

Crystal Classes

by

R. Ramesh Babu



Crystals & Applications

Tools and weapons

Sapphire

Magical crystals

knives and spears

amulets

Crystals & Applications

Solar Panel

Medicine surgery

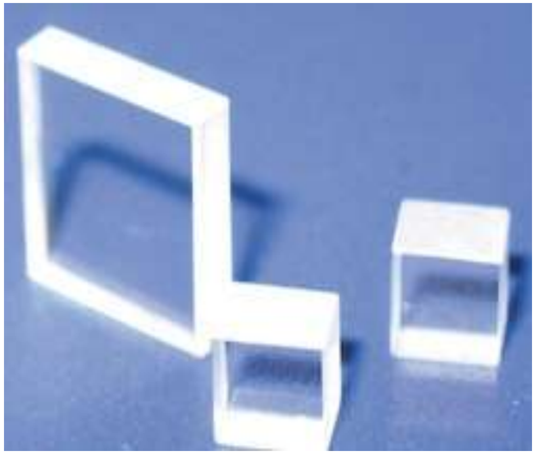
Satellite

Crystals

Snow

Quartz

NaCl



KDP

LBO

Ruby

Solid State

Matter -- Solid, liquid and gaseous states

Solid – Constituent of particles are fixed in position (atoms/ions/ molecules) except for thermal vibrations

Fluid – Material whose particles are in a state of constant translation motion

Classification of Solids

In terms of their degree and type of order

Crystalline

Semi-crystalline (poly crystalline)

Non-crystalline (amorphous)

Crystalline solid

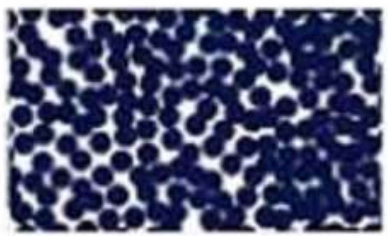
A solid in general is said to be crystal, if the constituent particles (atoms/ions/molecules) are arranged in a three dimensional periodic manner

Crystals are formed by a regular repetition of identical building blocks in 3D space.

Crystal are bounded by optically plane faces, sharp straight edges and interfacial angles.

Non-crystalline (amorphous) solids

-A lacks a systematic atomic arrangement.



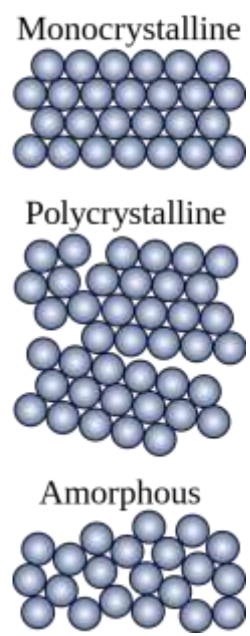
Amorphous Structure

Single crystal

-Atoms arrangements in long-range order

-Anisotropy behavior

-Sharp melting point

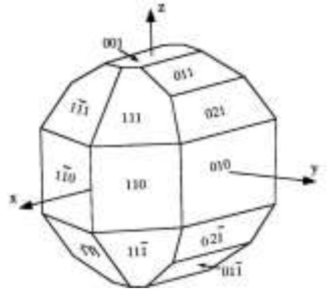


Crystalline Structure

Polycrystalline solids

-A solid consists of many crystallites oriented randomly and separated by well defined boundaries under the suitable conditions – they can be grown as single crystal.

Crystal



A **crystal form** is a set of faces which are geometrically equivalent and whose spatial positions are related to one another according to the symmetry of the crystal.

The concept of **symmetry** describes the periodic repetition of structural features.

Two general types of symmetry exist. These include **translational symmetry** and **point symmetry**.

Translational symmetry describes the periodic repetition of a motif across a length or through an area or volume.

Point symmetry, on the other hand, describes the periodic repetition of a motif around a point.

Space lattice & Translation vectors

Crystal : Constituent particles are arranged in a 3D periodic manner

In order to describe periodicity Bravais introduced the concept of space lattice.

Translation of an object to a finite distance ‘a’ then repeated systematically along three crystallographic directions, x,y and z to obtain three dimensional space lattice.

Replacing each repeated object in an array with a point. The collect of points is called a lattice.

1D - linear lattice
2D - two non collinear translations define plane lattice and
3D - three non-coplanar translation define a space lattice

Space lattice & Translation vectors

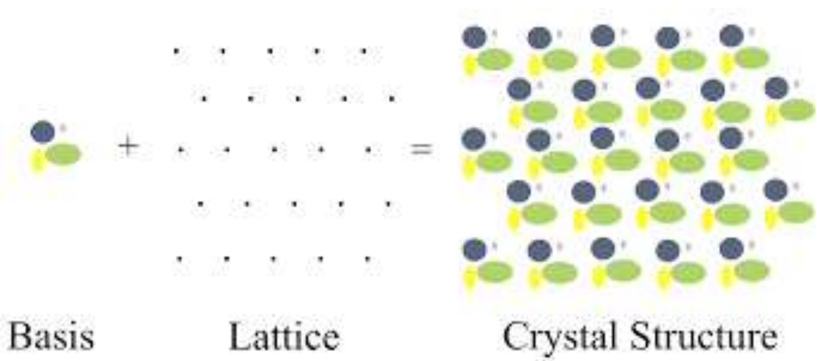
Space lattice can be visualized by considering a,b and c as translation vectors and three translations directions x,y and z as crystallographic axes with respect to any lattice point as the origin, then the location of any other lattice point can be defined as

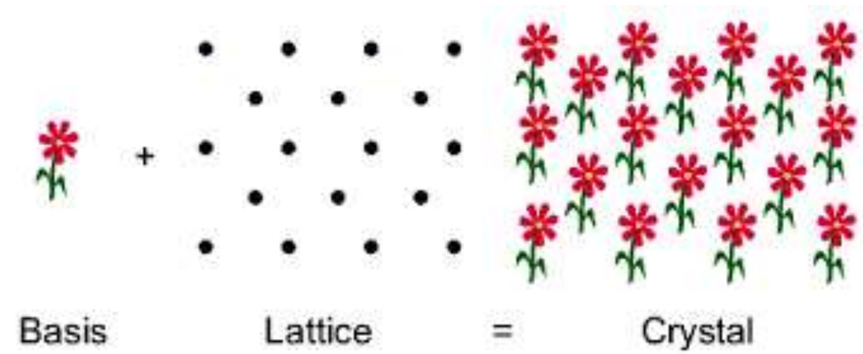
$$T = n_1a + n_2b + n_3c$$

Crystal Structure

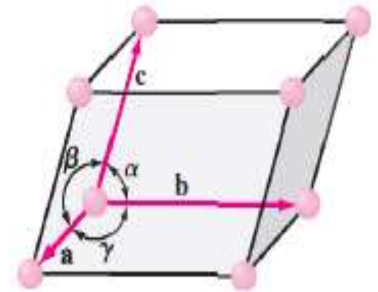
Properties of solids depend upon crystal structure and bonding force.

Lattice + Basis ------------- Crystal structure





Unit cell



Crystals are made of infinite number of unit cells

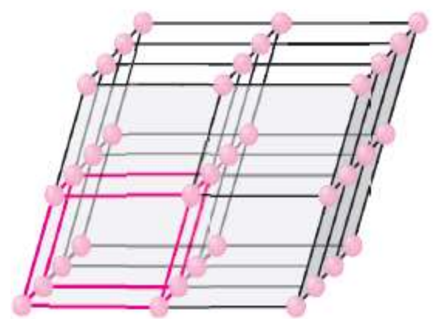
Simplest parallelepiped formed by the primitive translation operation T and is known as Unit cells

Unit cell is the smallest unit of a crystal, which, if repeated, could generate the whole crystal.

A crystal's unit cell dimensions are defined by six numbers, the lengths of the 3 axes, a, b, and c, and the three inter-axial angles, α, β and γ.

A crystal lattice is a 3-D stack of unit cells

Crystal lattice is an imaginative grid system in three dimensions in which every point (or node) has an environment that is identical to that of any other point or node.



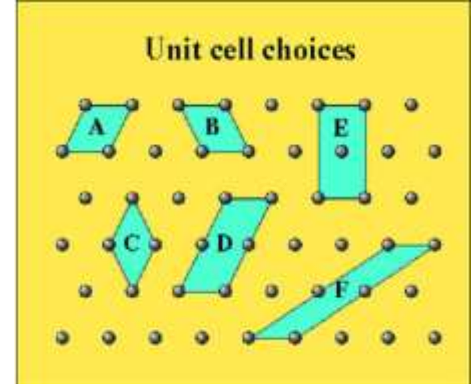
(a)

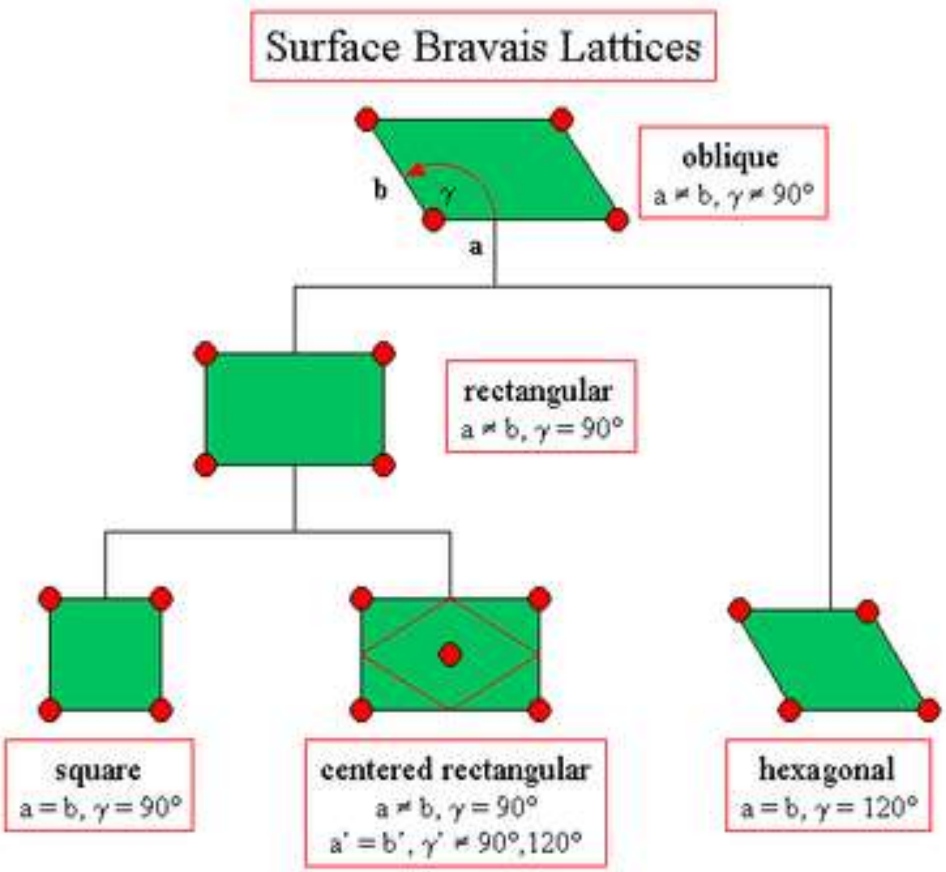
Bravais lattices

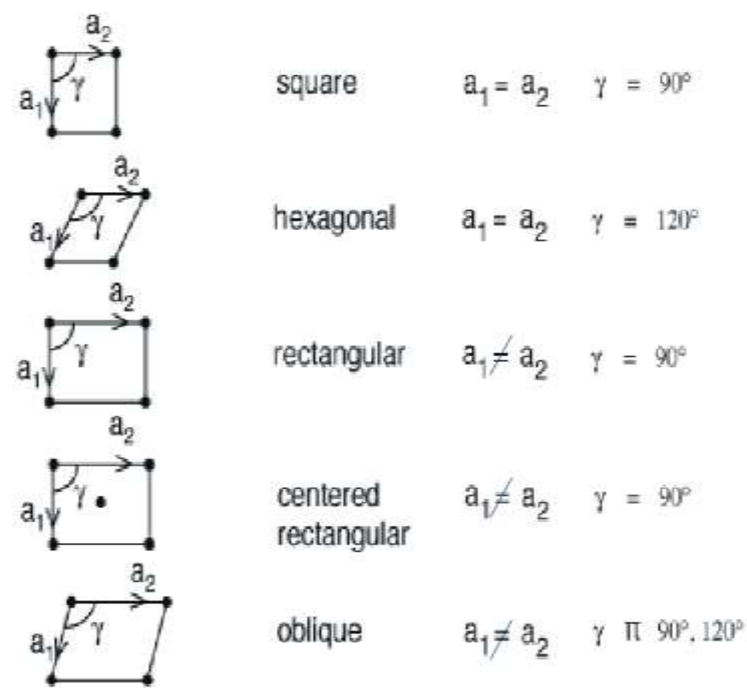
Auguste Bravais
(1811-1863)

- In 1848, Auguste Bravais demonstrated that in a 3-dimensional system there are fourteen possible lattices
- A Bravais lattice is an infinite array of discrete points with identical environment.
- Seven crystal systems + four lattice centering types = 14 Bravais lattices
- Lattices are characterized by translation symmetry

2D Bravais Lattices







3D Bravais lattices

The fourteen **Bravais lattices** may be divided among seven crystal systems. These are the cubic, tetragonal, orthorhombic, monoclinic, triclinic, trigonal and hexagonal systems.

The Bravais lattices are furthermore of **four different types**.

A **primitive lattice** has only a lattice point at each corner of the three-dimensional unit cell.

A **body-centered lattice** contains not only lattice points at each corner of the unit cell but also contains a lattice point at the center of the three-dimensional unit cell.

A **face-centered lattice** possesses not only lattice points at the corners of the unit cell but also at either the centers of just one pair of faces or else at the centers of all three pairs of faces.

Four lattice centering types

No.	Type	Description
1	Primitive	Lattice points on corners only. Symbol: P.
2	Base Centered	Lattice points on corners as well as centered on faces. Symbols: A (bc faces); B (ac faces); C (ab faces).
3	All-Face Centered	Lattice points on corners as well as in the centers of all faces. Symbol: F.
4	Body-Centered	Lattice points on corners as well as in the center of the unit cell body. Symbol: I.

Crystal system	Axial lengths and interaxial angles	Space lattice
Cubic	Three equal axes at right angles $a = b = c, \alpha = \beta = \gamma = 90^\circ$	Simple cubic Body-centered cubic Face-centered cubic
Tetragonal	Three axes at right angles, two equal $a = b \neq c, \alpha = \beta = \gamma = 90^\circ$	Simple tetragonal Body-centered tetragonal
Orthorhombic	Three unequal axes at right angles $a \neq b \neq c, \alpha = \beta = \gamma = 90^\circ$	Simple orthorhombic Body-centered orthorhombic Base-centered orthorhombic Face-centered orthorhombic
Rhombohedral	Three equal axes, equally inclined $a = b = c, \alpha = \beta = \gamma \neq 90^\circ$	Simple rhombohedral
Hexagonal	Two equal axes at 120°, third axis at right angles $a = b \neq c, \alpha = \beta = 90^\circ,$ $\gamma = 120^\circ$	Simple hexagonal
Monoclinic	Three unequal axes, one pair not at right angles $a \neq b \neq c, \alpha = \gamma = 90^\circ \neq \beta$	Simple monoclinic Base-centered monoclinic
Triclinic	Three unequal axes, unequally inclined and none at right angles $a \neq b \neq c, \alpha \neq \beta \neq \gamma \neq 90^\circ$	Simple triclinic

The 14 Bravais conventional unit cells grouped according to crystal system. The dots indicate lattice points that, when located on faces or at corners, are shared by other identical lattice unit cells.