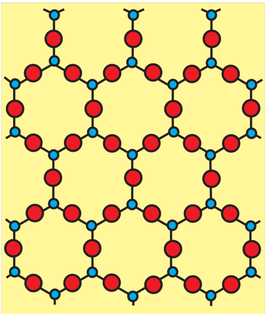
Crystalline types of solid, amorphous and glassy, liquid state

Crystalline types of solid:
Solids can be classified as crystalline or amorphous on the basis of the nature of order present in the arrangement of their constituent particles. A crystalline solid usually consists of a large number of small crystals, each of them having a definite characteristic geometrical shape. In a crystal, the arrangement of constituent particles (atoms, molecules or ions) is ordered. It has long range order which means that there is a regular pattern of arrangement of particles which repeats itself periodically over the entire crystal. Sodium chloride and quartz are typical examples of crystalline solids. An amorphous solid consists of particles of irregular shape. The arrangement of constituent particles (atoms, molecules or ions) in such a solid has only short range order. In such an arrangement, a regular and periodically repeating pattern is observed over short distances only. Such portions are scattered and in between the arrangement is disordered. The structures of quartz (crystalline) and quartz glass (amorphous) are shown in Fig. 1.1 (a) and (b) respectively. While the two structures are almost identical, yet in the case of amorphous quartz glass there is no long range order. The structure of amorphous solids is similar to that of liquids. Glass, rubber and plastics are typical examples of amorphous solids. Due to the differences in the arrangement of the constituent particles, the two types of solids differ in their properties.


(a)

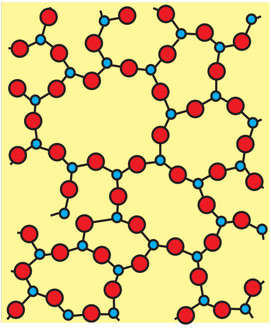

(b)

Figure 1: Two dimensional structure of (a) quartz and (b) quartz glass

Crystalline solids have a sharp melting point. On the other hand, amorphous solids soften over a range of temperature and can be moulded and blown into various shapes. On heating they become crystalline at some temperature. Some glass objects from ancient civilisations are found to become milky in appearance because of some crystallisation. Like liquids, amorphous solids have a tendency to flow, though very slowly. Therefore, sometimes these are called pseudo solids or super cooled liquids. Glass panes fixed to windows or doors of old buildings are invariably found to be slightly thicker at the bottom than at the top. This is because the glass flows down very slowly and makes the bottom portion slightly thicker. Crystalline solids are anisotropic in nature, that is, some of their physical properties like electrical resistance or refractive index show different values when measured along different directions in the same crystals. This arises from different arrangement of particles in different directions. This is illustrated in Fig. 1.2. Since the arrangement of particles is different along different directions, the value of same physical property is found to be different along each direction.

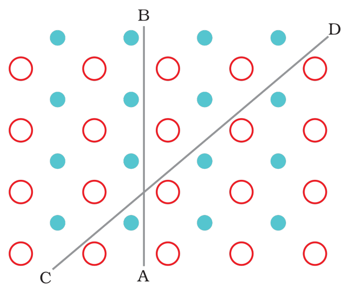


Figure 2: Anisotropy in crystals is due to different arrangement of particles along different directions.

Amorphous solids on the other hand are isotropic in nature. It is because there is no long range order in them and arrangement is irregular along all the directions. Therefore, value of any physical property would be same along any direction.

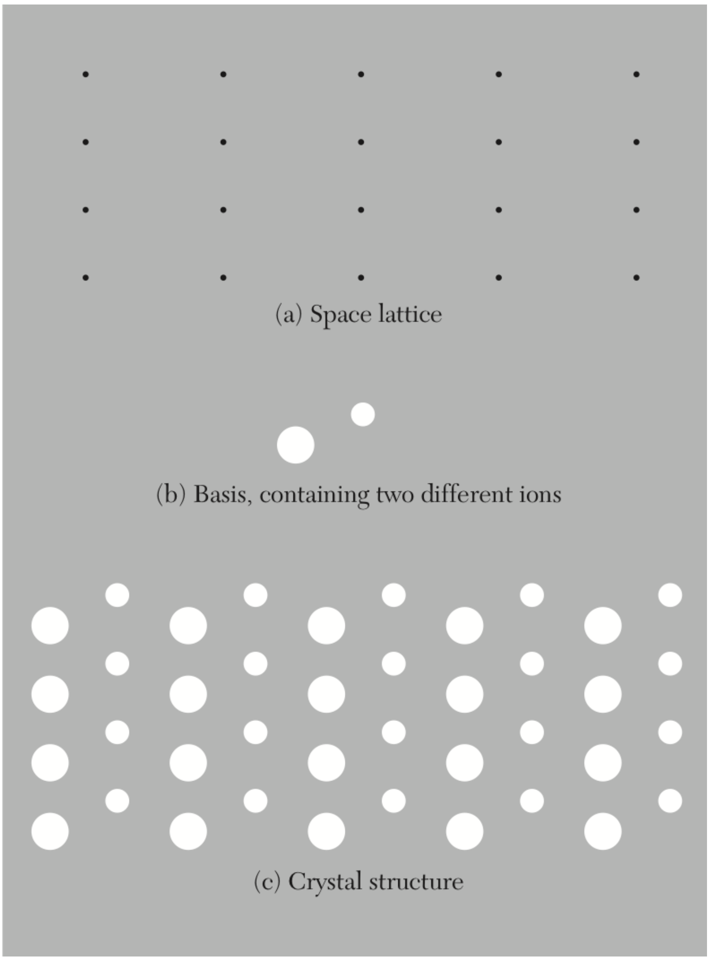
Lattice and lattice translational vector

An ideal crystal is constructed by the infinite repetition of identical groups of atoms. A group is called the **basis**. The set of mathematical points to which the basis is attached is called the **lattice**. The lattice in three dimensions may be defined by three translation vectors $\vec{a}$, $\vec{b}$, $\vec{c}$, such that the arrangement of atoms in the crystal looks the same when viewed from the point $\vec{r}$ as when viewed from every point $\vec{r'}$ translated by an integral multiple of the $\vec{a}$'s:

$$\vec{r'} = \vec{r} + n_1\vec{a} + n_2\vec{b} + n_3\vec{c} \qquad (1)$$

Here n_1, n_2, n_3 are arbitrary integers. The set of points $\vec{r'}$ defined by (1) for all n_1, n_2, n_3 defines the lattice.

The lattice is said to be **primitive** if any two points from which the atomic arrangement looks the same always satisfy (1) with a suitable choice of the integers n_i. This statement defines the **primitive translation vectors** $\vec{a}, \vec{b}$, and $\vec{c}$. There is no cell of smaller volume than $\vec{a} \cdot \vec{b} \times \vec{c}$ that can serve as a building block for the crystal structure. We often use the primitive translation vectors to define the **crystal axes**, which form three adjacent edges of the primitive parallelepiped.



(a) Space lattice

(b) Basis, containing two different ions

(c) Crystal structure

Figure 3: The crystal structure is formed by the addition of the basis (b) to every lattice point of the space lattice (a). By looking at (c), one can recognize the basis and then one can abstract the space lattice. It does not matter where the basis is put in relation to a lattice point.

Unit Cell

A unit cell may be defined as the smallest unit of lattice which, on continuous repitition, negerates the complete lattice. Primitive unit cell is the smallest volume cell. All the lattice points belonging to a primitive cell line at its corners. Therefore, the effective number of lattice points in a primitive unit cell is one. A non-primitive cell may have the lattice points at the corners as well as at other locations both inside and on the surface of the cell and, therefore, the effective number of lattice point in a non-primitive cell is greater than one.

Since there exists a number of ways of choosing a unit cell, the choice of conventional unit cell is a matter of convenience. Ideally, a primitive cell having the smallest volume should be chosen as the conventional unit cell. However, sometimes a non-primitive cell is selected as the conventional unit cell because it possesses higher symmetry than a primitive cell.

Basis

In order to obtain a crystal structure, an aom or a group of atoms must be placed on each lattice point in a regular fashion. Such an atom or a group of atoms is called the **basis** and acts as a building unit or a structural unit for a complete crystal structure. Thus a lattice combined with a basis generates the *crystal structure*. Thus, whereas a lattice is a mathematical concept, the crystal structure is a physical concept.

The number of atoms in a basis may vary from one to several thousands, whereas the number of

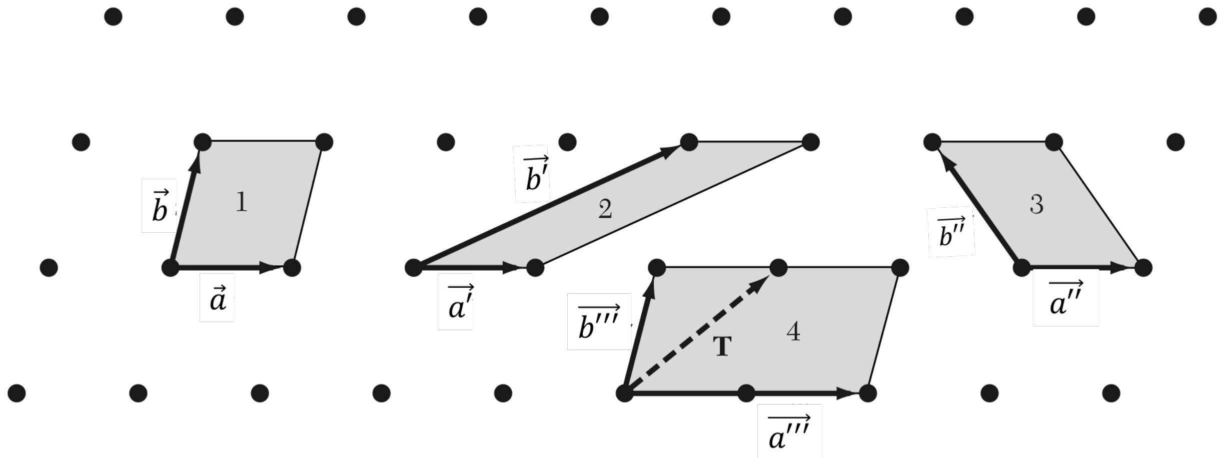


Figure 4: Lattice points of a space lattice in two dimensions. All pairs of vectors $\vec{a}, \vec{b}$ are translation vectors of the lattice. But $\vec{a'''}, \vec{b'''}$ are not primitive translation vectors because we cannot form the lattice translation T from integral combinations of $\vec{a'''}$, and $\vec{b'''}$. The other pairs shown of $\vec{a}$ and $\vec{b}$ may be taken as the primitive translation vectors of the lattice. The parallelograms 1, 2, 3 are equal in area and any of them could be taken as the primitive cell. The parallelogram 4 has twice the area of a primitive cell.

space lattices possible is only fourteen. Thus a large number of crystal structures may be obtained from just fourteen space lattice simply because of the different types of basis available.