

# Close Packing Of Crystalline Solids

Close packing means arranging spheres tightly in a space so that they take up as much room as possible, which makes the crystal as dense as it can be. The number of spheres that are closest to a given sphere is called the coordination number.

**a) Close packing in one dimension:** In a one-dimensional close packing, spheres are placed in a straight row and each sphere touches its neighbors.

## **b) Two-dimensional close packing:**

**(1) Square close packing:** Spheres are arranged so that each sphere touches four others.

In this arrangement, the second row is directly under the first row, forming an AAA type structure.

## **(2) Hexagonal close packing**

Hexagonal close packing is a way of arranging spheres so that each sphere touches six others. This number of contacts is called the coordination number. The second row of spheres is placed above the first in a staggered way, so each sphere fits into the spaces between the spheres in the first row. If the first row is labeled as type A, the second row is a different type, called B. When the third row is placed directly above the first row, it is also type A. This pattern, where rows alternate between A and B, is known as ABAB.

## **C) Three dimensional close packing**

In three-dimensional close packing, two types are formed from hexagonal close packing layers: a) Hexagonal close packing (hcp) and b) Cubic close packing (ccp).

Another two types of three-dimensional close packing come from square close packed layers: c) Body Centered cubic (bcc) and d) Simple cubic arrangement.

## **Hexagonal Close –packing (hcp)**

In this structure, atoms are placed at the corners and center of two hexagonal layers that are parallel to each other. Three more atoms are positioned in between these two layers, parallel to them.

### **Characteristic features of hcp are:**

(i) It has an ABAB... pattern of layer arrangement, meaning every alternate layer is the

same.

(ii) It has a 6-fold axis of symmetry.

(iii) Each atom is surrounded by 12 other atoms – 6 in its own layer, 3 in the layer above, and 3 in the layer below. This gives it a coordination number of 12.

(iv) In hcp, atoms occupy 74% of the space, leaving 26% empty.

(v) It has only one set of parallel close-packed layers, so the likelihood of one layer sliding over another is lower.

Examples of elements that have an hcp structure are: Be, Cd, Li, Ca, Cr, Mo, V, Mg, Zn, Ce, Zr, Os, Ru, He.

### **Cubic closed packing (ccp) or face centered cubic (fcc)**

In this type of close packing, atoms are placed at the corners of a cube and also at the centers of all six faces. If we begin with hexagonal layers of spheres, as shown in the figure, the second layer is arranged by placing spheres over the gaps in the first layer. Only half of these gaps can be filled by the spheres. The third layer is arranged so that it covers the gaps in the second layer. The third layer does not look like the first or the second layer. The fourth layer looks like the first, the fifth like the second, and the sixth like the third. This type of arrangement is called cubic close-packed (ccp) or face-centered cubic (fcc) arrangement. The percentage of free space is 26%, and the coordination number is 12.

#### **Characteristic features of ccp:**

(i) This packing has an ABCABC... arrangement of layers.

This means the first three layers are different from each other, but this sequence repeats as more layers are added.

(ii) It has cubic symmetry, and the whole structure has four 3-fold axes of symmetry.

(iii) Like in hcp, each atom in ccp has 12 nearest neighbors, so the coordination number is 12.

(iv) The ccp arrangement fills up 74% of the available space, leaving 26% empty.

(v) It has four sets of parallel close-packed layers, which means there are more chances for one layer to slip over another compared to hcp.

Metals with ccp structure

(vi) Examples include Cu, Ag, Au, Pt, Al, Cr, Co, Fe, Pb, Mn, Ni, Ca, Sr, and all noble gases except He.

Nearly 60% of the metals have either hcp or ccp structures.

### **Body – Centered cubic structure ( bcc)**

A key feature of the body centered cubic arrangement is that atoms are placed at the corners of a cube and also at the center of the cube. Each atom touches eight other atoms—four above and four below—so the coordination number is eight. This arrangement fills up only 68% of the space, which is why it is seen in metals like sodium, potassium, cesium, rubidium, tungsten, vanadium, molybdenum, and barium. Only about 20% of all metallic elements have this type of structure.

### **Simple cubic arrangement**

In a simple cubic arrangement, the atoms in one row are directly above or below the atoms in the next row, forming a cube.

In two dimensions, a central atom is surrounded by four others, and in three dimensions, it is surrounded by six atoms.