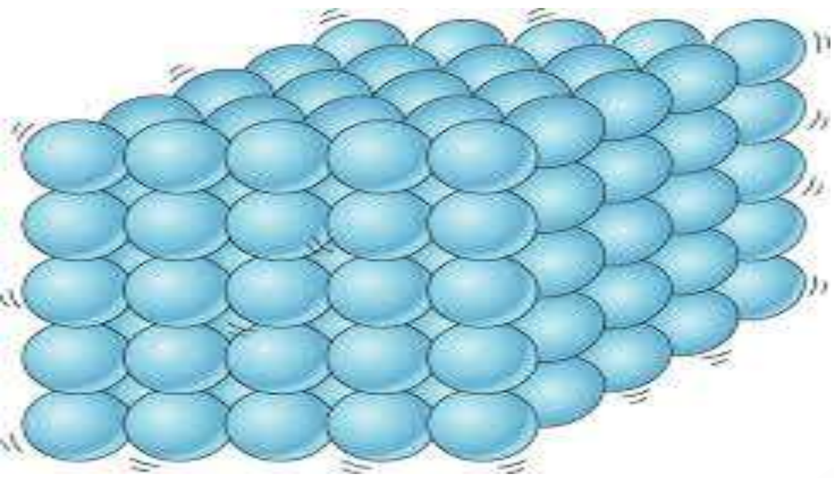

	Solids	Liquids	Gases
has particular shape	yes	no	no
has particular volume	yes	yes	no
spaces between molecules	no	yes	yes
Compressibility	a little bit	a little bit	yes

Solid

A solid is a state of matter characterized by particles arranged such that their shape and volume are relatively stable. The elements of a solid tend to be packed together, much closer than the particles in a gas or liquid. For Example a brick, a penny, a piece of wood, a chunk of aluminum metal.

Figure 1 Examples

When a solid is heated, the atoms or molecules gain Kinetic Energy (K.E). If the temperature becomes sufficiently high, kinetic energy disables the forces that hold the atoms or molecules in place. Then the solid may become a liquid or a gas, or it may react with chemicals in the environment.

- Water ice is an example of a solid that becomes liquid when it is heated gradually.
- Dry ice sublimates directly into the gaseous phase.
- Wood combines with oxygen in the atmosphere, undergoing combustion.

General Characteristic of Solids

The general characteristics of solids are as follows;

- They have strong intermolecular forces and short inter-nuclear distance due to close packing of constituent particles.
- Their constituent particles don't possess translator motion but can oscillate only around their mean position.

Due to these two basic properties, solids possess the following characteristic properties;

- They have definite shape, mass and volume.
- They are rigid and incompressible.
- They have high density.

Classification of Solid

Solids are classified into two types;

- Crystalline Solids
- Amorphous Solids

Crystalline Solids

Crystalline solids are those in which the basic particles possess a regular orderly arrangement. They are considered as true solids. For example, NaCl (Rock Salt), Sucrose (Sugar), Diamond, Quartz, etc.

Main Properties

The main properties of crystalline solids are gives as;

- Arrangement of constituent's particles
- Melting Point
- Anisotropy
- Clean Cleavage with Knife

Arrangement of Constituents Particles

In a crystalline solid, the particles (ion, molecule or atoms) are arranged in a definite geometric pattern in the three dimensional network. This is known as long range order. This arrangement repeats periodically over the entire crystal. Due to this arrangement, they have short range as well as long range order.

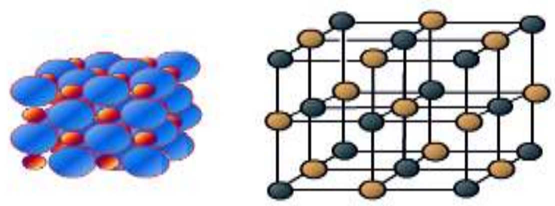

Figure 2 Arrangement of Constituents Particles

Melting Point

The crystalline solids have a sharp melting point, so possess definite heat of fusion.

Anisotropy

In a crystalline solid, the properties like electrical conductance, refractive index, thermal expansion, etc., have different values in different directions.

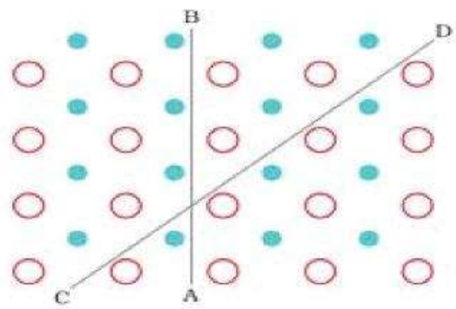

Figure 3 Anisotropy

This type of behavior is called Anisotropy and the substances with this property are called Anisotropic.

Clean Cleavage with Knife

A crystalline solid gives a clean surface with a knife rather than an irregular breakage.

Classification of Crystalline Solids

They can be classified into different categories depending upon the type of constituent particles and the nature of intermolecular forces between them. Various categories are:

- Ionic solid
- Molecular Solids
- Covalent or Network Solids
- Metallic Solids

Amorphous Solids

Amorphous solids are those in which particles don't possess a regular orderly arrangement.

Main Properties

The main properties of these solids are mentioned below:

- Arrangement of constituent's particles
- Melting point
- Isotropy
- Clean Cleavage with knife
- Super cooled liquid

Arrangement of Constituent Particles

In an amorphous solid, the particles are arranged in a regular manner up to a small region only. This is called short range order. In these solids, the particles are not in regular arrangement and possess only short range order and have irregular shape.

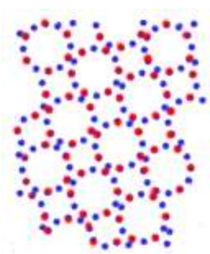

Figure 4 Arrangement of Constituents particles

Melting Point

The amorphous solids melt gradually over a temperature range, so do not possess definite heat of fusion.

Isotropy

In amorphous solids, the physical properties like electrical conductivity, refractive index, thermal expansion, etc. Are same in all directions just like liquids and gases. This type of behavior is called isotropy and the substances with this property are called isotropic.

Clean Cleavage with knife

Like a crystalline solid they don't give a clean surface after cleavage with knife.
They undergo an irregular breakage.

Super Cooled Liquid

They have a tendency to flow like liquid, although very slowly, so they are also called super cooled liquids. This tendency is illustrated by the fact that glass panes in the window of old historical buildings are found to be thicker at the bottom than at the top.

Pseudo Solids

They are not considered true solids. Due to short range order, small parts of amorphous solids may be crystalline and rest may be non-crystalline. This part of amorphous solids is called crystallizes, due to this they are also known as pseudo solids. This is the reason for the milkiness of window glass of old buildings because due to heating during the day and cooling at nights, glass acquires some crystalline character.

Solid Crystals

Solid crystals can be divided into four categories;

- Metallic Crystals
- Ionic Crystals
- Covalent Crystals
- Molecular Crystals

Metallic Crystals

In metallic crystals, atoms are joined together by metallic bond.

- Metallic crystals are very hard.
- They have high melting point and boiling point.
- They have shiny surface.
- They conduct electricity and heat.
- They are ductile.
- They are malleable.

Ionic Crystals

Solids that contain ionic bond in their structure consist of ionic crystals.

- In ionic crystals, opposite charged ions are joined together by strong electrostatic forces
- They are hard substances.
- They have high melting and boiling point.
- They possess ionic bond.
- They conduct electricity in molten state and in the form of solution.

- They are brittle.
- They are not ductile.
- They cannot be drawn into sheets.

Covalent Crystals

Solid substances in which atoms are held together by covalent bond are known as covalent crystals. These crystals are very stable. For example:

- Diamond
- Graphite

Molecular Crystals

Molecular molecules are those in which there are recognizable molecules in the structure and the crystal is held together by non-covalent interactions like van der Waals forces or hydrogen bonding. An example of this type of crystal would be sugar. Molecular crystals tend to be soft and have lower melting points.

- These substances have low melting point and boiling point.
- Generally they are volatile (evaporates)

Crystal Lattice Structure

In crystalline solids, the constituent particles are arranged in a regular pattern throughout the crystal lattice. This regular and repeating arrangement of points or particles in space is called as space lattice or crystal lattice structure. Since crystal lattice is a regular and repeating arrangement of partials, a small part of the lattice will be sufficient to explain all the properties and complete crystal lattice. This smallest part of the crystal lattice, which when repeated in different directions, produces a complete crystal lattice, is known as unit cell.

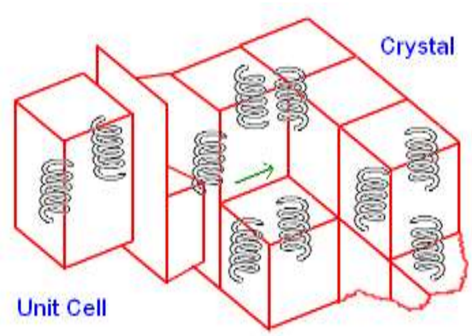

Figure 5 Crystal Lattice Structure

Properties of Crystal Lattice

In the crystal lattice, each point represents constituent particles (ion or atom or molecule) and is called as lattice point. These points joined by line to form a whole crystal lattice. The arrangement of lattice points in a crystal lattice gives the geometry to a crystal lattice. Crystal lattice can be of two types,

- Two Dimensional Lattices
- Three Dimensional Lattices

Two Dimensional Lattices

In two dimensional lattice arrangement of particles is on the plane of a paper.

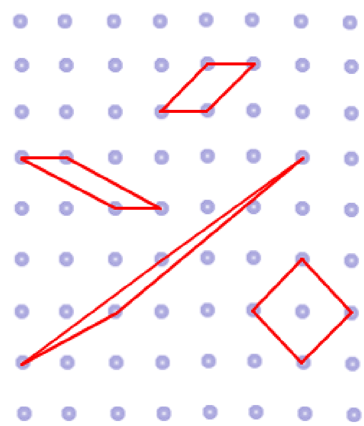

Figure 6 Two Dimensional Lattice

The type of crystal lattice depends on the type of unit cell. The complete crystal lattice is produced by repeatedly moving unit cells in the direction of its edge.

Lattice	Unit cell
Square lattice	Square
Rectangle lattice	Rectangle
Parallelogram lattice	Parallelogram
Hexagonal lattice	Rhombus with an angle of 60ºC

Three Dimensional Lattices

In these type of crystal lattices, the constituent particles are arranged in a three dimensional space.

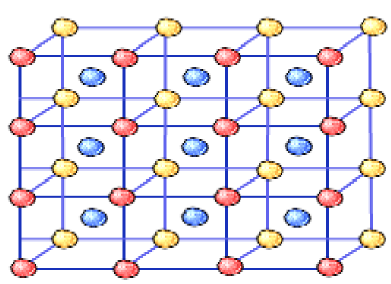

Figure 7 Three Dimensional Lattice

Unit Cell

The smallest building block of a crystal, consisting of atoms, ions, or molecules, whose geometric arrangement defines a crystal's characteristic symmetry and whose repetition in space produces a crystal lattice. A unit cell with a certain number of particles in its corner is known as a primitive unit cell, while a unit cell with corner as well as interior particles is known as interior unit cell. A unit cell can be explained by using certain parameters. These parameters are as follows. The edge of the unit cell represented by a, b and c. It is dimensions along the three edges. The angle between the edges are represented by α, β and γ. The angle between edge b & c is α, the angle between edge a & c is β, while γ is the angle between edges a & b. Thus there are a total of six parameters; a, b, c and α, β and γ.

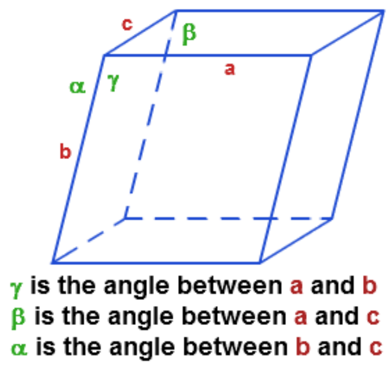

Figure 8 Unit Cell

Types of Unit Cells

Unit cell can be classified on two different basis;

- Based upon the parameters of unit cell
- Based upon the position of particles in unit cell

Based Upon the Parameters of Unit Cell

The unit cell can be classified into seven different types on the basis of the different parameters a, b and c edges and Î±, Î² and Ï’ angles. These seven unit cells are also known as Bravais Unit Cells.

Category	Edge lengths	Internal angles
Cubic	(a=b=c)	(α=β=γ=90º)
Tetragonal	(a=b≠ c)	(a=β=γ=90º)
Monoclinic	(a≠ b≠c)	(a=β>=90º=γ)
Orthorhombic	(a≠ b≠ c)	(a=β>=γ=90º)
Rhombohedral	(a=b=c)	(a=β>=γ≠ 90º)
Hexagonal	(a=b≠ c)	(a=β=90º, γ=120º)
Triclinic	(a≠ b≠ c)	(a≠β >≠ γ≠ 90º)

Based Upon the Position of Particles in Unit Cell

Each Bravais unit cell is further classified into two types on the basis of the position of the particles at the corner and center. The unit cells which have lattice points only at the corner are termed as primitive unit cells. While the unit cells in which the lattice points are located at the corner as well as at other positions also are called as non-primitive or centered unit cell.

Class of crystals	**Possible types of units**	**Examples**
Cubic	Primitive body centred face centred	Copper, KCl, NaCl zinc blende, diamond
Tetragonal	Primitive body centred	SnO_2, White tin, TiO_2
Orthorhombic	Primitive body centred, face centred and centred	Rhombic sulfur, KNO_3, $CaCO_3$
Hexagonal	Primitive	Graphie, Mg, ZnO
Trigonal or rhombohedral	Primitive	($CaCO_3$) Calcite, HgS(cinnabar)
Monoclinic	Primitive and end centred	Monoclinic sulfur, $Na_2SO_4.10H_2O$
Triclinic	Primitive	$K_2Cr_2O_7$, $CuSO_4.5H_2O$