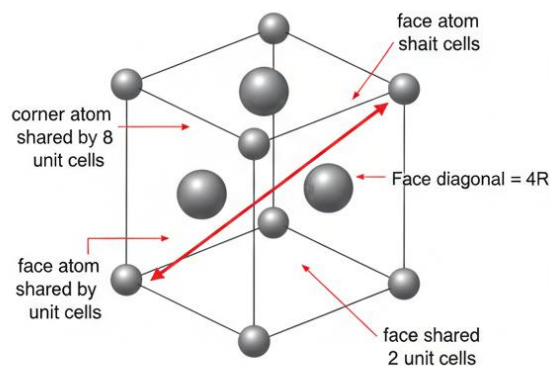


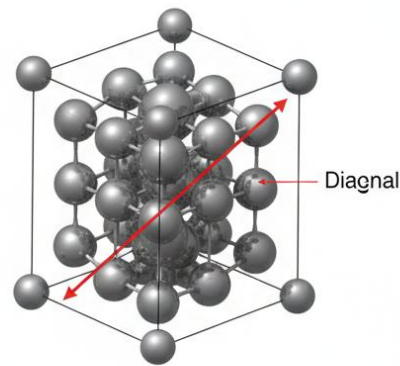


2.2 Face-Centered Cubic (FCC) Structure

Corner-sharing view



Space-filling view



Key Properties

- Atoms per unit cell (N) = 4
- Atoms per Number (CN) 12
- Coordination Number (CN) 12
- Atomic Packing Factor APF = 0.74
- Common Metals: Al, Cu, Au, Ag, Pb, Ni

Lattice Constant (a) Calculation

- Along face diagonal: $(4R)^2 = a^2 + a^2$
 $16R^2 = 2a^2$
 $a^2 = 8R^2$
 $a = (4R) \sqrt{2}$

5. Hexagonal Close-Packed (HCP) Structure

5.1 Description

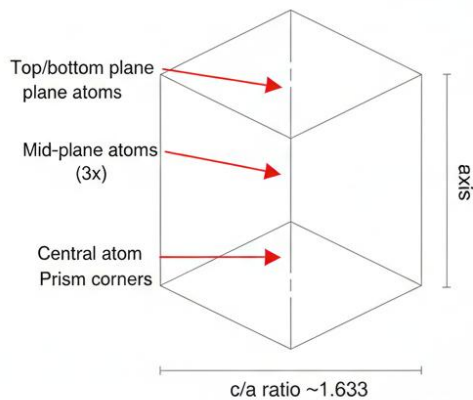
The HCP structure is a bit more complex than the cubic structures. It consists of three layers of atoms. The top and bottom layers have 6 atoms arranged in a regular hexagon with one atom in the center. The middle layer has 3 atoms nestled in the depressions of the layer below.

Take a look:

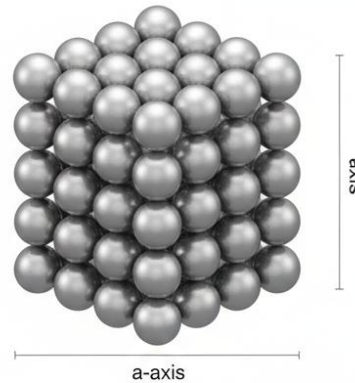


2.3 Hexagonal Close-Packed (HCP) Structure

Corner-sharing view



Space-filling view

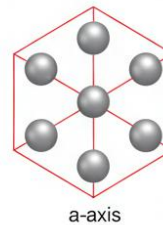


Key Properties

- Atoms per unit cell (N) = 6
- Coordination Number (CN) = 12
- Atomic Packing Factor APF = 0.74
- Common Metals: Mg, Ti, Zn, Co, Cd

c/ Ratio (Ideal)

- For ideal close packing: $c/a = 1.633$



5.2 Coordination Number

- Coordination number = 12

5.3 Atoms per Unit Cell

- 12 corner atoms (6 top, 6 bottom) contribute 1/6 each to the unit cell ($12 * 1/6 = 2$ atoms).



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- 2 face-centered atoms (1 top, 1 bottom) contribute 1/2 each ($2 * 1/2 = 1$ atom).
- 3 internal atoms contribute 1 each ($3 * 1 = 3$ atoms).
- Total: **6 atoms** per unit cell.

5.4 Examples of HCP Metals

- Magnesium
- Zinc
- Titanium

5.5 Layer Arrangement (HCP)

- Stacking sequence: **ABABAB**

6. Atomic Packing Factor (APF)

6.1 Definition

The **Atomic Packing Factor (APF)** is the fraction of the unit cell volume that is occupied by atoms.

$$APF = \frac{\text{Volume of atoms in unit cell}}{\text{Volume of unit cell}}$$

Where:

- Volume of atoms in unit cell = (Number of atoms per unit cell) * (Volume of one atom)
- Volume of one atom (assuming spherical atoms) = $\frac{4}{3}\pi R^3$ (where R is the atomic radius)

7. APF Calculations

7.1 APF for BCC Structure

Given:

- Number of atoms per unit cell (N): 2



- **Relationship between atomic radius (R) and lattice parameter (a):** For BCC, atoms touch along the body diagonal.

- Body diagonal = $a\sqrt{3}$
- Body diagonal = $4R$
- Therefore, $a\sqrt{3} = 4R \longrightarrow a = \frac{4R}{\sqrt{3}}$

- **Volume of unit cell:** $a^3 = \left(\frac{4R}{\sqrt{3}}\right)^3 = \frac{64R^3}{3\sqrt{3}}$

- **Volume of atoms in unit cell:** $2 \times \frac{4}{3}\pi R^3 = \frac{8}{3}\pi R^3$

Now, let's calculate APF

$$\text{APF}_{\text{BCC}} = \frac{\frac{8}{3}\pi R^3}{\frac{64R^3}{3\sqrt{3}}} = \frac{8\pi}{64/\sqrt{3}} = \frac{8\pi\sqrt{3}}{64} = \frac{\pi\sqrt{3}}{8} \approx 0.68$$

7.2 APF for FCC Structure

Given:

- **Number of atoms per unit cell (N):** 4
- **Relationship between atomic radius (R) and lattice parameter (a):** For FCC, atoms touch along the face diagonal.

- Body diagonal = $a\sqrt{2}$
- Body diagonal = $4R$
- Therefore, $a\sqrt{2} = 4R \longrightarrow a = \frac{4R}{\sqrt{2}} \longrightarrow a = 2R\sqrt{2}$

- **Volume of unit cell:** $a^3 = (2R\sqrt{2})^3 = 16R^3\sqrt{2}$

- **Volume of atoms in unit cell:** $4 \times \frac{4}{3}\pi R^3 = \frac{16}{3}\pi R^3$

Now, let's calculate APF



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$$APF_{\text{BCC}} = \frac{\frac{16}{3}\pi R^3}{16R^3\sqrt{2}} = \frac{16\pi}{48\sqrt{2}} = \frac{\pi}{3\sqrt{2}} \approx 0.74$$

7.3 APF for HCP Structure

$$APF_{\text{HCP}} = 0.74$$

8. Solved Numerical Problems

Problem 1: Number of Atoms in BCC

Question:

Calculate the number of atoms per unit cell in a BCC structure.

Solution:

- Corner atoms: $(8 \times 1/8 = 1)$
- Center atom: $(1 \times 1 = 1)$

Answer: 2 atoms

Problem 2: APF of FCC Structure

Question:

What is the atomic packing factor of an FCC crystal?

Solution:

$$APF = \frac{\text{Volume of atoms}}{\text{Volume of unit cell}} = 0.74$$

Answer: 0.74 (74%)

Problem 3: Comparison Question

Question:

Which structure is more densely packed: BCC or FCC?

Solution:



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- APF of BCC = 0.68
- APF of FCC = 0.74

Answer: FCC is more densely packed

Problem 4: Determining Lattice Parameter for BCC Iron

Question: Iron (α -Fe) has a BCC crystal structure, an atomic radius of 0.124 nm, and an atomic weight of 55.85 g/mol. Calculate its lattice parameter 'a'.

Understanding the Law/Formula:

For a BCC structure, the atoms touch along the body diagonal. The relationship between the atomic radius (R) and the lattice parameter (a) is given by:

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

Solution:

We are given:

- Atomic radius (R) = 0.124 nm

Using the formula for BCC:

$$a = \frac{4 \times 0.124 \text{ nm}}{\sqrt{3}}$$

$$a = \frac{0.496 \text{ nm}}{1.732}$$

$$a \approx 0.286 \text{ nm}$$

Answer: The lattice parameter 'a' for BCC iron is approximately 0.286 nm.



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9. Summary Table

Structure	Atoms/Unit Cell	Coordination No.	APF
BCC	2	8	0.68
FCC	4	12	0.74
HCP	6	12	0.74

10. References

1. *Engineering Materials: An Introduction to Their Properties and Applications*
2. *Materials Science*
3. *Engineering Metallurgy*
4. *Materials for the Engineering Technician*
5. الخواص الكهربائية والمغناطيسية للمواد
6. مبادئ علم المعادن

Questions

1. How many atoms are present in one BCC unit cell?
2. Define a unit cell.
3. Write the formula for Atomic Packing Factor (APF).
4. A metal has a BCC crystal structure. What is its atomic packing factor?
5. Why is the FCC structure more ductile than the BCC structure?
6. Give two examples of metals with HCP structure.