell

c. Centre of each face of the unit cell

d. One set of faces of the unit cell

Solution

Primitive cubic unit cells have atoms present in the corner of the unit cell only.

Hence, option (a) is the correct answer.

For orthorhombic system edge lengths are $a \neq b \neq c$ and the axial angles are:

Solution

a. $\alpha = \beta = \gamma \neq 90°$

b. $\alpha = \beta = \gamma = 90°$

c. $\alpha = \gamma = 90°, \beta \neq 90°$

d. $\alpha \neq \beta \neq \gamma \neq 90°$

Hence, option (b) is the correct answer.

NaCl is a well-known example of:

Solution

a. Triclinic system

b. Tetragonal system

c. Monoclinic system

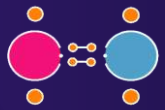
d. Cubic system

Crystal System

Crystal system	Edge length	Angles	Unit cell(s) found
Cubic	a = b = c	$\alpha = \beta = \gamma = 90^{o}$	Primitive, BCC, FCC
Tetragonal	a = b ≠ c	$\alpha = \beta = \gamma = 90^{o}$	Primitive, BC
Orthorhombic	a ≠ b ≠ c	$\alpha = \beta = \gamma = 90^{o}$	Primitive, BC, FC, EC

Crystal System

Crystal system	Edge length	Angles	Unit cell(s) found
Rhombohedral or Trigonal	a = b = c	$\alpha = \beta = \gamma \neq 90^\circ$	Primitive
Monoclinic	a ≠ b ≠ c	$\alpha = \gamma = 90^\circ$, $\beta \neq 90^\circ$	Primitive, EC
Triclinic	a ≠ b ≠ c	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	Primitive
Hexagonal	a = b ≠ c	$\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$	Primitive



Hint to memorize:

CuTeORHMT

The most unsymmetrical system is:

a Cubic

b Hexagonal

c Triclinic

d Orthorhombic

Solution

Unsymmetrical means neither any sides are equal nor any angles.
In triclinic system: a ≠ b ≠ c; $\alpha \neq \beta \neq \gamma \neq 90^{\circ}$.
Hence, option (c) is the correct answer.

The crystal system of a compound with unit cell dimensions, a = 0.387 and b = 0.387 and c = 0.504 nm and $\alpha = \beta = 90°$ and $\gamma = 120°$ is:

B

a Cubic

b Hexagonal

c Orthorhombic

d Rhombohedral

Solution

As we can see from given data; a = b ≠ c and $\alpha = \beta = 90^{\circ}$ and $\gamma = 120^{\circ}$. These parameters are best fit in a hexagonal crystal system.

Hence, option (b) is the correct answer.

In the body-centred unit cell, the lattice points are present at the:

a. Corners of the unit cell only

b. Corners and centre of the unit cell

c. Corners and centre of each face of the unit cell

d. Corners and at one set of faces of unit cell

B

If all three interfacial angles defining the unit cell are equal in magnitude, the crystals cannot be:

$\alpha = \beta = \gamma$

a. Rhombohedral

b. Cubic

c. Hexagonal

d. Tetragonal

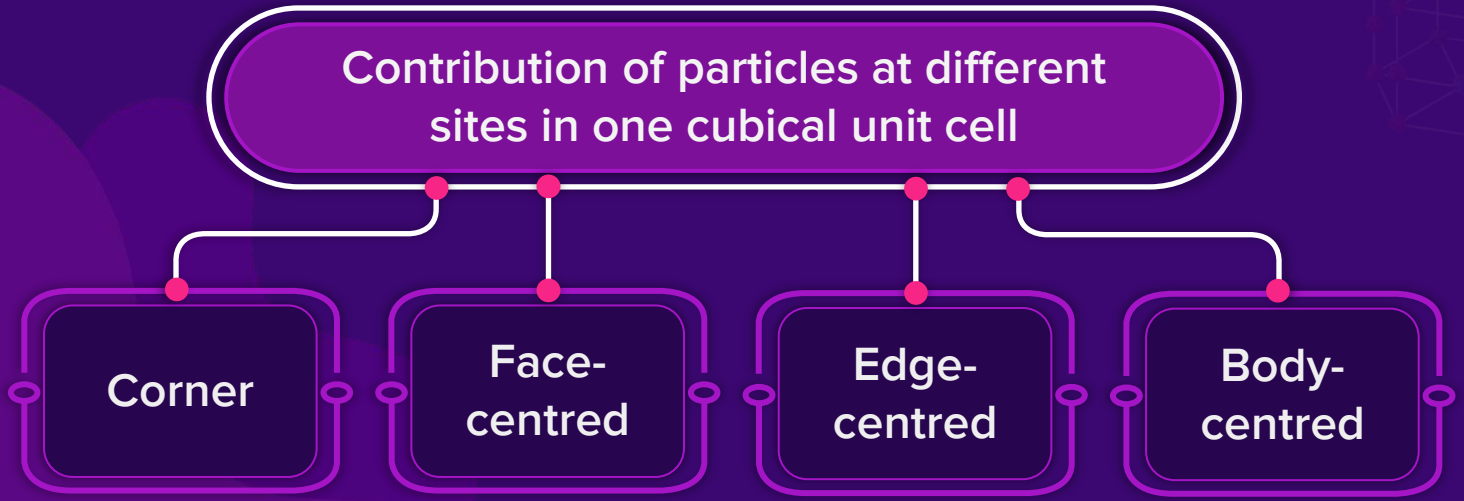
Solution

Angles in rhombohedral, cubic, tetragonal are equal but in hexagonal they are not equal.

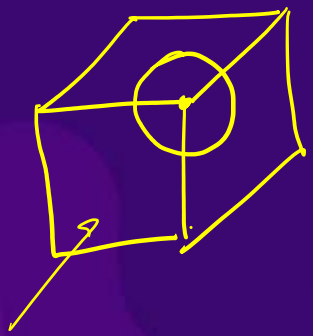
Hence, option (c) is the correct answer.

Contribution of Particles at Different Sites

Contribution of Particles



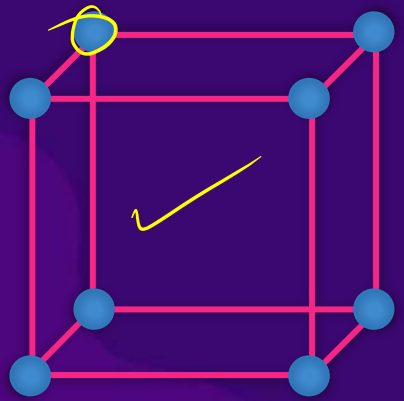
Contribution of Corner Particles

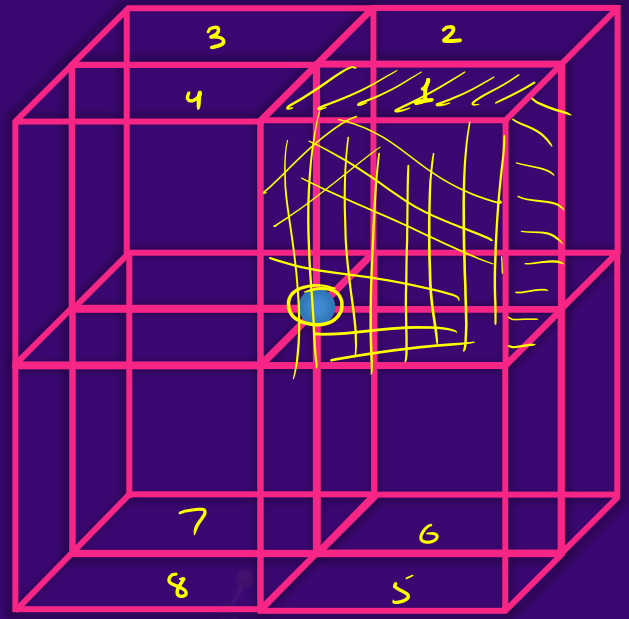


A particle at the corner of a unit cell is shared by **eight unit cells**.

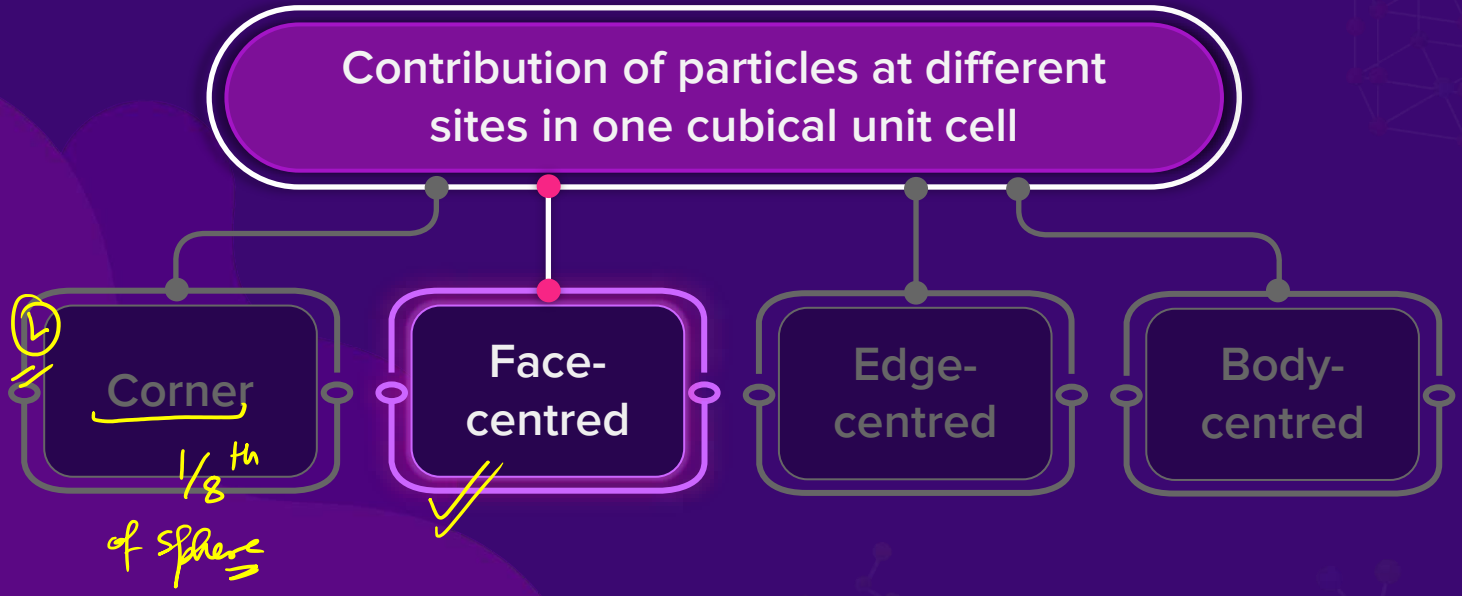
Contributes **1/8** part to the unit cell.

Contribution of Corner Particles



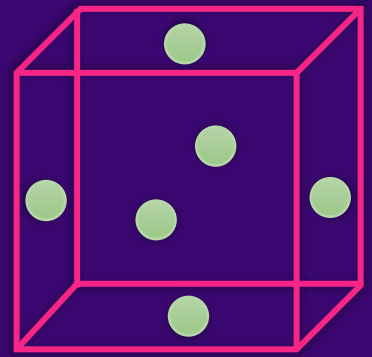


Contribution of Face-Centred Particles

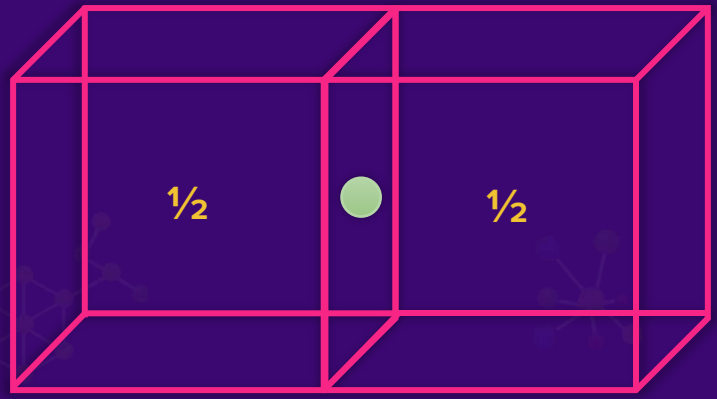


Contribution of Face-Centred Particles

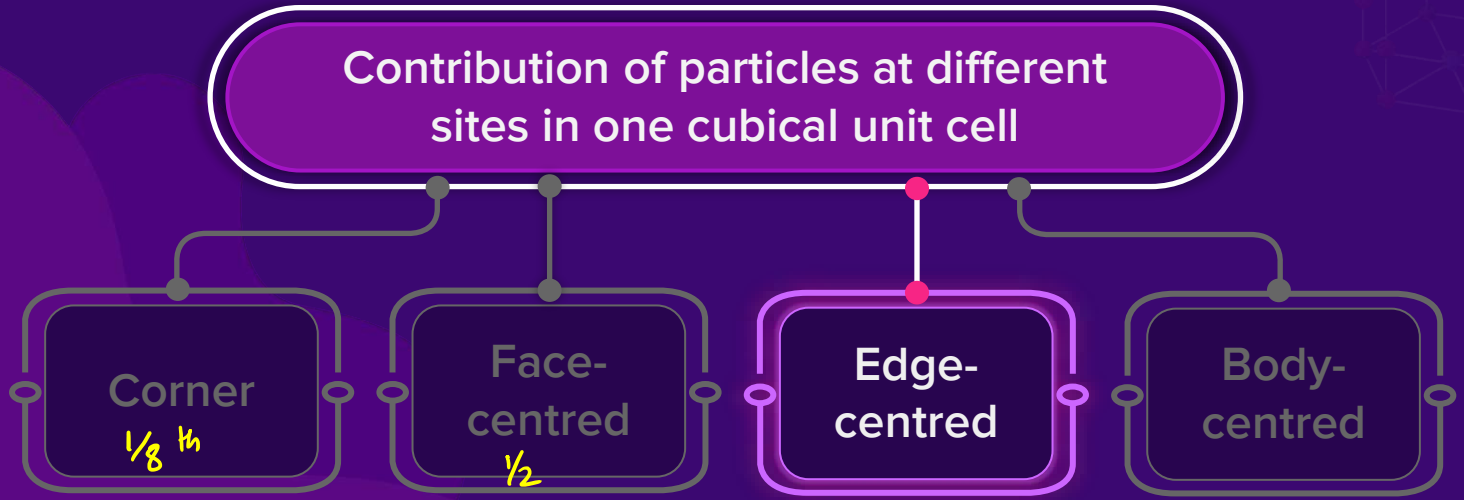
A particle at the face-centre is shared by **two unit cells**.



Contributes ½ part to the unit cell.



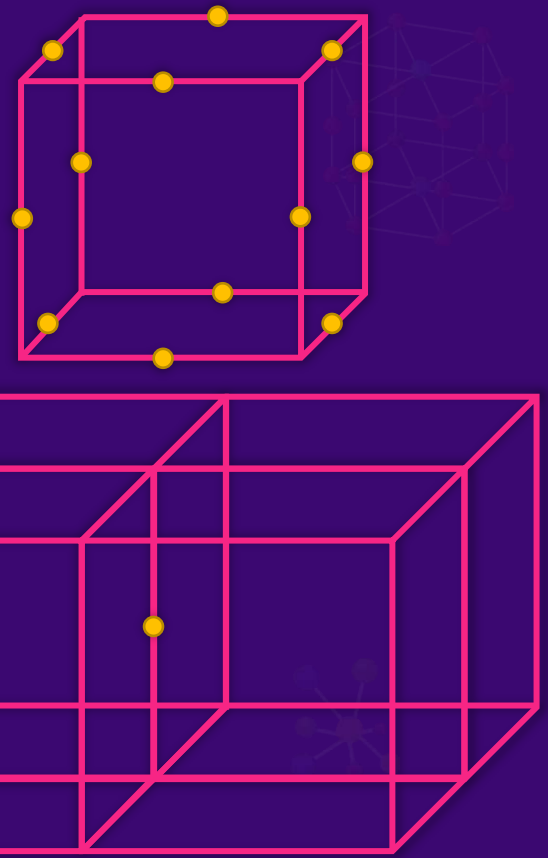
Contribution of Edge-Centred Particles



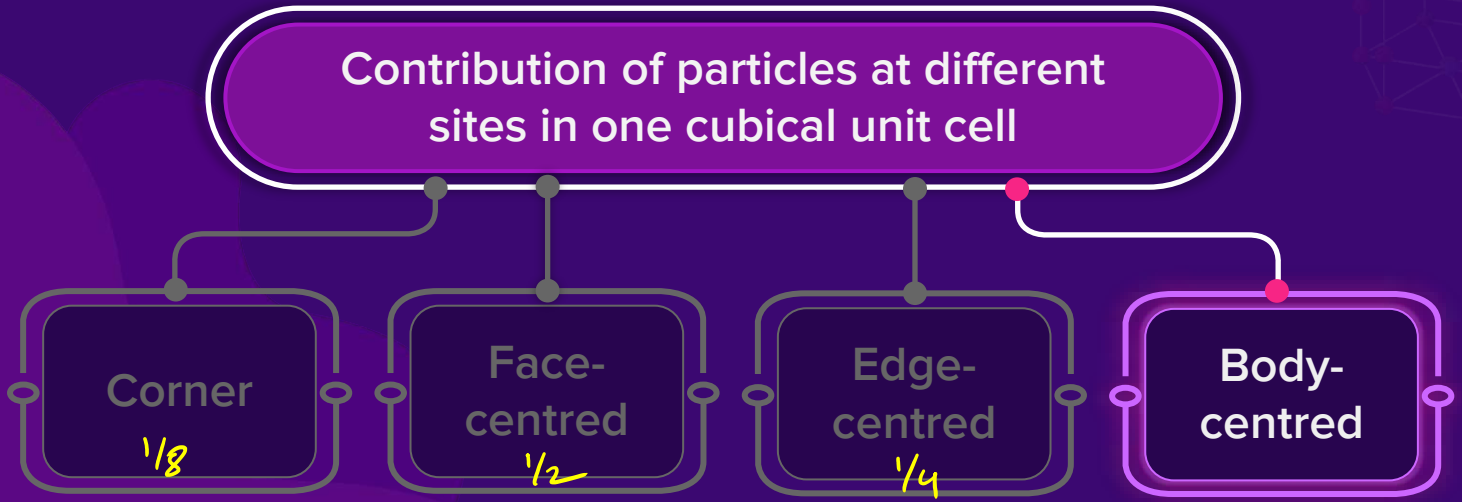
Contribution of Edge-Centred Particles

A particle present at the edge-centre is shared by **four unit cells**.

Contributes ¼ part to the unit cell.



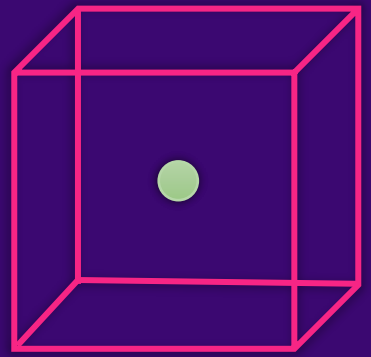
Contribution of Body-Centred Particles

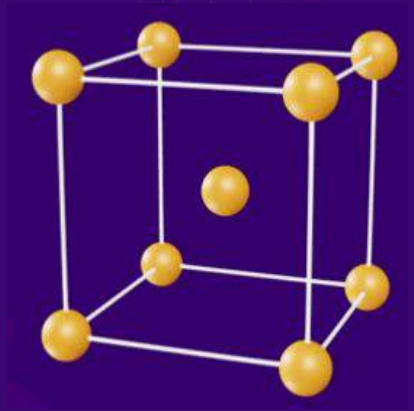


Contribution of Body-Centred Particles

A particle present at the body-centre wholly belongs to the **unit cell** in which it is present.

Contributes **1 part** (fully) to the unit cell.





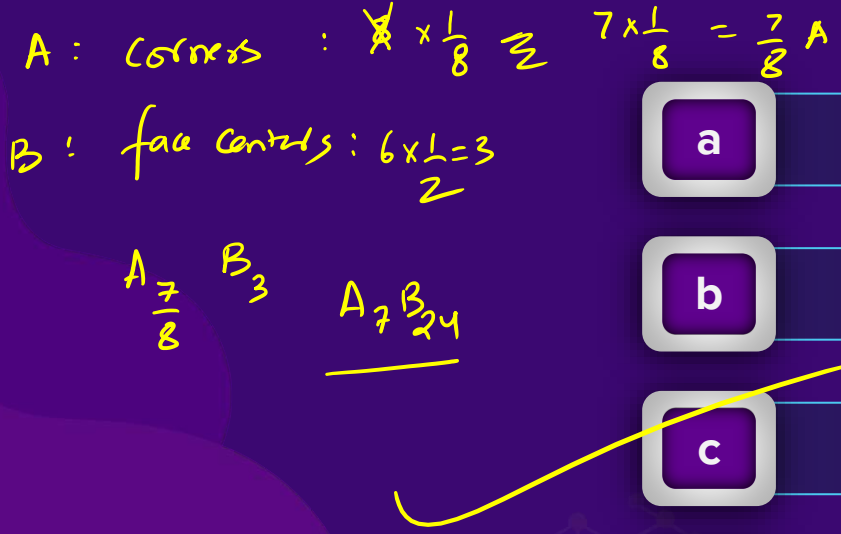
Contribution of Particles

of a sphere is present on

1. Corner → $\frac{1}{8}^{th}$ fraction of sphere inside the cube
2. edge center → $\frac{1}{4}^{th}$,,
3. face center → $\frac{1}{2}$,,
4. body center → 1 ⇒ fully inside

In a face-centred cubic arrangement of A and B atoms, A-atoms are at the corner of the unit cell and B atoms at the face-centres. One of the A atom is missing from one corner in the unit cell. What is the simplest formula of the compound?

Solution



a. A_7B_3

b. AB_3

c. A_7B_{24}

d. A_2B_3

A compound has cubical unit cell in which X atoms are present at 6 corners, Y atoms are at the remaining corners & only at those face-centres that are not opposite to each other, and Z atoms are present at remaining the face-centres and body-centre. Find the formula of the compound.

Solution

X 6 corners : $6 \times \frac{1}{8} = \frac{3}{4}$

Y 2 corners + 3 faces

$2 \times \frac{1}{8} + 3 \times \frac{1}{2} = \frac{1}{4} + \frac{3}{2} = 7/4$

Z 3 faces + bc

$3 \times \frac{1}{2} + 1 = \frac{5}{2} = \frac{10}{4}$

X : Y : Z : $\frac{3}{4} : \frac{7}{4} : \frac{10}{4}$ = $X_3Y_7Z_{10}$

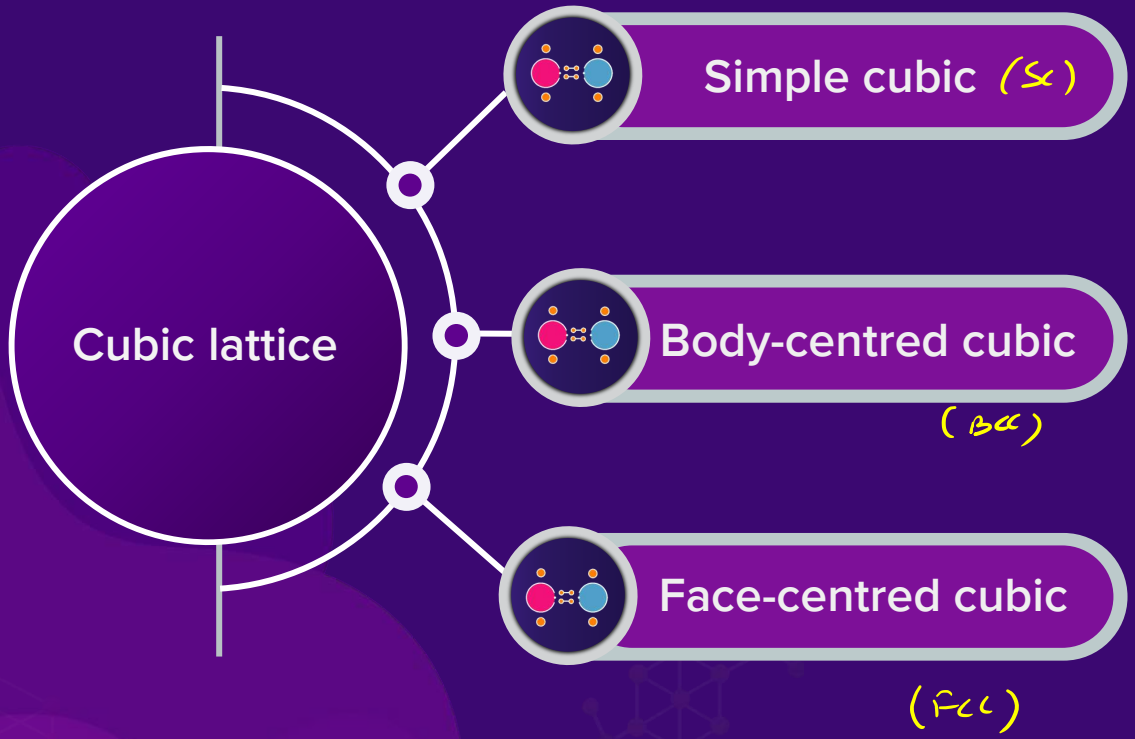
a. $X_7Y_3Z_{10}$

b. XY_7Z_{10}

c. $X_3Y_7Z_{10}$

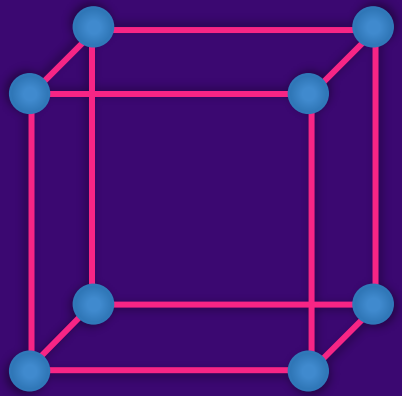
d. $X_{10}Y_7Z_3$

Cubic Lattice



Simple/Primitive Cubic Unit Cell

$8 \times \frac{1}{8} = 1$

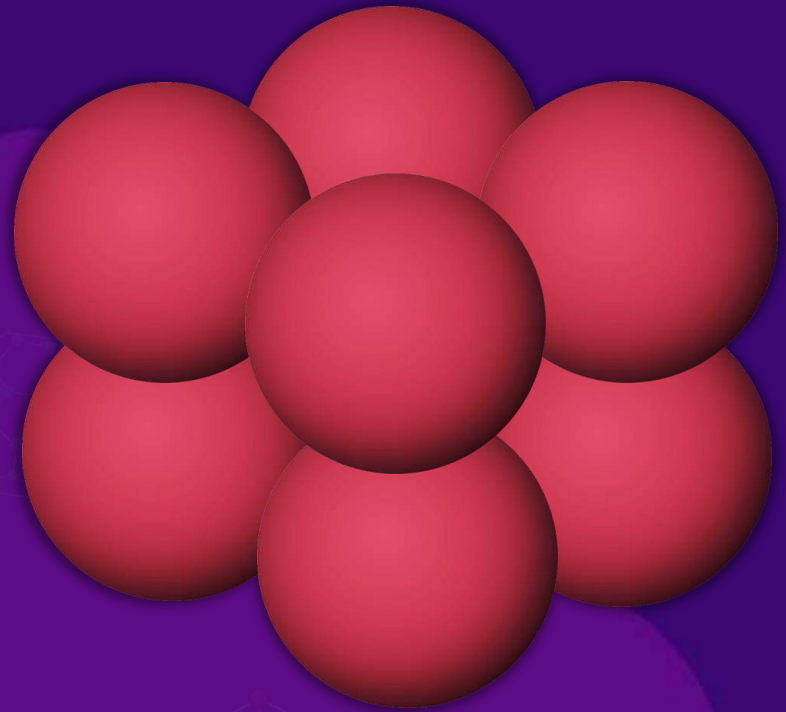


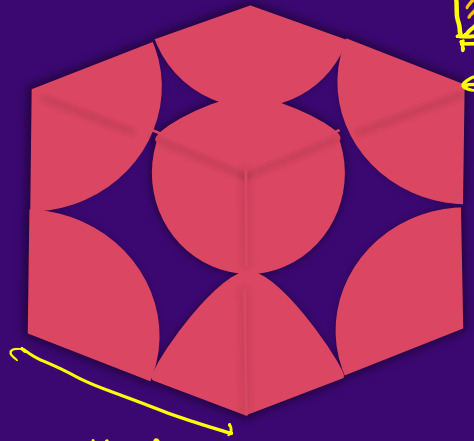
Effective number of particles in a unit cell $= 8 \times \frac{1}{8} = 1$

= occupancy of unit cell

Simple Cubic Unit Cell

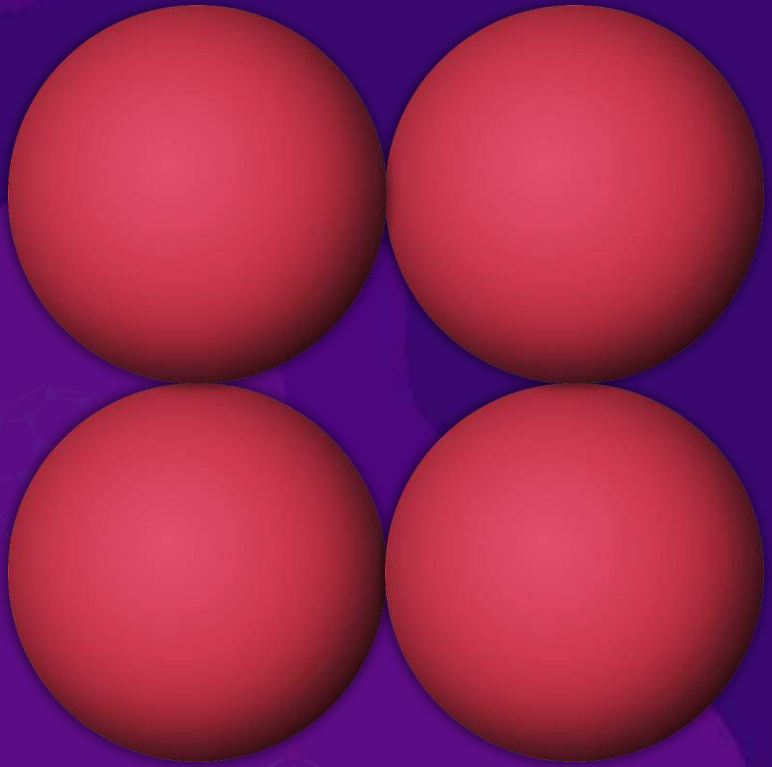
simple cubic





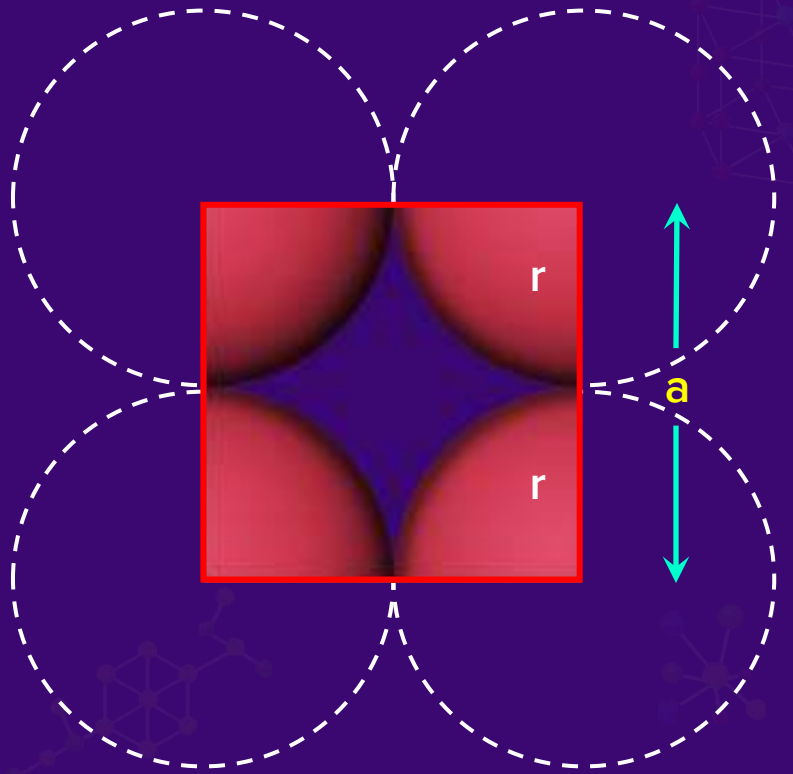
edge length of cube = $a = 2r$

Simple Cubic Unit Cell



Face of a simple cubic unit cell

$a = 2r \quad \therefore r = \frac{a}{2}$



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

Simple Cubic Unit Cell

Relation between a & r

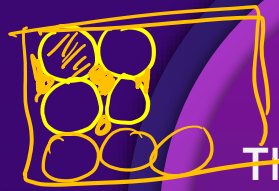
Corner atoms are touching each other.

$$a = 2r$$

- a = Edge length of a SC unit cell
- r = Radius of a particle present in that unit cell

Packing Efficiency

: Volume actually occupied by atoms/unit cell × 100
Total volume of crystal



The percentage of the total space filled by the particles

Packing Efficiency (P.E.)

vol. of cube $= a^3$

For 3-D arrangement

a = edge length

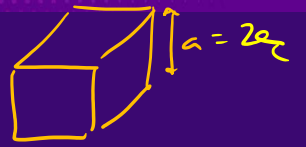
$$\text{P.E.} = \frac{\text{Volume occupied by particles in a unit cell}}{\text{Total volume of the unit cell}} \times 100$$

$$= \frac{Z \times \text{Volume of one particle}}{\text{Total volume of the unit cell}} \times 100$$

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

- Z = Effective number of atoms in the unit cell (one cube)

Packing Efficiency (P.E.)



Vol. of sphere $= \frac{4}{3}\pi r^3$

Total volume occupied by particles	=	$1 \times \frac{4}{3}\pi r^3$

Vol. of unit cell $= a^3 = (2r)^3 = 8r^3$

Volume of the unit cell	=	a^3	=	$(2r)^3$

$$\eta = \frac{V_{sphere} \times 1\omega}{V_{cube}} = \frac{\frac{4}{3}\pi r^3}{8r^3} \times \omega = \frac{\pi}{6} \times 1\omega = \underline{\quad}\%$$

Packing Efficiency (P.E.)

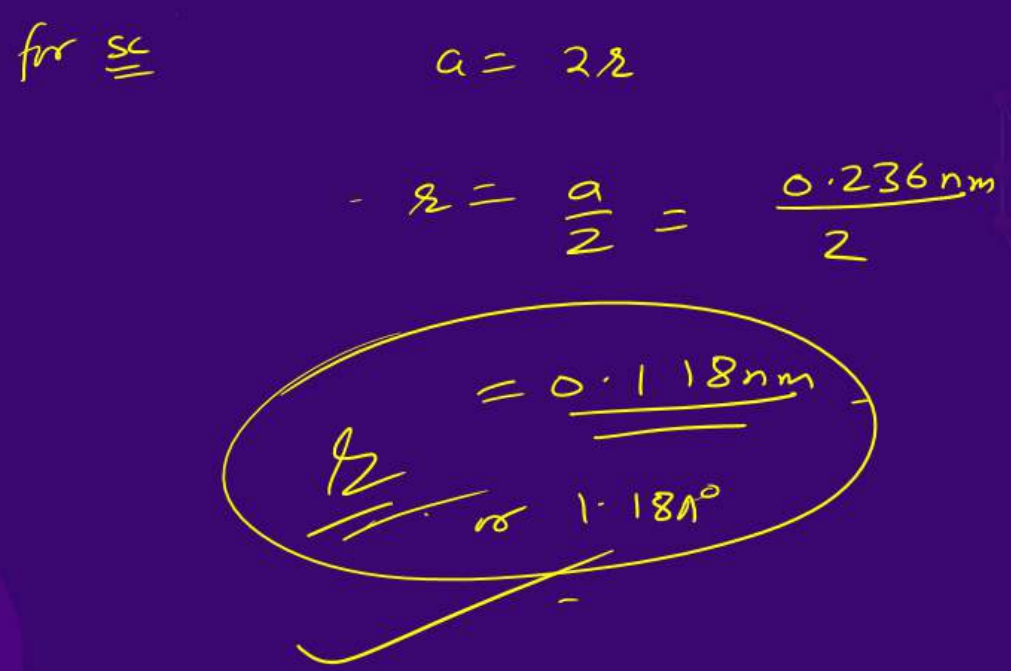
$$\text{P.E.} = \frac{1 \times (4/3)\pi r^3}{(2r)^3} \times 100$$

$$\eta \text{ (eta)} = \frac{\pi \times 100}{6}$$

$$\eta \simeq 52.33\%$$

Polonium crystallizes in a simple cubic structure. The edge of the unit cell is 0.236 nm. What is the radius of one polonium atom:

Solution



a. 0.144 nm

b. 0.156 nm

c. 0.118 nm

d. 0.102 nm

Hence, option (c) is the correct answer.

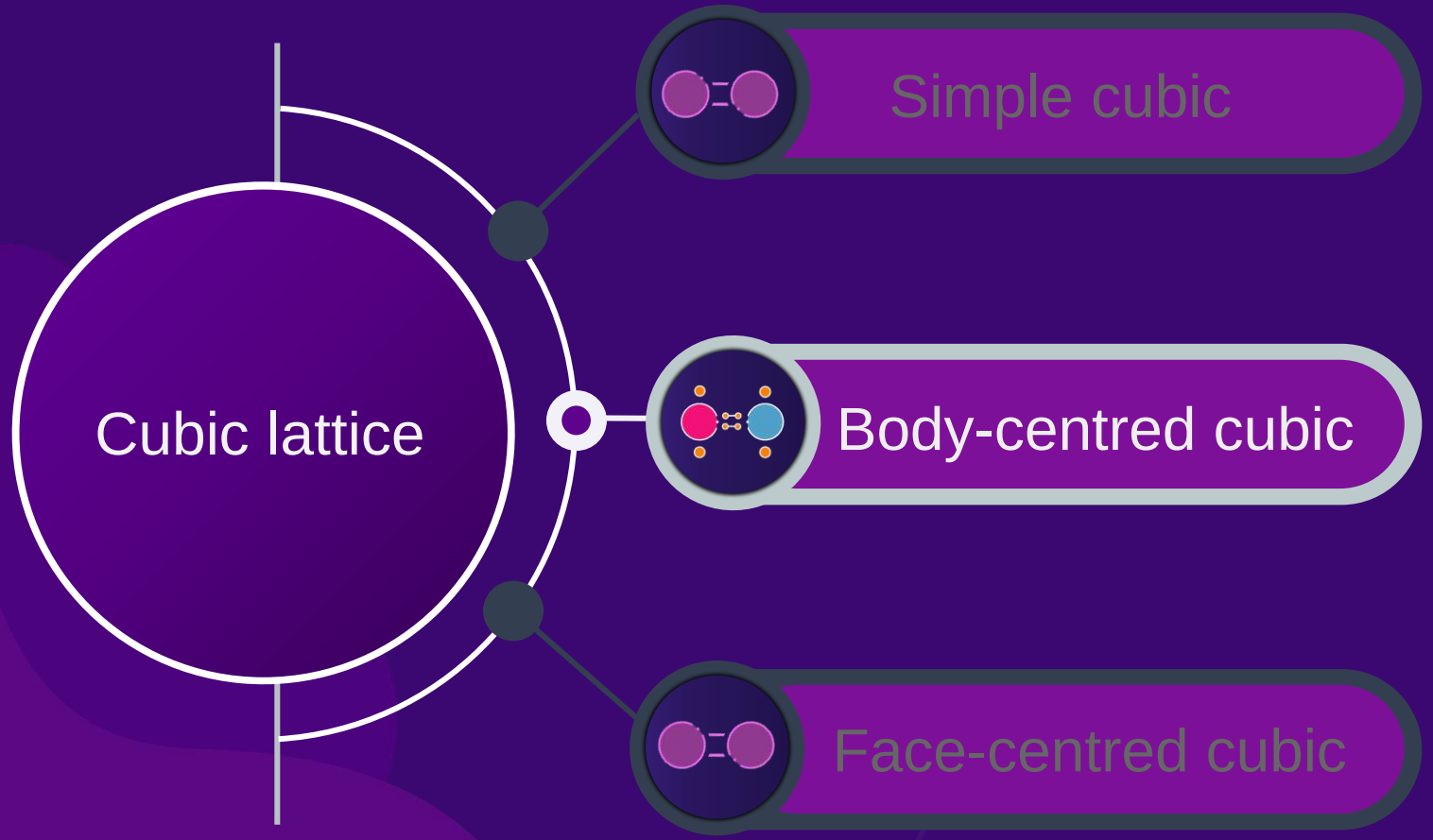
The fraction of volume occupied by atoms in a primitive cubic unit cell is nearly:

Solution

The fraction of volume occupied by atoms in a primitive cubic unit cell is nearly 0.52.

Hence, option (b) is the correct answer.

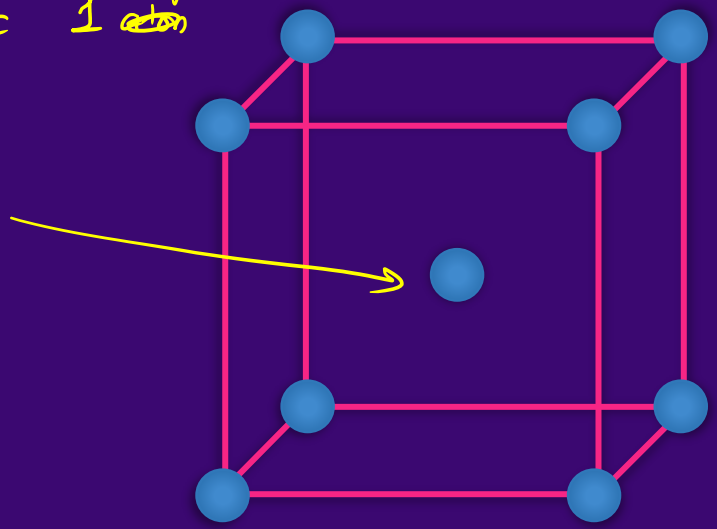
- **a** 0.48
- **b** 0.52
- **c** 0.55
- **d** 0.68


Cubic lattice
Simple cubic
Body-centred cubic
Face-centred cubic

Body-Centred Cubic Unit Cell

8 corner : $8 \times \frac{1}{8} = 1$ Sphere

+ 1 sphere at (BC)



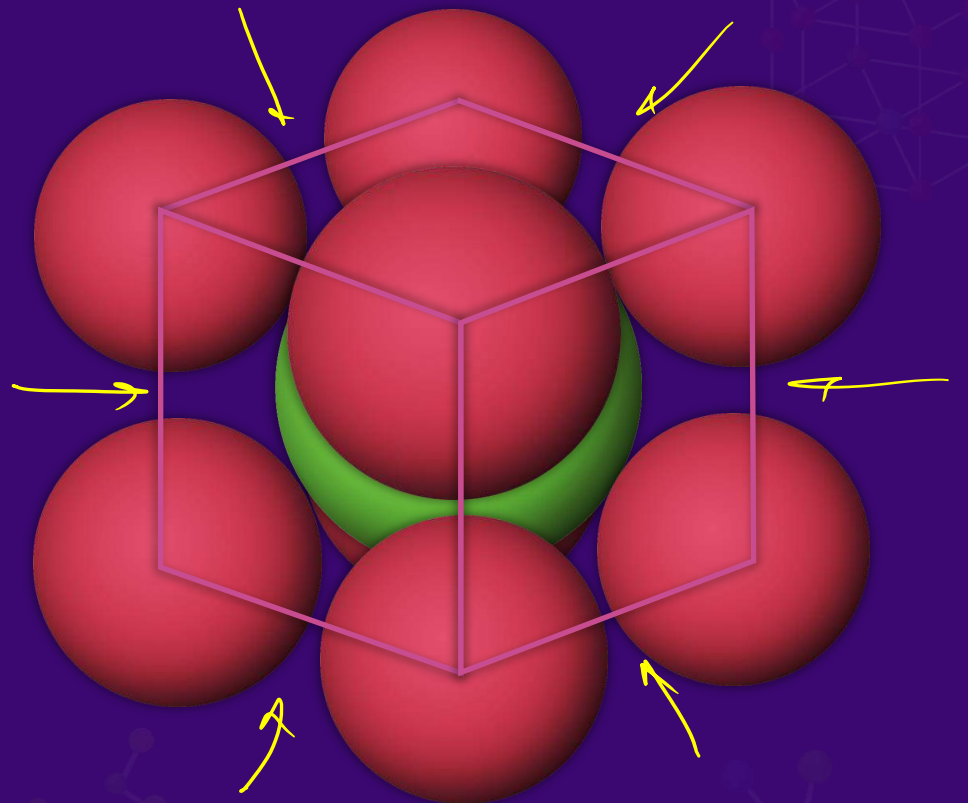
Effective number of particles in a unit cell $= 8 \times \frac{1}{8} + (1 \times 1) = 2$

(Z = 2)

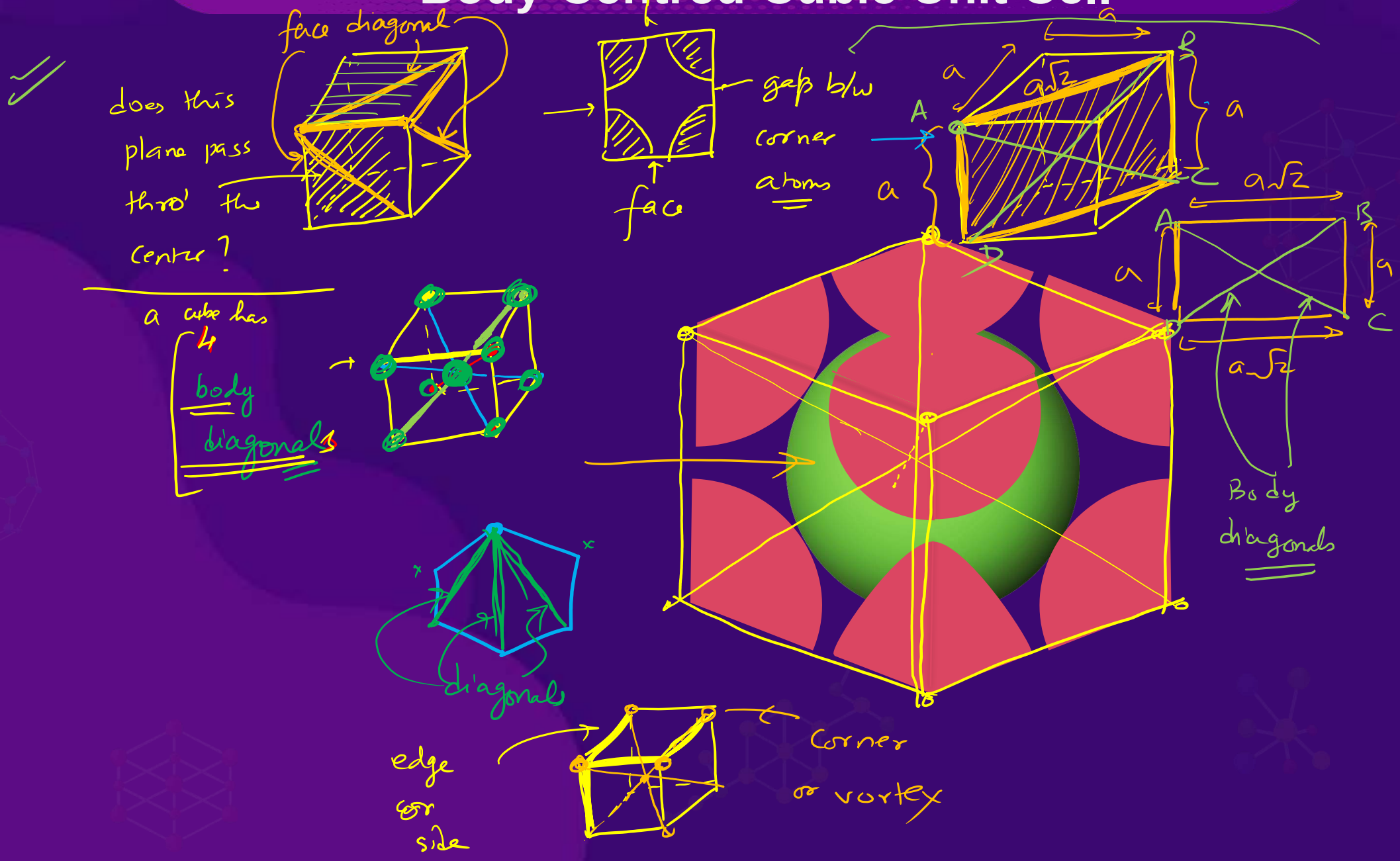
Body-Centred Cubic Unit Cell

In bcc ; Corner atom do not touch each other.

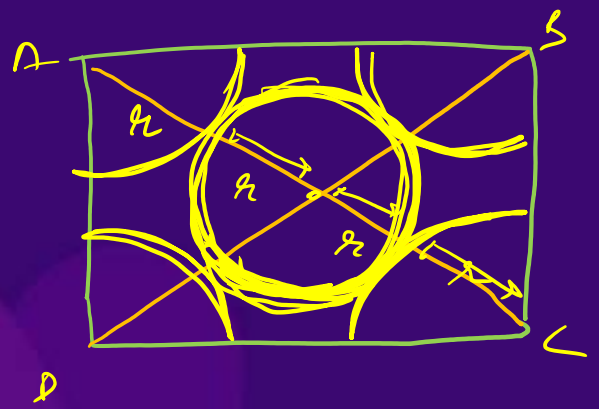
All 8 of them touch the atom at body center.



Body-Centred Cubic Unit Cell



Body-Centred Cubic Unit Cell

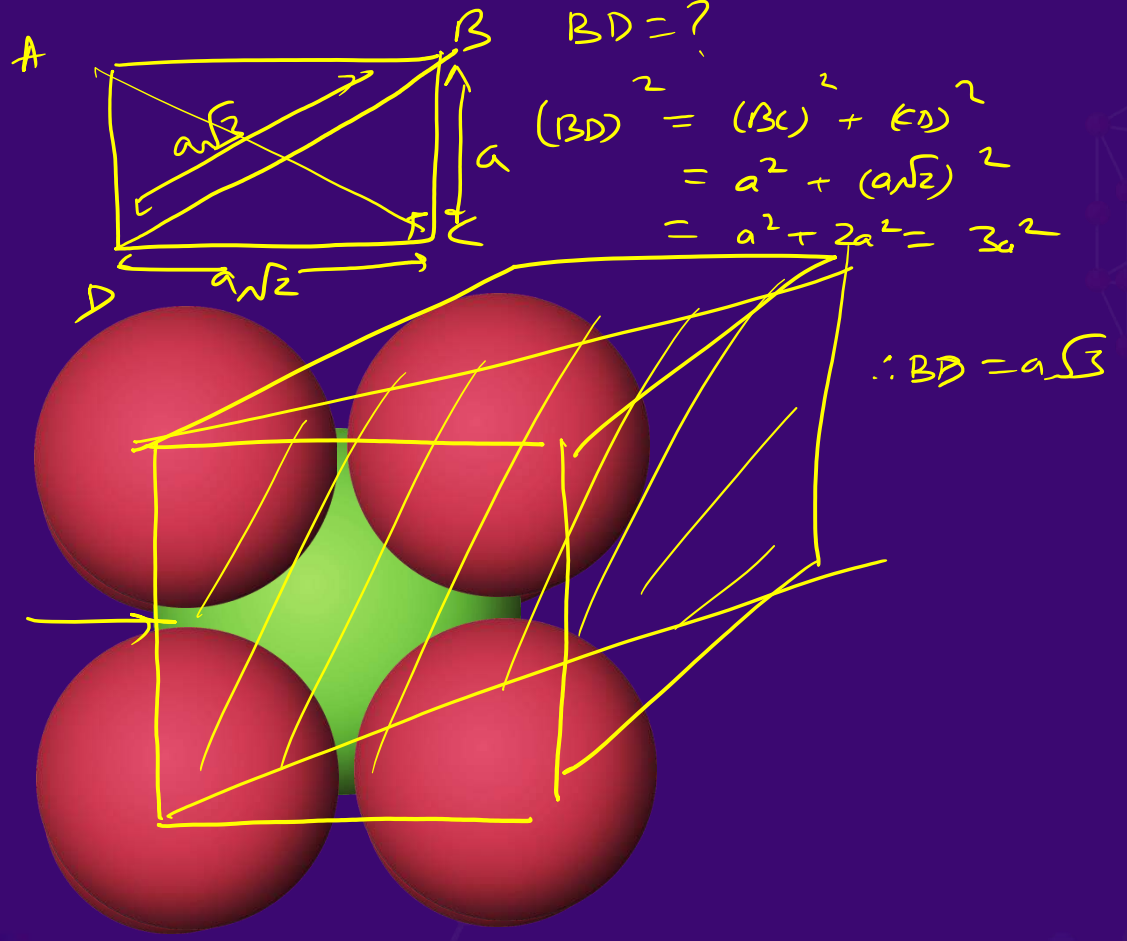


$l(AC) = R + r + r + R$

$= 4R$

$= a\sqrt{3}$

$\therefore \boxed{R = \frac{a\sqrt{3}}{4}}$ for bcc structure



$BD = ?$

$(BD)^2 = (BC)^2 + (CD)^2$

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

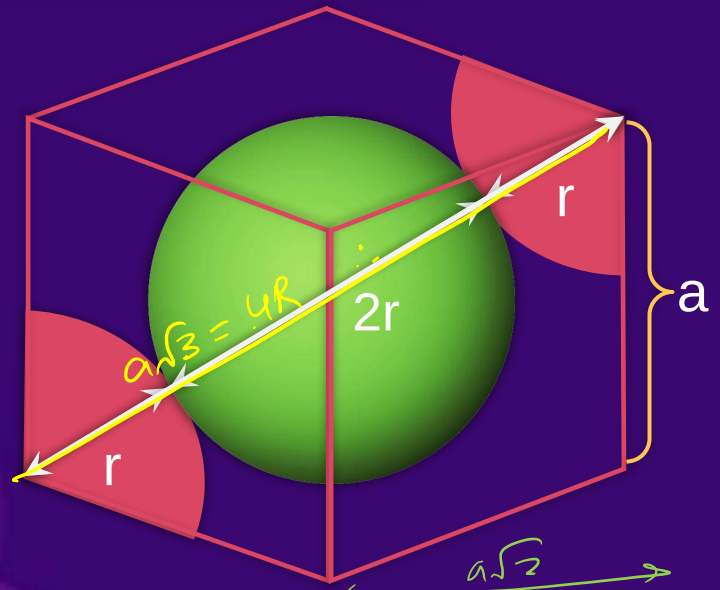
$= a^2 + 2a^2 = 3a^2$

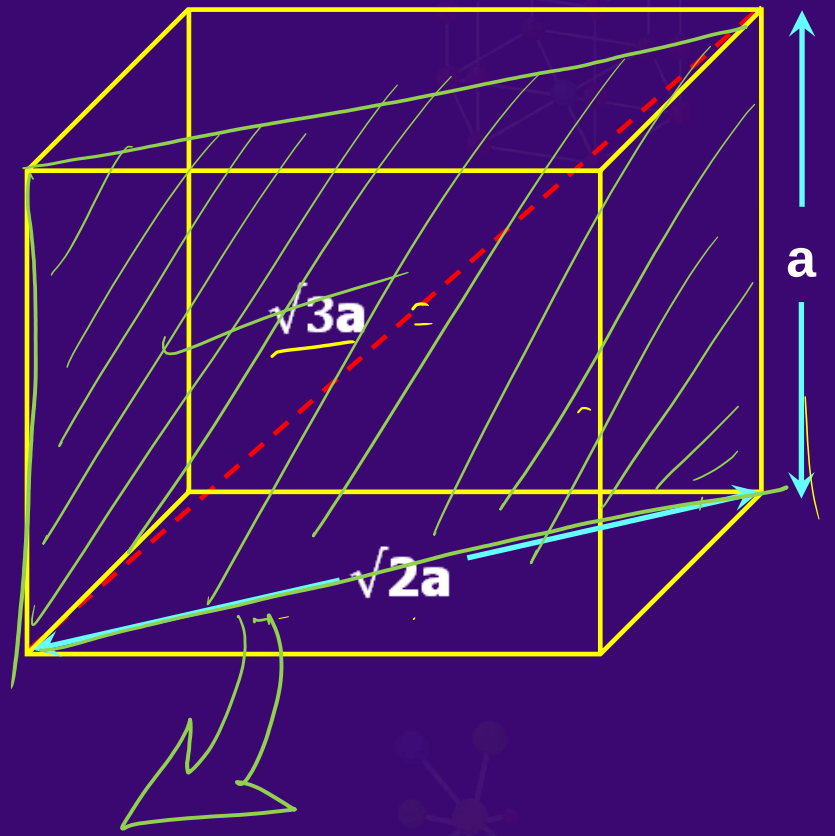
$\therefore BD = a\sqrt{3}$

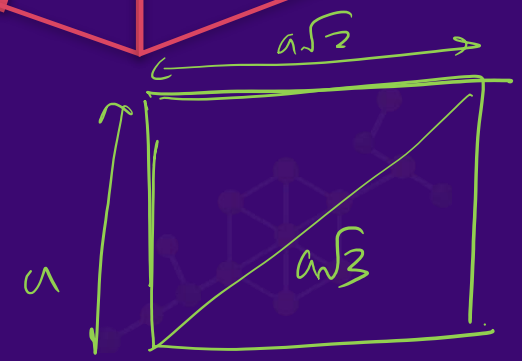
Face of a body-centred cubic unit cell

Body-Centred Cubic Unit Cell

Spheres are **not touching** along the **edge**.
They are **touching** along the **body diagonal**.







Body-Centred Cubic Unit Cell

Relation between a & r

Along the **body diagonal**

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

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

Or

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

Packing Efficiency (P.E.)

For **3D** arrangement

$$\text{P.E.} = \frac{\text{Volume occupied by particles in a unit cell}}{\text{Total volume of the unit cell}} \times 100$$

$$= \frac{Z \times \text{Volume of one particle}}{\text{Total volume of the unit cell}} \times 100$$

Packing Efficiency (P.E.)

Total volume occupied by particles $= 2 \times \frac{4}{3}\pi r^3$

Volume of the unit cell $= a^3 = (4r/\sqrt{3})^3$

$$\eta = \frac{2 * \text{Vol. of 1 sphere}}{a^3}$$

$$= \frac{\left(2 \times \frac{4}{3}\pi r^3\right)}{\left(\frac{4}{\sqrt{3}} r\right)^3} = \frac{2 \times 4\pi r^3}{3 \times 4 \times 4 \times 4} = \frac{\pi\sqrt{3}}{8}$$

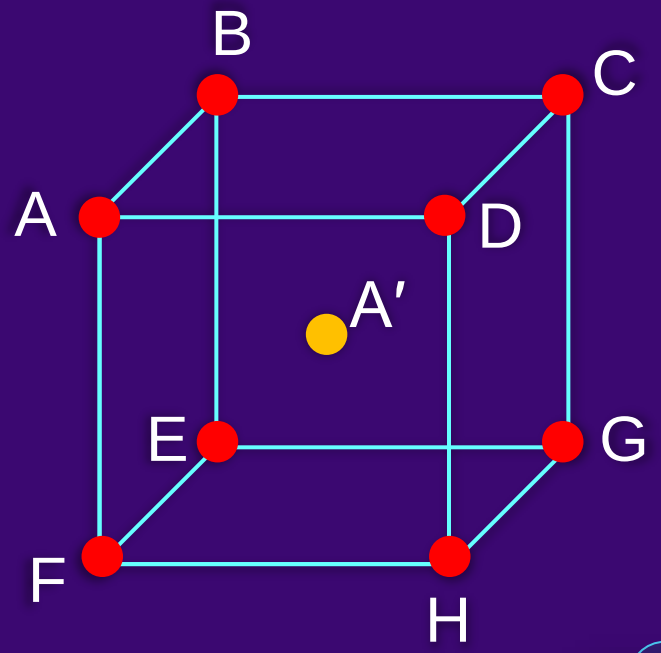
Packing Efficiency (P.E.)

$$\text{Packing efficiency} = \frac{2 \times (4/3)\,\pi r^3}{(4r/\sqrt{3})^3} \times 100$$

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

$$\approx 68\%$$

In the **body-centred cubic** lattice given below, which of the following options is **incorrect**?



a AB = a

b AC = $\sqrt{2}a$

c $AA' = \frac{\sqrt{3}a}{2}$

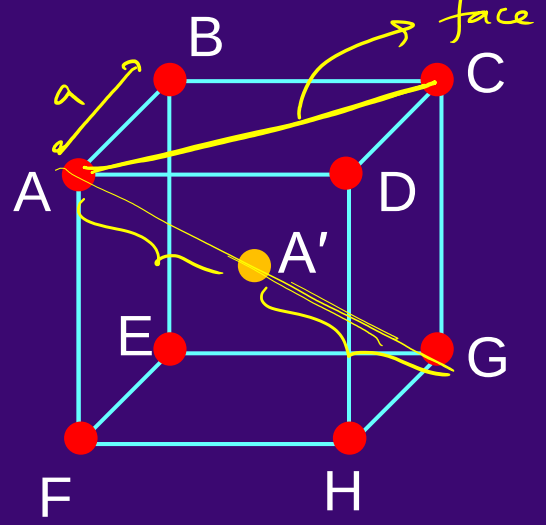
d $AA' = \sqrt{3}a$

Solution

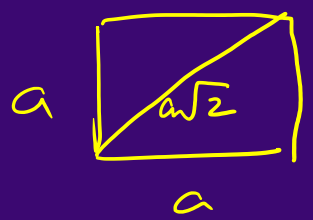
$AA' + A'G =$ Body diagonal AG

$2(AA') = a\sqrt{3}$

$\therefore AA' = \frac{a\sqrt{3}}{2}$



diagonal



a $AB = a$ — Correct

b $AC = \sqrt{2}a$ — Correct

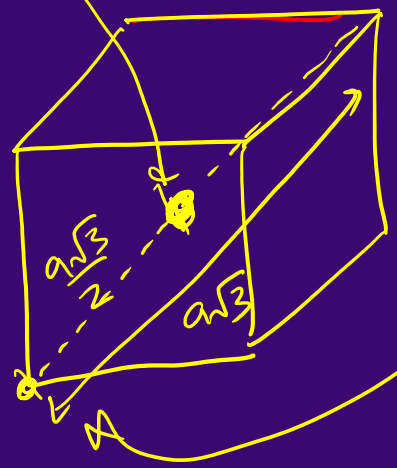
c $AA' = \frac{\sqrt{3}a}{2}$ — Correct

d $AA' = \sqrt{3}a$

$AG = a\sqrt{3}$

Hence, option (d) is the correct answer.

If 'a' is the length of the side of a cube, the distance between the body-centred atom and one corner atom in the cube will be:



a. $\frac{2}{\sqrt{3}}a$

b. $\frac{4}{\sqrt{3}}a$

c. $\frac{\sqrt{3}}{4}a$

d. $\frac{\sqrt{3}}{2}a$

Hence, option (d) is the correct answer.

The vacant space in a bcc lattice unit cell is:

Solution

68% occupied

100 − 68 = 32% vacant

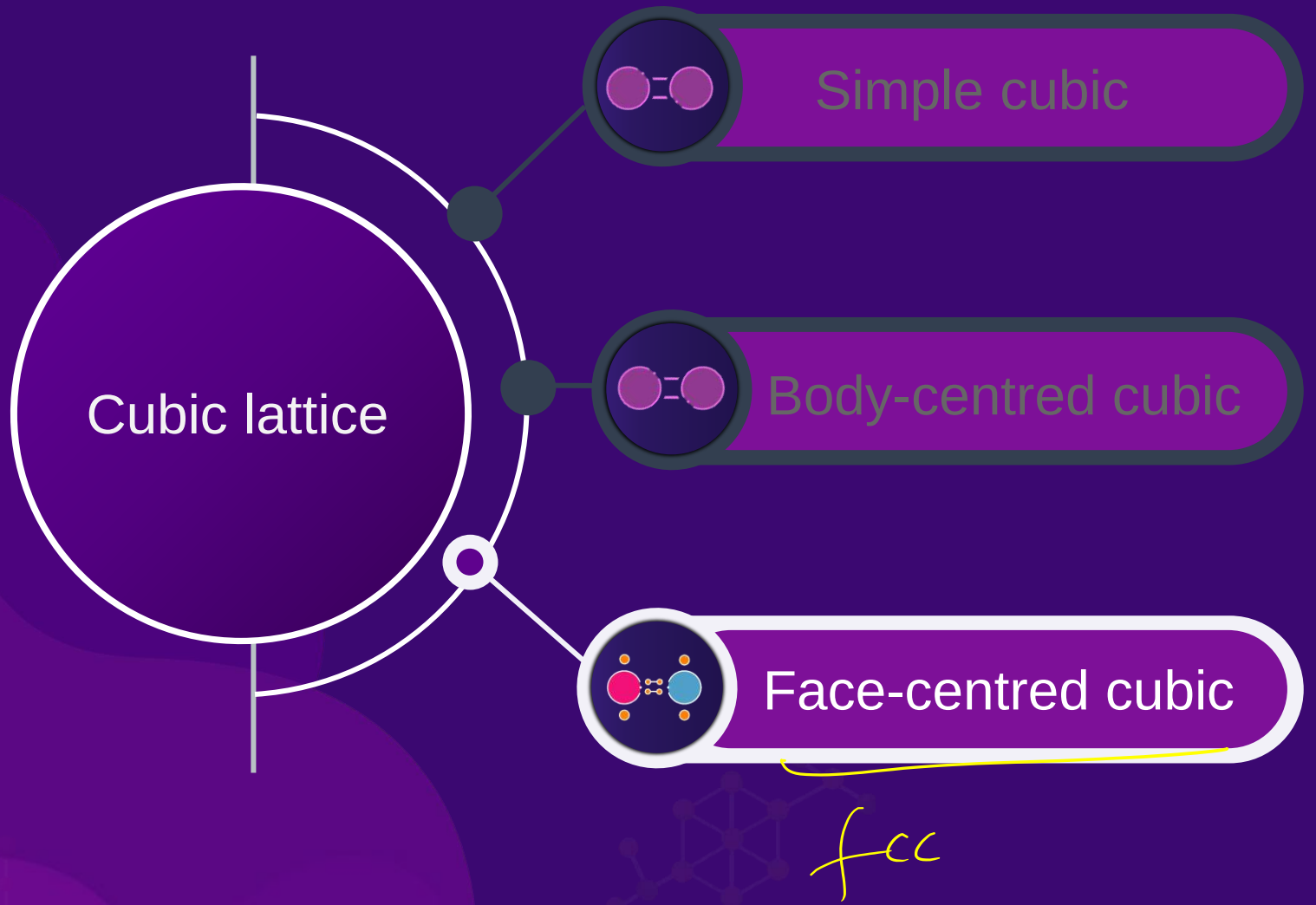
a. 48%

b. 32%

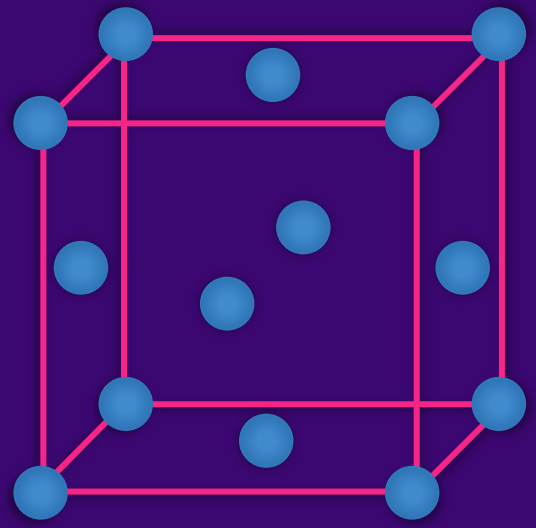
c. 23%

d. 26%

Face-Centred Cubic Unit Cell

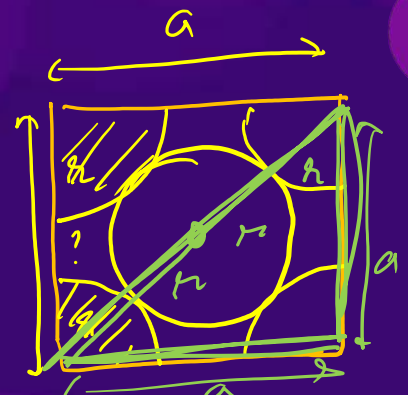


Face-Centred Cubic Unit Cell



Effective number of particles in a unit cell $= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

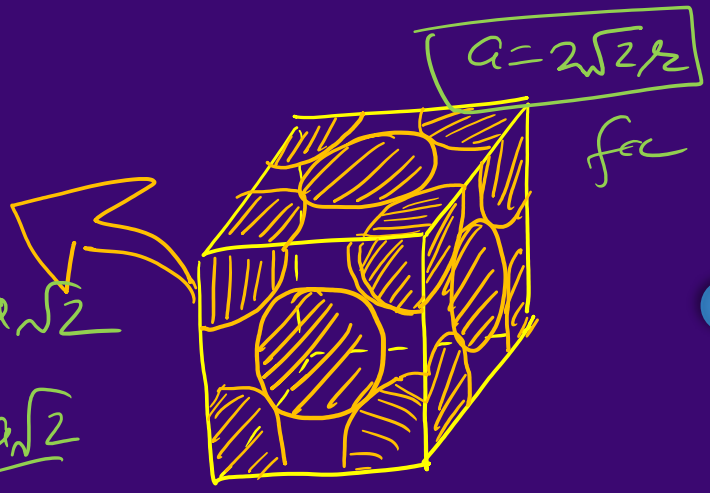
Face-Centred Cubic Unit Cell



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

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

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



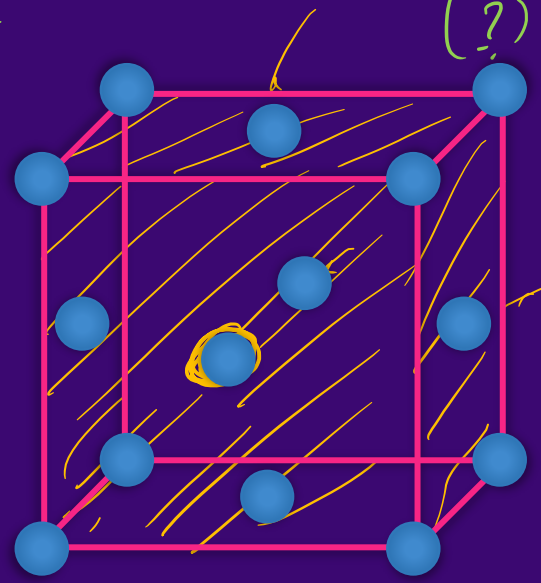
$a = 2\sqrt{2}r$

fcc

8 corner : $8 \times \frac{1}{8} = 1$

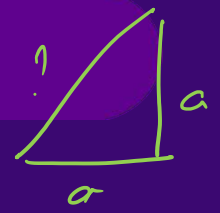
6 faces : $6 \times \frac{1}{2} = 3$

$1 + 3 = 4$



$(?)^2 = a^2 + a^2 = 2a^2$

$\therefore ? = a\sqrt{2}$



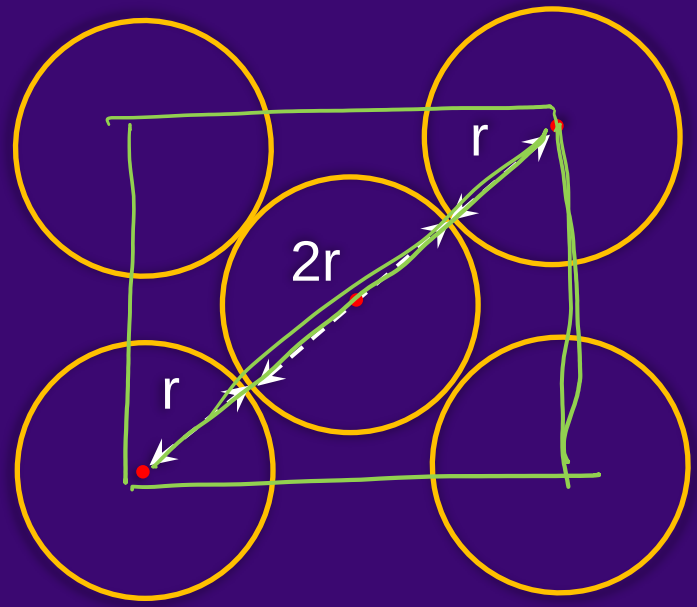
Effective number of particles in a unit cell $= 8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 4$

$Z = 4$ for fcc

Face-Centred Cubic Unit Cell

Relation between a and r

Face of unit cell



Spheres are touching along the face diagonal

$$a > 2r$$

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

Packing Efficiency in FCC

$$\text{P.E.} = \frac{4 \times (4/3)\,\pi r^3}{\left(\frac{4r}{\sqrt{2}}\right)^3} \times 100$$

$$= \frac{\pi \times 100}{3\sqrt{2}}$$

$$\approx 74\%$$

Copper crystallizes in a face-centred cubic lattice with a unit cell length of 361 pm. What is the radius of copper atom in pm?

a. 157

b. 181

c. 108

d. 128

$r = \frac{361}{2\sqrt{2}}\ pm \simeq \frac{360}{2\sqrt{2}}$

$a = 361 = 2\sqrt{2}r$

$= \frac{180}{\sqrt{2}} \quad \left(\frac{1}{\sqrt{2}} \simeq 0.7071\right)$

$\simeq 184 \times 0.7 \simeq 126\ pm$

	η	a	Z
SC	$\simeq 52\%$	$a = 2R$	1
BCC	$\simeq 68\%$	$a = \frac{4}{\sqrt{3}}R$	2
FCC	$\simeq 74\%$	$a = \frac{4}{\sqrt{2}}R = 2\sqrt{2}R$	4

Hence, option (d) is the correct answer.

The fcc crystal contains how many effective atoms in each unit cell?

Solution

In fcc crystal contains, effective atoms in each unit cell is 4.

a. 6

b. 8

c. 4

d. 5

Lithium metal crystallizes in a body-centred cubic crystal. If the length of the side of the unit cell of lithium is 351 pm, the atomic radius of lithium will be:

B

Solution

$a = 351$ $\quad r = ? = \frac{\sqrt{3}}{4} a = \frac{\sqrt{3}}{4} \times 351$

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

$< \frac{\sqrt{3}}{4} \times 360^{90}$

1.732×90

$15 \quad 1w$

150

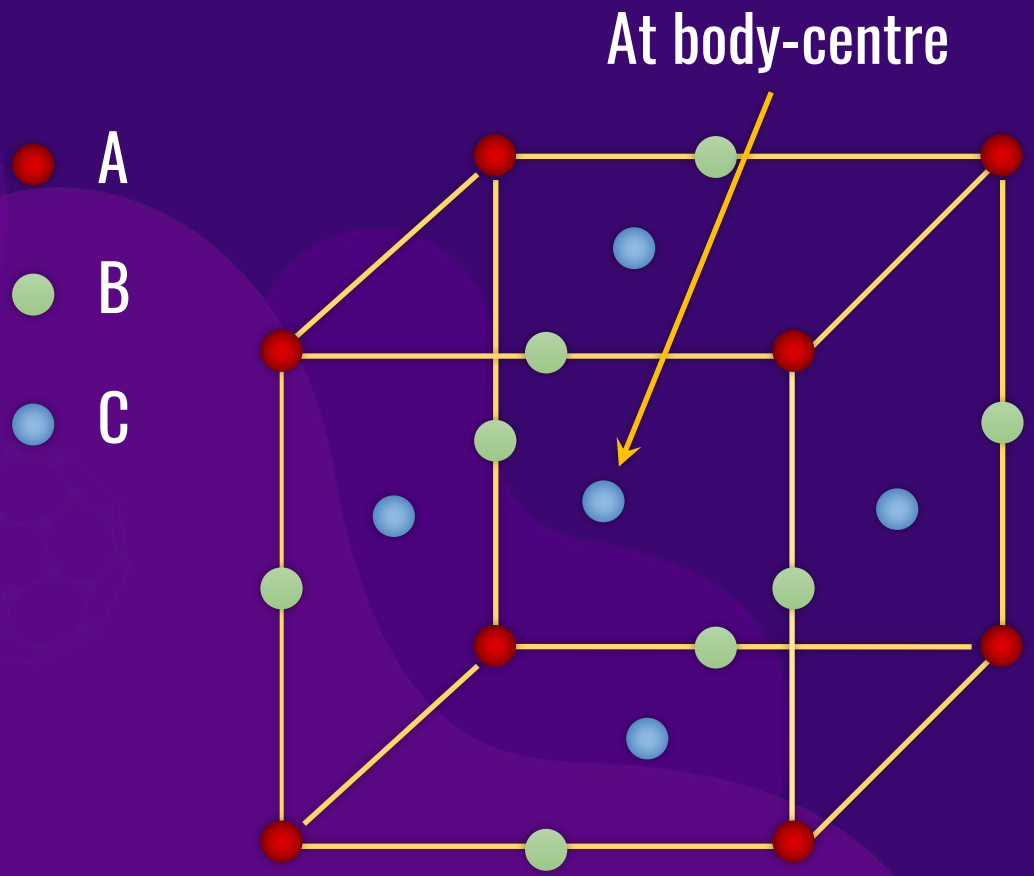
$\sqrt{3} = 1.732$

- **a** 151.8 pm
- **b** 75.5 pm
- **c** 300.5 pm
- **d** 240.8 pm

r = 151.8 pm

Hence, option (a) is the correct answer.

The unit cell structure of compound is shown below. The formula of compound is:



a. $A_8B_{12}C_5$

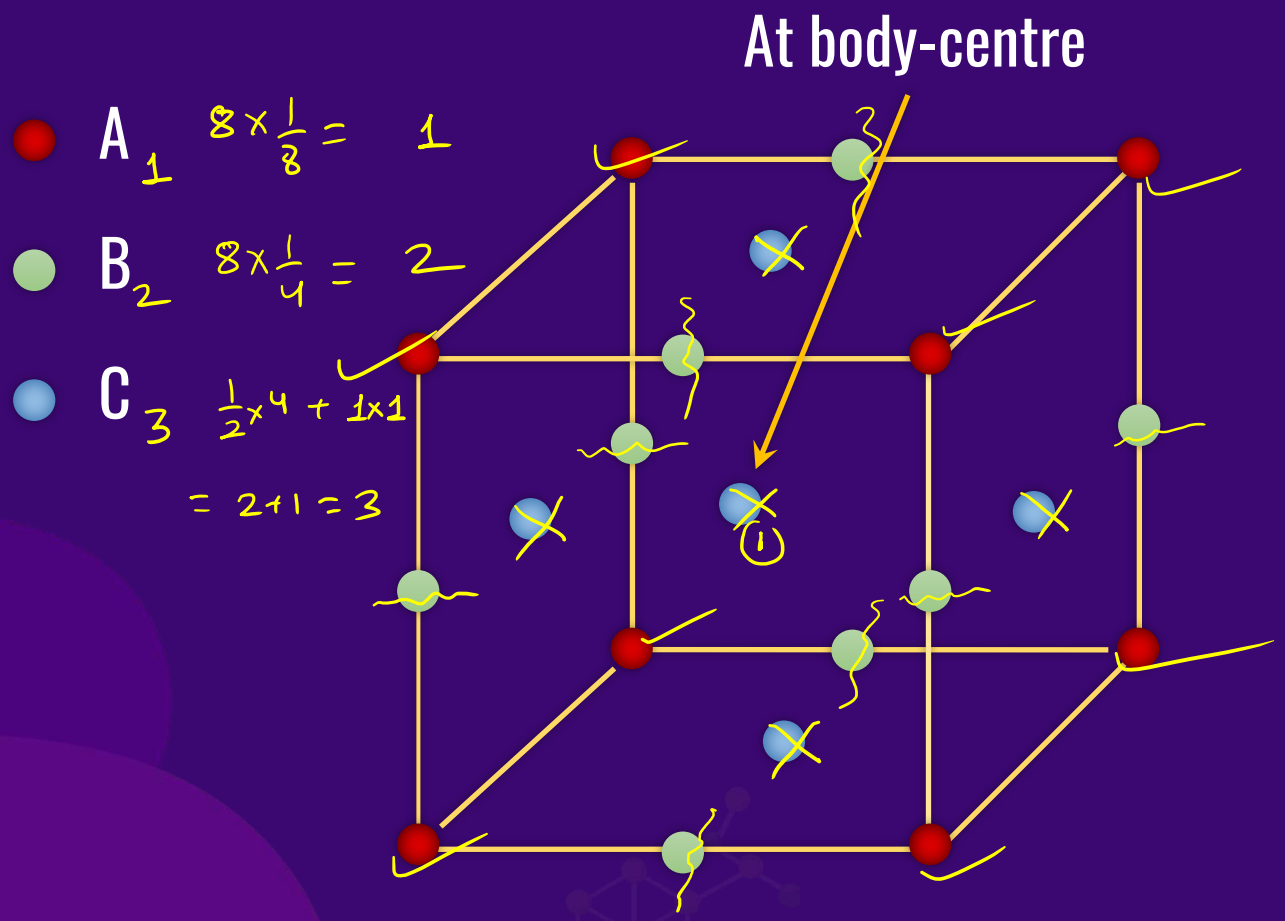
b. AB_2C_3

c. $A_2B_2C_5$

d. ABC_5

Solution

AB_2C_3



Hence, option (b) is the correct answer.

Density of a Unit Cell

$$\rho = \frac{m}{V}$$

It is the **ratio** of **mass** of the spheres present in unit cell and **total volume** of unit cell.

Density of a Unit Cell

$$\text{Density of the unit cell} = \frac{\text{Total mass of particles in the unit cell}}{\text{Volume of the unit cell}}$$

$$\text{Density of the unit cell} = \frac{\text{Total number of particles in the unit cell} \times \text{mass of single particle}}{\text{Volume of the unit cell}}$$

Density of a Unit Cell

$$\text{Mass of a single particle} = \frac{\text{Molar mass}}{N_A}$$

$$\text{Density } (\rho) = \frac{(\text{Total number of particles in unit cell}) \times (\text{Molar mass})}{(\text{Volume of unit cell}) \times (N_A)}$$

$$= \frac{(Z)\left(M/N_A\right)}{a^3} = \frac{ZM}{N_A \cdot a^3}$$

Density of a Unit Cell

Density of unit cell = Density of crystal

$$\text{Density } (\rho) = \frac{Z \times M}{N_A \times a^3}$$

At room temperature, Polonium crystallizes in cubic primitive cell. If edge length is 3.0 Å, calculate the theoretical density of Po. (Atomic wt. of Po = 207 g/mol)

a. 25/3 amu/Å^3

b. 23/3 amu/Å^3

c. 21/3 amu/Å^3

d. 27/3 amu/Å^3

B

Solution

A primitive cubic unit cell contains atoms only at the 8 corners with each $\left(\frac{1}{8}\right)^{th}$ corner contributing of an atom.

Hence $n = 8 \times \left(\frac{1}{8}\right) = 1$. Volume $V = a^3 = (3.0\ Å)^3$

$$\rho = \frac{m}{V}$$

Where, m = Mass of the unit cell

V = Volume of the unit cell

Atomic mass in g = Atomic mass in amu × Avogadro no.

$$\Rightarrow \frac{M}{N_a} = 207 \text{ amu}$$

Since, Z = 1 for primitive cubic unit cell

$$\rho = \frac{1 \times 207 \text{ amu}}{(3.0\ Å)^3}$$

$$\rho = \frac{23}{3}$$

Therefore option (b) is the correct answer.

A solid having a density of 9×10^3 kg m^{-3} forms a face-centred cubic crystal of edge length $200\sqrt{2}$ pm. What is the molar mass of the solid? (Avogadro constant = 6×10^{23} mol^{-1}, $\pi = 3$)

B

a. 0.0432 kg mol^{-1}

b. 0.0305 kg mol^{-1}

c. 0.4320 kg mol^{-1}

d. 0.0216 kg mol^{-1}

Solution

For a face-centred cubic crystal Z = 4
a = 200√2 pm
d = 9 × 10^3 kg m^{-3}

$$\text{Density } (\rho) = \frac{Z \times M}{N_A \times a^3}$$

$$9 \times 10^3 \text{ kg m}^{-3} = \frac{4 \times M}{6 \times 10^{23} \text{ mol}^{-1} \times (200\sqrt{2} \times 10^{-12} \text{ m})^3}$$

$$M = \frac{9 \times 10^3 \text{ kg m}^{-3} \times 6 \times 10^{23} \text{ mol}^{-1} \times (2\sqrt{2} \times 10^{-10} \text{ m})^3}{4}$$

$$M = 305.470 \times 10^3 \times 10^{23} \times 10^{-30} \text{ kg mol}^{-1}$$

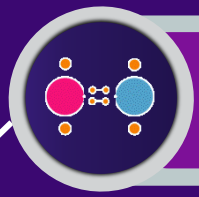
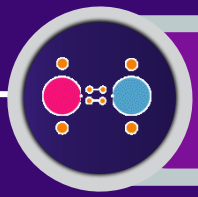
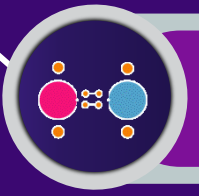
$$M = 0.0305 \text{ kg mol}^{-1}$$

Therefore, option (b) is the correct answer.

Coordination Number (C.N.)

Number of nearest neighbour particles in a packing is called **coordination number.**

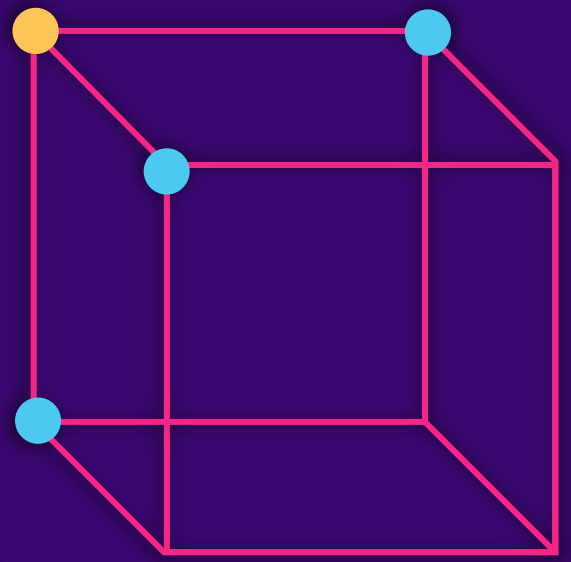
Coordination number in

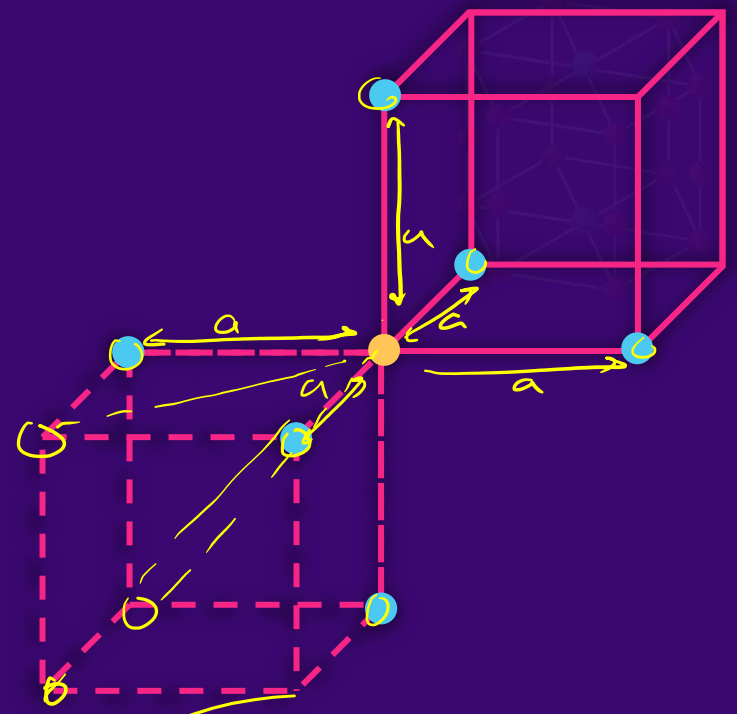
-  Simple cubic
-  Body-centred cubic
-  Face-centred cubic

Coordination Number

Simple cubic unit cell

- Reference particle
- Nearest particle



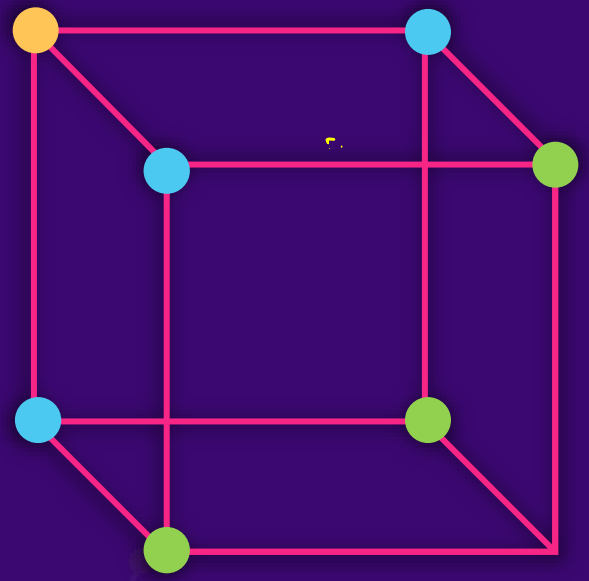


C.N. = 6

Nearest Neighbour

Simple cubic unit cell

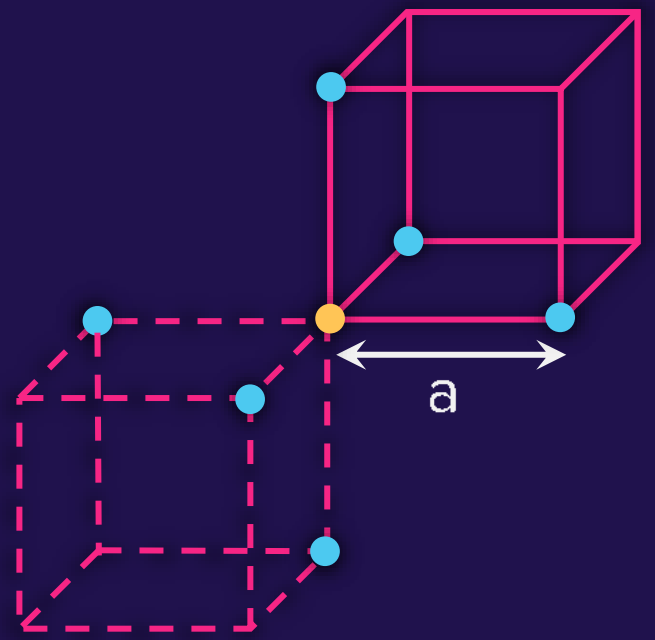
- Reference particle
- Nearest particle
- Next nearest particle



Nearest Neighbour

Simple cubic unit cell

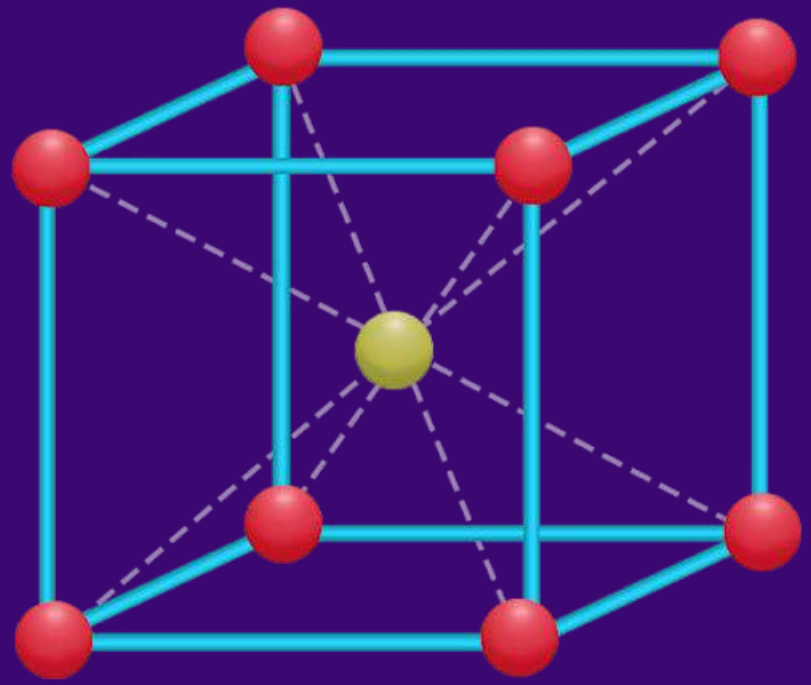
Number of nearest neighbour is **same** as coordination number.



Distance of the **nearest** particle	=	a	=	2r
Number of nearest particles	=	6		

Nearest Neighbour in BCC

- Reference particle
- Nearest particle

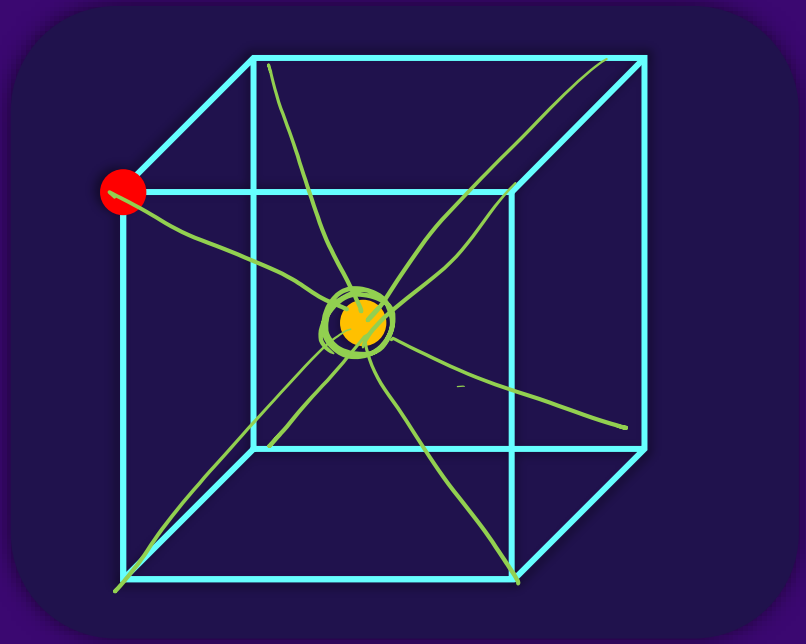


Number of nearest particles = 8 C.N.

Nearest Neighbour in BCC

$\frac{a\sqrt{3}}{2}$

- Reference particle
- Nearest particle

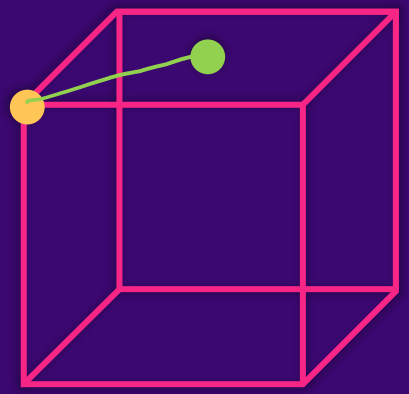


Distance of **nearest** particle in BCC $= \frac{\sqrt{3}a}{2} = 2r$

Nearest Neighbour in FCC

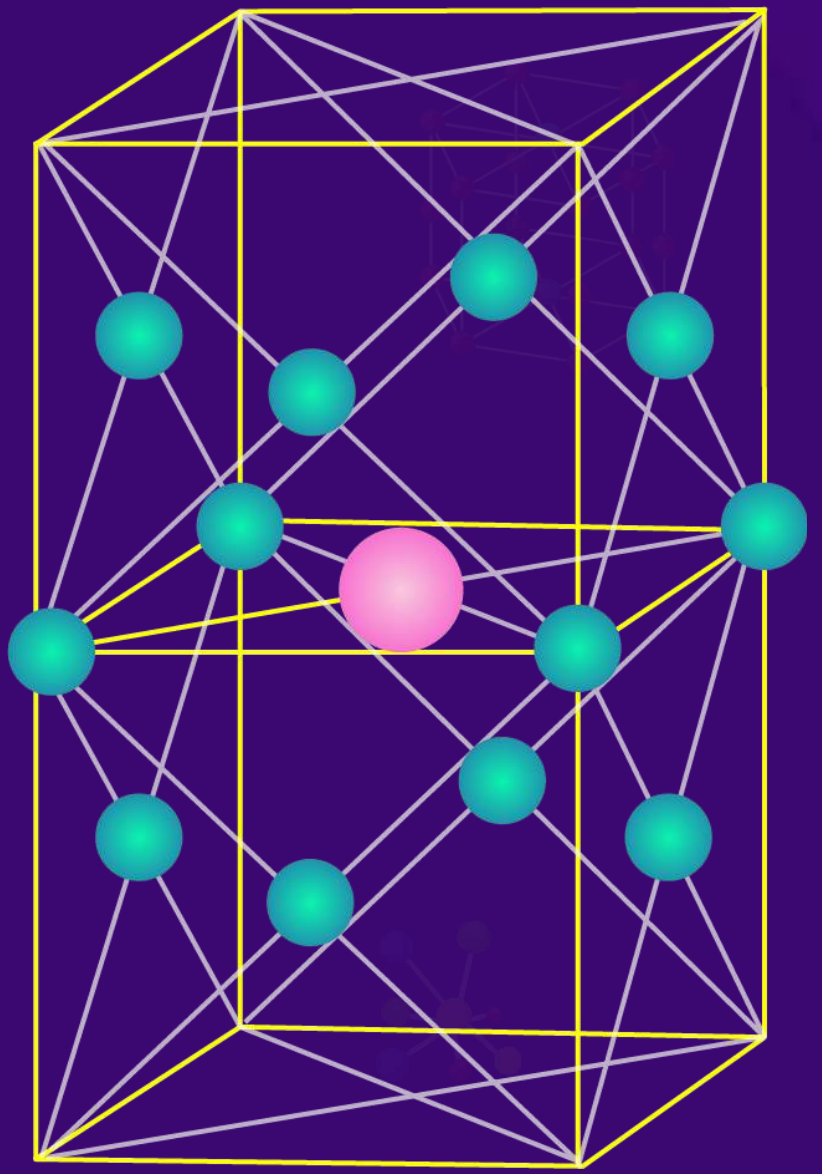
- Reference particle
- Nearest particle

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



Distance of **nearest** particle in FCC $= \frac{a}{\sqrt{2}} = 2r$

Number of nearest particles $= 12$



What are the number of atoms per unit cell and the number of nearest neighbours in a body-centred cubic structure?

Solution

For body-centred cubic structure
Number of atoms per unit cell = 2
Number of nearest neighbours = 8

Hence, option (c) is the correct answer.

a. 4, 12

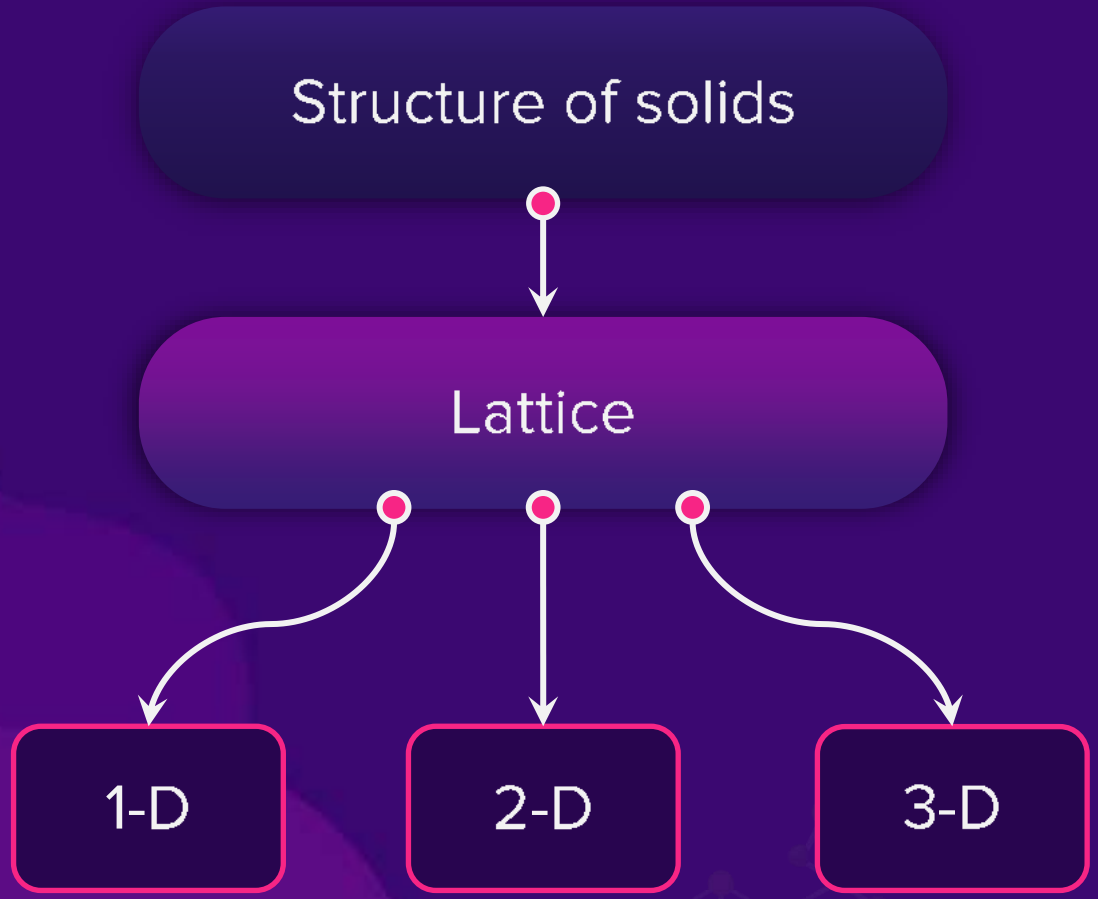
b. 1, 6

c. 2, 8

d. 2, 5

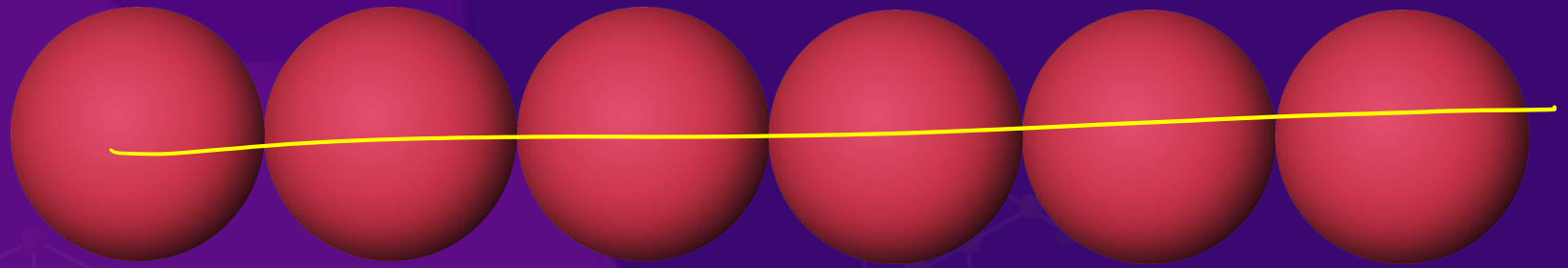
Structure of Solids

Structure of Solids



Structure of Solids

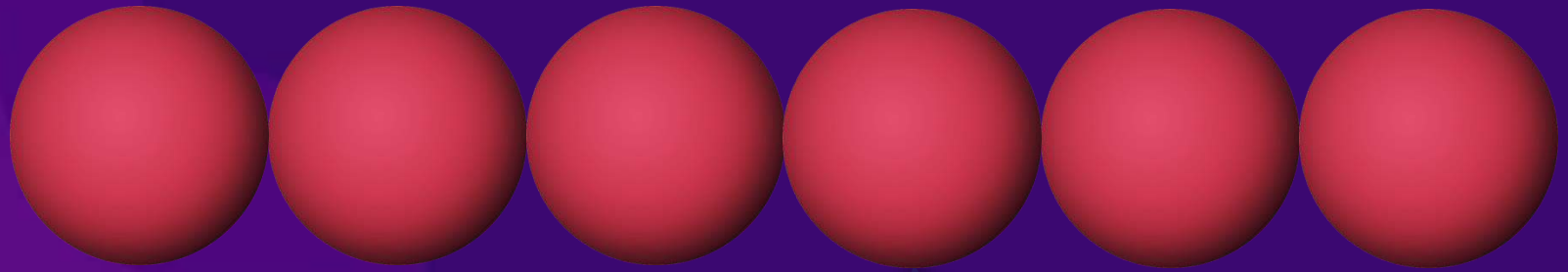
In 1-D, for **efficient packing**, spheres are arranged in a row and touch each other.



Structure of Solids

Coordination number (C.N.)

Number of nearest neighbour particles in a packing is called **coordination number.**



C.N. = **2**

Structure of Solids

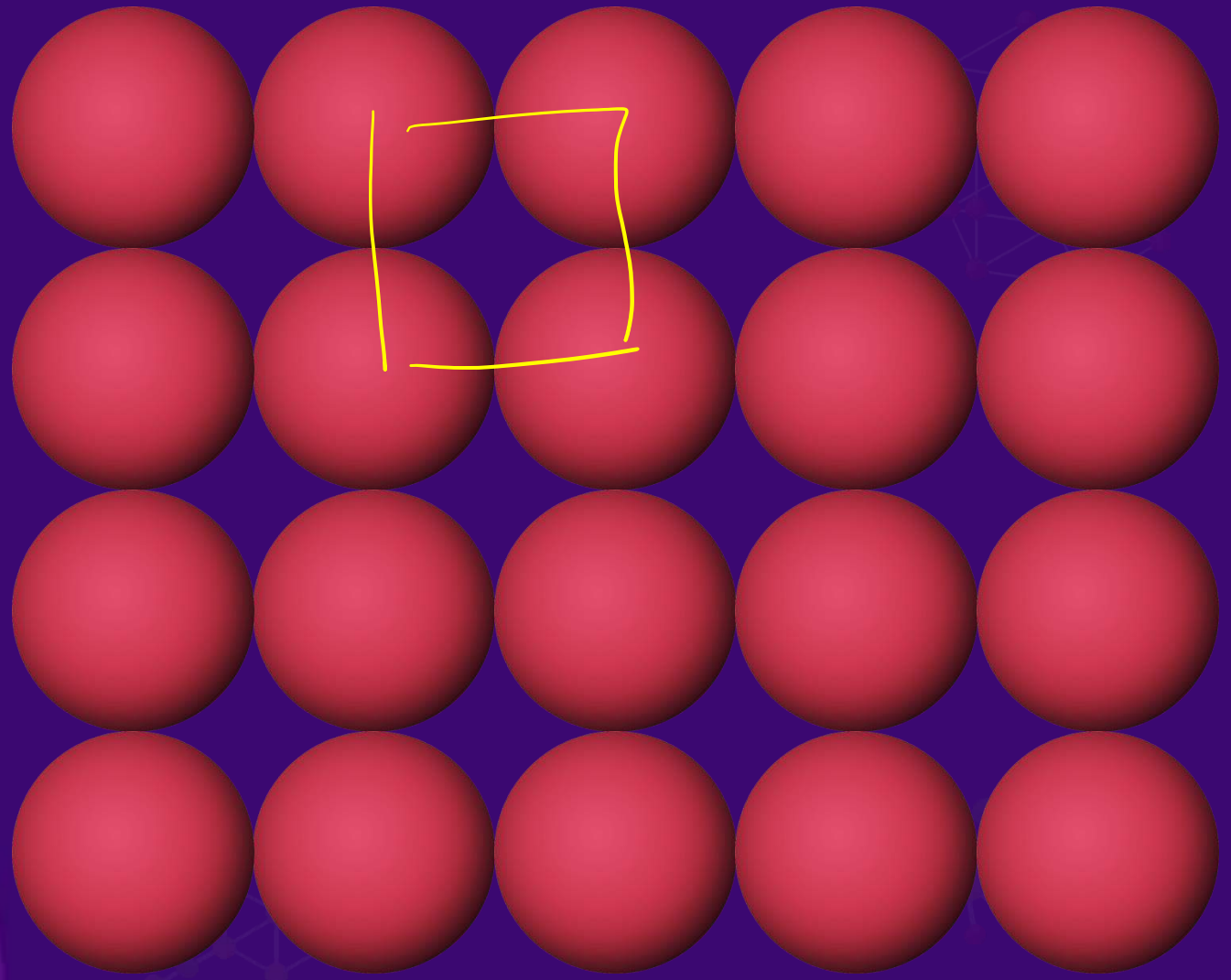
Packing in 2-D Lattice

2-D lattice can be considered to be made of 1-D array

- Square arrangement
- Hexagonal arrangement

Structure of Solids

Square arrangement in 2-D lattice

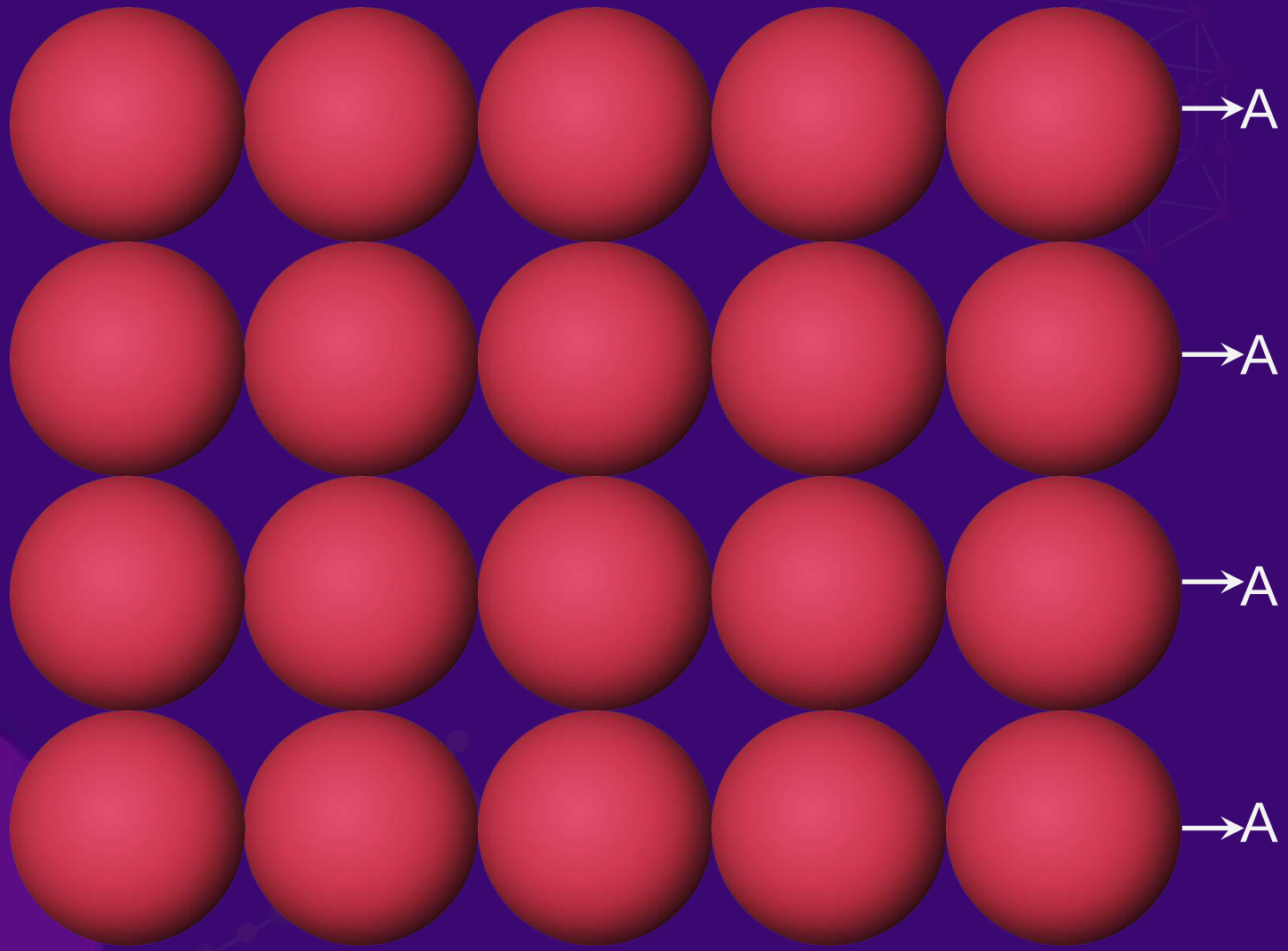


Array are arranged such that spheres of one array are **exactly above** the sphere of another array.

Structure of Solids

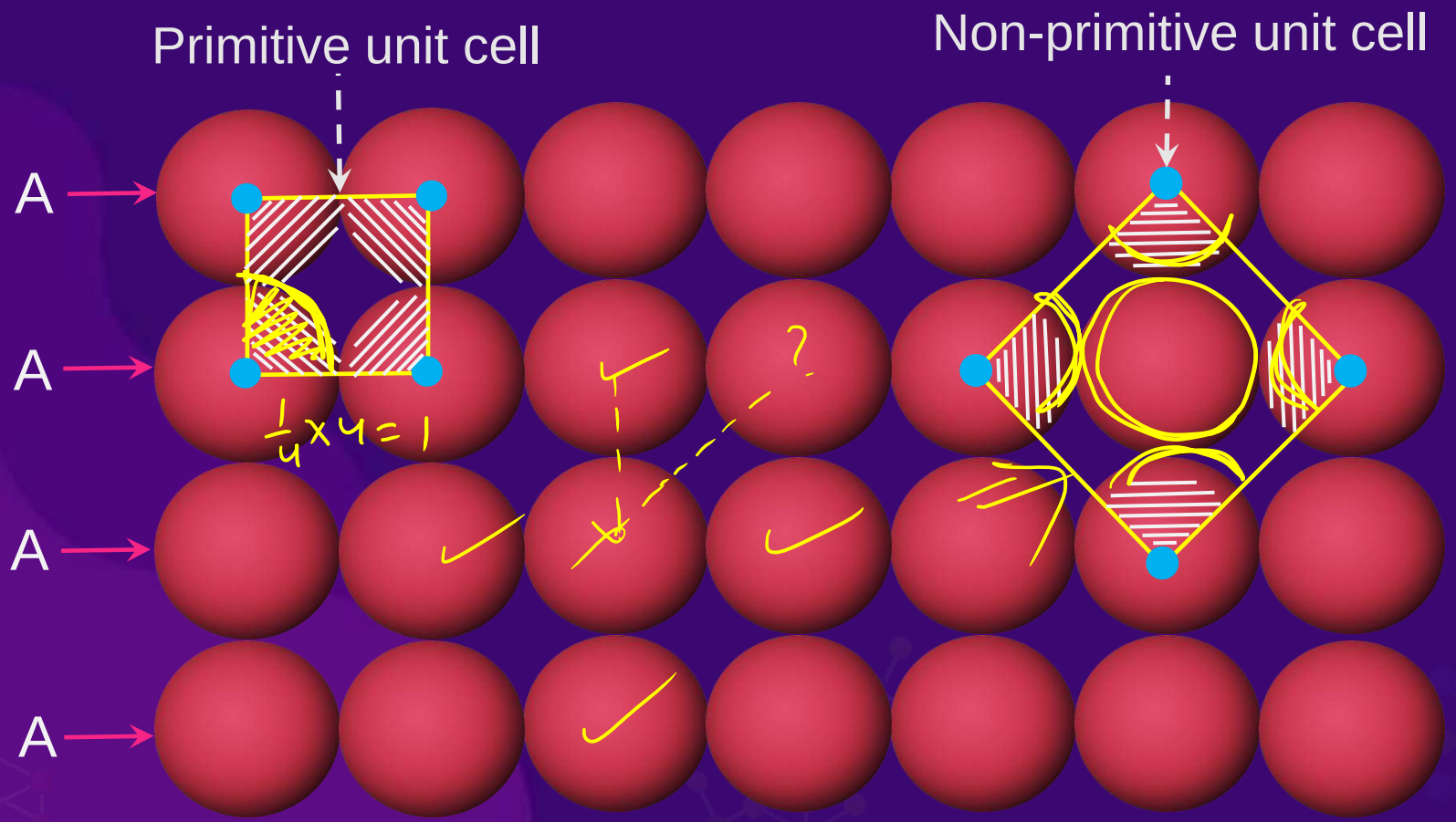
Square arrangement in 2-D lattice

AAA type packing



Structure of Solids

Square arrangement in 2-D lattice



AAA type of arrangement

Structure of Solids

Square arrangement in 2-D lattice

Square packing in **2-D**

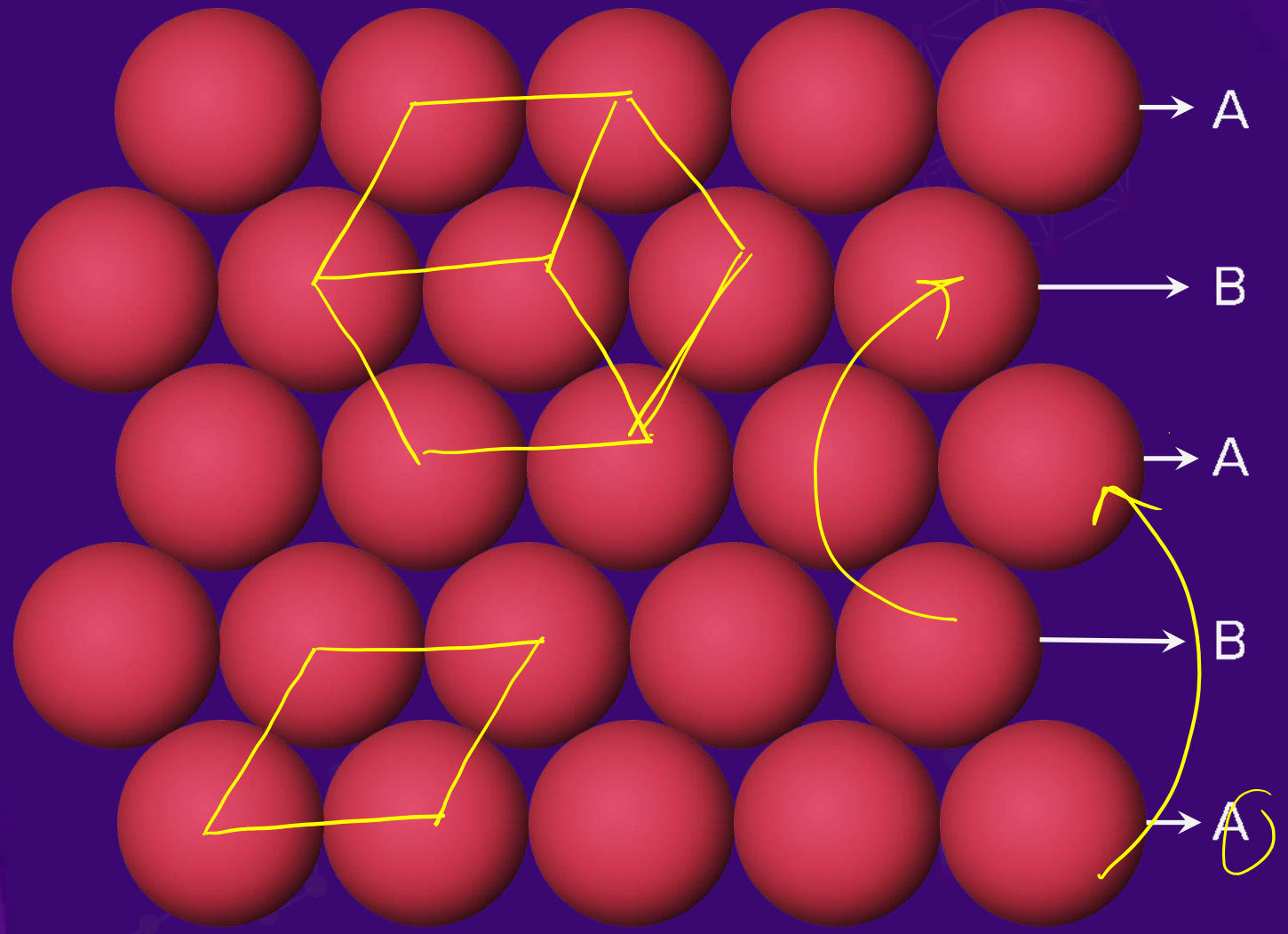
Unit cell

	Primitive	Non-primitive
Effective number of particles (Z)	1	2
C.N.	4	4

Structure of Solids

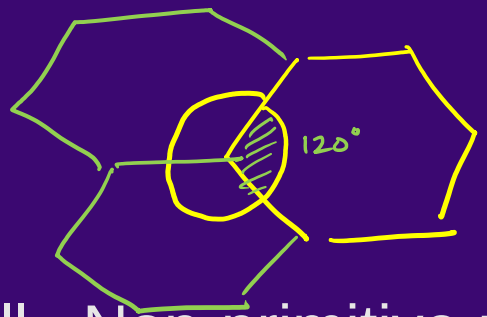
Hexagonal arrangement in 2-D lattice

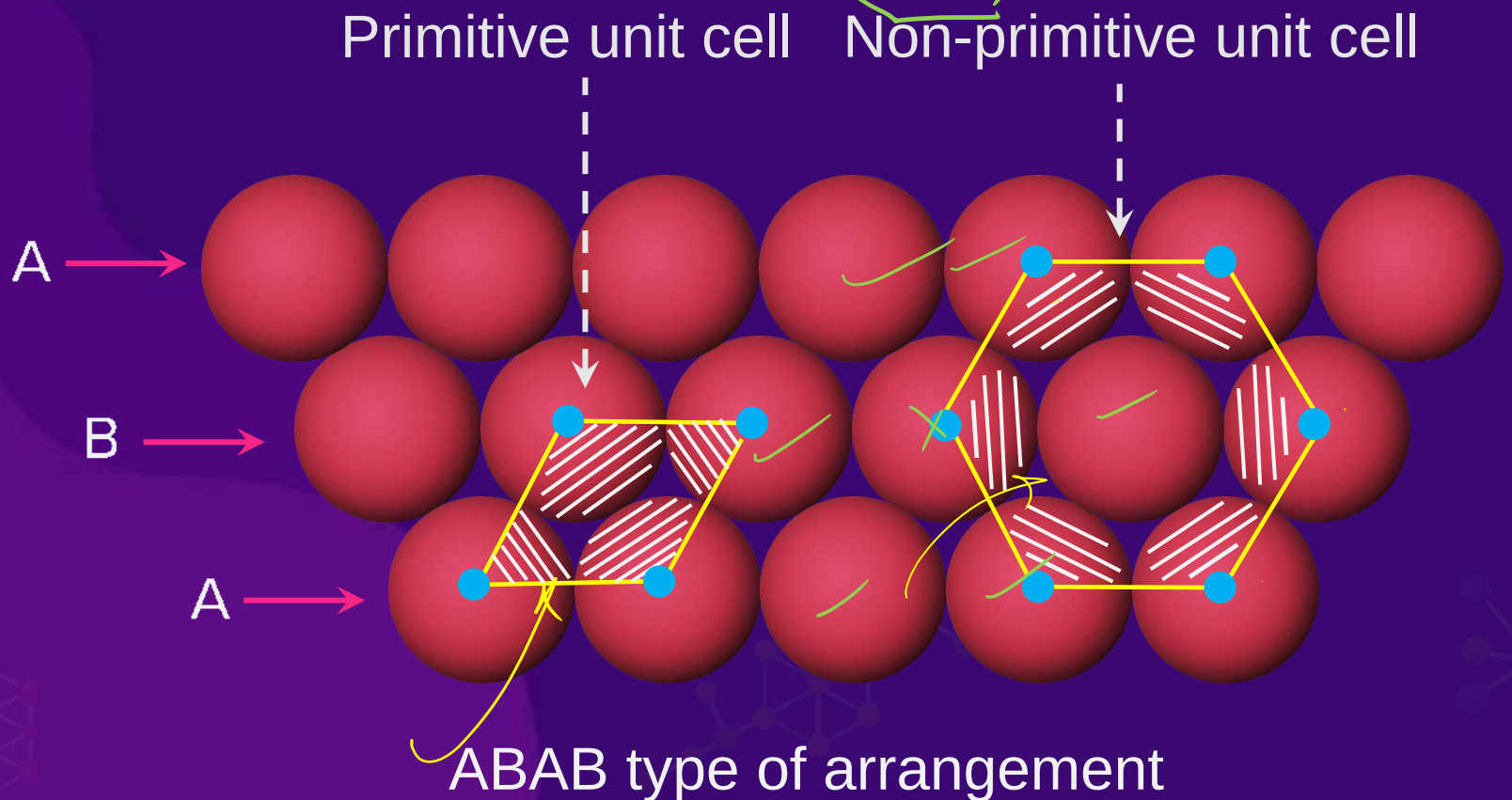
1-D array are arranged such that the spheres of one array **occupies** **the depression** of other array



Structure of Solids

Hexagonal arrangement in 2-D lattice





Structure of Solids

Hexagonal arrangement in 2-D lattice

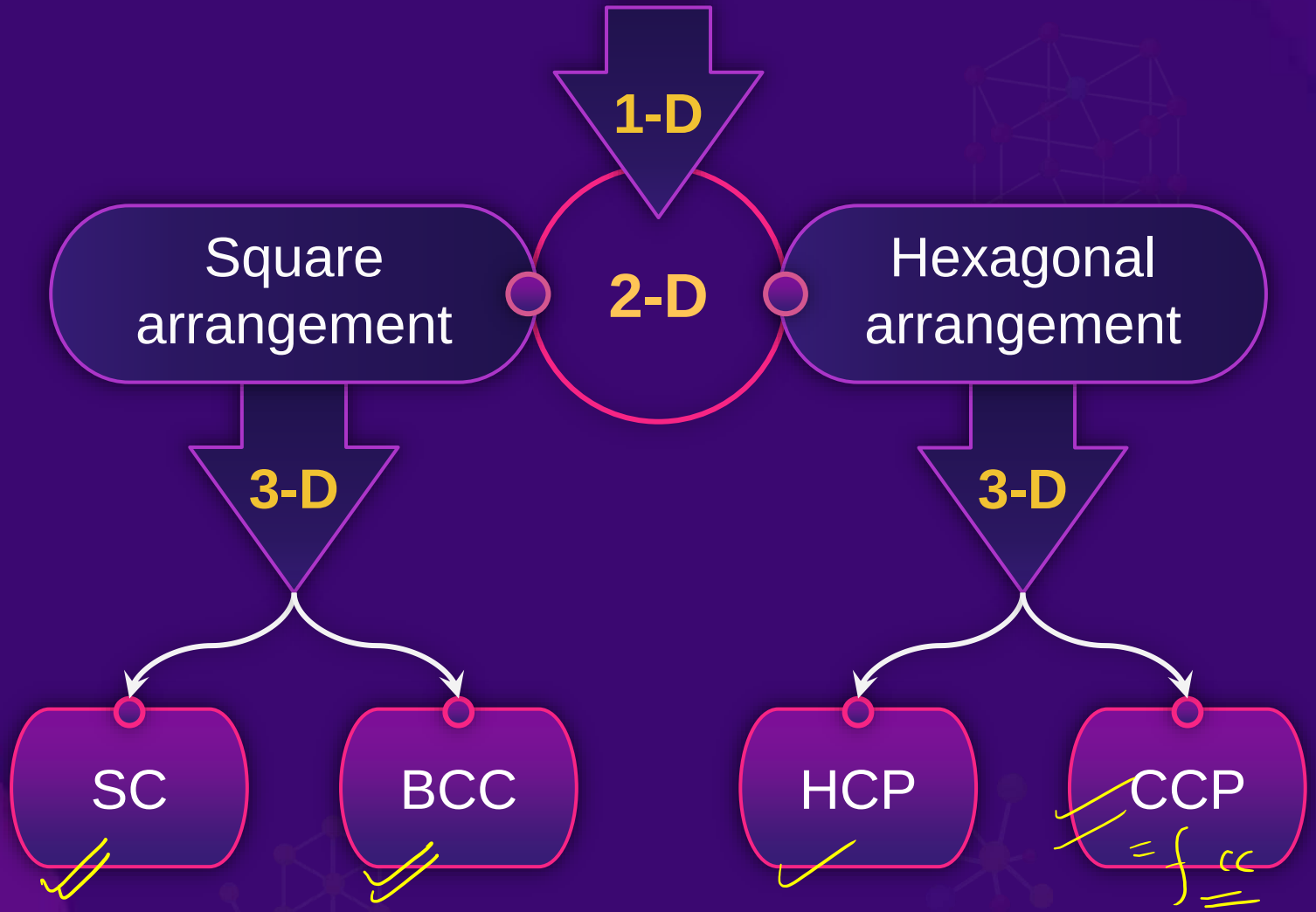
Hexagonal packing in **2-D**

Unit cell

	Primitive	Non-primitive
Effective number of particles (Z)	1	3
C.N.	6	6

Structure of Solids

When **2-D** arrangements are **kept on each other, 3-D** packing will be generated.



Structure of Solids

Square arrangements in 3-D lattice (Simple cubic)

Square packed sheets are kept on another such that

→ Spheres of one sheet are **exactly above** the spheres of other sheet.

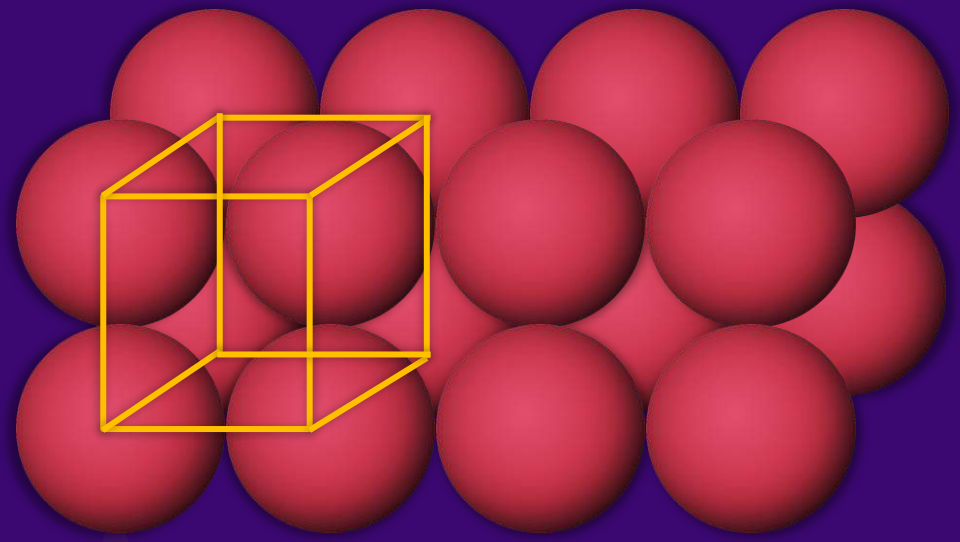
↓

AAA….. pattern repeated.

Structure of Solids

Square arrangements in 3-D lattice (Simple cubic)

Simple cube can be taken as **unit cell** of this particular lattice.



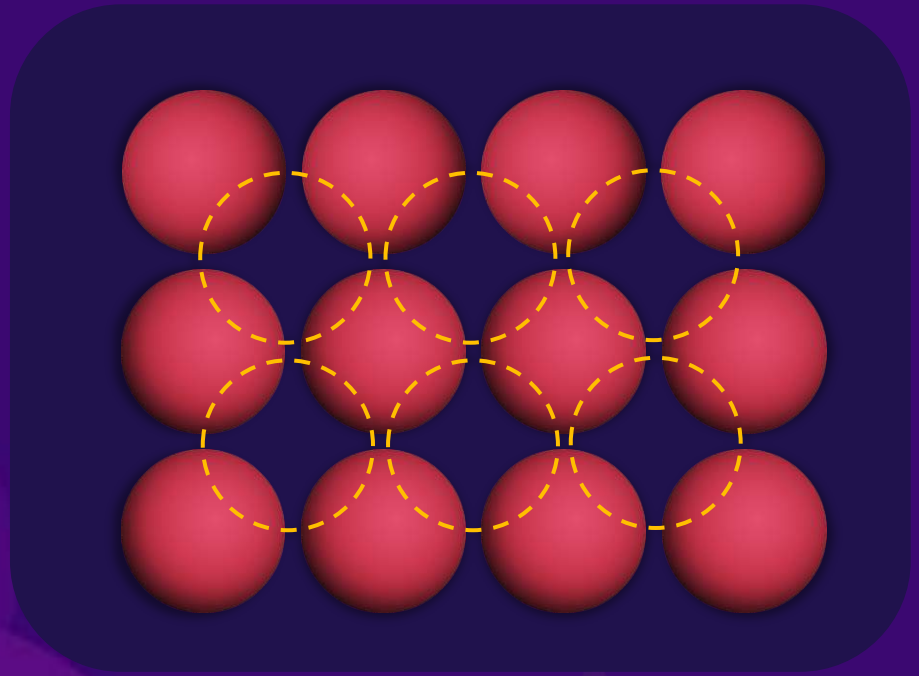
Structure of Solids

Square arrangements in 3-D lattice (Body centred cubic)

Square packed layer are placed such that **sphere of one layer** occupy the **depression of other layer**.

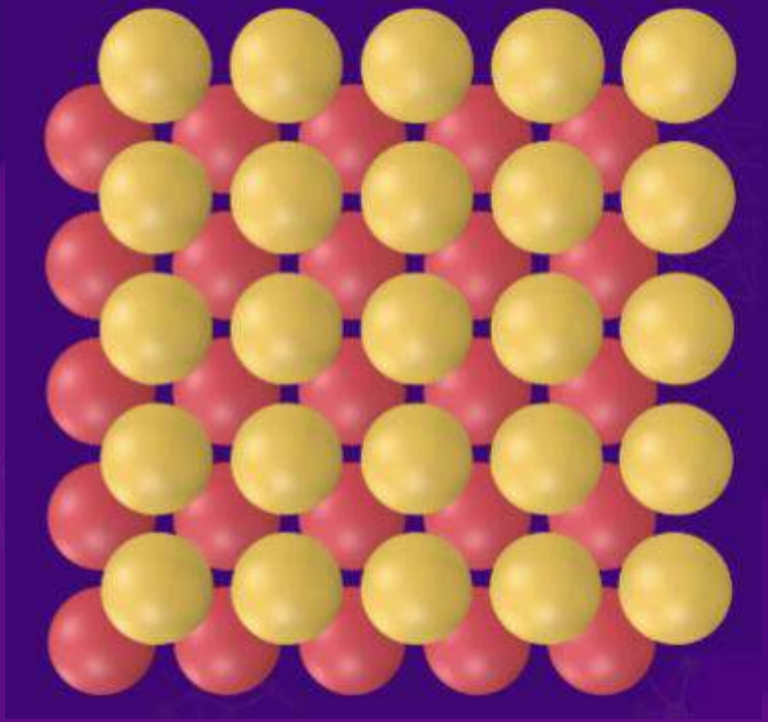
Structure of Solids

Square arrangements in 3-D lattice
(Body centred cubic)

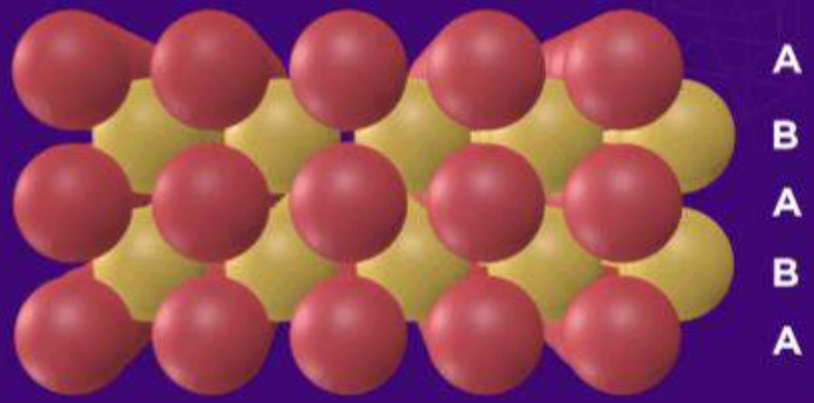


ABAB type of arrangement of square sheet in 3-D.

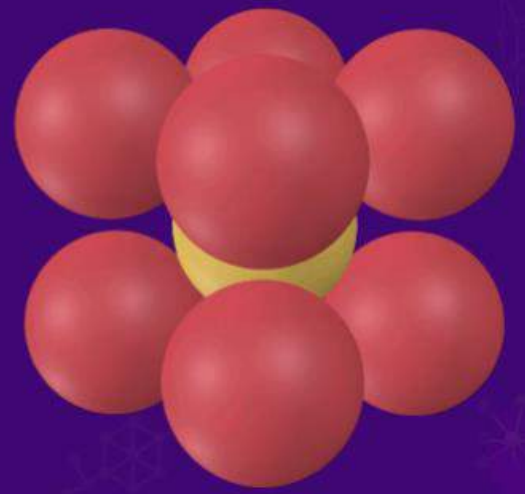
Structure of Solids



Body centred cubic lattice

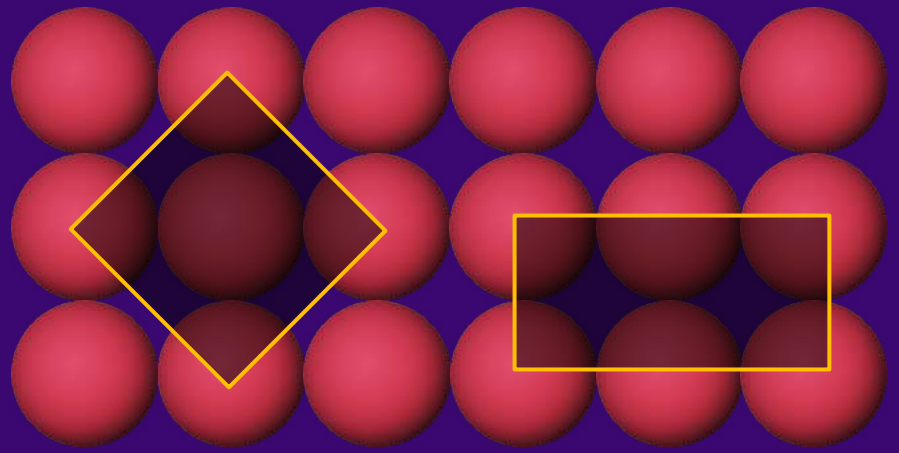


AB type of arrangement



Body centred cubic unit cell

Given below are two-dimension lattices with shaded regions. Find the effective number of particles in the shaded regions.



(i) (ii)

a 3

b 4

c 5

d 6

Solution

In the shaded region (i), the number of particles present are - 1 complete and 1/4th part of 4 particles and hence number of particles is

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

In shaded region (ii), 4 number of particles are contributing 1/4th part to the shaded region and 2 particles are present 1/2 in the shaded region hence number of particles are

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

Effective number of particles in the shaded regions is 2 + 2 = 4

Stacking of square packed layers give rise to:

a FCC structure

b HCP structure

c Simple cubic structure

d None of these

Solution

Stacking of square packed layers give rise to two type of structures simple cubic and body centred and in the given options, simple cubic structure is given.

Hence, option c is the correct answer.

How many nearest neighbours do potassium have in a BCC lattice?

a 10

b 8

c 6

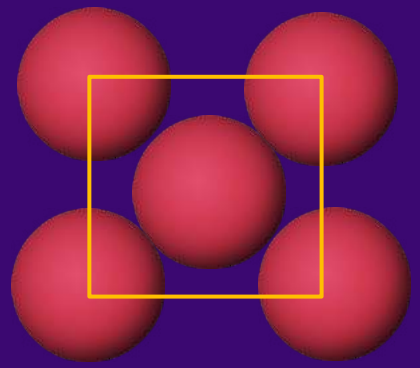
d 4

Solution

In BCC, the number of nearest particles i.e., coordination number is 8.

Hence, option b is the correct answer.

The packing efficiency of the two-dimensional square unit cell shown below is:



a 39.27%

b 68.02%

c 74.05%

d 78.54%

Solution

The cell shown has 1 particle is completely inside and 4 particles contributing 1 / 4^{th} and hence effective number of particles are

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

Packing efficiency = Area of circles in the unit cell / Area of square unit cell

Packing efficiency = $\frac{2\pi r^2}{a^2}$

Relation between r and a :

$$a = 2(2)^{\frac{1}{2}} r$$

Putting the value of a in above equation we get,

Packing efficiency = 78.54 %

Hence, option d is the correct answer.

In a square packing pattern, one atom is in contact with how many atoms in the 2D plane base?

a. 3

b. 4

c. 5

d. 6

Solution

In a square close packing any atom is in direct contact with 4 other atoms.

Hence, option b is the correct answer.

A metal has an FCC lattice. The edge length of the unit cell is 404 pm, and the density of the metal is 2.72 g cm^{-3}. The molar mass of the metal is:
(Avogadro's constant = 6.02×10^{23} mol^{-1})

B

a. 27 g mol^{-1}

b. 20 g mol^{-1}

c. 40 g mol^{-1}

d. 30 g mol^{-1}

Solution

Given : a= 404 pm , M = ? , = 2.72 g cm^{-3}

$$\text{Density } (\rho) = \frac{Z \times M}{N_A a^3}$$

$$\text{So, } M = \frac{\rho \times N_A \times a^3}{Z}$$

$$\mathbf{M} = \frac{2.72 \times 6.023 \times 10^{23} \times (404)^3 \times 10^{-30}}{4}$$

So putting value of all parameters, we get

M = 27 *g* mol^{-1}

Lithium has a bcc structure. Its density is 530 kg m^{-3} and its atomic mass is 6.94 g mol^{-1}. Calculate the edge length of a unit cell of lithium metal. ($N_A = 6.02 \times 10^{23}$ mol^{-1})

a. 527 pm

b. 264 pm

c. 154 pm

d. 352 pm

Solution

Density (ρ) = $\frac{Z \times M}{N_A a^3}$

$$a = \left(\frac{Z \times M}{N_A \times \rho}\right)^{\frac{1}{3}}$$

$$a = \left(\frac{2 \times 6.94}{6.02 \times 10^{23} \times 530 \times 10^{-3}}\right)^{\frac{1}{3}}$$

a = 352 *pm*

Hence, option d is the correct answer.

An element (atomic mass = 100 g mol^{-1}) having a bcc structure has a unit cell edge of 400 pm. Then, the density of the element is

a. 10.376 g cm^{-3}

b. 5.188 g cm^{-3}

c. 7.289 g cm^{-3}

d. 2.144 g cm^{-3}

Solution

BCC lattice, atomic mass (M) = 100 g mol^{-1}, edge length (a) = 400 pm = 4 x 10^{-8} cm

For BCC , Z = 2

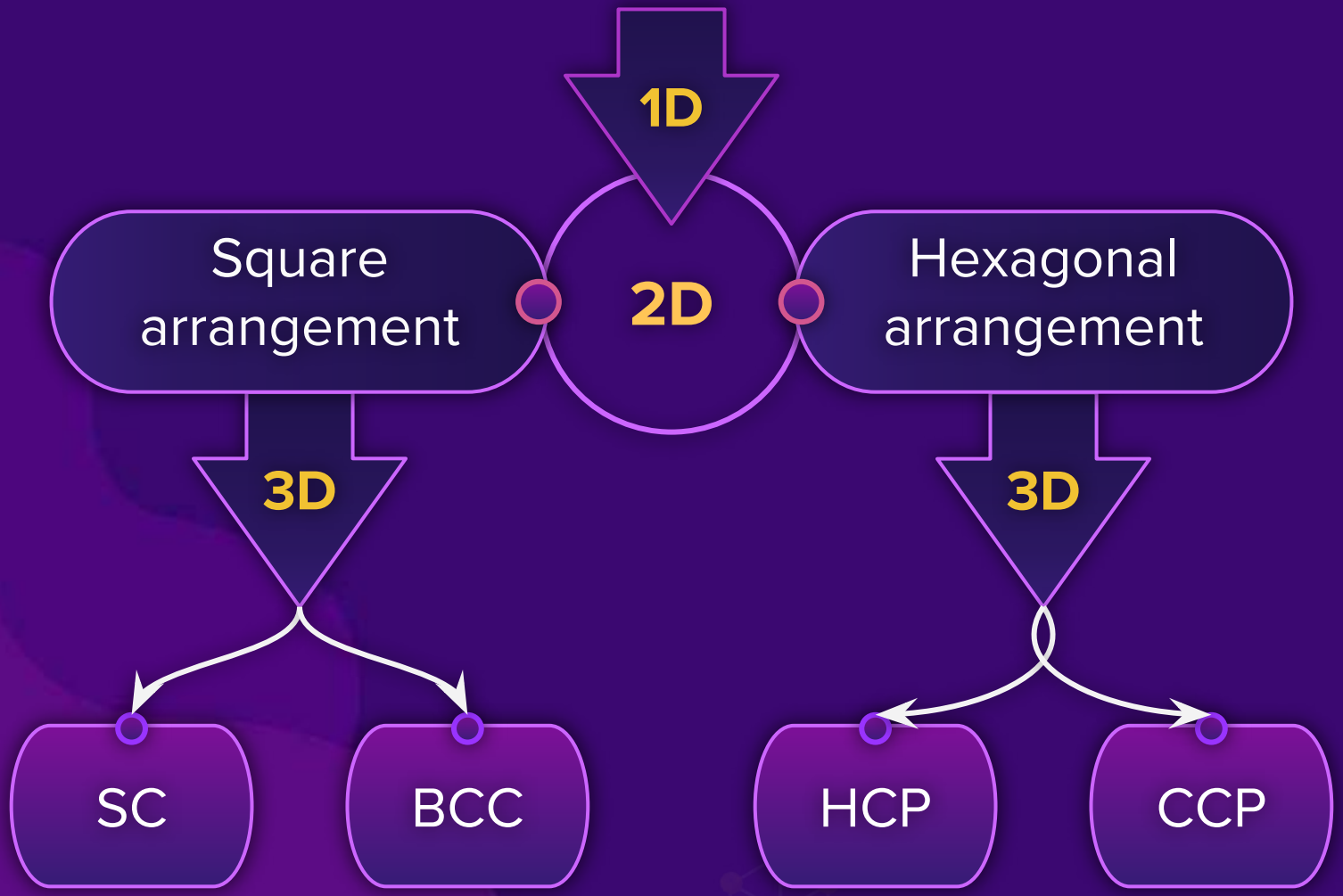
$$\text{Density } (\rho) = \frac{Z \times M}{N_A a^3}$$

Substituting the value in above equation we get

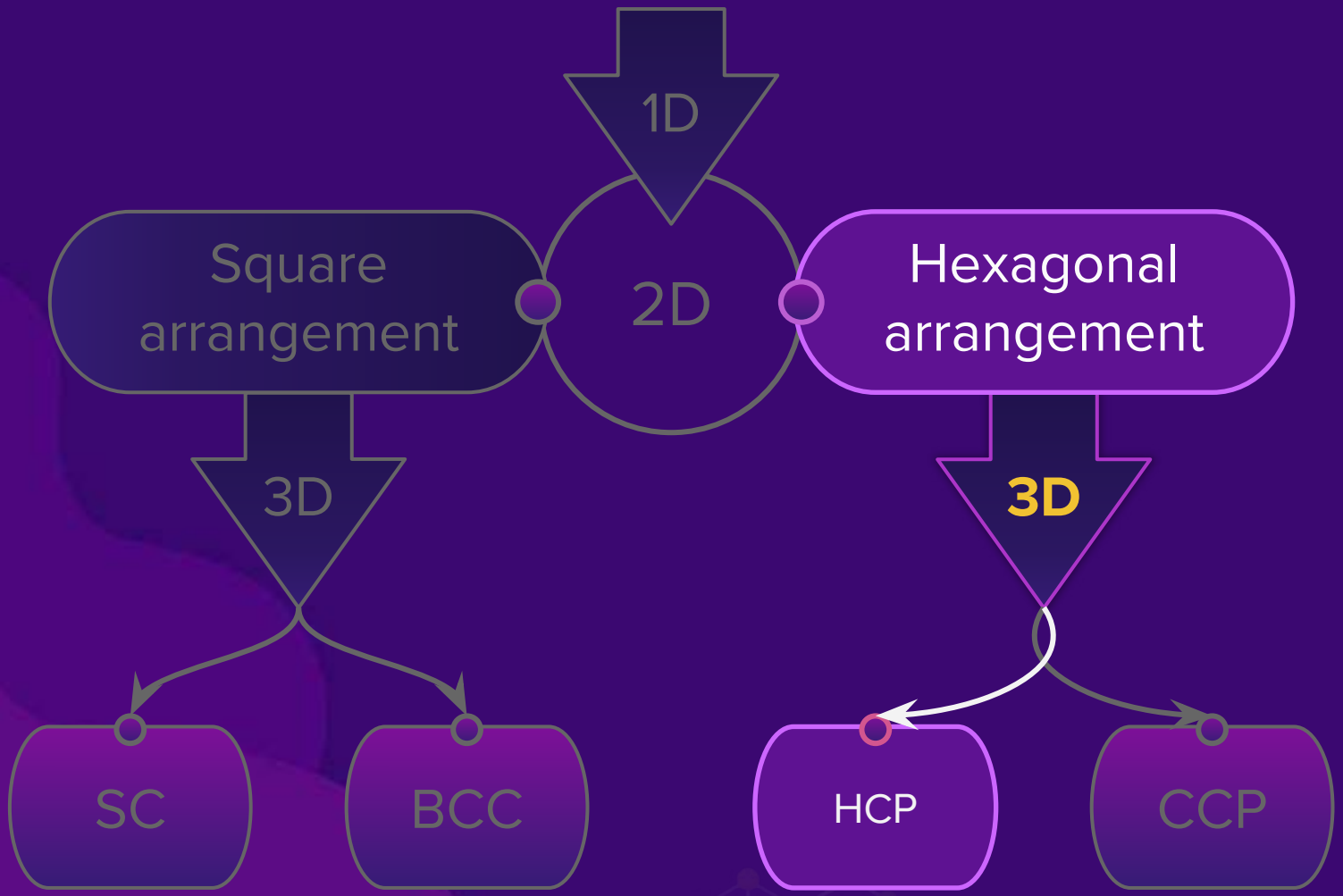
Density (ρ) = 5.188 g cm^{-3}

Hence, option b is the correct answer.

Packing in 1D, 2D and 3D



Arrangement of Hexagonal-Packed Sheets

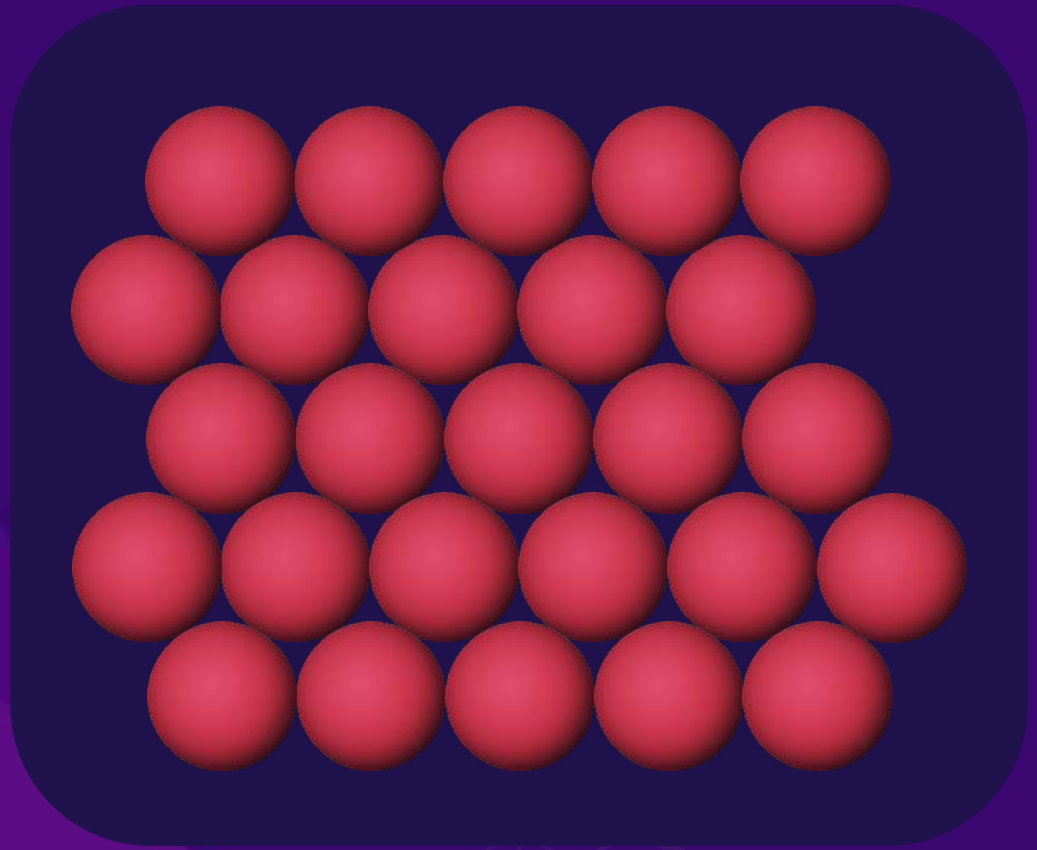


Arrangement of Hexagonal-Packed Sheets

To generate **close packing,** the 2D arrangement **must be hexagonal**.

The sheets are arranged such that **depressions** of one sheet are **occupied** by the **spheres** of the other sheet.

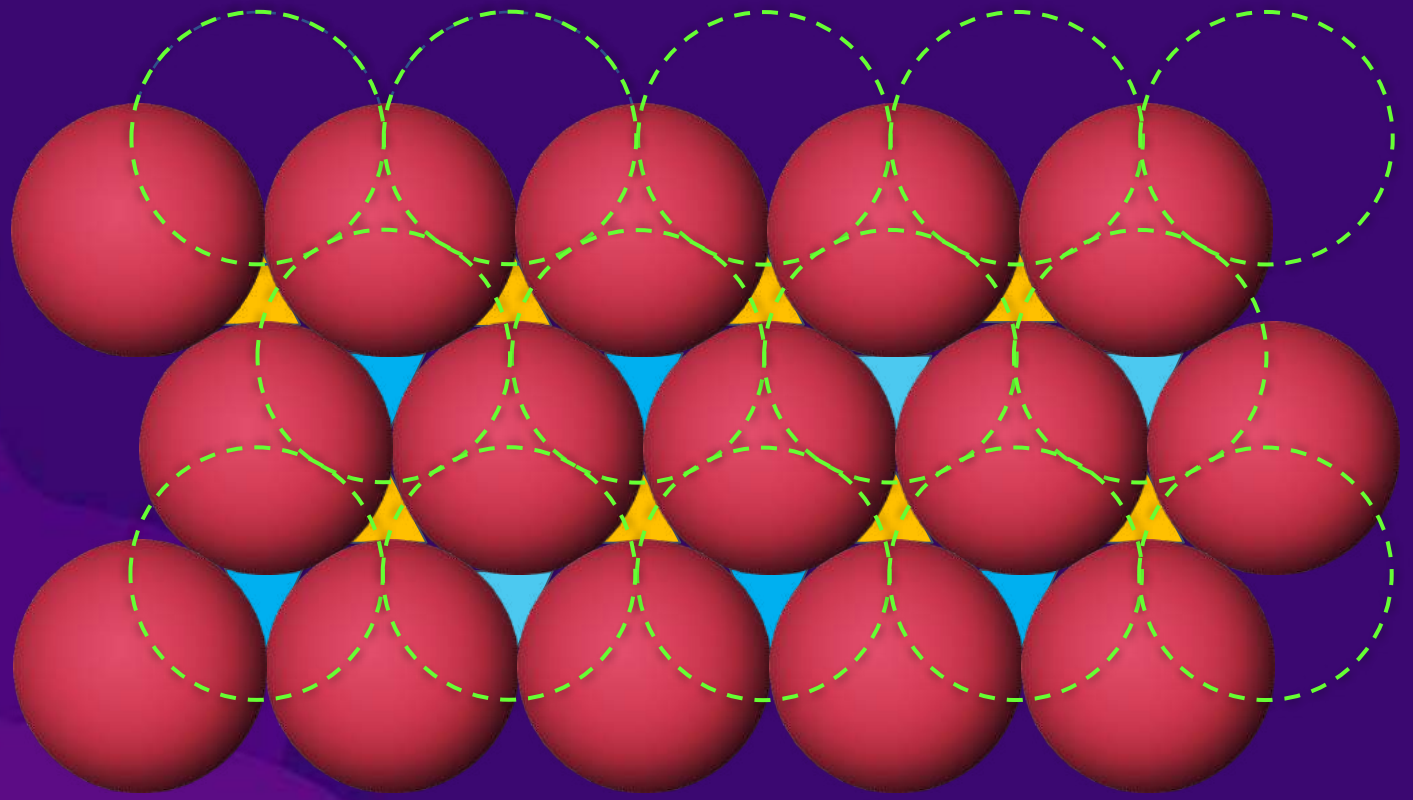
Arrangement of Hexagonal-Packed Sheets



Arrangement of Hexagonal-Packed Sheets

Only **50% depressions** of one layer can be occupied by the spheres of another layer (**II layer**).

Depressions Covered by Second Layer



Types of Voids

On placing the second layer in the depressions of the first layer, two types of voids are generated.

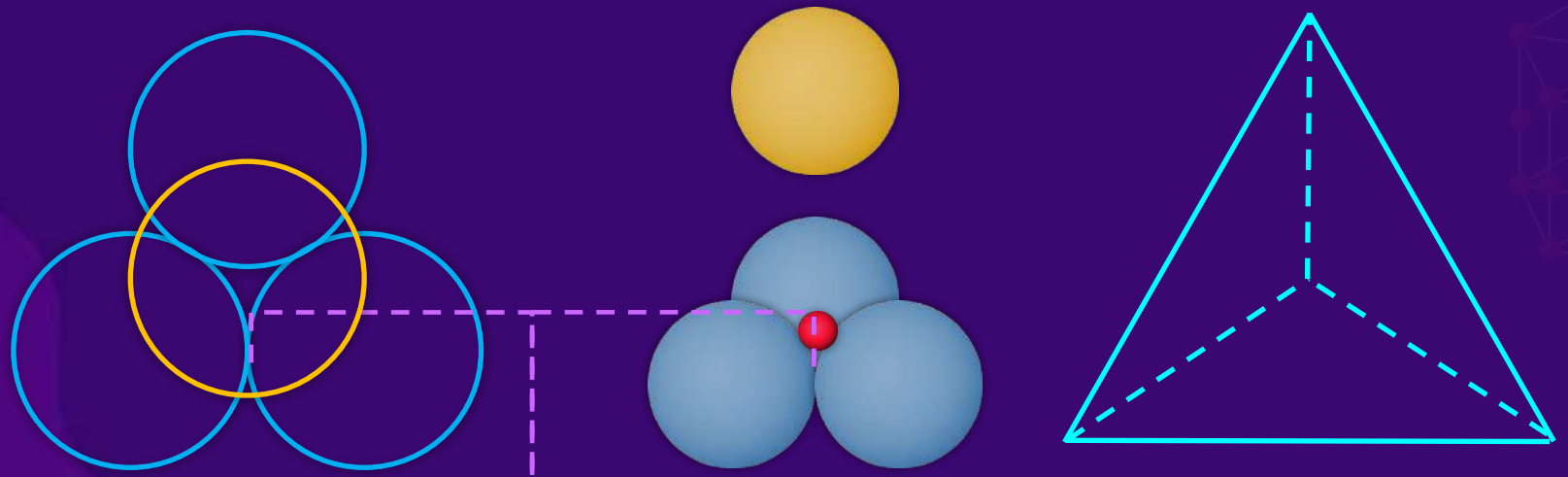
- Tetrahedral voids
- Octahedral voids

Voids

Although the close-packed structures have the maximum packing efficiency, there are **empty spaces** in the arrangements.

These empty spaces are known as **voids or interstitial voids**.

Tetrahedral Void



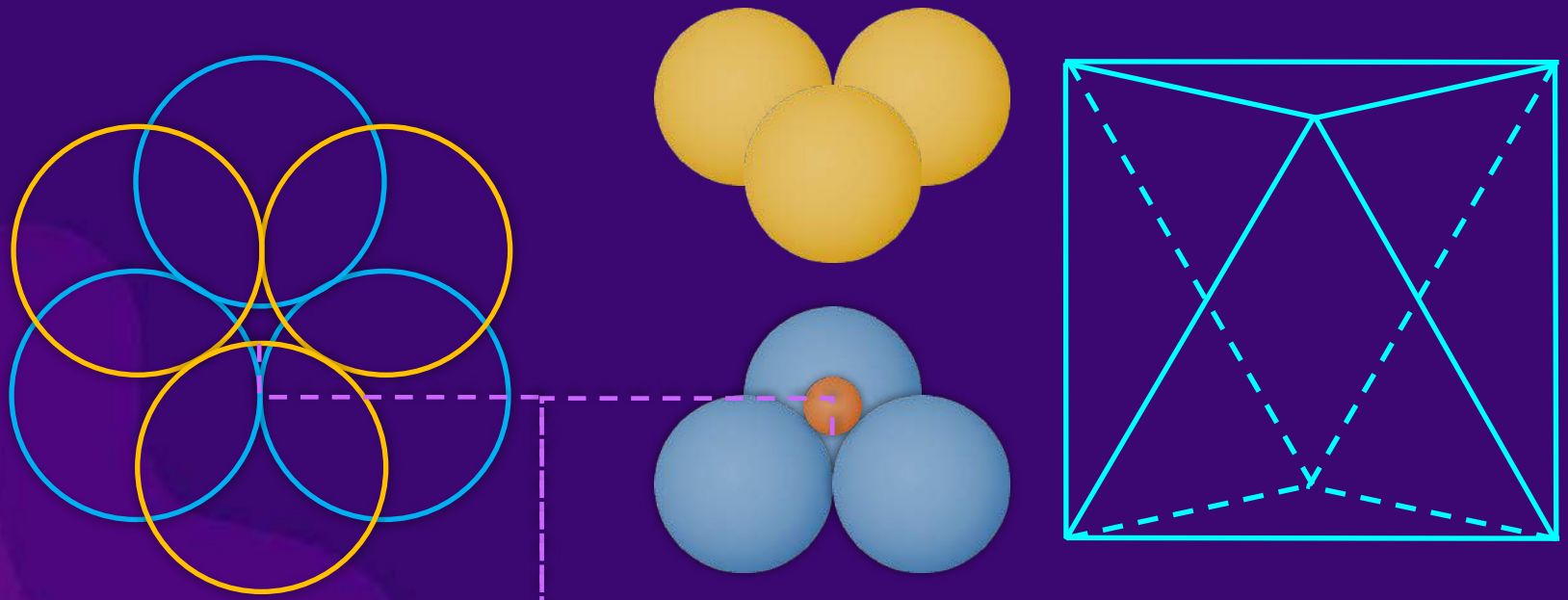
Tetrahedral void

Types of Voids

On placing the second layer in the depressions of the first layer, two types of voids are generated.

- Tetrahedral voids
- Octahedral voids

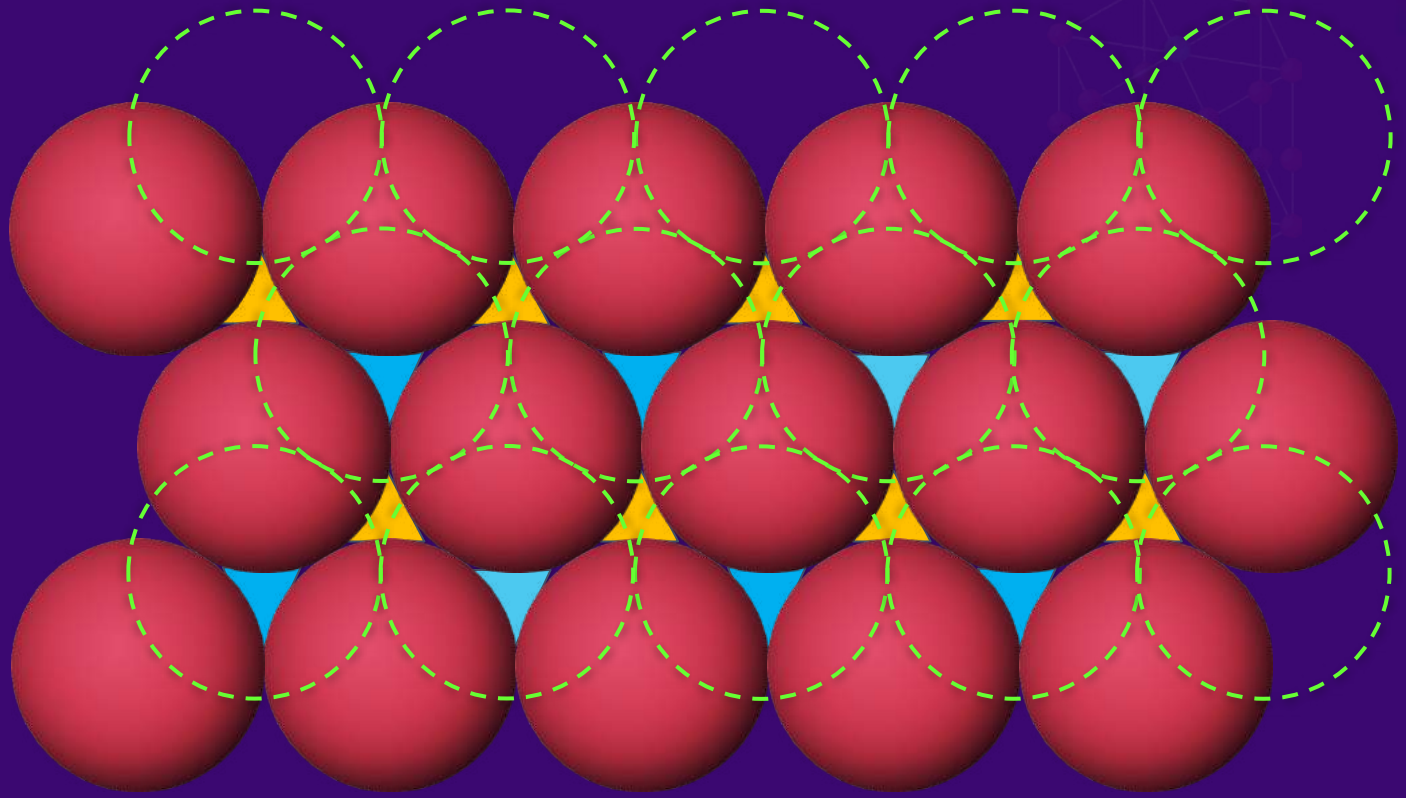
Octahedral Void

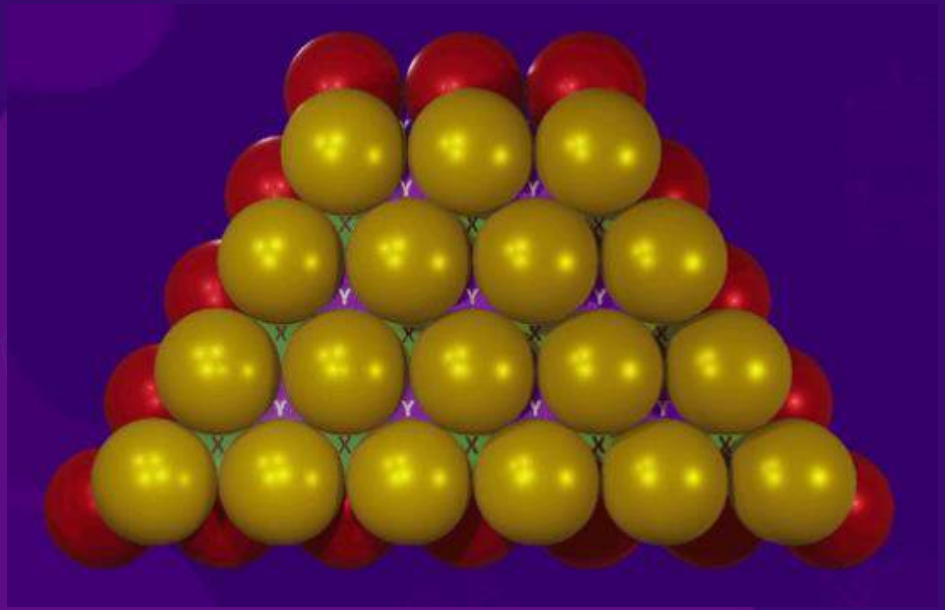


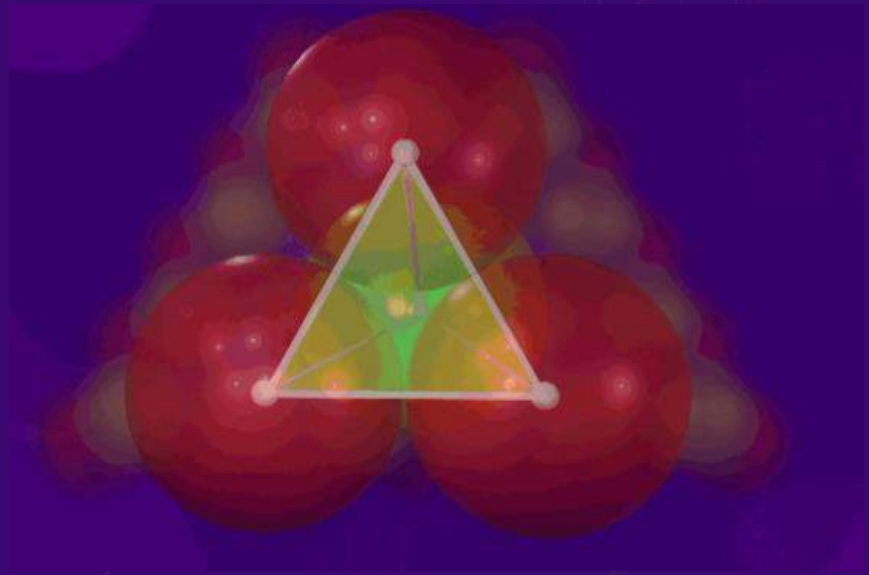
Octahedral void

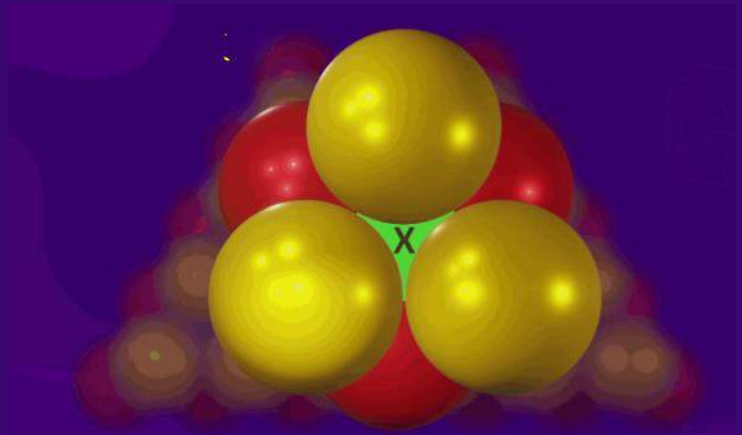
Octahedral void

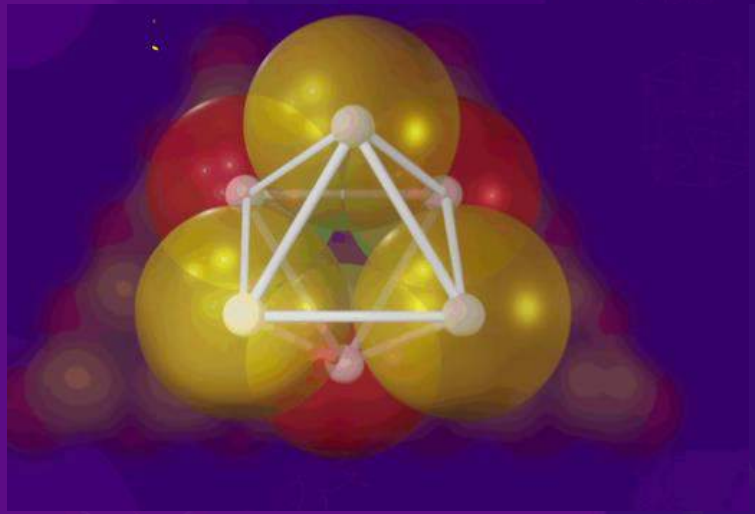
Tetrahedral void

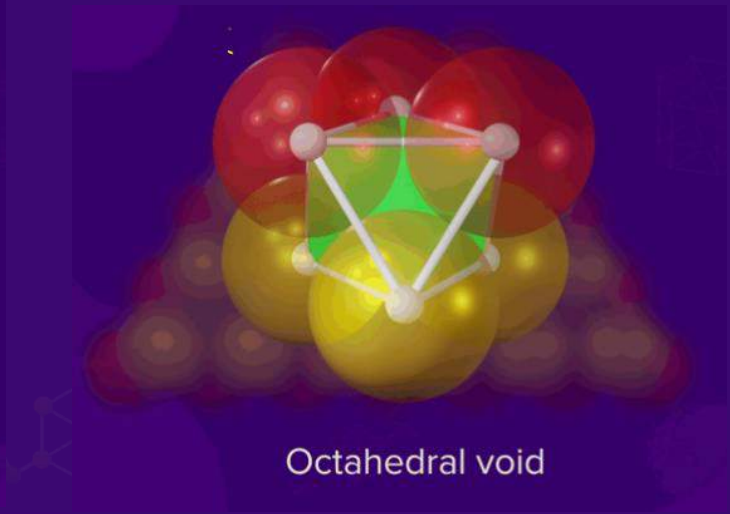




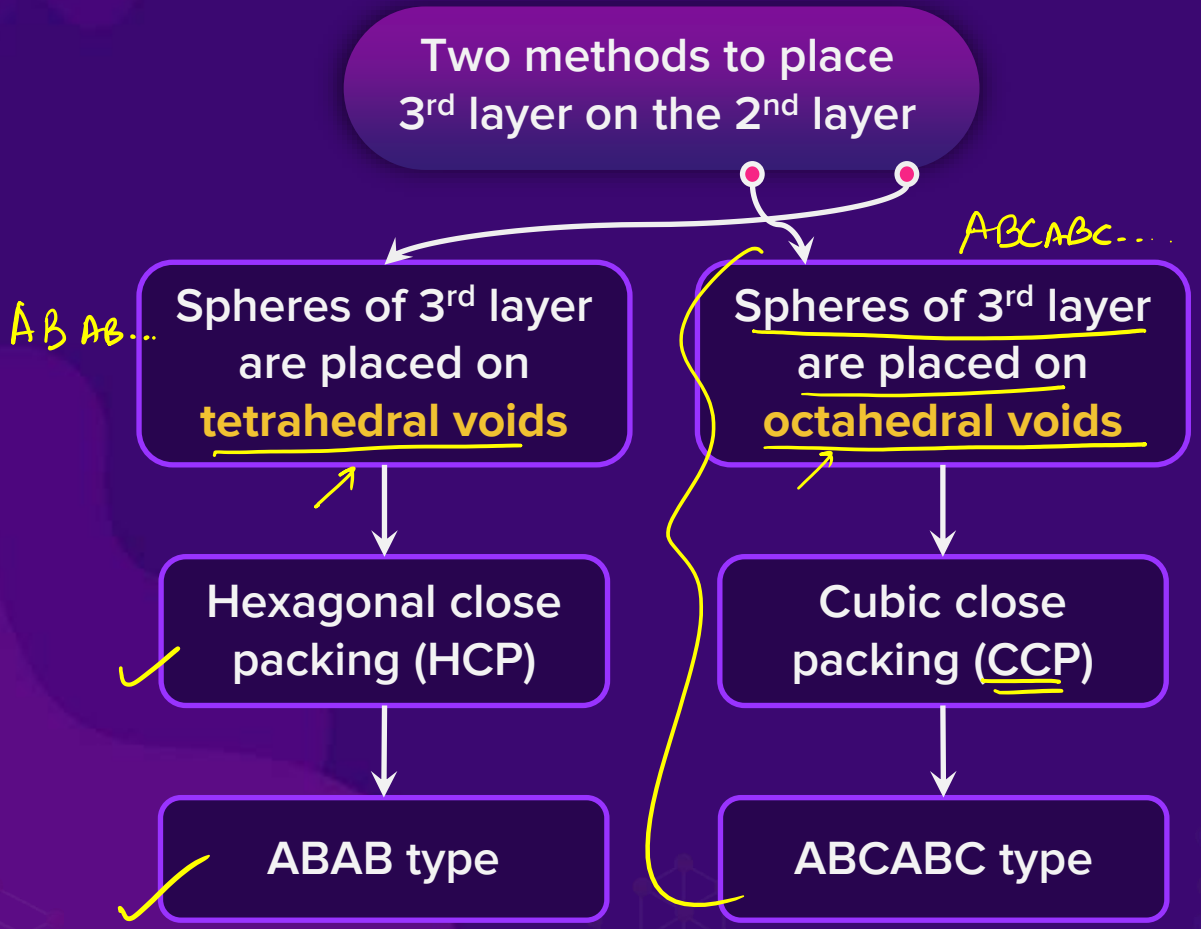


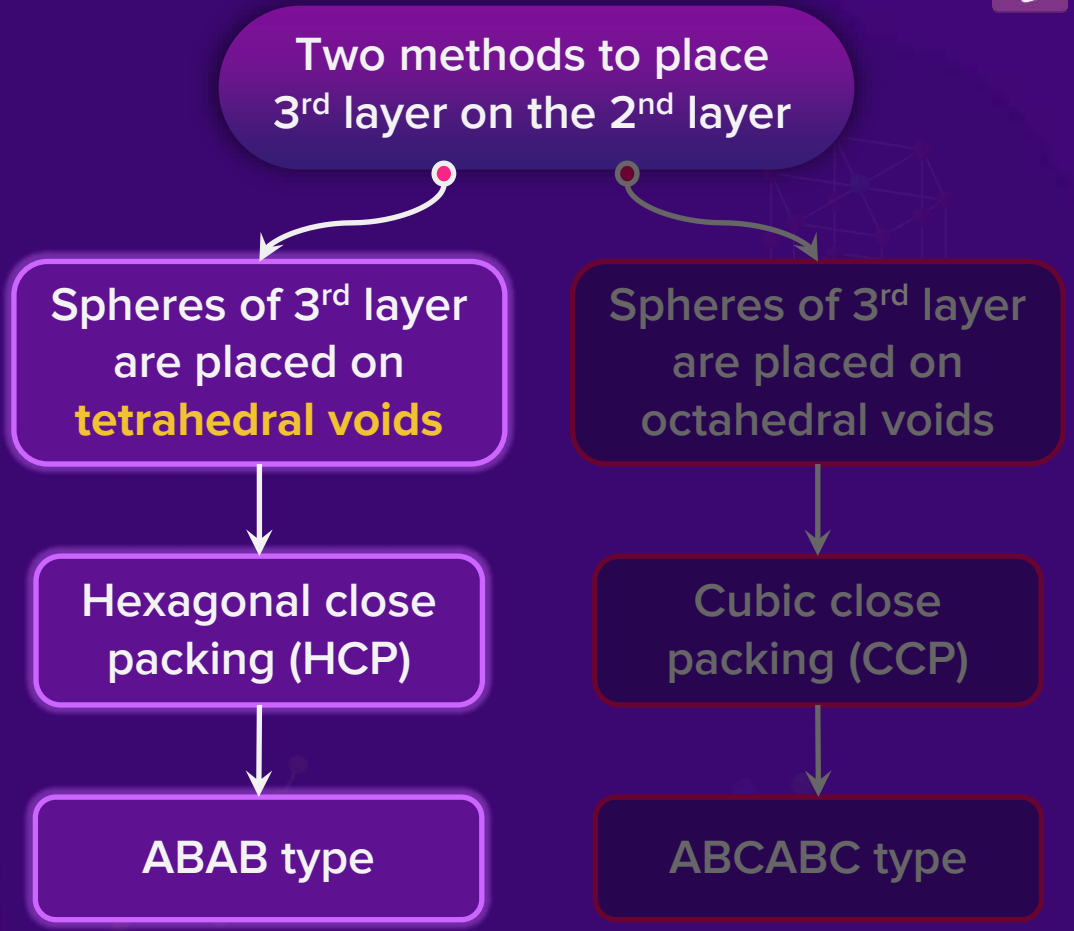






Octahedral void


Two methods to place 3rd layer on the 2nd layer
ABAB...
Spheres of 3rd layer are placed on tetrahedral voids
ABCABC...
Spheres of 3rd layer are placed on octahedral voids
Hexagonal close packing (HCP)
Cubic close packing (CCP)
ABAB type
ABCABC type


Two methods to place 3rd layer on the 2nd layer
Spheres of 3rd layer are placed on tetrahedral voids
Spheres of 3rd layer are placed on octahedral voids
Hexagonal close packing (HCP)
Cubic close packing (CCP)
ABAB type
ABCABC type

Hexagonal Close Packing (HCP)

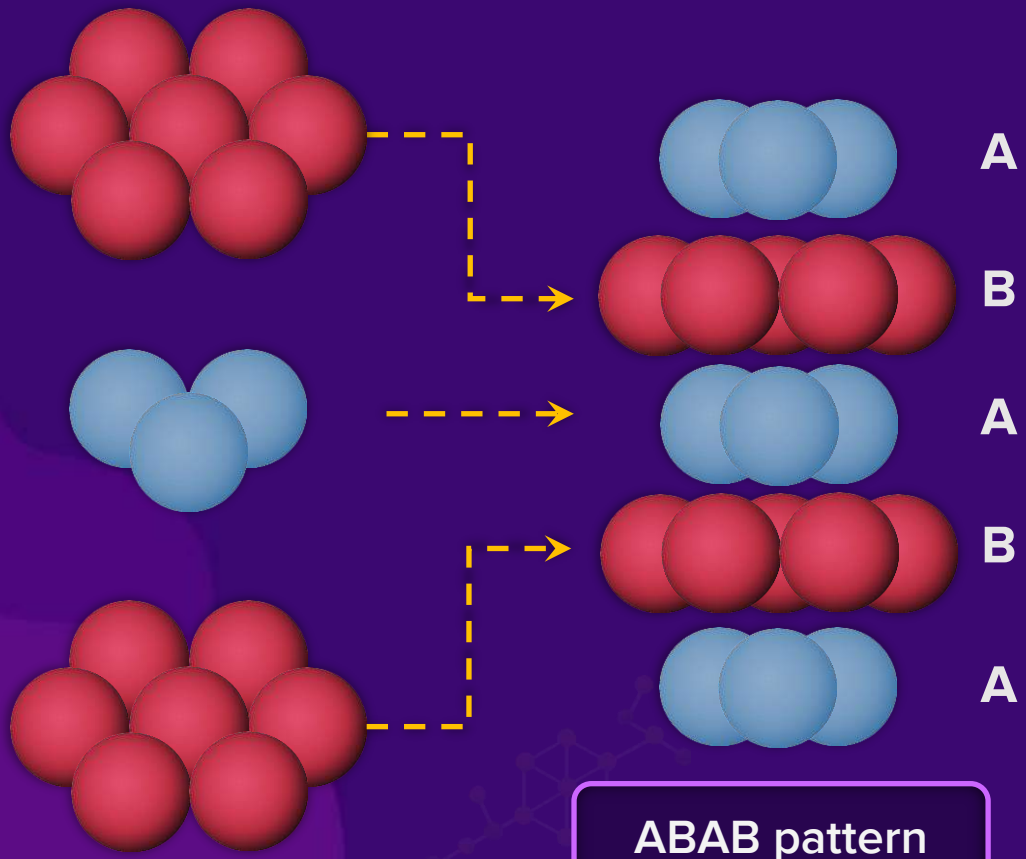
alternate layers are just one above the other.

Sphere of the third layer occupy those **voids** of the second layer **under** which there are **sphere of the first layer i.e., T.V.**

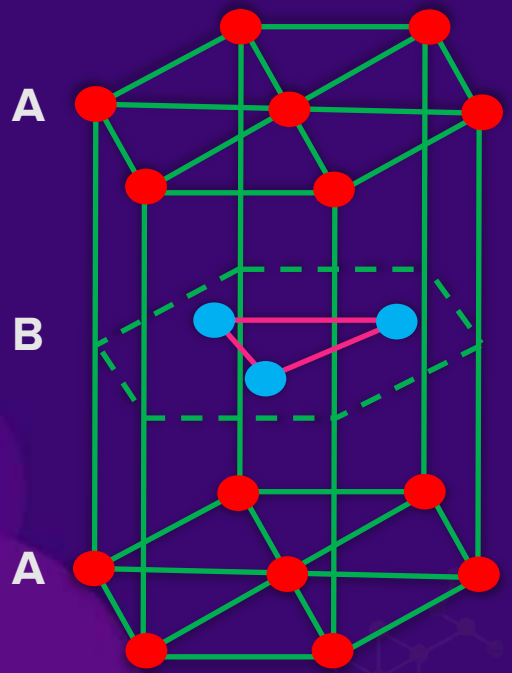
So, the third layer is **exactly identical** to the first layer. This generates the **ABAB - - - AB pattern.**

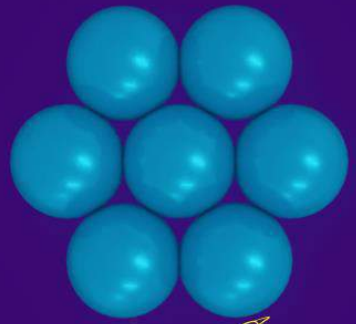
One type of void always remains **unoccupied, i.e., O.V.**

Hexagonal Close Packing (HCP)

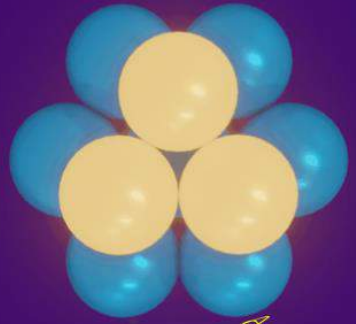


Unit Cell

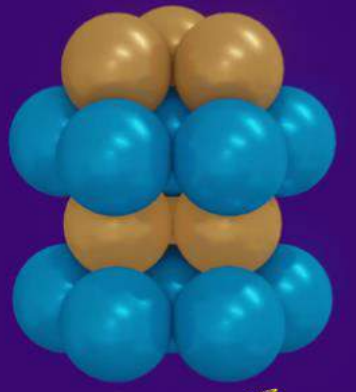




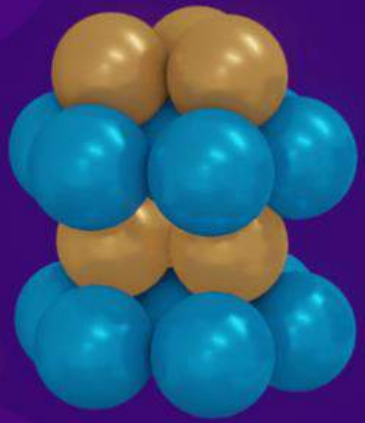
Hexagonal close packed layer A

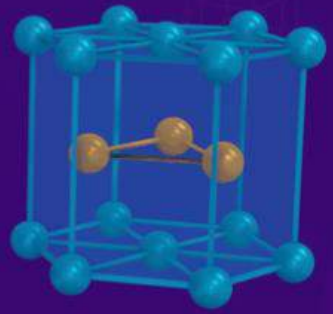


Hexagonal close packed layer B



AB Type of arrangement



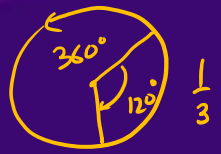


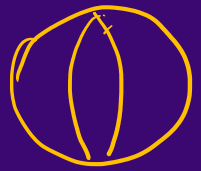
Effective Number of Particles in Hexagonal Unit Cell

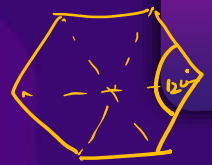
Effective number of particles (Z) = $12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 \times 1$

- $12 \times \frac{1}{6}$: Corner particles of two hexagonal layers
- $2 \times \frac{1}{2}$: For the centre particles of two hexagonal layers
- 3×1: For the particles of middle layer

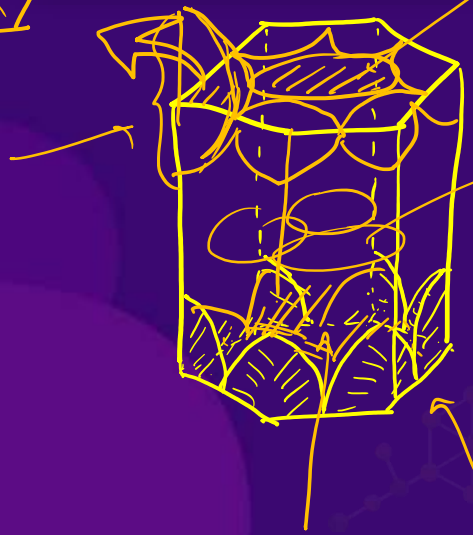
Effective Number of Particles in Hexagonal Unit Cell







Effective number of particles (Z) = $12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 \times 1$



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

face, corners

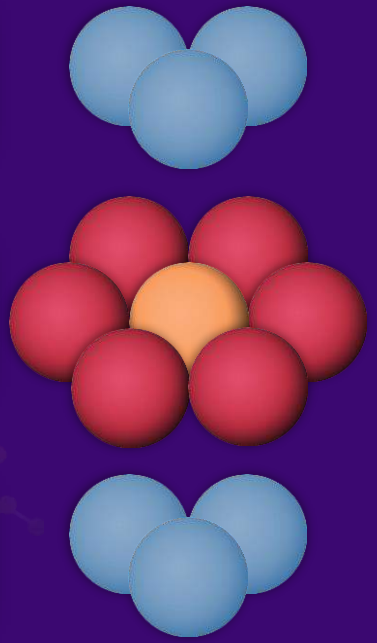
$2 + 1 + 3 = 6$

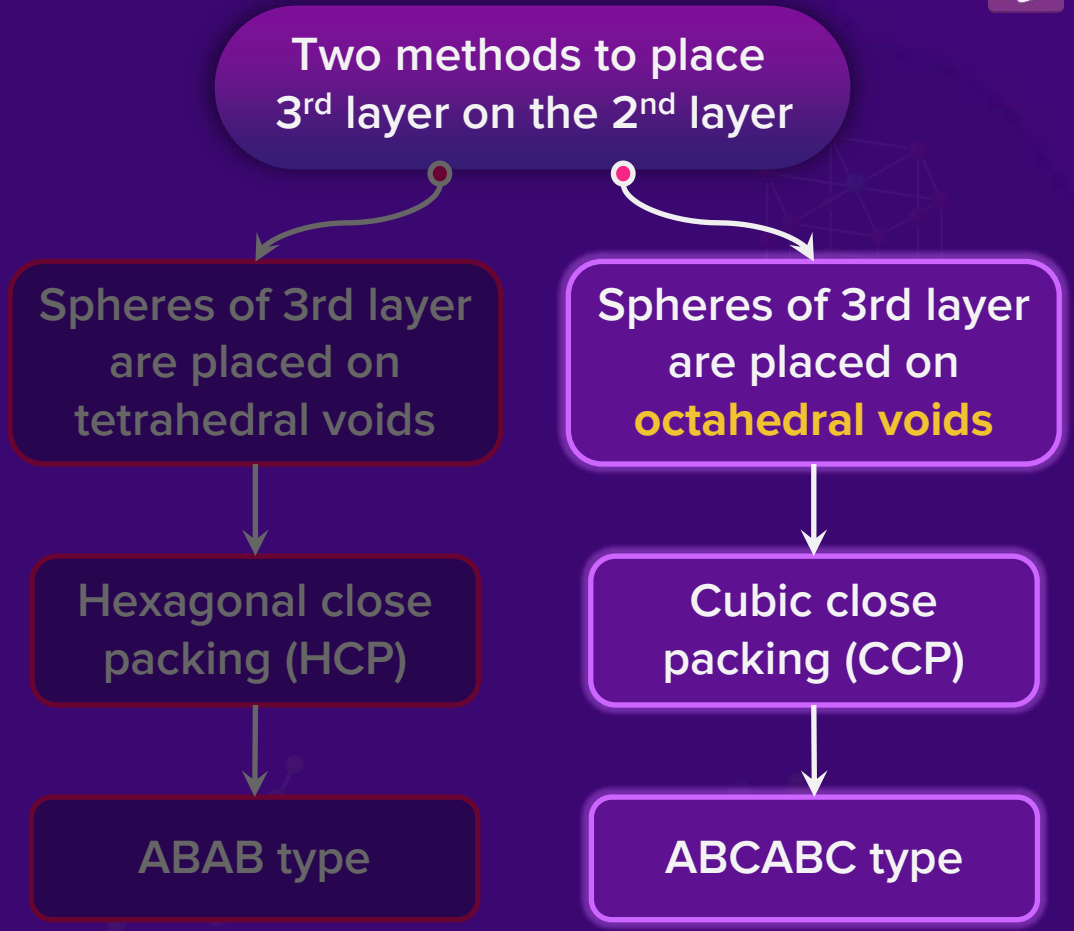
Coordination Number (C.N.)

C.N. = 12

Each sphere touches

- 3 spheres above the layer
- \+
- 6 spheres in its layer
- \+
- 3 spheres below the layer




Two methods to place 3rd layer on the 2nd layer
Spheres of 3rd layer are placed on tetrahedral voids
Hexagonal close packing (HCP)
ABAB type
Spheres of 3rd layer are placed on octahedral voids
Cubic close packing (CCP)
ABCABC type

Cubic Close Packing (CCP)

The spheres of the third layer are placed such that they occupy **50% voids of the second layer**, under which there are **voids of the first layer, i.e., O.V.**

Cubic Close Packing (CCP)

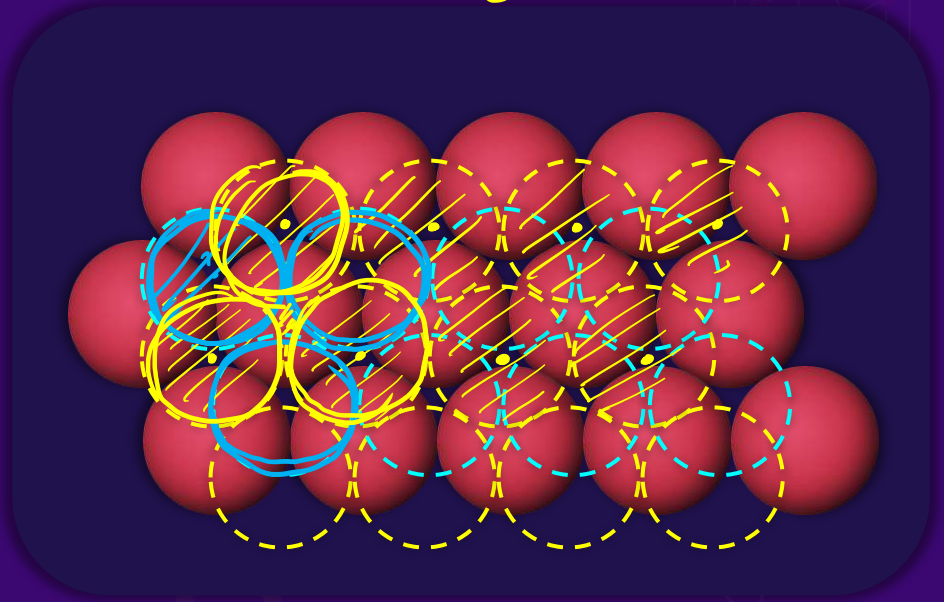
The third layer is **different** from the first layer as well as the second layer. Thus, it has an **ABCABC** type of arrangement.

It is known as **cubical close packing**; the unit cell chosen is **face-centred cubic** (FCC).

Cubic Close Packing (CCP) = FCC

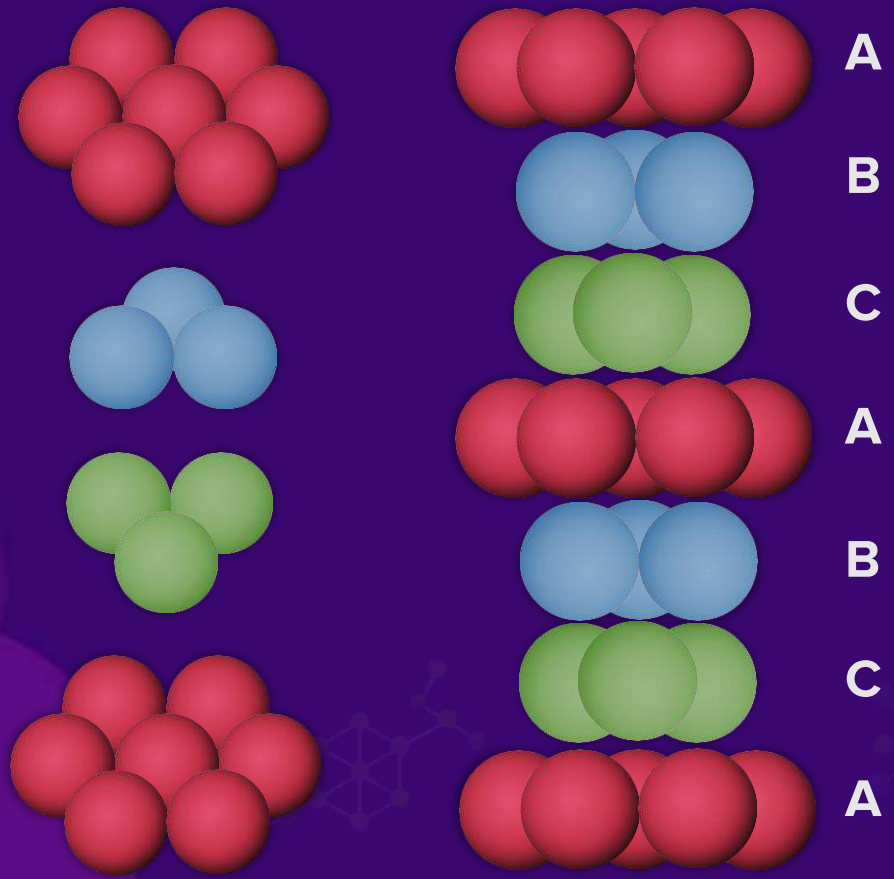
? : void in Layers 1 & 2 & 3

Red - Layer - 1
Yellow - " - 2
→ TVs

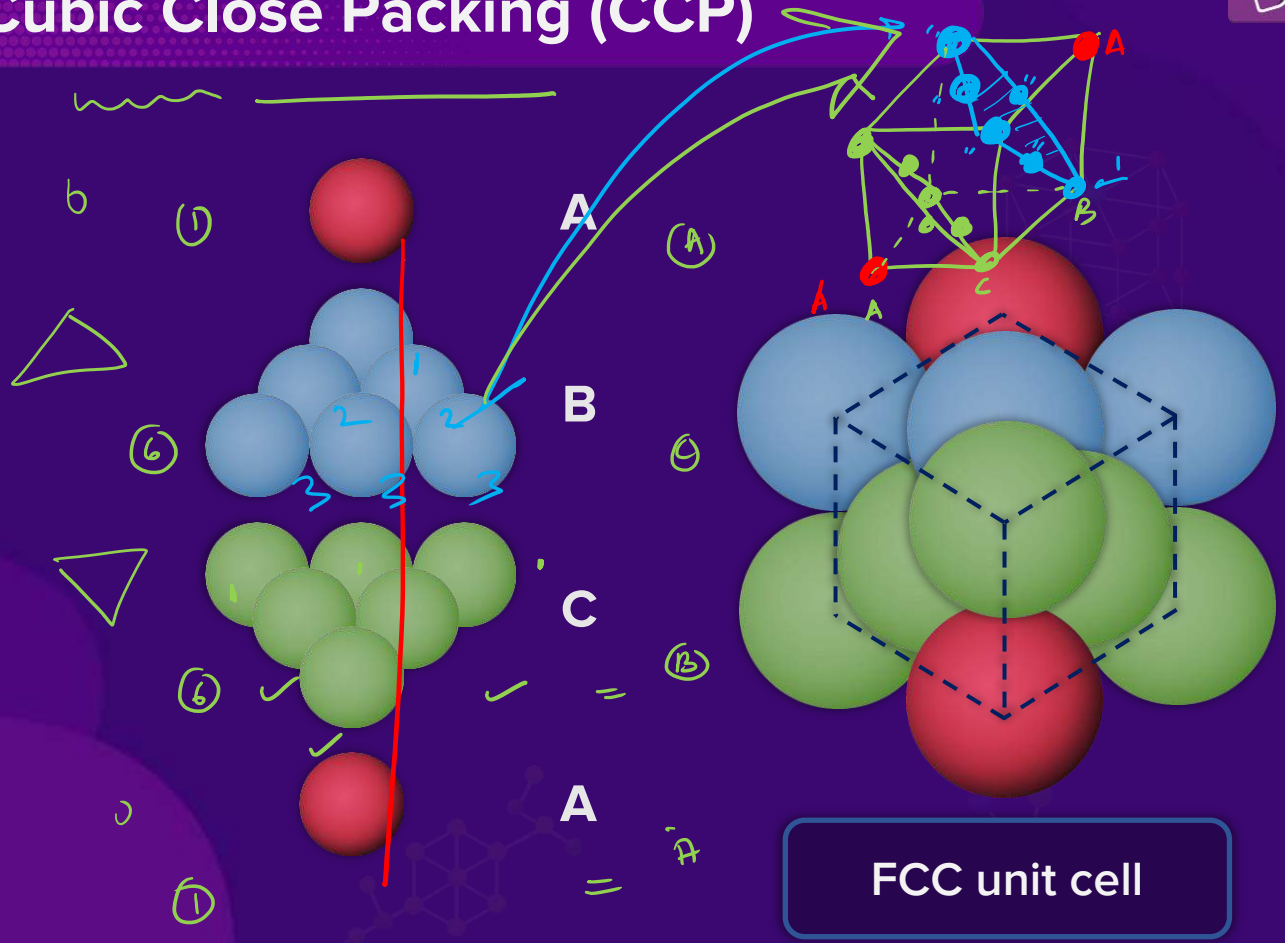


Cubic Close Packing (CCP)

ABCABC pattern



Cubic Close Packing (CCP)

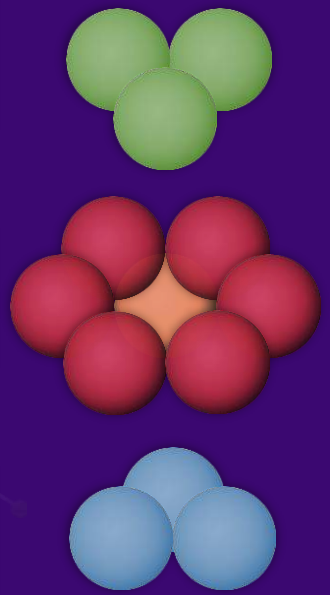


Coordination Number (C.N.)

C.N. = 12

Each sphere touches

- 3 spheres above the layer
- +
- 6 spheres in its layer
- +
- 3 spheres below the layer



Note

CCP = FCC

HCP & CCP

Closest packed structures

HCP and **CCP** are the **only** closely packed lattices (because of their efficiency, **74%**).

What is the fraction of empty space in an ABAB type arrangement in 3D (3D close packing from 2D hexagonal close packed layers)?

B

a 0.74

b 0.26

c 0.68

d 0.32

Solution

0.26 is the fraction of empty space in an ABAB type arrangement in 3D (3D close packing from 2D hexagonal close packed layers).

Hence, the correct answer is option(b).

What is the number of nearest neighbours for a given lattice point in a face-centered cubic lattice?

a 6

b 8

c 12

d 14

Solution

12 is the number of nearest neighbours for a given lattice point in a face-centered cubic lattice.

Hence, the correct answer is option(c).

Which one of the following schemes of ordering closed-packed sheets of equal-sized spheres does not generate close-packed lattice?

a ABCABC

b ABACABAC

c ABBAABBA

d ABCBCABCBC

Solution

The correct answer is option(c).

Voids in FCC Unit Cell

Voids in FCC Unit Cell

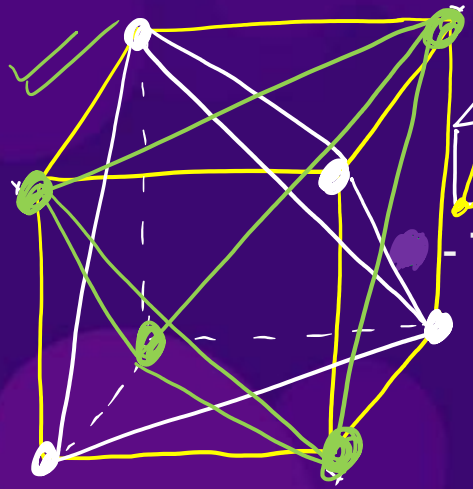
(1) Tetrahedral voids

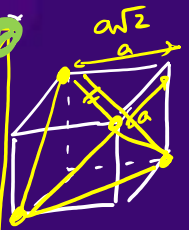
(2) Octahedral voids

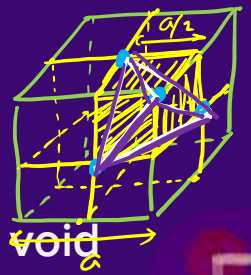
Tetrahedral Voids in FCC Unit Cell

FCC unit cell has

8 tetrahedral voids

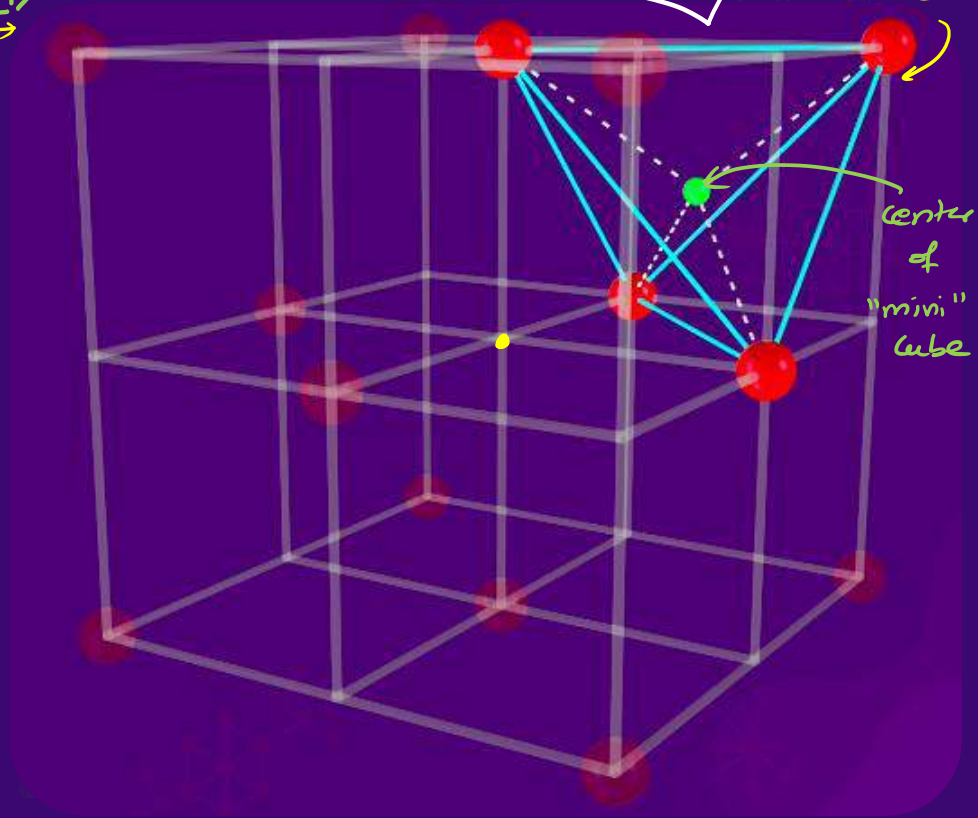


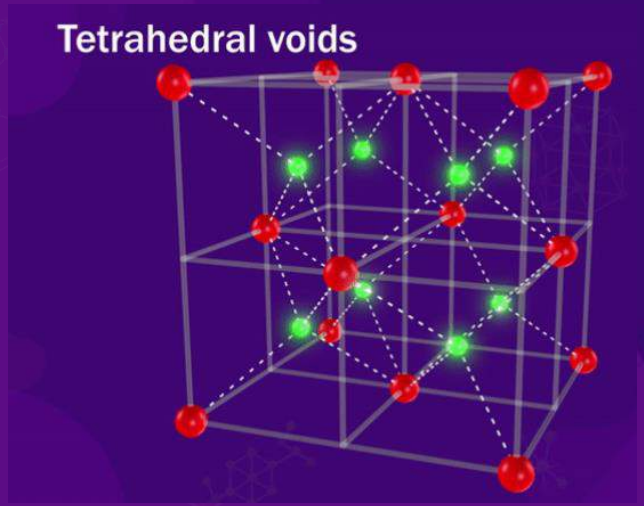




- Tetrahedral ~~void~~

1 Cube → Split in '8' 'mini' cubes



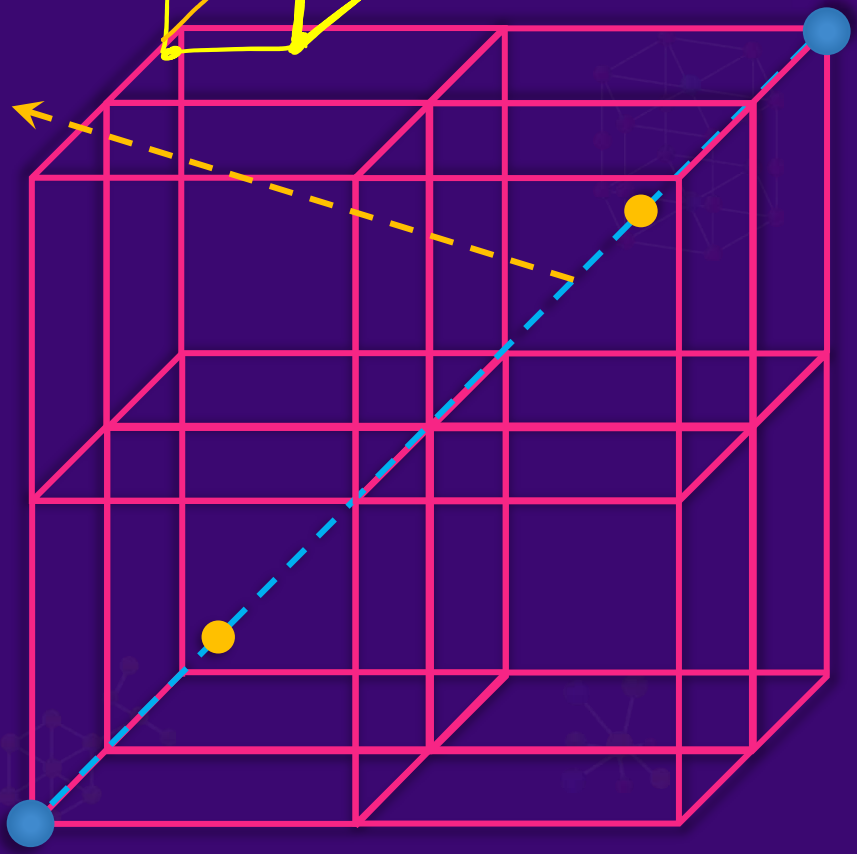


Tetrahedral Voids in FCC Unit Cell

face diagonal

① 4 Body diagonals

② Two TVs are present on each BD. These TVs are completely inside the cube.



Number of Tetrahedral Voids in FCC

Each tetrahedral void is present on the **body diagonal** of the FCC unit cell.

Each FCC unit cell has **4** body diagonals.

Each body diagonals contains **2** tetrahedral voids.

Number of Tetrahedral Voids in FCC

Each tetrahedral void contributes **fully** to the unit cell and is **not shared** with other unit cells.

Total tetrahedral voids = **8**

Number of Tetrahedral Voids in FCC

For FCC unit cell

$Z = 4$

$T.V. = 8$

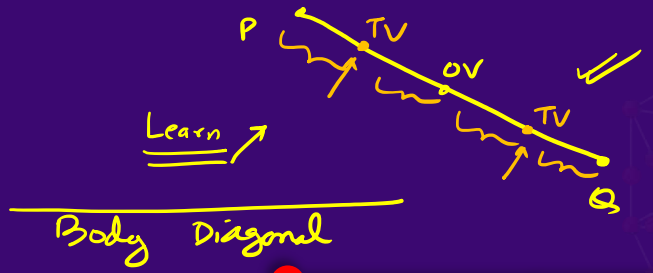
So, $T.V. = 2 \times Z$

Octahedral Voids in FCC

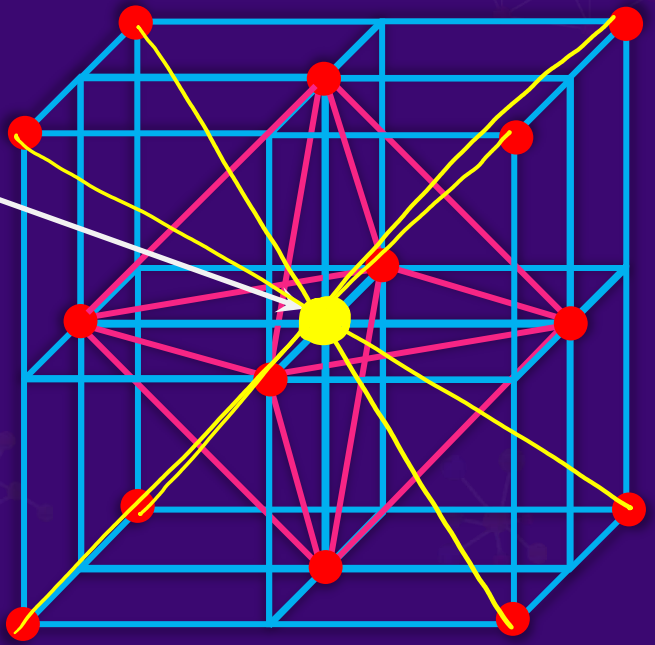
Present at each **edge centre** and at the **body centre** of the FCC unit cell

Location of Octahedral Voids in FCC

Each Body Diagonal passes thro' an OV



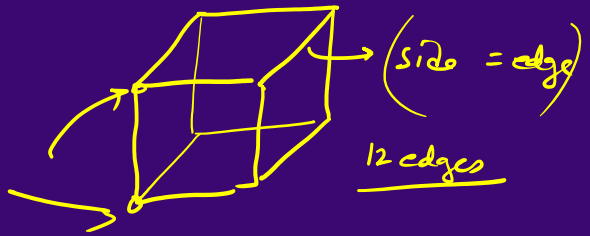
O.V. at **body centre**



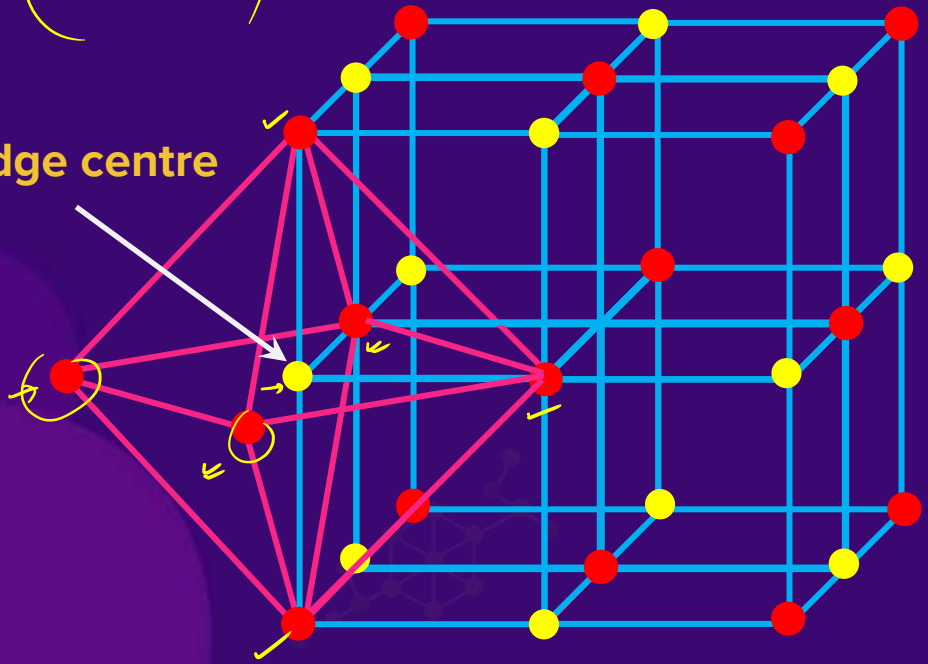
Location of Octahedral Voids in FCC

Vertices = more than one vertex

(= Corner = vertex)

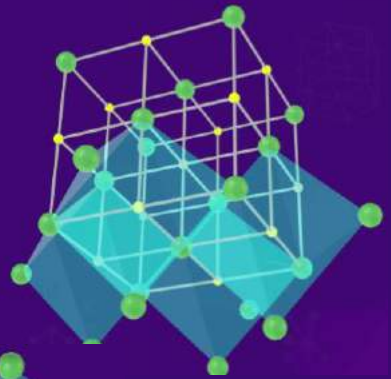


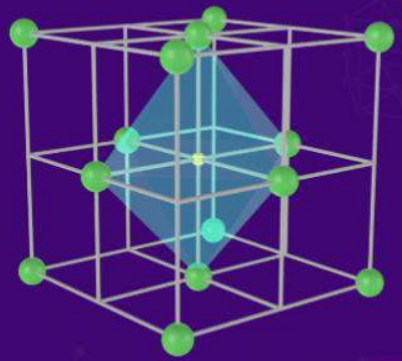
O.V. at edge centre

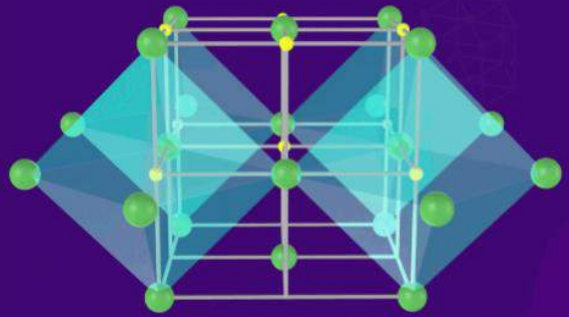


Octahedral Voids

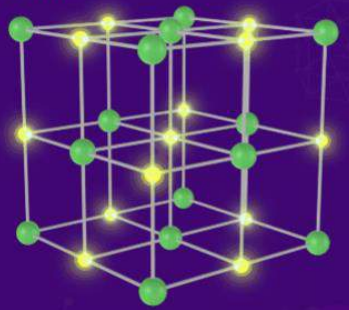
Octahedral void







Octahedral voids



Number of Octahedral Voids in FCC or CCP

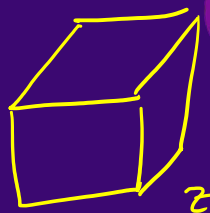
Number of octahedral voids per unit cell = 1 + $12 \times \frac{1}{4}$

1 — Void at body centre

$12 \times \frac{1}{4}$ — Void at edge centre

= 4

Note



Fcc = ccp

Z = 4

O.V = 4

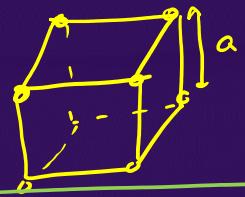
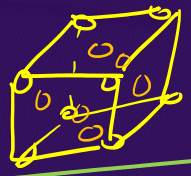
T.V = 8

In general, in close-packed structures (HCP and FCC) = ccp

Number of O.V. = Z

Number of T.V. = 2 Z

Z	Effective number of particles in one unit cell

	SC	BCC	FCC = CCP	HCP
Unit cell				
Z	1	2	4 | 4 OVs, 8 TVs	Z = 6 | OV = 6, TV = 12
CN.	6	8	12	(12)
	$\leftarrow a = 2r$ ✓	$\leftarrow a = \frac{4}{\sqrt{3}} r$	$\leftarrow a = 2\sqrt{2}r$	$a = b = 2r$, c
	do corner atoms touch each other	Corner atoms touch bc but not each other	Corner atoms touch face centre but not each other	

OVs: 12 BC (4), (4) EC

TVs: Two on each Body Diagonal (8)

Voids: TV, OV

Closest packed structures

TVs = 2 × Z

OVs = Z

Voids in HCP Unit Cell

Number of Tetrahedral Voids in HCP

Effective number of particles per unit cell (Z)	=	6		
Number of tetrahedral voids	=	2 Z		
Number of tetrahedral voids	=	2 × 6	=	12

Number of Octahedral Voids in HCP

Effective number of particles per unit cell (Z)	=	6
Number of octahedral voids	=	Z
Number of octahedral voids	=	6

Remember

Unit cell	Z	Tetrahedral void (2Z)	Octahedral void (Z)
FCC	4	8	4
HCP	6	12	6

Formula of Ionic Compounds

Anions : FCC

Cations : edge centers
Body center

Oppositely charged ions touch each other

Rock Salt structure

$a = 2r_\oplus + 2r_\ominus$

→ anions DO NOT touch each other

→ Cations " " " " "

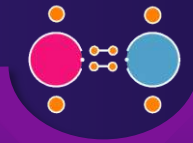
Rock Salt structure

Ionic Compounds

Na^+Cl^-

Cations are usually smaller

Anions " " bigger



Larger ions
(Generally anion)

Form the lattice

Ionic Compounds

NaCl

Rock Salt Structure

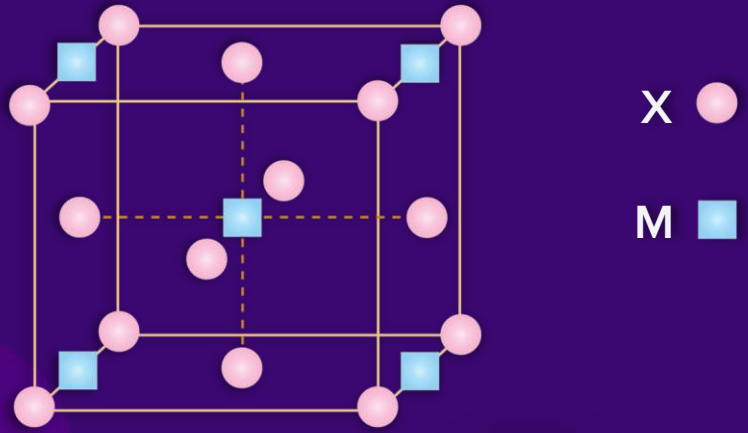
Anions occupy fcc positions

Cations ,, all the OVs

Smaller ions
(Generally cation)

Occupy the voids
such as T.V., O.V., etc.

A compound M_PX_q has a cubic close packing (CCP) arrangement of X. Its unit cell structure is shown below. The empirical formula of the compound is:



a MX

b MX_2

c M_2X

d M_5X_{14}

Solution

In the cubic close packing of M_pX_q, the M atoms occupies all the corners and faces of the given arrangement and X atoms are present only on the centre of the cubic arrangement and centre of the edges.

Since, contribution of one atom present on the face of this cubic arrangement is half. Contribution of one atom present on the centre of the edge of this cubic arrangement is one fourth.

Contribution of one atom present on the centre of this cubic arrangement is one.

Thus, the total number of M atoms = 2

the total number of X atoms = 4

Thus, the empirical formula of the compound is MX_2.

Hence, the correct answer is option (b).

The number of octahedral void(s) per atom present in a cubic close-packed structure is:

a. 1

b. 2

c. 3

d. 4

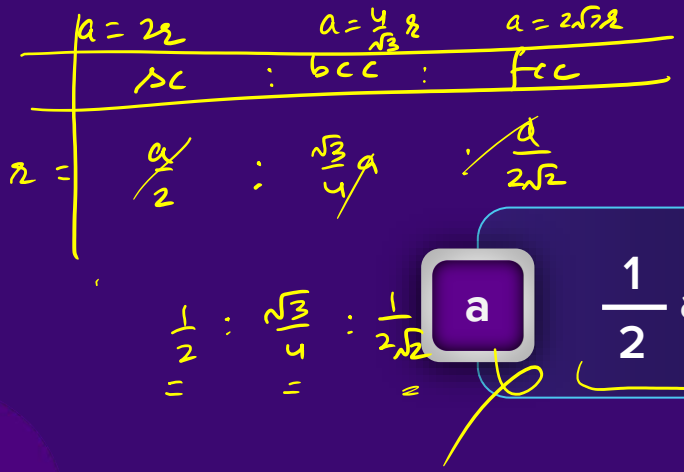
Solution

In cubic close packed arrangement, the total number of atoms present are four. Thus, total octahedral voids are also four.

Hence, the number of octahedral void(s) per atom present in a cubic close-packed structure is one.

Hence, the correct answer is option (a).

If ‘a’ stands for the edge length of the cubic systems: simple cubic, body-centred cubic, and face-centred cubic, then the ratio of radii of the spheres in these systems will be, respectively :



a. $\frac{1}{2}a : \frac{\sqrt{3}}{2}a : \frac{\sqrt{2}}{2}a$

b. $1a : \sqrt{3}a : \sqrt{2}a$

If ‘a’ stands for the edge length of the cubic systems: simple cubic, body-centred cubic, and face-centred cubic, then the ratio of radii of the spheres in these systems will be, respectively:

c $\frac{1}{2}a : \frac{\sqrt{3}}{4}a : \frac{1}{2\sqrt{2}}a$

d $\frac{1}{2}a : \sqrt{3}a : \frac{1}{\sqrt{2}}a$

Solution

Hence, the correct answer is option (c).

If Z (effective number) is the number of atoms in the unit cell which represents the closest packing sequence ABCABC ....., the number of tetrahedral voids in the unit cell is equal to:

a. Z

b. 2Z

c. $\frac{Z}{2}$

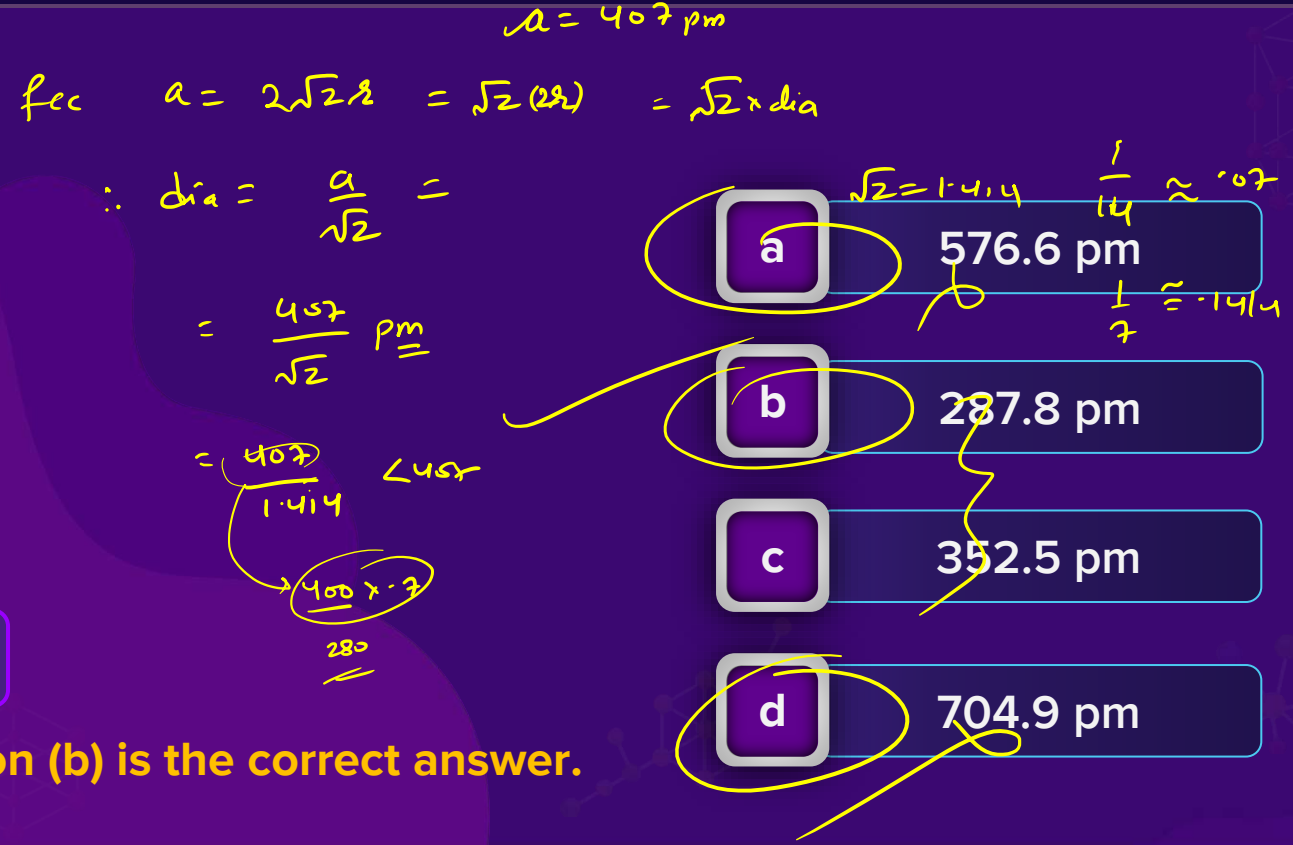
d. $\frac{Z}{4}$

Solution

If Z (effective number) is the number of atoms in the unit cell which represents the closest packing sequence ABCABC ....., the number of tetrahedral voids in the unit cell is equal to 2Z.

Hence, the correct answer is option (b).

Gold has a face-centred cubic lattice with an edge length of the unit cube of 407 pm. Assuming the closest packing, the diameter of the gold atom is:



Solution

Hence, option (b) is the correct answer.

Which one of the following statements about packing in solids is incorrect?

B

a. Coordination number in BCC packing is 8.

b. Coordination number in HCP packing is 12.

c. Void space in HCP packing is 32%.

d. Void space is CCP packing is 26%.

Solution

The occupancy by atoms is 74% in HCP/CCP arrangement. Thus, the void occupancy is 26%.

Hence, the correct answer is option (c).

Crystal Imperfections/ Defects

Defects

Although crystalline solids have **short-range as well as long-range order** in the arrangement of their constituent particles, crystals are **not perfect**.

Usually, a solid consists of an aggregate of a large number of **small crystals**.

These small crystals have **defects** in them because crystallisation process occurs at a **fast or moderate** rate.

Defects

Single crystals are formed when the process of crystallisation occurs at an **extremely slow rate**.

Even these crystals are **not free from defects**.

The defects are basically **irregularities** in the arrangement of the constituent particles.

Defects in Crystals

In a **perfect crystal**, all atoms would be on their **correct lattice positions** in the structure.

A perfect crystal can exist only at the **absolute zero of temperature**, 0 K. **Above** 0 K, **defects** occur in the structure.

Imperfections can be because of:

1. **Conditions** under which crystals have been developed.
2. **Impurities**
3. **Temperature** (because of thermal conductivity some atoms/ions can get displaced).

Point Defects

Point Defects

Defects will only be **at** certain **lattice positions**.

Point defects in ionic solids

- Stoichiometric defects
- Non-stoichiometric defects
- Impurity defects

Stoichiometric Defects

The **formula** of a compound remains **unchanged** despite the presence of these defects.

Also known as **thermodynamic** or **intrinsic defects.**

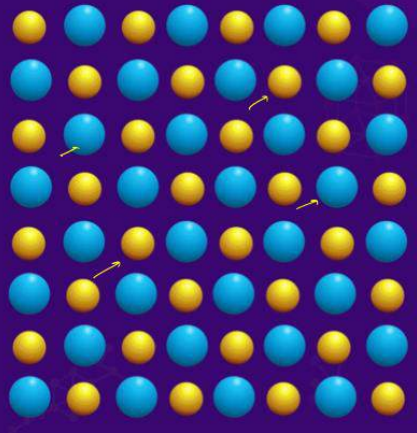
Point defects in ionic solids

- Stoichiometric defects (most imp.)
  - Schottky
  - Frenkel
- Non-stoichiometric defects
- Impurity defects

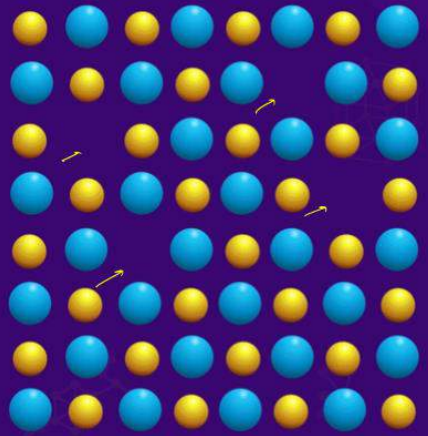
Schottky Defect

NaCl

Perfect crystal



Schottky defect



Schottky defect consists of ion vacancy in a crystal lattice, but the stoichiometry of the compound (and thus, electrical neutrality) is retained.

Characteristics

LiF NaF
LiCl NaCl
LiBr NaBr
LiI NaI

In NaCl, there is approximately one Schottky defect per 10^{16} ions at room temperature.

(i) Shown by ionic substances in which the cation and anion are of almost similar sizes.
E.g.: NaCl, KCl, AgBr, and CsCl

(ii) Schottky defect decreases the density of the substance.

B

Schottky defect in crystals is observed when:

a. Density of the crystal is increased

b. Unequal number of cations and anions are missing from the lattice

c. An ion leaves its normal site and occupies an interstitial site.

d. Equal number of cations and anions are missing from the lattice

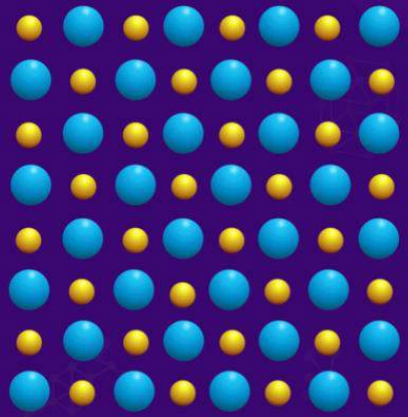
Solution

Schottky defect in crystals is observed when equal number of cations and anions are missing from the lattice.

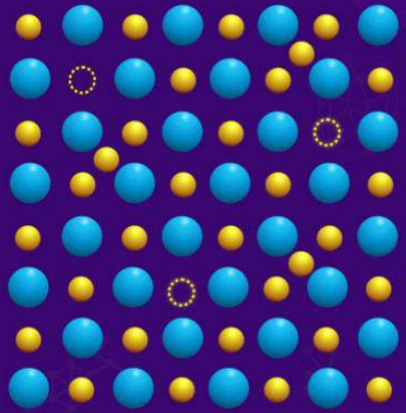
Hence, option (d) is the correct answer.

Frenkel Defect

Perfect crystal



Frenkel defect



When ions are **displaced from normal lattice positions** and are present in some interstitial voids, it is known as Frenkel defect.

Frenkel defect is also known as **dislocation defect**.

Characteristics

(i) Shown by **ionic solids** having **large difference** in size between the positive & negative ions.
E.g: ZnS, AgCl, AgBr, & AgI

(ii) **Density** of a solid **does not change.**

AgBr shows both **Frenkel** as well as **Schottky** defect.

Effect of Schottky & Frenkel Defect on Properties of Crystal

(i) **Stability** of crystal

Defects ↑

↓

Repulsions between like-charged ions ↑

↓

Stability ↓

(ii) Electrical conductivity

Defects ↑

↓

Mobility of ions in the crystal ↑

↓

Electrical conductivity ↑

The theoretical density of ZnS is d g/cm^3. If the crystal has 4% Frenkel defect, then the actual density of ZnS should be:

a. d g/cm^3

b. 0.04d g/cm^3

c. 0.96d g/cm^3

d. 1.04d g/cm^3

Solution

The theoretical density of ZnS is d g/cm^3. If the crystal has 4% Frenkel defect, then the actual density of ZnS does not changes because cations missing from their lattice sites occupies the interstitial sites. Therefore, it should be d g/cm^3

Hence, option (a) is the correct answer.

Which of the following may have Frenkel defect?

a ZnS

b AgCl

c AgBr

d All of these

Solution

All the given compounds have Frenkel defect.
Hence, option (d) is the correct answer.

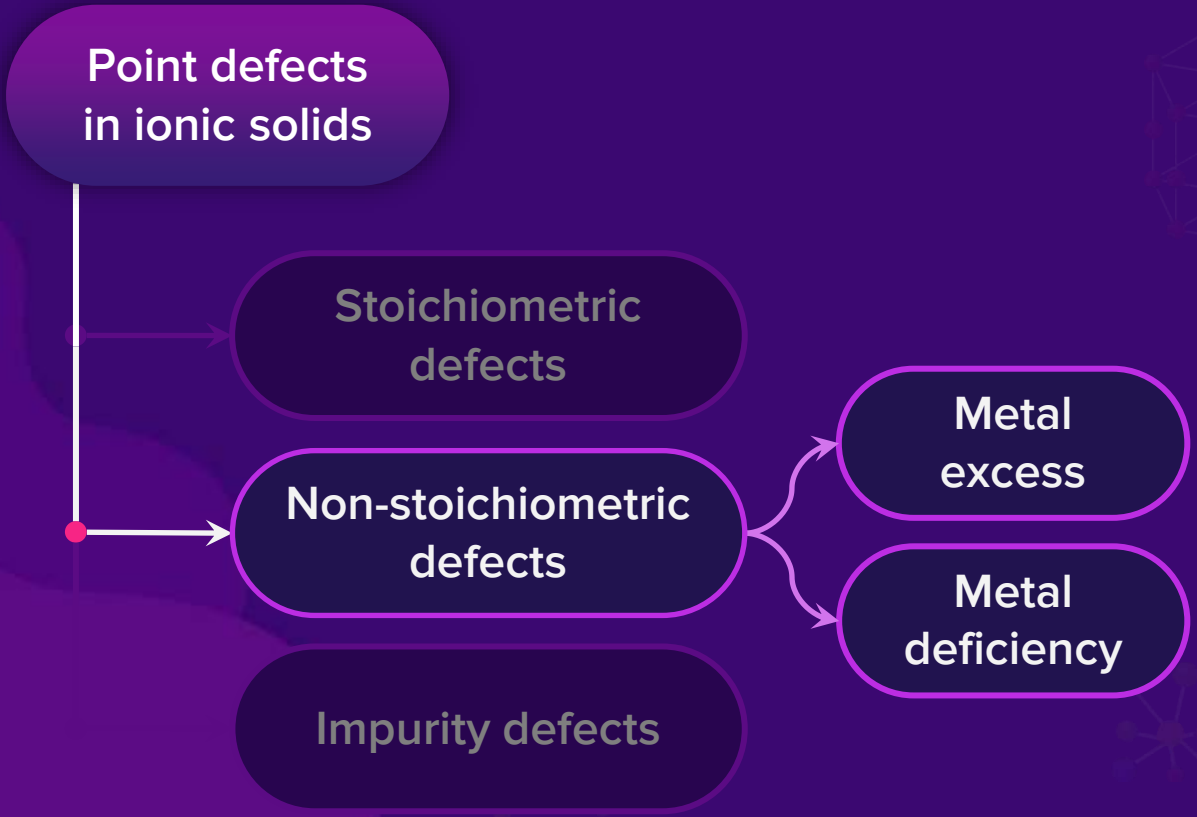
Non-Stoichiometric Defects

Point defects in ionic solids

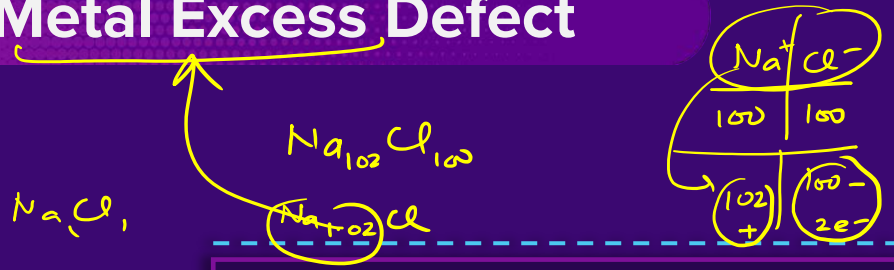
- Stoichiometric defects
- **Non-stoichiometric defects**
- Impurity defects

The formula of compound gets **modified** because of the presence of these defects.

Non-Stoichiometric Defects



Metal Excess Defect



Instead of anion, electron **occupies** the lattice site of **anion**.

Example:
NaCl and **KCl** show such defects

Heating of NaCl

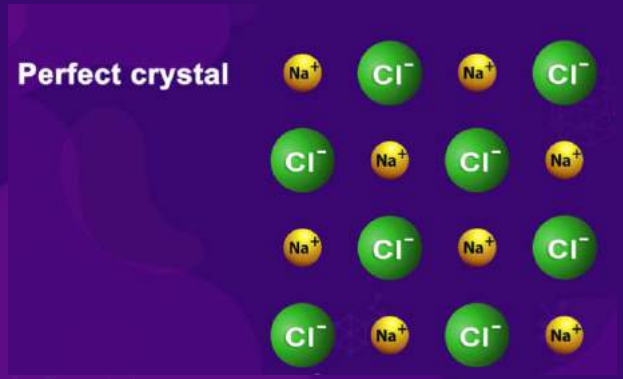
$Na \rightarrow Na^+ + e^-$

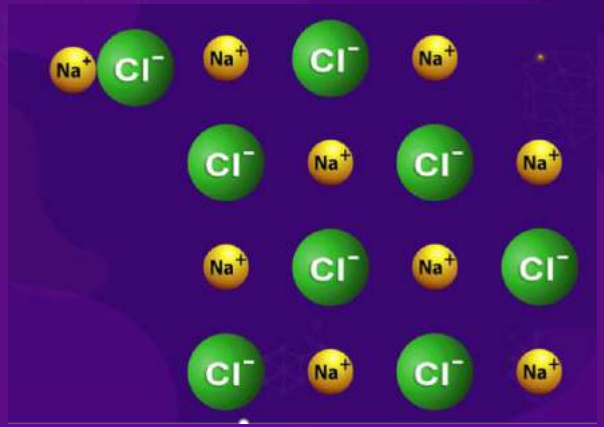
When crystals of NaCl are **heated** in an atmosphere of sodium vapour

Cl^- ions diffuse to the **surface** of the crystal and combine with the Na atoms to give NaCl

This happens due to **loss of electron** by Na atoms to form Na^+ ions.

Heating of NaCl





F-centre

The **released electrons** diffuse into the crystal and **occupy anionic sites.**

These anionic sites occupied by unpaired electrons are called **F-centres.**

ZnO is white when cold & yellow when hot

$O^{2-} \xrightarrow{\Delta} \frac{1}{2}O_2 + 2e^-$ (cool)

Metal Excess Defect

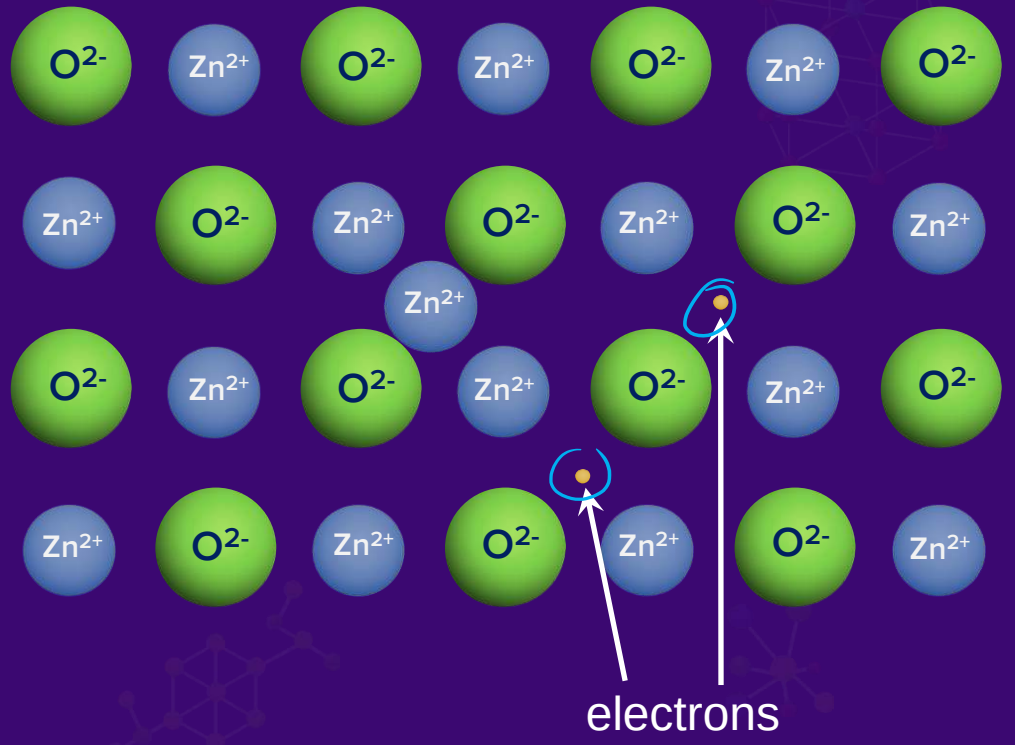
Zinc oxide is **white** in colour at room temperature.

On heating, it **loses some** O^{2-} ions in the form of O_2 and turns yellow.

$$ZnO \xrightarrow{\Delta} Zn^{2+} + \frac{1}{2}O_2 + 2e^-$$

Metal Excess Defect

$Zn_{1+x}O$



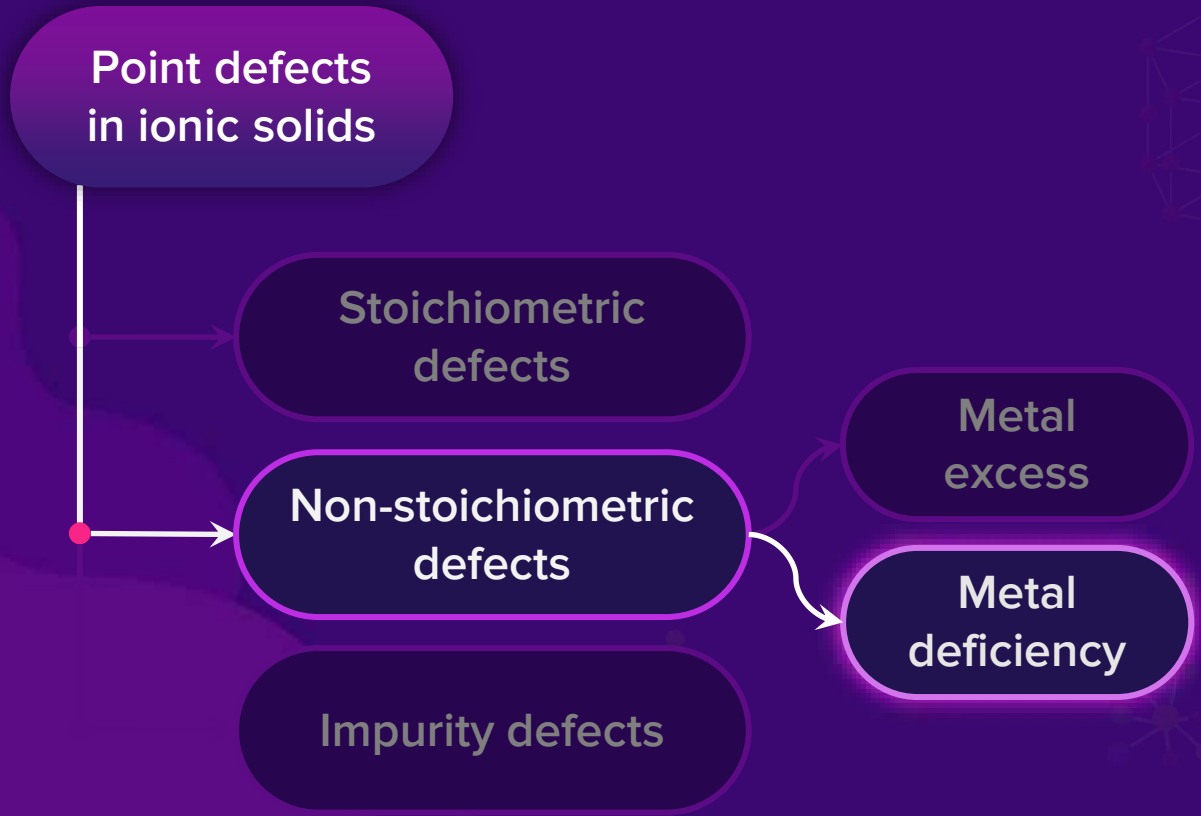
Metal Excess Defect

The electrical property and colour of a solid gets modified.

E.g.: Crystal of NaCl is yellow, KCl is violet or lilac, and LiCl is pink.

The substance becomes paramagnetic

Non-Stoichiometric Defects



Metal Deficiency Defect

100 O^{2-} : Charge -200

x (98) Fe ions : $+200$

$(98-x) \rightarrow Fe^{2+}$

$x \rightarrow Fe^{3+}$

Σ charge $= +2(98-x) + 3(x)$

$= 196 - 2x + 3x = +200$

$x = 200 - 196 = 4$

$[4\ Fe^{3+}, 94\ Fe^{2+}]$

$Fe^{2+}O^{2-}$

$Fe_{0.98}O$

If a **positive charge is absent** from its lattice site, the charge can be balanced by an **adjacent metal ion** with an extra positive charge.

[100 O^{2-} Charge : -200; 100 Fe^{2+} charge : $+200$] FeO

Metal Deficiency Defect

$Fe_{93}O_{100}$

(x) Fe : +3

(93-x) Fe : +2

$\frac{1}{0.93} = \frac{1}{1-0.07} \approx 1+0.07 = 1.07$

$\therefore$ Total charge $= +3x + 2(93-x) - 2\times100 = 0$

Example,

$186 + x = 200$

$x = 14$

% of Fe in +3

$= \frac{\text{no. of Fe ions in +3}}{\text{total no. of Fe ions}} \times 100$

$= \frac{14}{93} \times 100$

$= \frac{14}{0.93}$

$\approx 14 \times 1.07 = 14.98\ \%$

$\approx 15\%$

what % of Fe ions are present as Fe : +3 in $Fe_{0.93}O$

FeO is mostly found with a composition of $Fe_{0.93}O$ to $Fe_{0.96}O$.

Loss of some Fe^{2+} ions is compensated by the presence of the required number of Fe^{3+} ions.

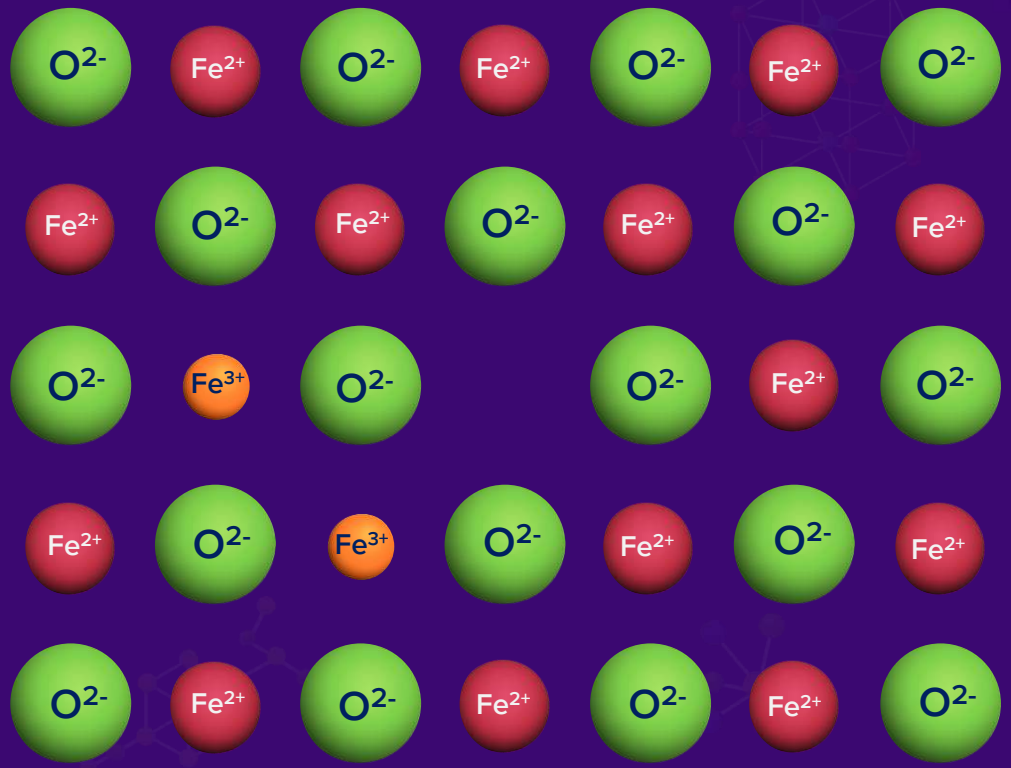
$\frac{1}{1+x} \approx 1-x$

$\frac{1}{1-x} \approx 1+x$

} if $x \ll 1$

Metal Deficiency Defect

FeO



Experimentally, it was found that a metal oxide has the formula $M_{0.98}O$. Metal M is present as M^{2+} and M^{3+} in its oxide. A fraction of the metal which exists as M^{3+} would be:

a. 7.01%

b. 4.08%

c. 6.05%

d. 5.08%

Solution

%

$M_{0.98}O = M_{98}O_{100}$

x M^{3+}

$(98-x)$ M^{+2}

$+3x + 2(98-x) - 2(100) = 0$

$196 + x = 200$

$x = 4$

% of M in +3

$= \left(\frac{\text{no. of metal ions in +3}}{\text{total no. of metal ions}}\right) \times 100$

$= \frac{4}{98} \times 100 = 4 \times 1.02 = 4.08\%$

Hence, option (b) is the correct answer.

The correct statement(s) regarding defects in solids is(are):

a. Frenkel defect is usually favoured by a very small difference in the sizes of cation and anion.

b. Schottky defect is a dislocation defect.

The correct statement(s) regarding defects in solids is(are):

B

c

Trapping of an electron in the lattice leads to the formation of F-centre.

d

Schottky defects have no effect on the physical properties of solids.

Solution

Hence, option (c) is the correct answer.

The correct statement regarding defects in crystalline solids is:

a. Frenkel defects decrease the density of crystalline solids.

b. Frenkel defect is a dislocation defect.

The correct statement regarding defects in crystalline solids is:

B

c Frenkel defect is found in halides of alkaline metals.

d Schottky defects have no effect on the density of crystalline solids.

Solution

Hence, option (b) is the correct answer.

Assertion: No compound has both Schottky and Frenkel defects.

Reason: Both defects change the density of the solid.

a. If both assertion and reason are correct, and reason is the correct explanation of assertion.

b. If both assertion and reason are correct, but reason is not the correct explanation of assertion.

Assertion: No compound has both Schottky and Frenkel defects. **Reason:** Both defects change the density of the solid.

c If assertion is correct but reason is incorrect.

d If both the assertion and reason are incorrect.

Solution

Hence, option (d) is the correct answer.

Which is ~~not correct~~ about the Schottky defects?

a. Both cations and anions are missing from their lattice sites without affecting the stoichiometry of the compound.

T

b. The presence of holes causes the stability of the crystal to increase.

F

Which is not correct about the Schottky defects?

B

c

The presence of holes causes the density of the crystal to decrease.

T

d

The defect increases the electrical conductivity of the solid due to migration of the ions into the holes.

T

Solution

Hence, option (b) is the correct answer.

When LiCl is heated in the vapour of lithium, the crystal acquires pink colour. This is due to:

a. Schottky defects

b. Frenkel defects

c. Metal excess defect leading to F-centres

d. Electronic defect

Solution

Hence, option (c) is the correct answer.

When anion leaves the normal lattice site and electron occupies interstitial sites in its crystal lattice, it is called:

a. Schottky defect

b. Frenkel defect

c. Metal excess defect

c. Stoichiometric defect

Solution

Hence, option (c) is the correct answer.

Strongly heated ZnO crystal can conduct electricity. This is due to:

B

a. Movement of extra Zn^{2+} ions present in the interstitial sites

b. Movement of electrons in the anion vacancies

c. Movement of both Zn^{2+} ions and electrons

d. None of these

Solution

Hence, option (b) is the correct answer.

Schottky defect appears in:

a. NaCl

b. CsCl

c. AgBr

d. All of these

Solution

Hence, option (d) is the correct answer.

The presence of excess sodium in sodium chloride makes the crystal appearance yellow. This is due to the presence of:

a. Schottky defect

b. Frenkel defect

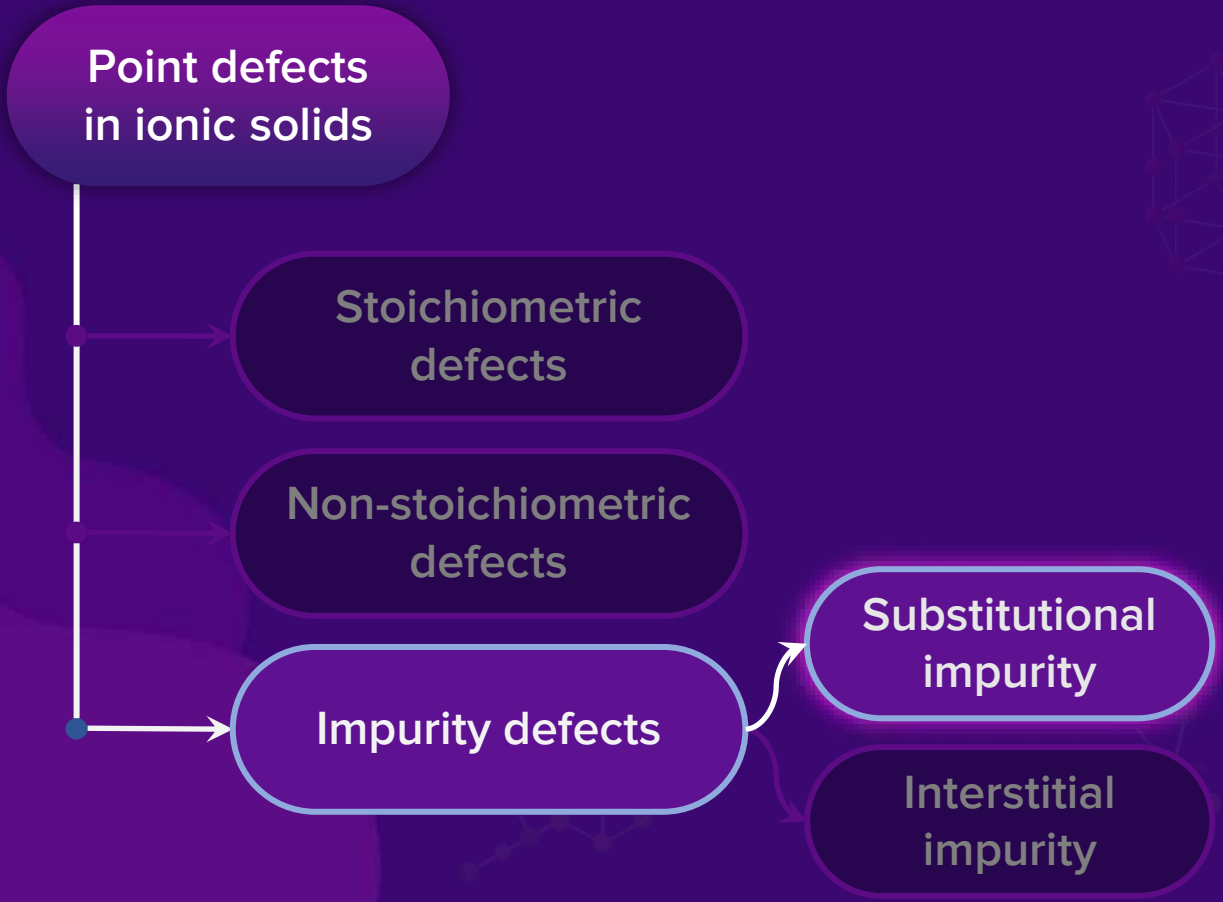
c. F-centres

d. Interstitial defects

Solution

Hence, option (c) is the correct answer.

Impurity Defects



Substitutional Impurity Defects

beryllosis

Be

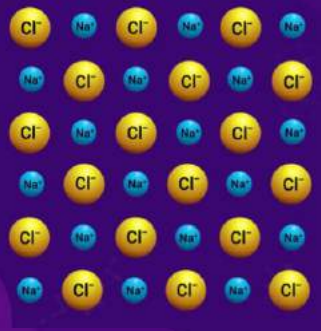
$Ca_3(PO_4)_2$

Defects in ionic crystals, can be introduced by **adding impurities**.

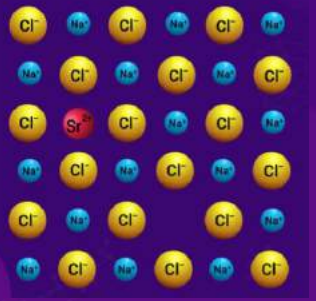
Similar sized (charged) cation **substitute** the existing cation of ionic crystal.

Substitutional Impurity Defects

Perfect crystal



Impurity defect



For example:

When molten **NaCl** is crystallised having a small amount of $SrCl_2$

Some Na^+ ions' locations are occupied by Sr^{2+} ions

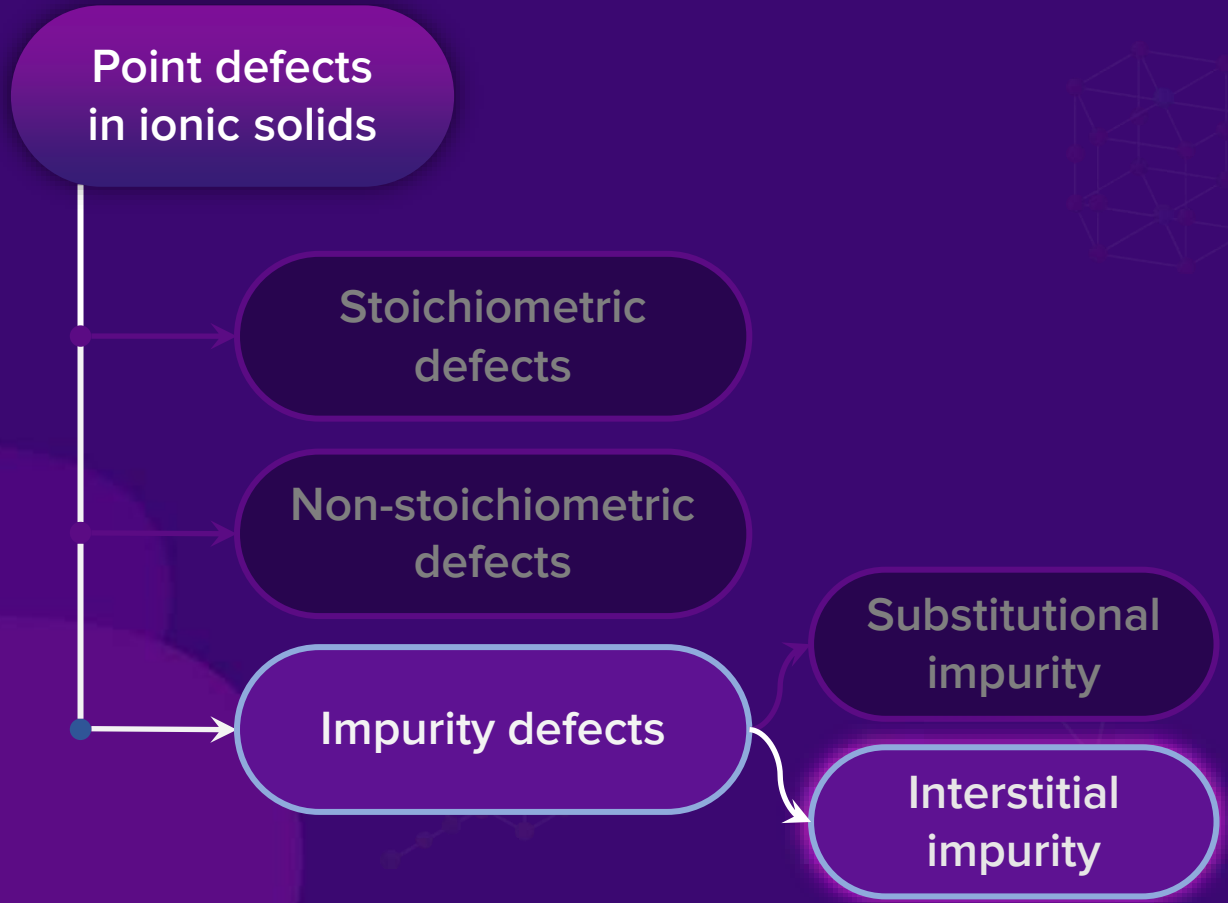
Each Sr^{2+} replaces **two** Na^+ sites by occupying a site of one Na^+ and other site remaining vacant.

Substitutional Impurity Defects

Number of cationic vacancies generated = Number of Sr^{2+} in the crystal

Other example: solid solution of $CdCl_2$ and AgCl.

Impurity Defects



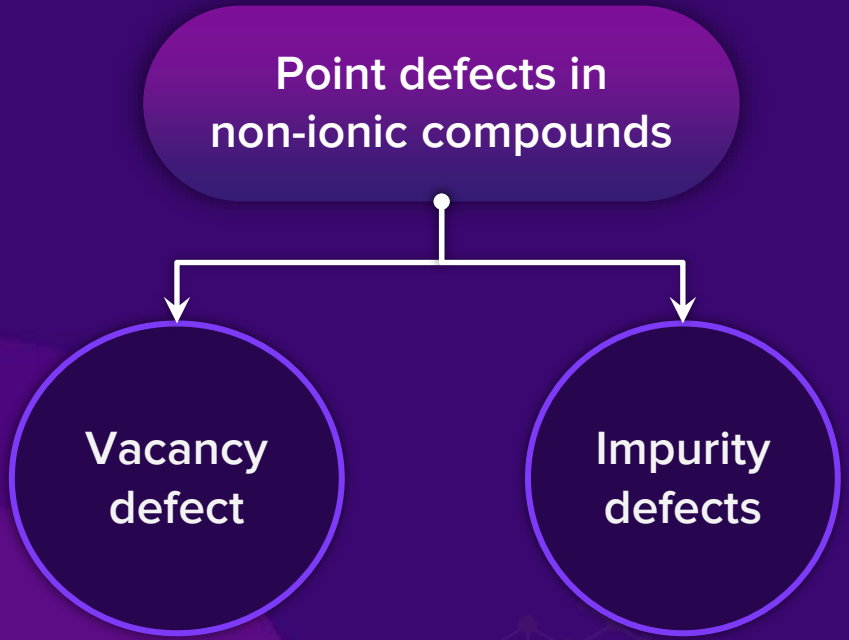
Interstitial Impurity Defect

When some **small foreign atoms** (like B, C, N, H) are **trapped** in interstitial voids of the lattice without any chemical reaction.

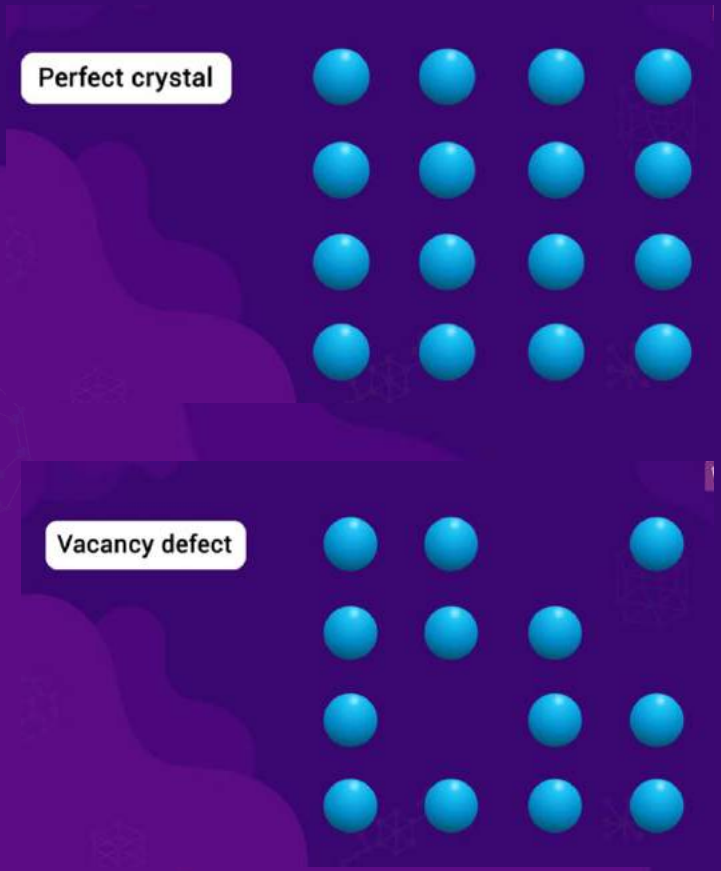
Formula remains the **same**.

$d_{exp} > d_{theoretical}$

Point defects in non-ionic compounds



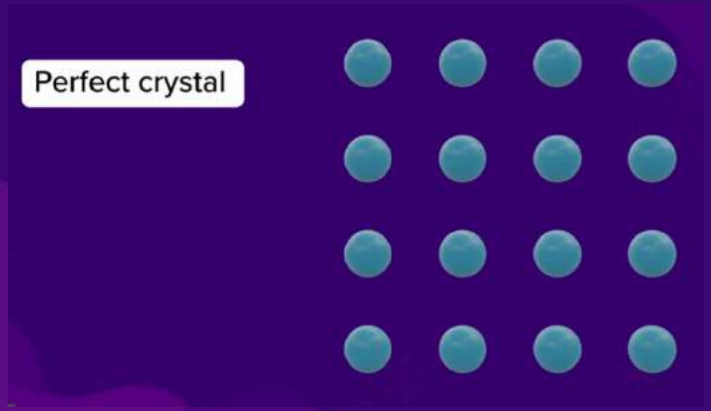
Vacancy Defect

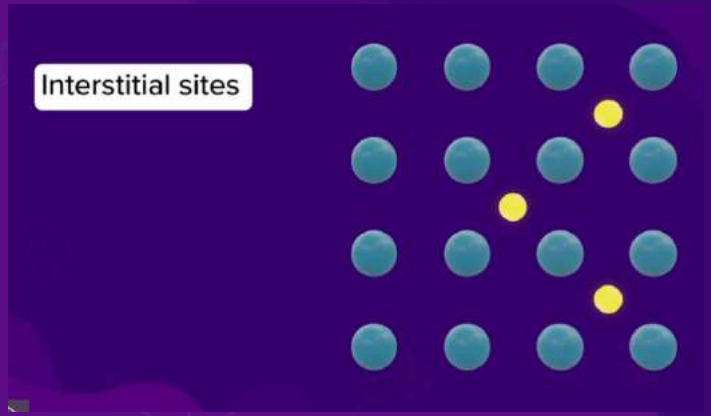


Such defect arises when some of the **lattice sites** in the crystal are **vacant**.

Density of crystal **decreases**.

Interstitial Defect





Arises when some small **foreign atoms** (like B, C, N, H) are trapped in interstitial voids of the lattice without any chemical reaction.

Density of crystal **increases**.

Which type of 'defect' has the presence of cations/atoms in the interstitial sites?

a. Schottky defect

b. Metal deficiency defect

c. Interstitial defect

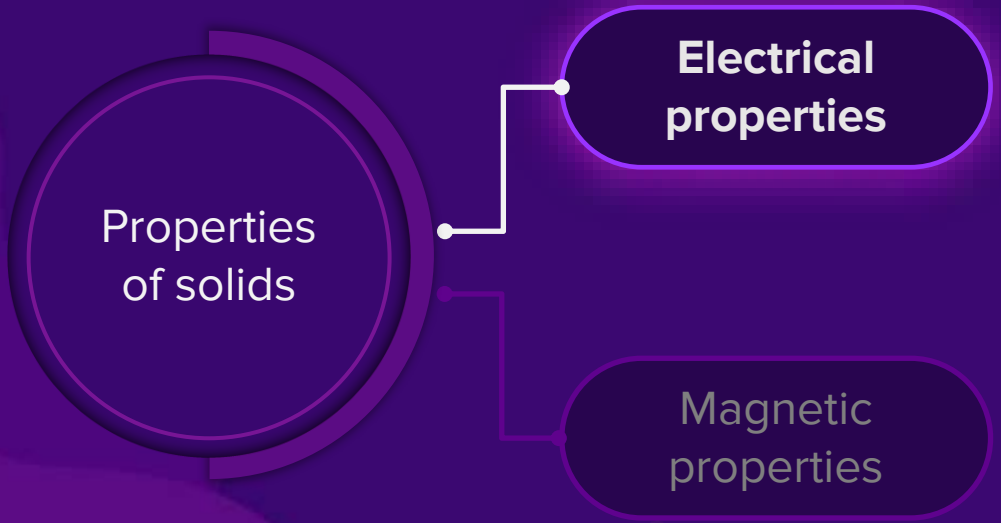
d. Vacancy defect

Solution

Hence, option (c) is the correct answer.

Properties of Solids

Properties of Solids

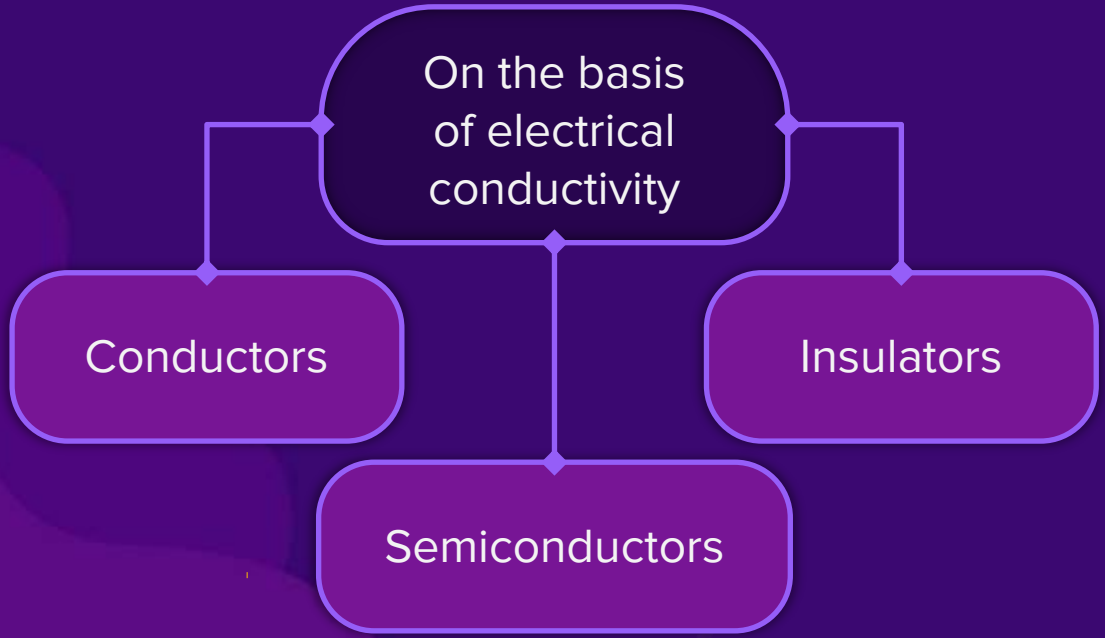


Electrical Properties of Solids

Solids exhibit an amazing range of **electrical conductivities**.

The range of electrical conductivities varies from **10^{-20} to 10^{7} ohm^{-1} m^{-1}**.

Classification of Solids



Electrical Properties of Solids

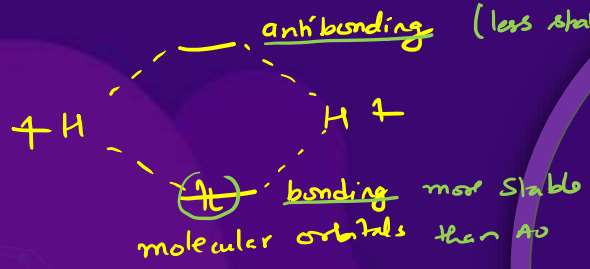
Type of solid	Conductivity range ($ohm^{-1}\ m^{-1}$)	Examples
Conductor	10^4 to 10^7	Metal
Semiconductor	10^{-6} to 10^4	Germanium (Ge), Silicon (Si) etc.
Insulator	10^{-20} to 10^{-10}	MnO, CoO; NiO, CuO

Band Theory

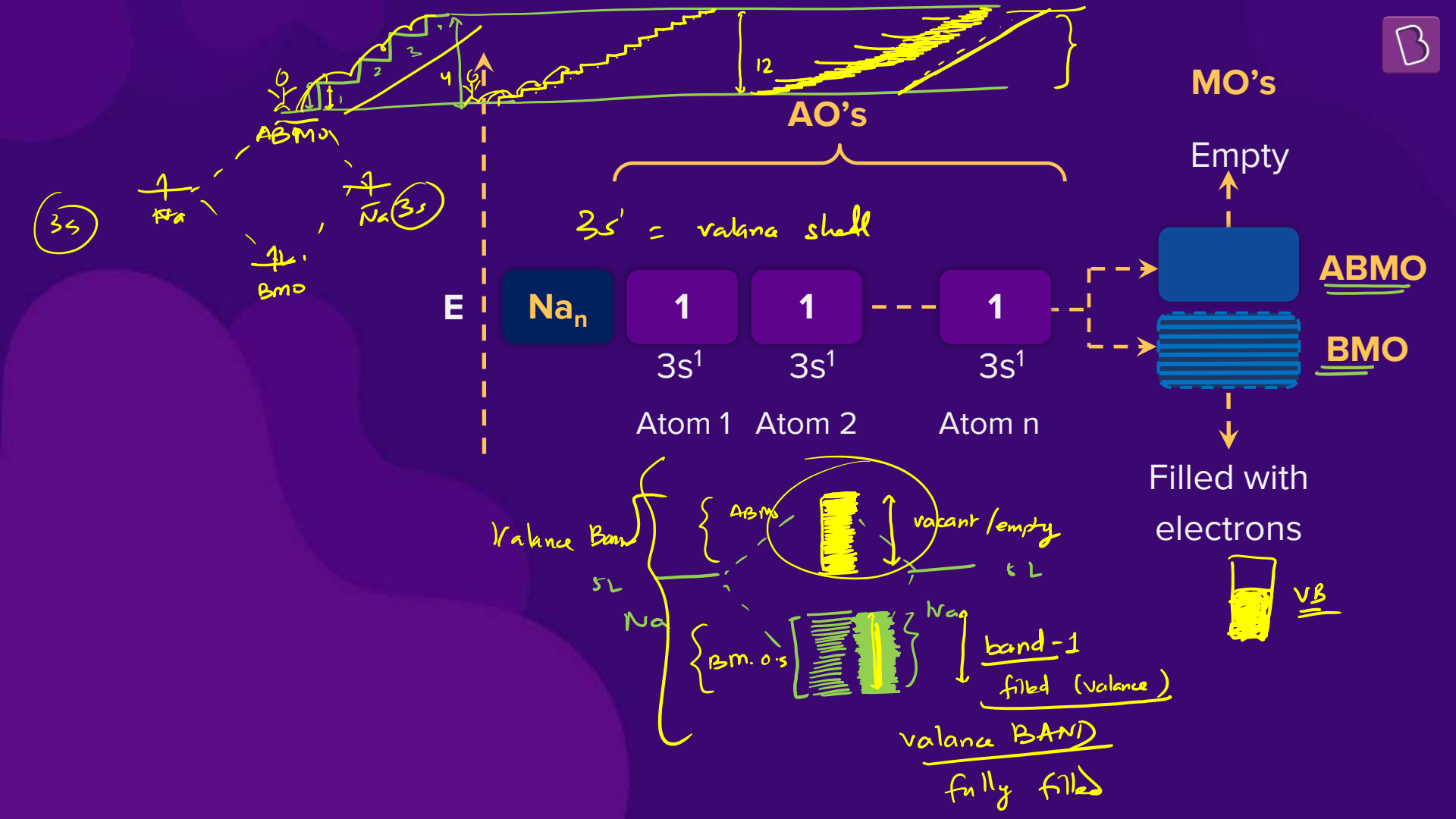
Band Theory

Electrons : atomic Orbitals s/p/d/f

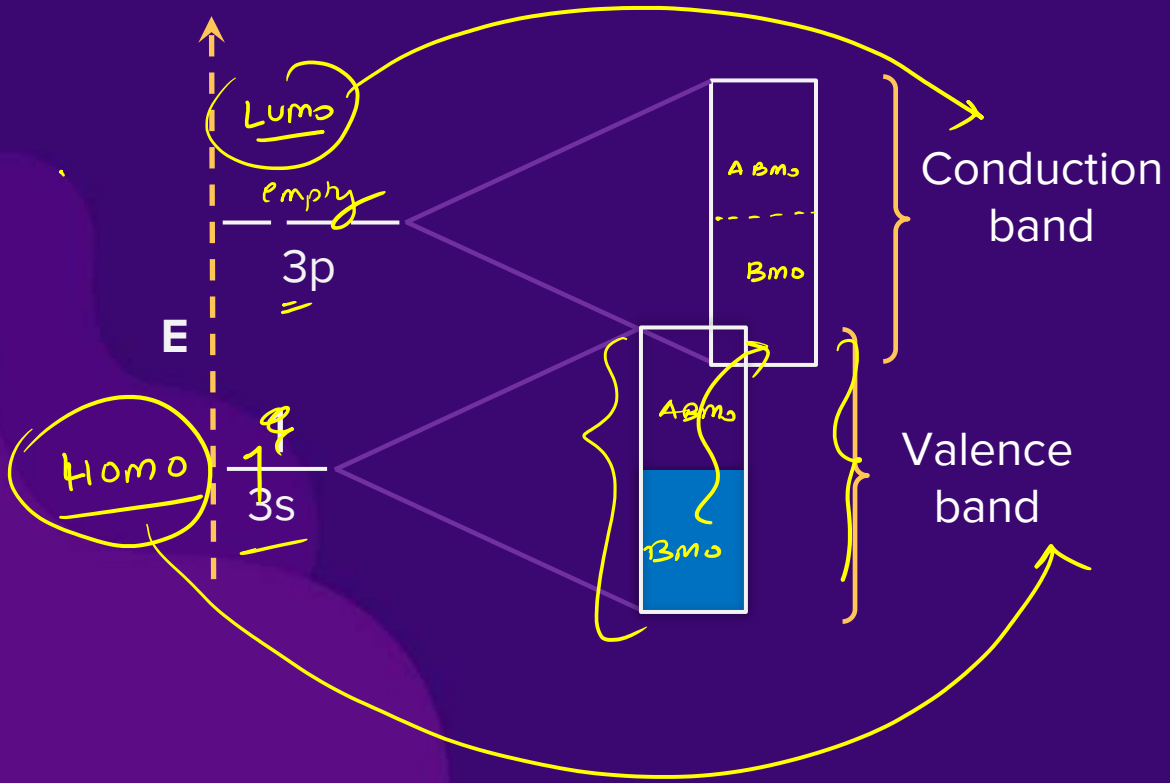
Na Na IVa IVa Na



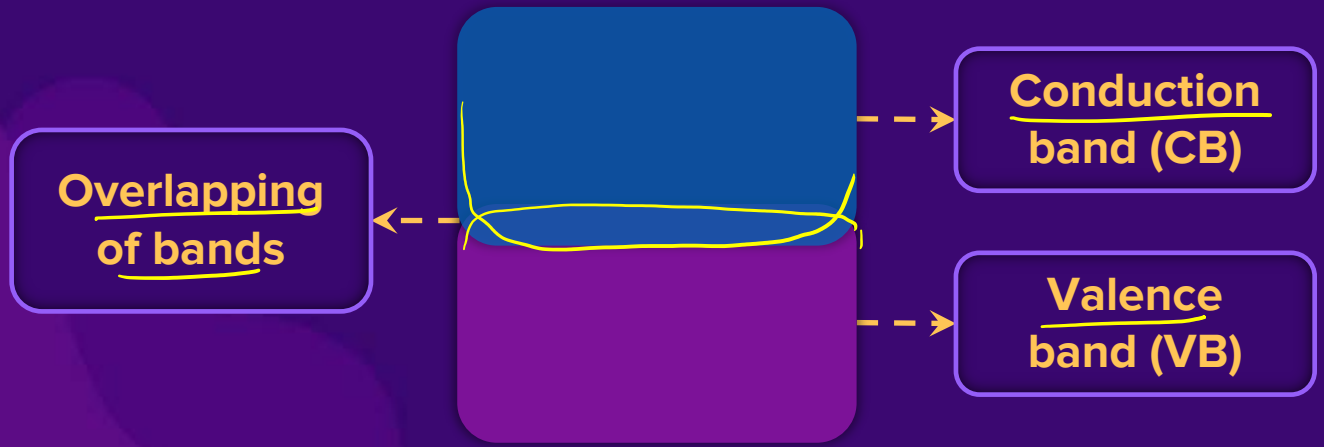
Overlap of atomic orbitals in solids gives rise to **bands of energy levels.**


AO's
MO's
3s' = valana shell
E
Na_n
1
1
1
3s¹
3s¹
3s¹
Atom 1
Atom 2
Atom n
Empty
ABMO
BMO
Filled with electrons
VB
ABMO
BMO
3s
Na
Na
12
Valance Band
vacant / empty
band-1
filled (valance)
valance BAND
fully filled

Band of Orbital in Crystal of Sodium



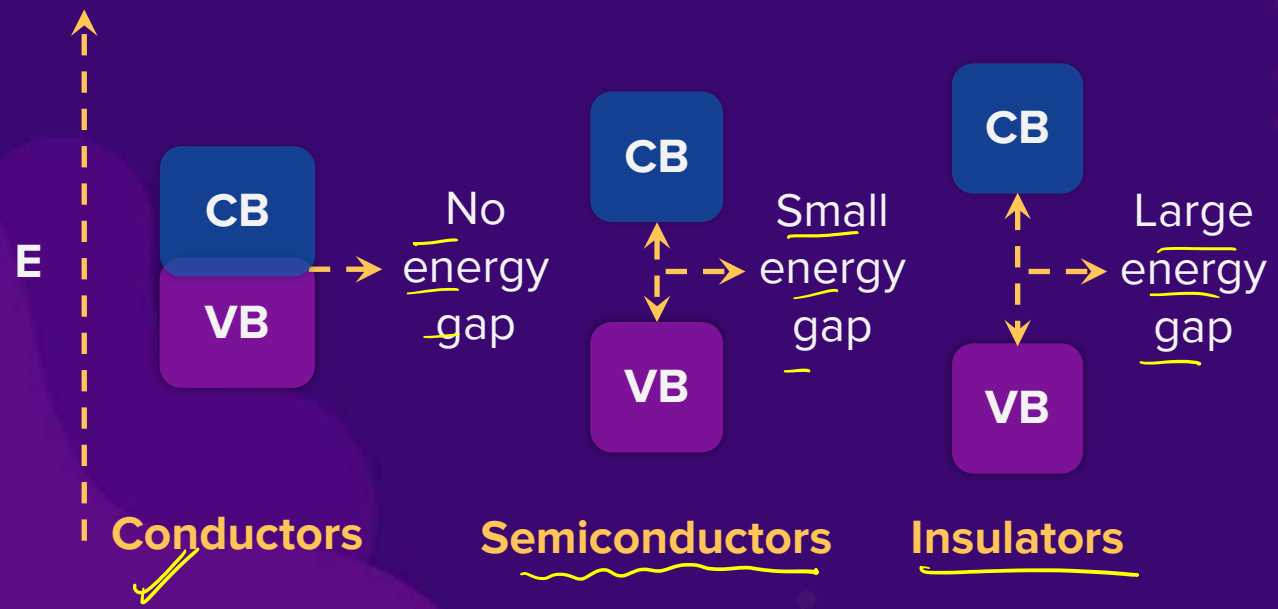
Overlapping of Bands



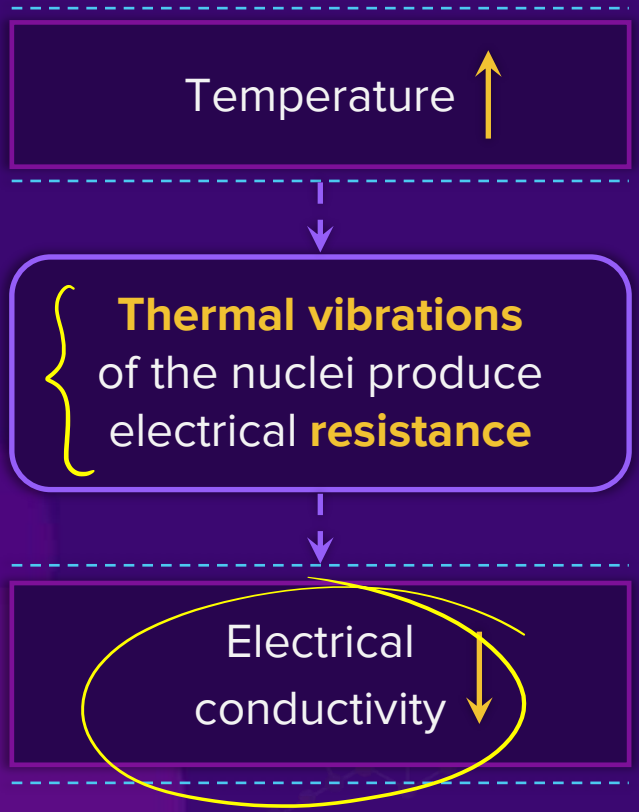
Band Gap

Energy difference between the valence band and the conduction band

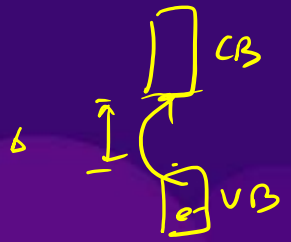
Electrical Conductivity



Metals


Temperature
Thermal vibrations
of the nuclei produce
electrical resistance
Electrical
conductivity

Semiconductors



Temperature ↑ >> Electrical conductivity ↑

On heating >> **Electron easily jumps** from VB to CB

Note

(1) TiO, CrO_2 & ReO_3 behave like **metals** with respect to **electrical conductivity**.

(2) VO, VO_2, VO_3 & TiO_3 show **metallic or insulating** properties depending on **temperature**.

How does the conductivity of a semiconductor change if its temperature is raised?

a. Conductivity increases with increase in temperature

b. Conductivity decreases with increase in temperature

c. No effect

d. Conductivity may increase or decrease

Solution

Hence, option (a) is the correct answer.

Statement-1: Electrical conductivity of semi-conductors increases with increasing temperature.
Statement-2: With increase in temperature, higher number of electrons from the valence bond can jump to the conduction band in semi-conductors.

a. If both statements are true and statement-2 is the correct explanation of statement-1.

b. If both statements are true but statement-2 is not the correct explanation of statement-1.

c. If statement-1 is true and statement-2 is false.

d. If statement-1 is false and statement-2 is true.

Hence, option (a) is the correct answer.

Which of the following is/are correct?

TiO CrO_2 ReO_3

(Ti^{2+} Cr^{+4} Re^{+6}) Oxides

a TiO, behaves like metals with respect to electrical conductivity.

True

b The range of electrical conductivities of solid varies from 10^{-20} to 10^{7} ohm^{-1} m^{-1}.

True

c TiO_3 show metallic or insulating properties depending on temperature.

True

d All of these

Hence, option (d) is the correct answer.

Which of the following defects in the crystal cannot lower the density?

a. Interstitial defect

b. Vacancy defect

c. Schottky defect

d. Impurity defect

Solution

(a) Interstitial defect:
Arises when some small foreign atoms (like B, C, N, H) are trapped in interstitial voids of the lattice without any chemical reaction. Density of crystal increases.

(b) Vacancy defect:

Such defect arises when some of the lattice sites in the crystal are vacant. Density of crystal decreases.

(c) Schottky defect:

It consists of ion vacancy in a crystal lattice, but the stoichiometry of a compound (and thus, electrical neutrality) is retained.

Schottky defect decreases the density of the substance.

(d) Impurity defect:

Sometimes have a decrease in density and sometimes increase in density.

Hence, option (a) is the correct answer.

If NaCl is doped with 10^{-4} mol % of $SrCl_2$, the concentration of cation vacancies will be ($N_A = 6.02 \times 10^{23}$ mol^{-1}):

no. of cation vacancies = no. of Sr^{2+} ions

100 mol NaCl → 10^{-4} mol $SrCl_2$

1 mol NaCl (→ 1 mol Na^+ ion) → $\frac{10^{-4}}{100} = 10^{-6}$ mol $SrCl_2$ ≡ 10^{-6} mol Sr^{2+} ions

∴ no. of cationic vacancies = 10^{-6} mol / mol of NaCl

$= 10^{-6} \times 6.02 \times 10^{23}$ / mol of NaCl

$= 6.02 \times 10^{17}$

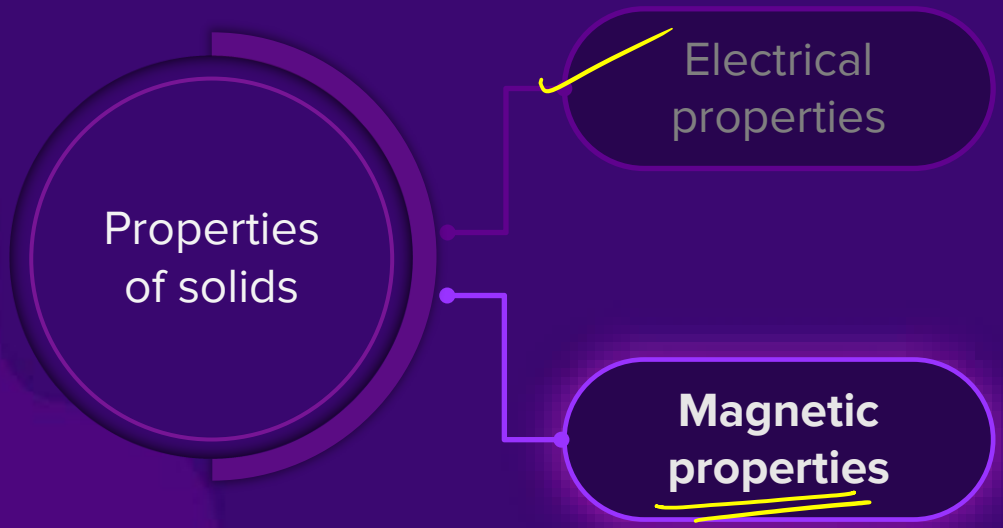
a. 6.02×10^{16} mol^{-1}

b. 6.02×10^{17} mol^{-1}

c. 6.02×10^{14} mol^{-1}

d. 6.02×10^{15} mol^{-1}

Hence, option (b) is the correct answer.


Properties of solids
Electrical properties
Magnetic properties

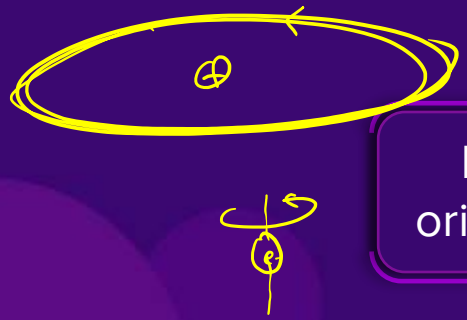
Magnetic Properties

moving charge is called current

Every substance has some **magnetic properties** associated with it. The origin of these properties lies in the **electrons**.

Each electron in an atom behaves like a tiny magnet.

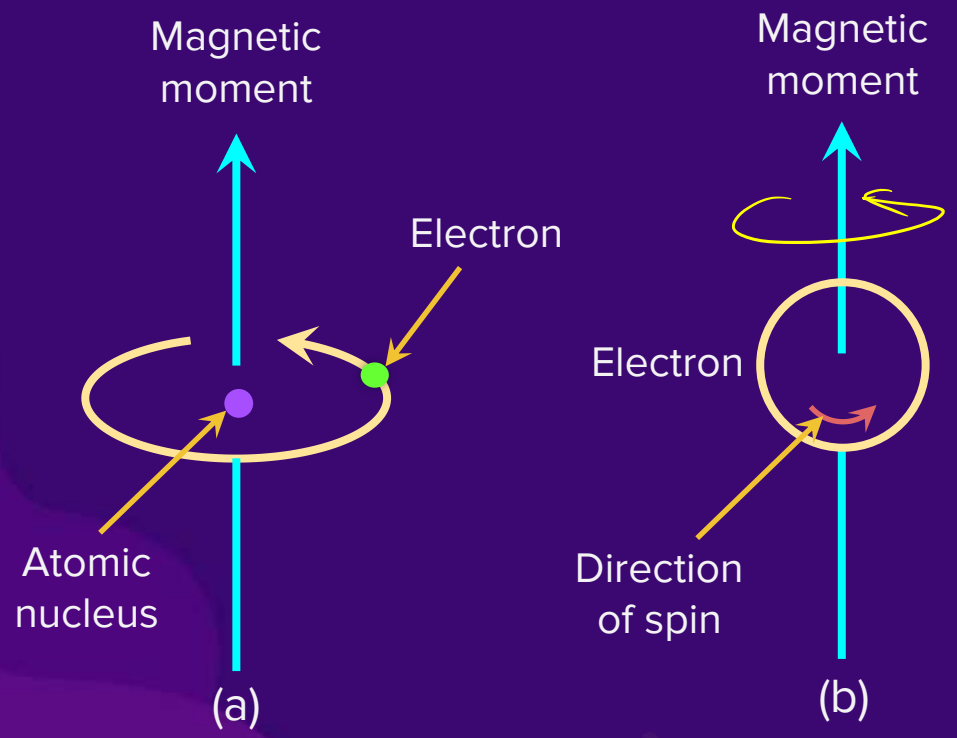
Magnetic Properties



Magnetic moment of an electron originates from **two types of motion**.

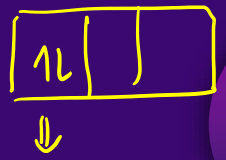
(1) Its **orbital** motion around the nucleus.

(2) Its **spin** around its own axis.



Demonstration of the magnetic moment associated with (a) an orbiting electron and (b) a spinning electron.

paired e⁻s cancel out the magnetic field produced by each other



On the basis of their magnetic properties, substances are

Unpaired e⁻s give rise to a net magnetic field. Such atoms/species

no unpaired e⁻s actually behave like tiny magnets

- **Paramagnetic**
- Diamagnetic
- Ferromagnetic
- Antiferromagnetic
- Ferrimagnetic

Paramagnetic Substances

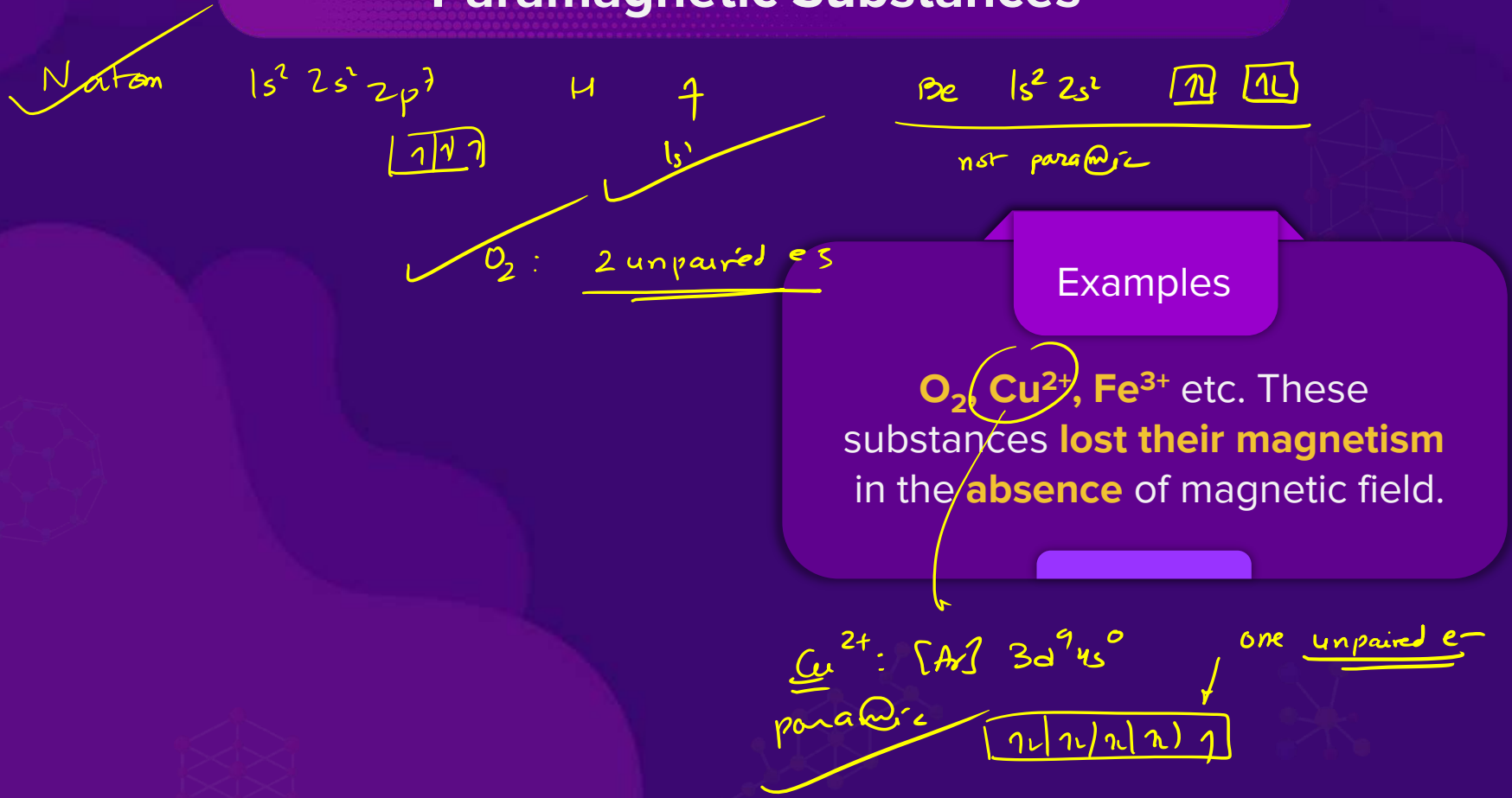
= at least one unpaired e⁻

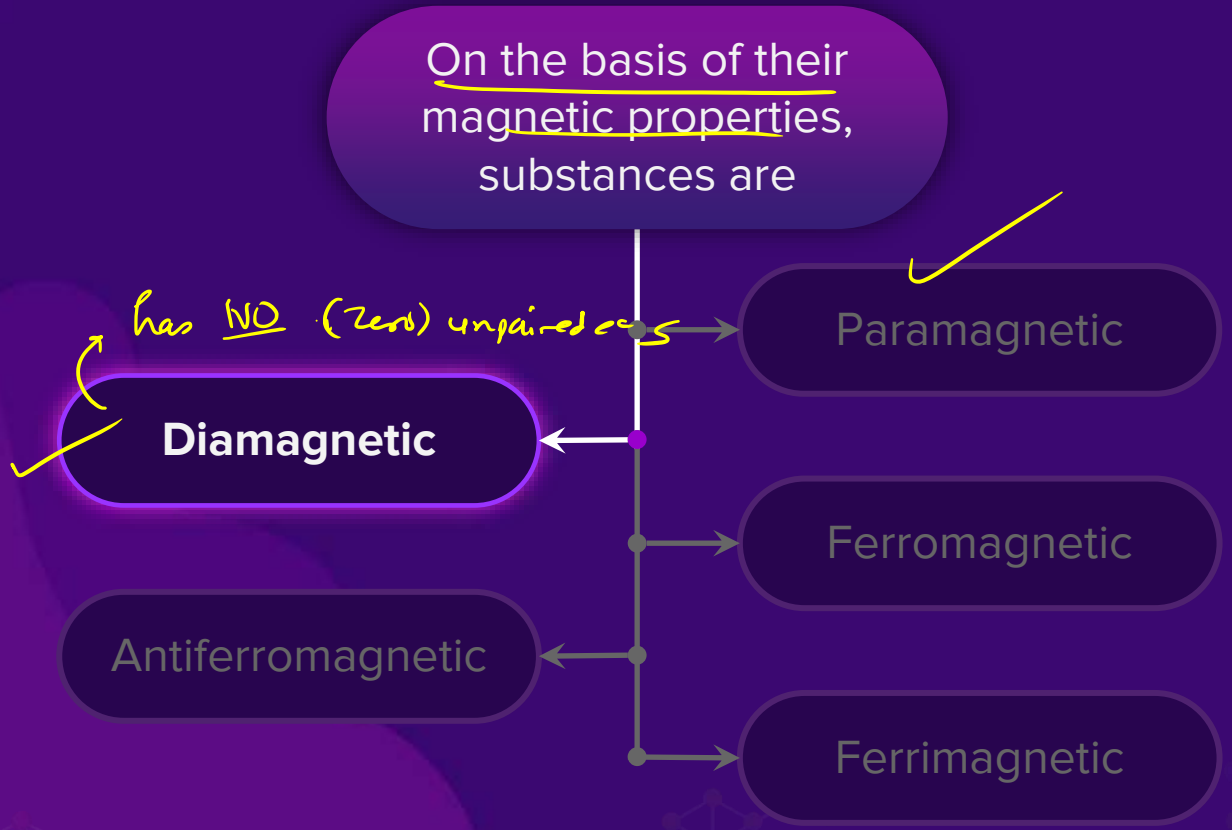
Substances that are **attracted by the external magnetic field**

↓

Atoms, ions or molecules containing **unpaired electron** show this property.

Paramagnetic Substances




On the basis of their magnetic properties, substances are
has NO (zero) unpaired e⁻s
Diamagnetic
Paramagnetic
Ferromagnetic
Antiferromagnetic
Ferrimagnetic

Diamagnetic Substances

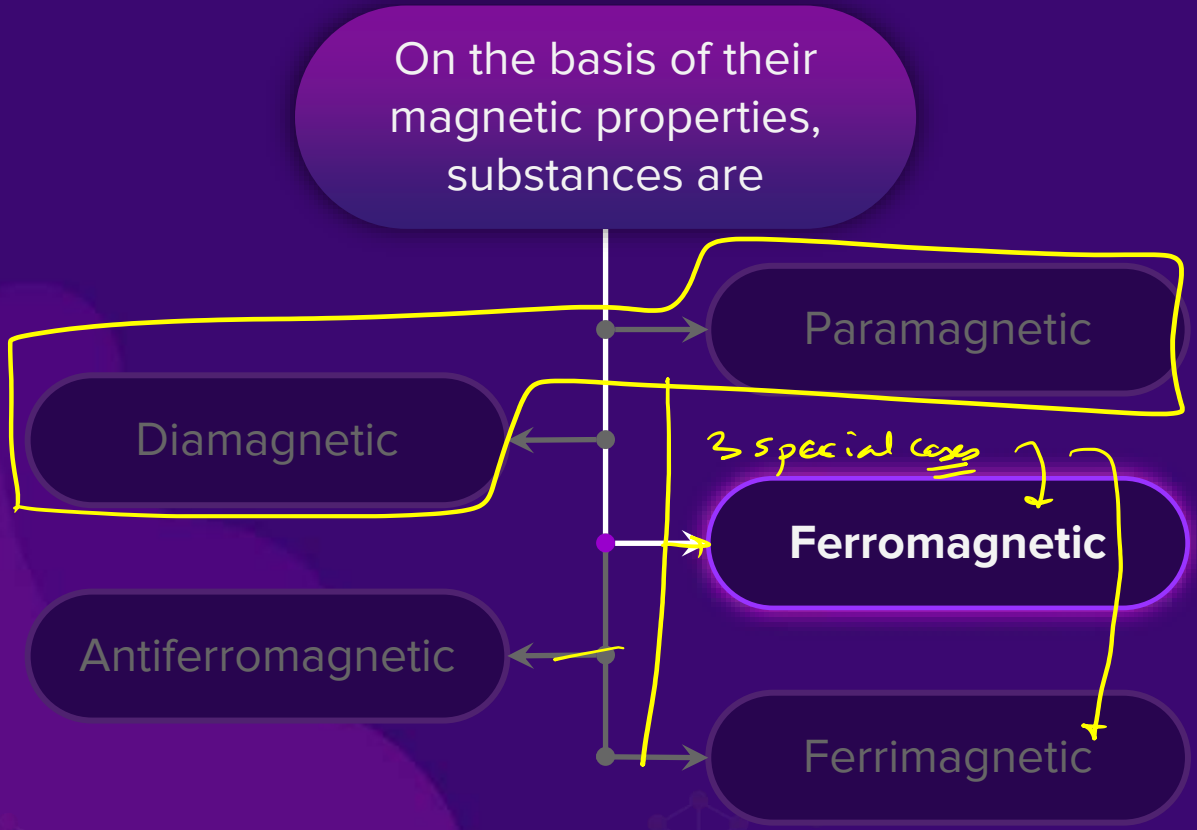
Substances that are unaffected or **very weakly repelled by magnetic field**

They **do not** have **unpaired electrons**.

Diamagnetic Substances

Examples

Cu^+, TiO_2, $NaCl$, and C_6H_6

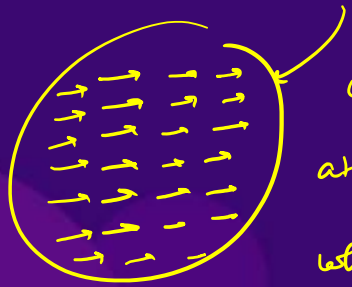

On the basis of their magnetic properties, substances are
Paramagnetic
Diamagnetic
3 special cases
Ferromagnetic
Antiferromagnetic
Ferrimagnetic

Ferromagnetic Substances

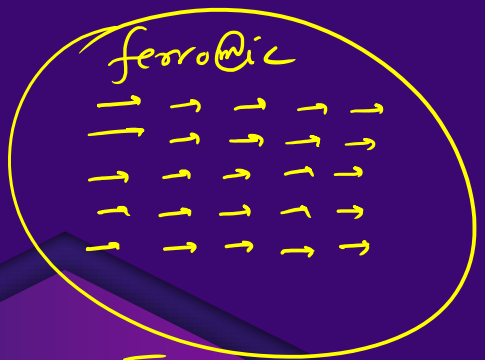
Substances that are **attracted very strongly** by a magnetic field

Substances that show **permanent magnetism** even in the **absence** of the magnetic field.

Domain



Collection of many atoms/molecules/ions which have ⓜ field in same direction.



only solid state

In a solid state, the metal ions of ferromagnetic substances are **grouped** together into **small regions** called domains.

ⓜ

any paraⓜic

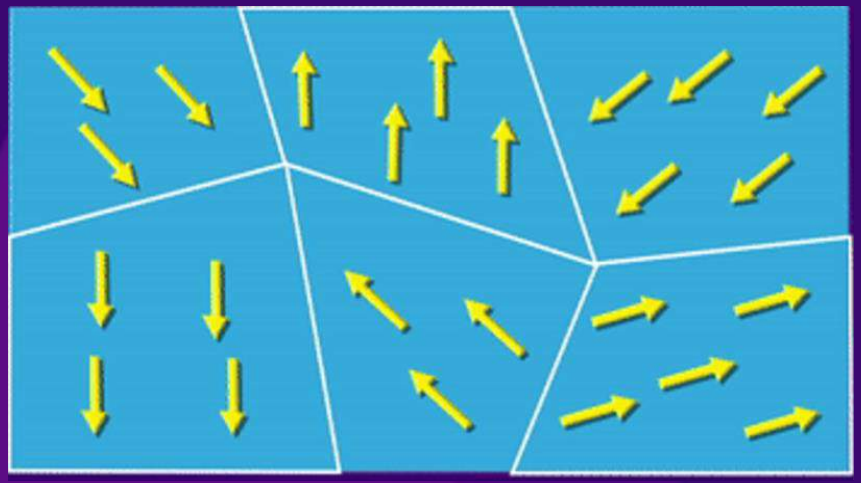
Ferromagnetic Substances

Fe | Co | Ni

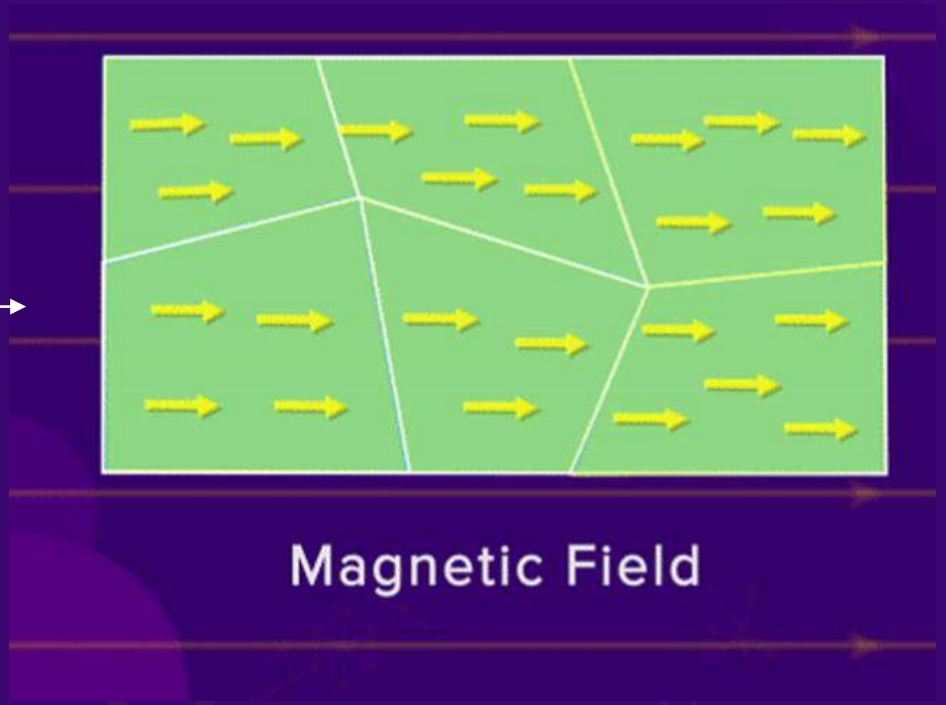
In an unmagnetised piece of a ferromagnetic substance, the domains are **randomly oriented** and their magnetic moments get **cancelled.**

When the substance is placed in a magnetic field, all **domains get oriented** in the direction of the magnetic field and a **strong magnetic effect** is produced.

Ferromagnetic Substances



Domain

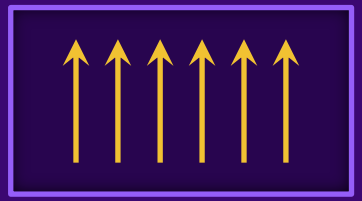


Magnetic Field

Ferromagnetic Substances

This ordering of domains persist even when the magnetic field is removed & the substance becomes a **permanent magnet**.

Ferromagnetic Substances



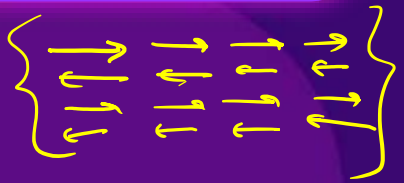
Examples

Fe, Ni, Co, and CrO_2

On the basis of their magnetic properties, substances are

- Paramagnetic
- Diamagnetic
- Ferromagnetic
- Antiferromagnetic
- Ferrimagnetic

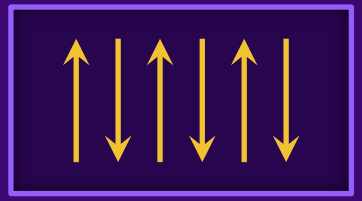
possible only in solid state



Antiferromagnetic Substances

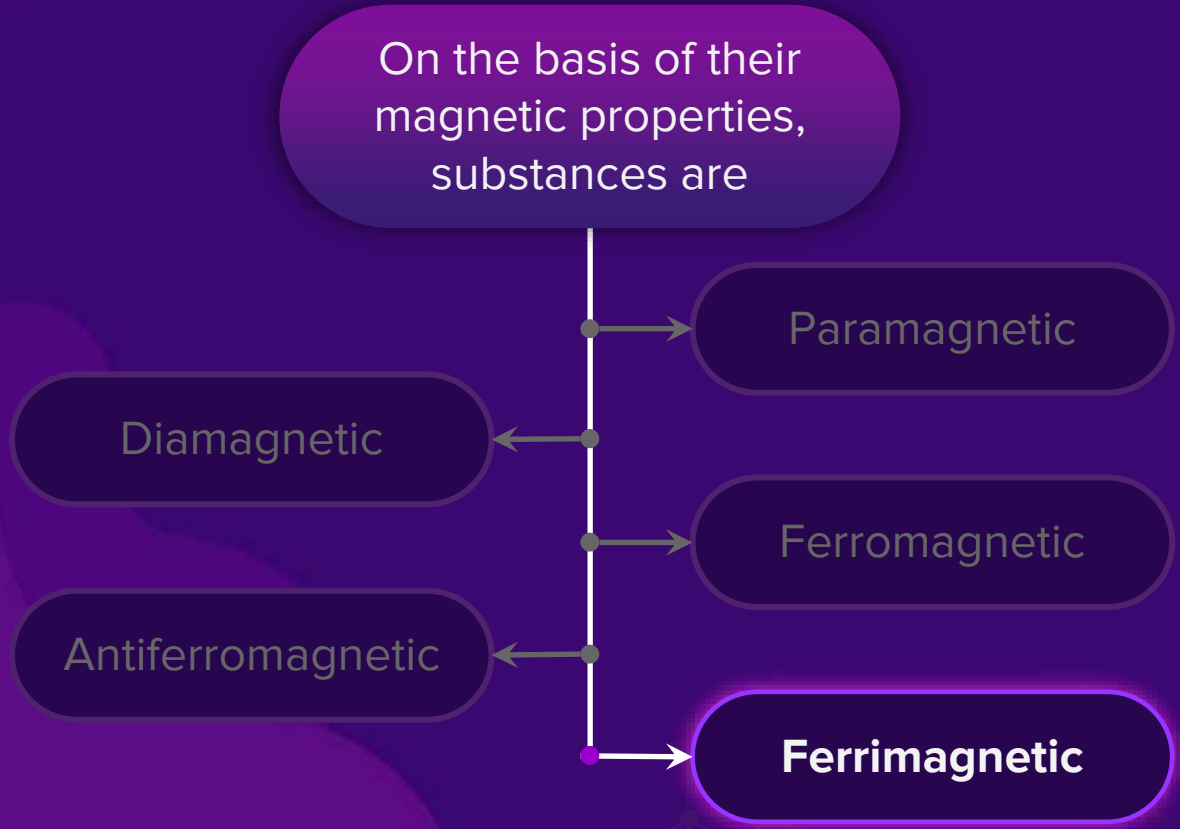
Substances showing anti-ferromagnetism have domain structure **similar** to ferromagnetic substance, but their domains are **oppositely oriented** and **cancel out** each other's magnetic moment.

Antiferromagnetic Substances

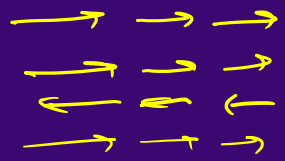


Example

MnO


On the basis of their magnetic properties, substances are
Paramagnetic
Diamagnetic
Ferromagnetic
Antiferromagnetic
Ferrimagnetic

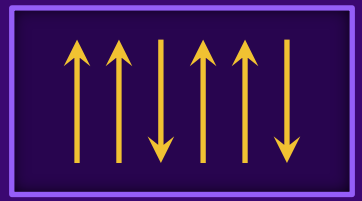
Ferrimagnetic Substances



Substances in which the magnetic moments of the domains are aligned in **parallel & anti-parallel** directions in **unequal numbers**.

They are **weakly attracted** by magnetic field as compared to ferromagnetic substances.

Ferrimagnetic Substances



Fe_3O_4

Examples

Fe_3O_4, ferrites like $MgFe_2O_4$ and $ZnFe_2O_4$

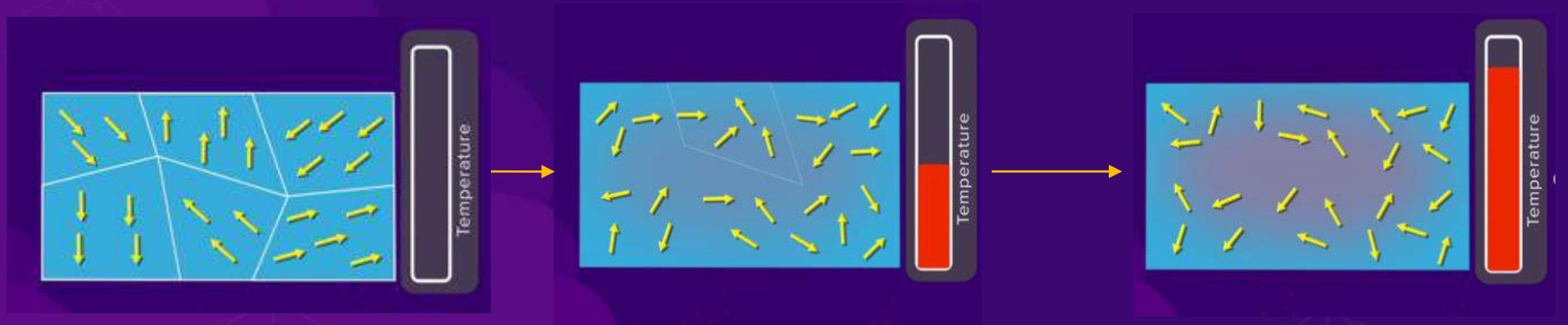
Curie Point

On **heating, ferrimagnetic, ferromagnetic & antiferromagnetic** substance convert into **paramagnetic** substances.

Curie Point

When ferromagnetic material is heated, due to thermal energy the dipole moment within the domain start coming out of alignment and become random. The randomization goes on increasing then at particular temperature the domain structures becomes completely destroyed and ferromagnetic material becomes Paramagnetic material, this particular point is known as Curie point.

Curie point



Which of the following compounds is metallic and ferromagnetic?

a CrO_2

b VO_2

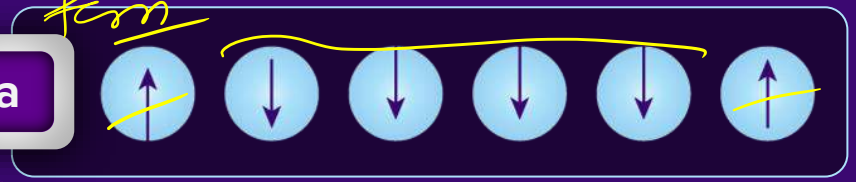
c MnO_2

d TiO_2

Hence, option (a) is the correct answer.

Which of the following arrangements shows the schematic alignment of magnetic moments of antiferromagnetic substance?

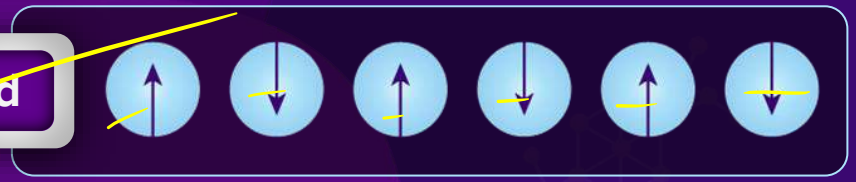
a



b

c

d



Hence, option (d) is the correct answer.

Which of the following is ferromagnetic?

a. Cobalt

b. Iron

c. Nickel

d. All of these

Hence, option (d) is the correct answer.

Fe_3O_4 is ferrimagnetic at room temperature but at 850 *K* it becomes:

a. Diamagnetic

b. Non-magnetic

c. Ferromagnetic

d. Paramagnetic

Hence, option (d) is the correct answer.

Practice Questions

The radius of the largest sphere which fits properly at the centre of the edge of a body-centred cubic unit cell is: (Edge length is represented by 'a'):

B

a. 0.047a

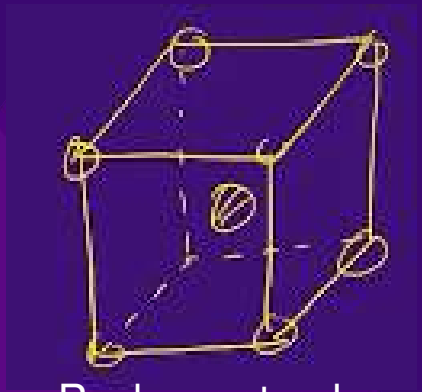
b. 0.027a

c. 0.134a

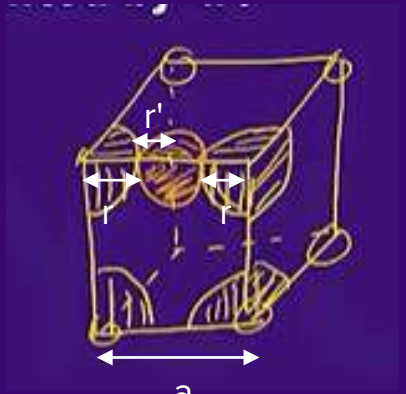
d. 0.067a

Solution

Given: BCC unit cell with an edge length ‘a’. Let, the radius of the largest sphere which fits properly at the center of the edge of a bcc unit cell be r’.



Body-centred cubic unit cell



For BCC unit cell, $a = \frac{4r}{\sqrt{3}}$

$a = r + r' + r' + r \Rightarrow a = 2(r + r')$

$2(r + r') = \frac{4r}{\sqrt{3}}$

$\Rightarrow (r + r') = \frac{2r}{\sqrt{3}}$

$$r' = \left(\frac{2}{\sqrt{3}} - 1\right) r$$

$$\Rightarrow r' = \left(\frac{2}{\sqrt{3}} - 1\right) \frac{\sqrt{3}a}{4}$$

$$\Rightarrow r' = \left(\frac{2}{\sqrt{3}} \times \frac{\sqrt{3}}{4} - \frac{\sqrt{3}}{4}\right) a$$

$$\Rightarrow r' = (0.5 - 0.433)\, a$$

$$\Rightarrow r' = 0.067a$$

Hence, option (d) is the correct answer.

Which of the following is incorrect?

(a) Schottky defect arises due to the absence of cations and anions from positions which they are expected to occupy.

(b) The density of crystal having Schottky defect is smaller than that of a perfect crystal.

(c) Schottky defect is more common in covalent compounds with higher coordination number.

(d) The crystal having Schottky defect is electrically neutral as a whole.

Solution

(a) Schottky defect arises due to the absence of cations and anions from positions which they are expected to occupy. This statement is true.

(b) The density of crystal having Schottky defect is smaller than that of a perfect crystal. This statement is true.

(c) Schottky defect is more common in covalent compounds with higher coordination number. This statement is wrong as Schottky defect is more common for ionic compounds and alkali metals .

(d) The crystal having Schottky defect is electrically neutral as a whole. This statement is true.

Hence, option (c) is the correct answer.

How many number of atom effectively present in a cubic unit formed by an arrangement of eight BCC unit cell?

Solution

1 BCC unit cell has 2 atoms.
Therefore , 8 BCC unit cells will have $8 \times 2 = 16$ atoms

- a. 12
- b. 14
- c. 16
- d. 18

Hence, option (c) is the correct answer.

A substance A_xB_y crystallizes in a face-centred cubic lattice in which atoms 'A' occupy each corner of the cube and atoms 'B' occupy the centres of each face of the cube. Identify the correct composition of the substance A_xB_y.

B

a AB_3

b A_4B_3

c A_3B

d Composition can't be specified

Solution

Given: A_xB_y crystallizes in a fcc lattice:
'A' atoms occupy each corner of the cube
'B' atoms occupy the centres of each face of the cube.

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

B occupies center of each face; $B = \frac{1}{2} \times 6 = 3$

Therefore, composition of the substance A_1B_3 i.e., AB_3.

Hence, option (a) is the correct answer.

For a unit cell edge length = 5 Å, the element of atomic mass 75, has density of 2 g/cc. Calculate atomic radius of the element.

B

a. 143.7 pm

b. 216.5 pm

c. 321.4 pm

d. 498.1 pm

Solution

Given:

Edge length = 5 Å, Atomic mass of the element = 75, density = 2 g/cc.

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

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

$$Z = \frac{2\ g\ cm^{-3} \times (5 \times 10^{-8}\ cm)^3 \times 6.022 \times 10^{23}\ mol^{-1}}{75\ g\ mol^{-1}}$$

$$Z = \frac{2 \times 25 \times 5 \times 6.022 \times 10^{-1}}{75}$$

$$Z = 2$$

Therefore , it has a BCC structure because Z = 2.

For BCC unit cell $a = \frac{4r}{\sqrt{3}}$

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

$$r = \frac{1.732 \times 5\ Å}{4} \Rightarrow r = 2.165\ Å$$

$\Rightarrow$ r = 216.5 pm

Hence, option (b) is the correct answer.

AgCl is crystallised from molten AgCl containing a little $CdCl_2$. The solid obtained will have:

B

a. Cationic vacancies equal to number of Cd^{2+} ions incorporated

b. Cationic vacancies equal to double the number of Cd^{2+} ions

c. Anionic vacancies

d. Neither cationic nor anionic vacancies

Solution

- When we crystallize AgCl from molten AgCl containing $CdCl_2$, the Cl^- ions occupy the location of anions but for cations, we have Ag^+ and Cd^{2+} both.
- Because Cd^{2+} has twice the charge of Ag^+, hence two Ag^+ will be removed to add one Cd^{2+} cation which will create a cationic vacancy.
- The cationic vacancies will be equal to the number of Cd^{2+} incorporated.

Hence, option (a) is the correct answer.

An FCC lattice has lattice parameter a = 400 pm. Calculate the molar volume of the lattice including all the empty space.

B

a 10.8 mL

b 96 mL

c 8.6 mL

d 9.6 mL

Solution

FCC lattice with lattice parameter a = 400 pm.
Molar volume means volume of 1 mole of substance.

Density, $\rho = \frac{\text{Mass}}{\text{Volume}}$

$$\frac{\text{Density}}{\text{Molar mass}} = \frac{\rho}{M} = \frac{\text{Mass}}{\text{Molar mass}} \times \frac{1}{\text{Volume}}$$

$$\frac{\rho}{M} = \frac{\text{Moles}}{\text{Volume}} \; ; \text{Moles} = \frac{\text{Mass}}{\text{Molar mass}}$$

$$\frac{\text{Volume}}{\text{Moles}} = \frac{M}{\rho}$$

Therefore , Molar volume = $\frac{\text{Molar mass}}{\text{Density}}$

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

$$\frac{\text{Molar mass}}{\text{Density}} = \frac{N_A \times a^3}{Z}$$

Molar volume =

$$\frac{6.022 \times 10^{23} \text{mol}^{-1} \times (400 \times 10^{-10} \text{ cm})^3}{4}$$

Molar volume = 9.6 mL

Hence, option (d) is the correct answer.

Titanium metal has a density of 4.54 g/cm^3 and an edge length of 412.6 pm. In what cubic unit cell does titanium crystallize? (Molar mass of Ti = 48 g/mol)

B

a FCC

b BCC

c Simple cubic

d Need more information

Solution

Given: Density of Ti metal = 4.54 g/cm^3

Edge length of 412.6 pm, molar mass of Ti = 48 g/mol

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

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

$$Z = \frac{4.54\ g\ cm^{-3} \times (4.126 \times 10^{-8}\ cm)^3 \times (6.022 \times 10^{23}) mol^{-1}}{48\ g\ mol^{-1}}$$

$$Z = 4$$

Therefore , it is FCC unit cell as Z = 4

Hence, option (a) is the correct answer.

Sodium metal crystallizes in body-centred cubic lattice with cell edge = 4.29 Å. What is the radius of sodium atom?

a. 1.27 Å

b. 2.73 Å

c. 1.86 Å

d. 1.54 Å

Solution

Given , Sodium metal crystallizes in bcc lattice with cell edge = 4.29 Å
Z = 2 for BCC unit cell

For BCC unit cell, $a = \frac{4r}{\sqrt{3}}$

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

$r = 0.433 \times 4.29\ \text{Å} = 1.857 = 1.86\ \text{Å}$

Hence, option (c) is the correct answer.

Platinum (Atomic radius = 1.38 Å) crystallizes in a cubic close packed structure. Calculate the density of the FCC unit cell of platinum. (Molar mass of Pt = 195 g/mol).

B

a. $21.83\ g/cm^3$

b. $18.54\ g/cm^3$

c. $30.88\ g/cm^3$

d. $25.57\ g/cm^3$

Solution

Pt, Atomic radius = 1.38 Å, FCC unit cell,
Molar mass of Pt = 195 g/mol
Cubic close packing = Face centred cubic

For FCC unit cell $a = 2\sqrt{2}r$

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

$$\rho = \frac{4 \times 195\ \text{g mol}^{-1}}{6.022 \times 10^{23}\ \text{mol}^{-1} \times (2\sqrt{2} \times 1.38 \times 10^{-8}\ \text{cm})^3}$$

$$\rho = \frac{195\ \text{g cm}^{-3}}{3.394 \times (1.38)^3}$$

Density = 21.83 g cm^{-3}

Hence, option (a) is the correct answer.

The effective radius of an iron atom is 1.42 Å. It has a rock-salt structure. Calculate its density (Molar mass of Fe = 56 g/mol).

B

a. $5.743\ g/cm^3$

b. $8.932\ g/cm^3$

c. $4.059\ g/cm^3$

d. $3.876\ g/cm^3$

Solution

Given: The effective radius of an iron atom = 1.42 Å. It has a rock-salt structure. Molar mass of Fe = 56 g/mol.

Given Fe is forming rock salt structure that is fcc structure (Face centred cubic).

Iron is present at corner and face center = 4 atoms, Octahedral voids = 4 atoms

Total effective atoms of iron in a cube (Z)= 8

For rock salt structure [(2) [r(Cl^-) + r(Na^+)] = a

Since all the atoms are same that is iron atoms; ⇒ a = 4r

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

$$\rho = \frac{8 \times 56\ g\ mol^{-1}}{6.022 \times 10^{23}\ mol^{-1} \times (4 \times 1.42 \times 10^{-8}\ cm)^3}$$

$$\rho = 4.06\ g\ cm^{-3}$$

Hence, option (c) is the correct answer.

Iron has a body-centred cubic lattice structure. The edge length of the unit cell is found to be 286 pm. What is the radius of an iron atom?

B

a. r = 124 pm

b. r = 128 pm

c. r = 124 Å

d. r = 128 Å

Solution

Given: Iron has a bcc lattice, edge length of the unit cell = 286 pm

In body centred cubic (bcc) unit cell, Z = 2

For BCC unit cell, $a = \frac{4r}{\sqrt{3}}$

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

$$r = 0.433 \times 286 \text{ pm}$$

$$r = 124 \text{ pm}$$

Hence, option (a) is the correct answer.

A metal crystallizes in a body-centred cubic lattice (BCC) with the edge of the unit cell 5.2 Å. The distance between the two nearest neighbours is:

B

a. 10.4 Å

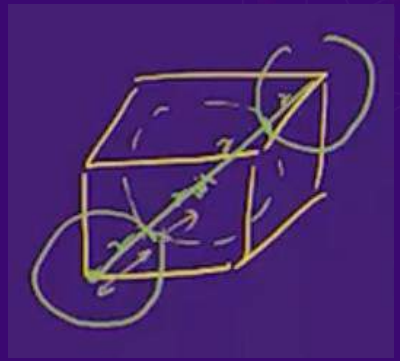
b. 4.5 Å

c. 5.2 Å

d. 9.0 Å

Solution

Given: BCC lattice, edge length of the unit cell = 5.2 Å
In BCC atoms touch along the body diagonal.



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

Distance between nearest neighbours = $2r = \frac{\sqrt{3}a}{2}$

Distance between nearest neighbours = 0.866×5.2 Å

$= 4.5$ Å

Hence, option (b) is the correct answer.

What is the number of atoms in a unit cell of face-centred cubic crystal?

a. 4

b. 6

c. 2

d. 1

Solution

A face-centred cubic (fcc) unit cell contains atoms at all the corners and at the centre of all the faces of the cube. Each atom located at the face-centre is shared between two adjacent unit cells and only $\frac{1}{2}$ of each atom belongs to a unit cell.

Effective number of particles in a fcc unit cell:

(i) 8 corners atoms $\times \frac{1}{8}$ atoms per unit cell $= 8 \times \frac{1}{8} = 1$ atom

(ii) 6 face-centred atoms $\times \frac{1}{2}$ atom per unit cell $= 6 \times \frac{1}{2} = 3$ atoms

Total number of atoms per unit cell = 4 atoms

Hence, option (a) is the correct answer.

The maximum percentage of available volume that can be filled in a face-centred cubic system by atoms is:

a. 74%
b. 68%
c. 34%
d. 26%

Solution

The maximum percentage of available volume that can be filled i.e., packing efficiency.
We know that for an FCC unit cell, Packing efficiency = 74%

Hence, option (a) is the correct answer.

If the anions (A) form hexagonal close packing and cations (C) occupy only $^{2}/_{3}$ octahedral voids in it, then the general formula of the compound is:

B

a. CA

b. CA_2

c. C_2A_3

d. C_3A_2

Solution

Given A anions forms HCP packing and C cations are present at $^{2}/_{3}$ octahedral void.

Let's say in one unit cell of HCP there are Z anions, then octahedral voids is also Z and tetrahedral voids is 2Z.

Number of cations (C) = $\frac{2}{3} \times Z$

Number of anions (A) = Z

Then the formula of the compound is C_2A_3.

Hence, option (c) is the correct answer.

F-centres are:

a. The electrons trapped in anionic vacancies

b. The electrons trapped in cationic vacancies

c. Non-equivalent sites of stoichiometric compound

d. All of the above

Solution

- When crystals of NaCl are heated in an atmosphere of sodium vapour, Cl^- ions diffuse to the surface of the crystal and combine with Na atoms to give NaCl. This happens by loss of electron by sodium atoms to form Na^+ ions.
- The released electrons diffuse into the crystal and occupy anionic sites. These anionic sites occupied by unpaired electrons are called **F-centres or colour centers.**

Hence, option (a) is the correct answer.

Total volume of atoms present in a face-center cubic unit cell of a metals (r is atomic radius).

a $\frac{20}{3}\pi r^3$

b $\frac{24}{3}\pi r^3$

c $\frac{12}{3}\pi r^3$

d $\frac{16}{3}\pi r^3$

Solution

A face-centred cubic (fcc) unit cell contains atoms at all the corners and at the centre of all the faces of the cube. Each atom located at the face-centre is shared between two adjacent unit cells and only $\frac{1}{2}$ of each atom belongs to a unit cell.

Effective number of particles in a fcc unit cell:

(i) 8 corners atoms $\times \frac{1}{8}$ atoms per unit cell = $8 \times \frac{1}{8}$ = 1 atom

(ii) 6 face-centred atoms $\times \frac{1}{2}$ atom per unit cell = $6 \times \frac{1}{2}$ = 3 atoms

Total number of atoms per unit cell = 4 atoms

Volume of sphere = $\frac{4}{3}\pi r^3$

Volume of atoms present in FCC unit cell is = $4 \times \frac{4}{3}\pi r^3$

Volume of atoms present in FCC unit cell is = $\frac{16}{3}\pi r^3$

Hence, option (d) is the correct answer.

Percentages of free space in cubic close packed structure and in body centered packed structure are respectively.

a. 30% and 26%

b. 26% and 32%

c. 32% and 48%

d. 48% and 26%

Solution

Percentage space occupied by atoms in FCC structure = 74%

Percentage space occupied by atoms in BCC structure = 68%

Therefore, percentage empty space = 100% – (Percentage space occupied by atoms)

Percentage empty space or free space in FCC structure = $100\% - 74\% = 26\%$

Percentage empty space or free space in BCC structure = $100\% - 68\% = 32\%$

Hence, option (b) is the correct answer.

Lithium forms body-centred cubic structure. The length of the side of its unit cell is 351 pm. Atomic radius of the lithium will be:

a. 75 pm

b. 300 pm

c. 240 pm

d. 152 pm

Solution

Given length of the side of unit cell = a = 351 pm

For BCC unit cell, $a = \frac{4r}{\sqrt{3}}$

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

$$r = 0.433 \times 351 \text{ pm}$$

$$r = 152 \text{ pm}$$

Hence, option (d) is the correct answer.

Experimentally it was found that a metal oxide has formula $M_{0.98}O$. Metal M, present as M^{2+} and M^{3+} in its oxide. Fraction of the metal which exists as M^{3+} would be:

a. 7.01%

b. 4.08%

c. 6.05%

d. 5.08%

Solution

- $M_{0.98}O = M_{98}O_{100}$
- Let's say x M has +3 charge. So, (98 – x) M will have +2 charge
- If 1 M has +3 charge then x M will have +3x charge Similarly, 1 M has +2 charge then (98 – x) M will have +2 × (98 – x) charge.
- And if 1 oxygen has –2 charge then 100 oxygen will have (–2 × 100) charge.
- Total charge = +3x + 2 (98 – x) + (–2 × 100) = 0

  196 + x = 200 ⇒ x = 4

Therefore, 4 M ions has +3 charge

$$\% \text{ of M in } +3 = \frac{\text{Number of M ions in } +3}{\text{Total number of M ions}} \times 100$$

$$\% \text{ of M in } +3 = \frac{4}{98} \times 100$$

% of M in +3 = 4.08 %

Hence, option (b) is the correct answer.

CsCl crystallises in **body-centred cubic lattice**. If 'a' is its edge length, which of the following expressions is correct?

a $r_{Cs^+} + r_{Cl^-} = 3a$

b $r_{Cs^+} + r_{Cl^-} = \frac{3a}{2}$

c $r_{Cs^+} + r_{Cl^-} = \frac{\sqrt{3}a}{2}$

d $r_{Cs^+} + r_{Cl^-} = \sqrt{3}a$

Solution

Let's say Cs^+ is present at the corners and Cl^- is present at the body centre.
So, on a body diagonal $2Cs^+$ are present at the corners and one Cl^- is present at body centre.
Therefore, Cl^- is touching 2 Cs^+ along the body diagonal.
As, length of body diagonal = $\sqrt{3}a$

Therefore, $r_{Cs^+} + r_{Cl^-} = \frac{\sqrt{3}a}{2}$

Hence, option (c) is the correct answer.