THE SOLID STATE

TYPES OF SOLIDS AND CRYSTAL SYSTEMS

VERY SHORT ANSWER QUESTIONS

1. **Name an element that forms monoclinic crystals**?

ANS: Monoclinic sulphur (S).

2. **What is the crystalline structure of orange coloured oxidising agent used in lab?**

Ans: The orange coloured oxidising agent used in lab is $\mathbf{K_2Cr_2O_7}$. The crystal structure of $\mathbf{K_2Cr_2O_7}$ is Triclinic.

3. **Graphite crystallizes in hexagonal solid form. Give its characteristics. ?**

Ans: The Axial and angular characteristics of Graphite is

→ **$a = b \neq c$**

→ **$\alpha = \beta = 90$**

→ **$\gamma = 120$**

4. **Explain ferromagnetic soli materials?**

Ans: Ferromagnetic materials show permanent magnetism even after the applied magnetic field is removed, i.e. once such materials are magnetised they retain their mangnetism.

Ex: Fe, Co, Ni are only three elements which show ferromagnetism at room temperatue.

5. **What is meant by space lattice?**

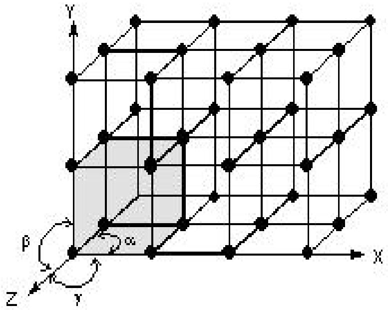
Ans: All crystals consist of regularly repeating array of atoms, molecules or ions which are the structural units (or basic units). It is much more convenient to represent each unit of pattern by a point, called lattice point, rather than drawing the entire unit of pattern. This results in a three dimensional orderly arrangement of points called a space lattice or a crystal lattice

Thus, a space lattice may be defined as a regular three dimensional arrangement of identical points in space or it can be defined as an array of points showing how molecules, atoms or ions are arranged at different sites in three dimensional space.

It must be noted that:

(a) Each lattice point has the same environment as that of any other point in the lattice

(b) The constituent particles have always to be represented by a lattice point, irrespective of whether it contains a single atom or more than one atom



A crystal or space lattice - The shaded portion represents the unit cell

Space lattice

6. **Name the crystal systems?**

Ans: There are Seven Crystal Systems**.** To describe a unit cell, six parameters are required. These are the three basis vectors along the three crystallographic axes (represented by the symbols a, b and c and the three angles between the crystallographic axes (represented by the symbols α, β and γ).

The seven types of crystal systems are; a) Cubic, b) Tetragonal, c) Orthorhombic d) Hexagonal e) Trigonal or Rhombohedral f) Monoclinic and g)Triclinic.

7. **How many unit cells share each of the lattice points in a cubic lattice?**

The no of atom in a unit cell can be calculated by keeping in view following points

1. An atom at the corners is shared by eight unit cells. Hence the contribution of an atom at the corner to a particular cell = 1/8.

2. An atom at the face is shared by two unit cells. Hence the contribution of an atom at the face to a particular cell = 1/2

3. An atom at the edge centre is shared by four unit cells in the lattice and hence contributes only 1/4 to a particular unit cell.

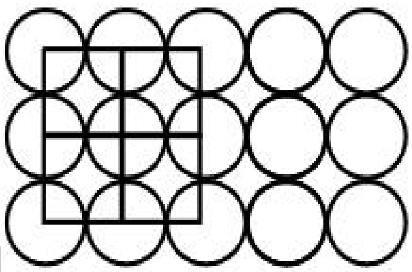
4. An atom at the body centre of a unit cell belongs entirely to it, so its contribution = 1

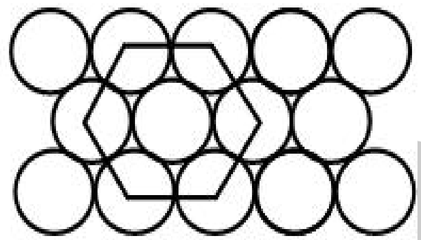
8. **Explain two dimensional close packing in crystals**?

Ans: When the rows are combined touching each other, the crystal plane is obtained. The rows can be combined in two different ways

(i) The particles when placed in the adjacent rows show a horizontal as well as vertical alignment and form squares. This type of packing is called square close packing

(ii) The particles in every next row are placed in the depressions between the particles of the first row. The particles in the third row will be vertically aligned with those in the first row. This type of packing gives a hexagonal pattern and is called hexagonal close packing





Square close packing **Hexagonal close packing (coordination**
no 4) **(coordination no 6)**

9. Explain three dimensional close packing in crystals?

Ans: In two dimensional packing, a more efficient packing is given by hexagonal close packing. In order to develop three dimensional close packing let us retain the hexagonal close packing in the first layer. If the spheres in the second layer are just placed over the spheres in the first layer so that the spheres in the two layers are vertically aligned, its voids will come above the voids in the first layer. This is an inefficient way of filling the space.

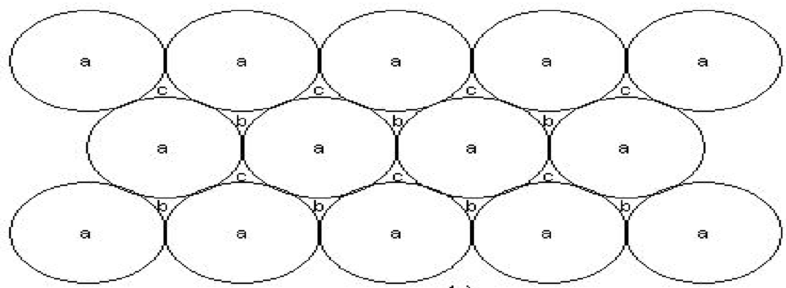
When the second layer is placed in such a way that its spheres find place in the 'b' voids of the first layer, the 'c' voids will be left unoccupied. Since under this arrangement no sphere can be placed in them, (c voids), i.e. only half the triangular voids in the first layer are occupied by spheres in the second layer (i.e. either b or c)

There are two alternative ways in which spheres in the third layer can be arranged over the second layer

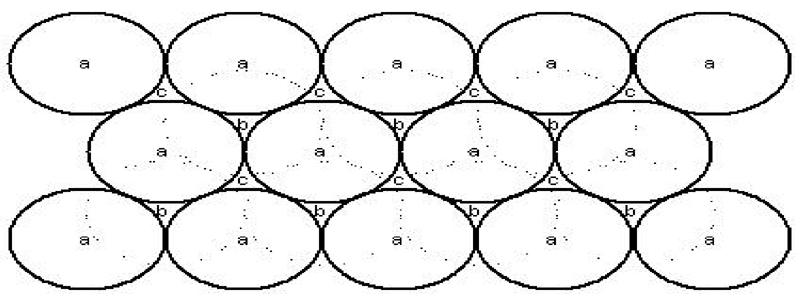
(1) When a third layer is placed over the second layer in such a way that the spheres cover the tetrahedral or 'a' voids; a three dimensional closest packing is obtained where the spheres in every third or alternate layers are vertically aligned (i.e. the third layer is directly above the first, the fourth above the second layer and so on) calling the first

layer A and second layer as layer B, the arrangement is called ABAB ………… pattern or hexagonal close packing (HCP) as it has hexagonal symmetry.

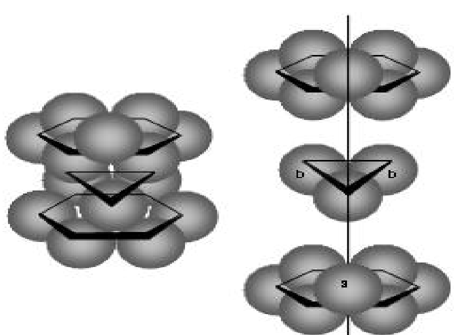
(2) When a third layer is placed over the second layer in such a way that spheres cover the octahedral or 'c' voids, a layer different from layers A and B is produced. Let it be layer 'C'. Continuing further a packing is obtained where the spheres in every fourth layer will be vertically aligned to the spheres present in the first layer. This pattern of stacking spheres is called ABCABC ……….. pattern or cubic close packing (ccp). It is similar to face centred cubic (fcc) packing as it has cubic symmetry



(a)

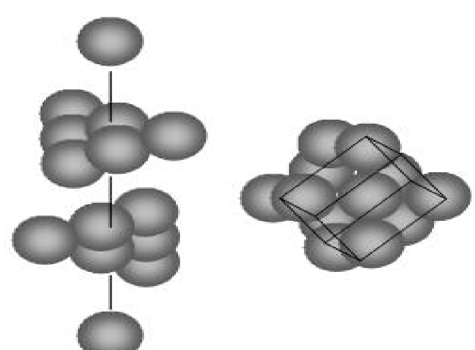


(b)



(a) (b)

Fig. (X) Hexagonal closest packing of spheres: (a) normal and (b) exploded view



(a) (b)

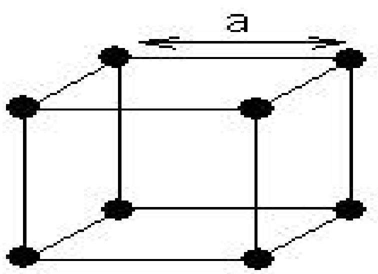
Fig (X): Cubic closest packing of spheres: (a) generation of unit from closest-packed layers, and (b) rotation to show cubic symmetry

10. What is unit cell and how many different types of unit cells are possible?

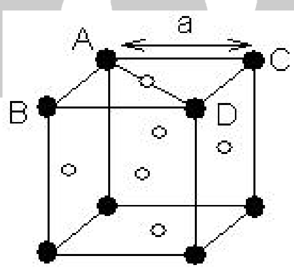
Ans: A unit cell is the smallest repeating unit in space lattice which when repeated over and over again results in a crystal of the given substance. Unit cell may be also defined as a three dimensional group of lattice points that generates the whole lattice on repetition.

Types of unit cells

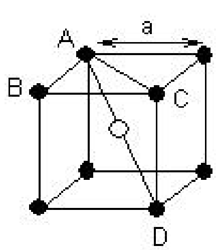
1. **Simple unit cell** having lattice points only at the corners is called simple, primitive or basic unit cell. A crystal lattice having primitive unit cell is called simple crystal lattice



2. **Face centred cubic lattice** (fcc) – A unit cell in which the lattice point is at the centre of each face as well as at the corner.



3. **Body centred cubic lattice** (bcc) A unit cell having a lattice point at the centre of the body as well as at the corners.



4. **Another type of unit cell, called end – centred unit cell** is possible for orthorhombic and monoclinic crystal types. In an end centred there are lattice points in the face centres of only one set of faces in addition to the lattice pints at the corners of the unit cell

10. Derive relations between the density of the crystalline substance and the unit cell length?

Ans: From the unit cell dimensions, it is possible to calculate the volume of the unit cell. Knowing the density of the metal, we can calculate the mass of the atoms in the unit cell. The determination of the mass of a single atom gives an accurate determination of Avogadro constant.

Suppose edge of unit cell of a cubic crystal determined by X – Ray diffraction is a, d is density of the solid substance and M is the molar mass, then in case of cubic crystal

Volume of a unit cell = a^3

Mass of the unit cell = no. of atoms in the unit cell × mass of each atom = Z × m

Here Z = no. of atoms present in one unit cell

m = mass of a single atom

Mass of an atom present in the unit cell = m/N_A

Density d = mass of unit cell / volume of unit cell = Z.m / a^3

$$\mathbf{d = Z.M. / a^3 \times N_A}$$

Note: Density of the unit cell is same as the density of the substance

LONG ANSWER QUESTIONS

1. How do you recognize crystal lattice and unit cell?

Ans: All crystals consist of regularly repeating array of atoms, molecules or ions which are the structural units (or basic units). It is much more convenient to represent each unit of pattern by a point, called lattice point, rather than drawing the entire unit of pattern. This results in a three dimensional orderly arrangement of points called a space lattice or a crystal lattice

Thus, a space lattice may be defined as a regular three dimensional arrangement of identical points in space or it can be defined as an array of points showing how molecules, atoms or ions are arranged at different sites in three dimensional space.

It must be noted that

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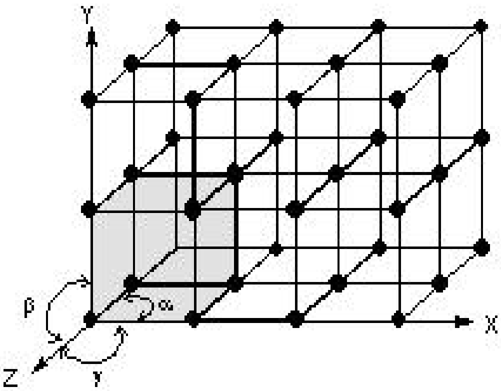


A crystal or space lattice - The shaded portion represents the unit cell

UNIT CELL

A unit cell is the smallest repeating unit in space lattice which when repeated over and over again results in a crystal of the given substance. Unit cell may be also defined as a three dimensional group of lattice points that generates the whole lattice on repetition.

Types of unit cells

1. **Simple unit cell** having lattice points only at the corners is called simple, primitive or basic unit cell. A crystal lattice having primitive unit cell is called simple crystal lattice

2. **Face centred cubic lattice** (fcc) – A unit cell in which the lattice point is at the centre of each face as well as at the corner.

3. **Body centred cubic lattice** (bcc) A unit cell having a lattice point at the centre of the body as well as at the corners.

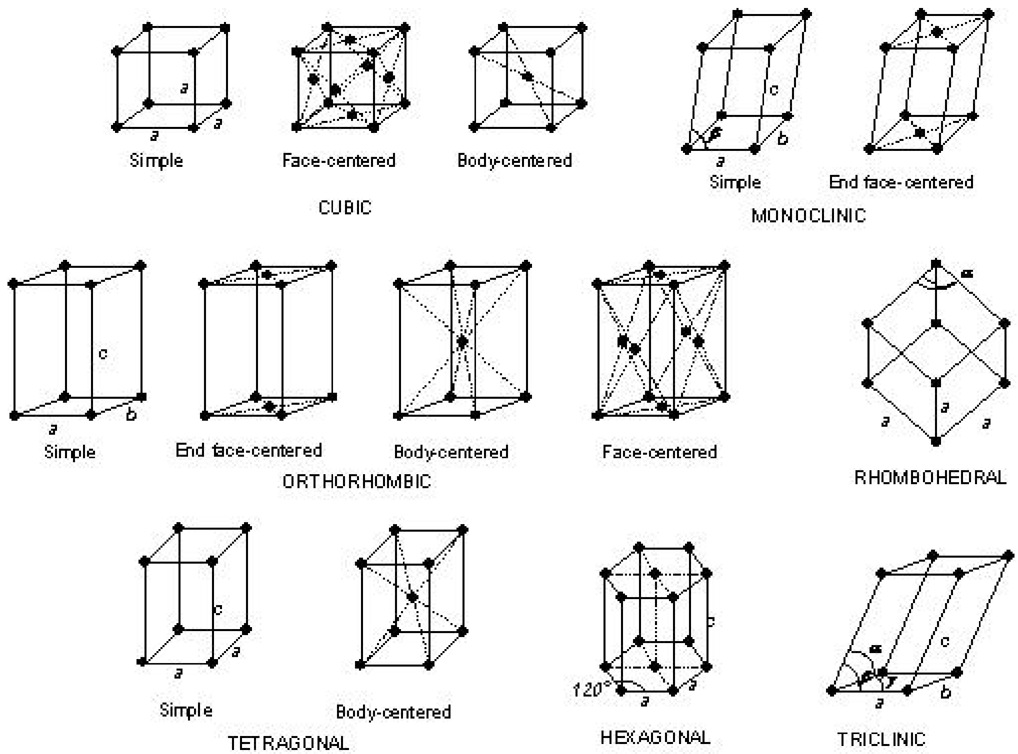
Another type of unit cell, called end – centred unit cell is possible for orthorhombic and monoclinic crystal types.

In an end centred there are lattice points in the face centres of only one set of faces in addition to the lattice pints at the corners of the unit cell. The various types of unit cells possible for different crystal classes (in all seven) are given below in tabular form

Crystals class	Axial distances	Angles	Possible types of unit cells	Examples
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$	Primitive, Body centred face	Copper , KCl, NaCl zinc blende,

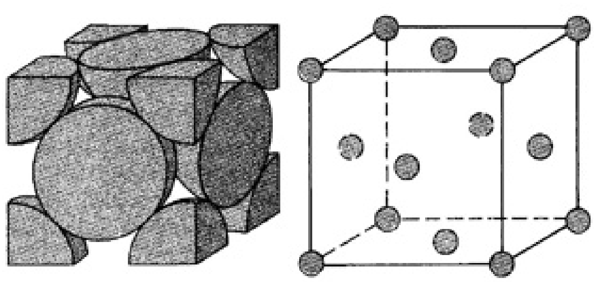
			centred	diamond
Tetragonal	a = b ≠ c	α = β = γ = 90°	Primitive, body centred	SnO_2, White tin, TiO_2
Orthorhombic	a ≠ b ≠ c	α = β = γ = 90°	Primitive body centred, face centred end centred	Rhombic sulphur, KNO_3, $CaCO_3$
Hexagonal	a = b ≠ c	α = β = 90° γ = 120°	Primitive	Graphite, Mg, ZnO
Trigonal or Rhombohedral	a = b = c	α = β = γ ≠ 90°	Primitive	($CaCO_3$) Calcite, HgS(Cinnabar)
Monoclinic	a ≠ b ≠ c	α = β = 90° γ ≠ 90°	Primitive and end centred	Monoclinic sulphur, $Na_2SO_4.10H_2O$
Triclinic	a ≠ b ≠ c	α ≠ β ≠ γ ≠ 90°	Primitive	$K_2Cr_2O_7$, $CuSO_4.5H_2O$

The Bravais space lattices associated with various crystal system are show in fig below



2. **Place the atoms of an element 'A' in the lattice points of face centered cubic structure?**

Ans: A face centred cubic (fcc) unit cell contains atoms at all the centers of all the faces of the cube. The following is the structure of fcc unit cell



- The characteristics of fcc structure are;
- Each atom is located at the face-center is shared between two unit cells.
- Each atom located at the corner is shared between eight adjacent unit cells
- The structure has a cubic close packing symmetry.

3. **What do you know about amorphous substances? Discuss**?

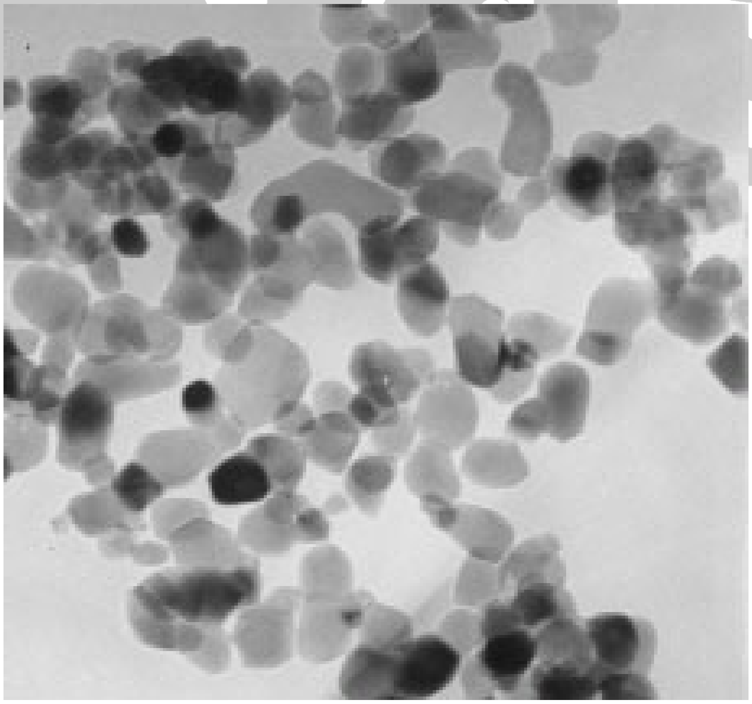
Ans: An amorphous solid is a substance whose constituent particles do not possess a regular orderly arrangement e.g. glass, plastics, rubber, starch, and proteins. Though amorphous solids do not possess long range regularity, in some cases they may possess small regions of orderly arrangement. These crystalline parts of an otherwise amorphous solid are known as **crystallites.**

An amorphous solid does not posses a sharp melting point. It undergoes liquefication over a broad range of temperature. The amorphous solid do not posses any characteristic heat of fusion. When an amorphous solid is cut with the help of sharp edged knife it results in an irregular cut.

Amorphous substances are also, sometimes, referred to as super cooled liquids because they posses disorderly arrangement like liquids. In fact many amorphous solids such as glass are capable flowing. Careful examination of the window panes of very old houses reveals that the panes are thicker at the bottom than at the top because the glass has flown under constant influence of gravity.

USES OF AMORPHOUS SOLIDS

Amorphous solids such as glass and plastics are very important materials and are widely used in construction, house ware, laboratory ware etc. Amorphous silica is likely to be the best material for converting sunlight into electricity (photovoltaic). Another well known amorphous solid is rubber which is used in making tyres shoes soles etc.



4. Draw distinction between space lattice and crystal lattice?

Ans: All crystals consist of regularly repeating array of atoms, molecules or ions which are the structural units (or basic units). It is much more convenient to represent each unit of pattern by a point, called lattice point, rather than drawing the entire unit of pattern. This results in a three dimensional orderly arrangement of points called a space lattice or a crystal lattice

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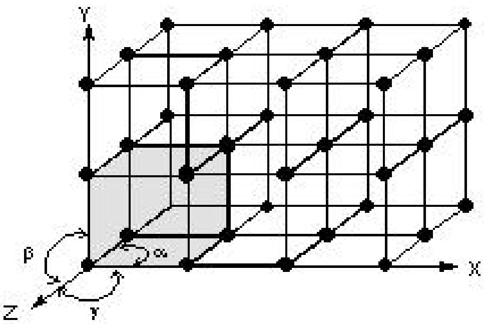

A crystal or space lattice - The shaded portion represents the unit cell

5. Write the differences between crystalline and amorphous solids?

DISTINCTION BETWEEN CRYSTALLINE AND AMORPHOUS SOLIDS

Crystalline solids	Amorphous solids
1. The internal arrangement of particles is regular so they possess definite and regular geometry	1. The internal arrangement of particles is irregular. Thus they do not have any definite geometry.
2. They have sharp melting points	2. They do not have sharp melting points
3. There is regularity in the external form when crystals are formed	3. There is no regularity in the external form when amorphous solids are formed

4. Crystalline solids give a regular cut when cut with a sharp – edged knife	4. Amorphous solids give irregular cut.
5. They have characteristic heat of fusion.	5. They do not have characteristic heat of fusion.
6. Crystalline solids are rigid and their shape is not distorted by mild distorting forces	6. Amorphous solid are not very rigid. These can be distorted by bending or compressing forces.
7. Crystalline solids are regarded as true solids	7. Amorphous solids are regarded as super cooled liquids or pseudo solids
8. Crystalline solids are anisotropic. This implies that physical properties such as refractive index, conductivity, thermal expansion etc are different in different directions. This is due to orderly arrangement of particles	8. Amorphous solids are isotropic in nature. This implies that various physical properties are same in all the directions. This is because of random arrangement of particles.