ENVIRONMENTAL GEOSCIENCES

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Lecture-19

Crystals and its Characteristics

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are continuing the module four today in which we will discuss the crystal system, different crystal classes, concepts of minerals, its properties, properties of common silicate minerals, sulphide and oxide minerals. Today we will start the lecture one that is crystal and its characteristics. In this lecture, the important concepts will be covered like crystallography, characteristics of crystals, elements of crystal forms, common forms in crystallography, elements of symmetry and laws of crystallography. First of all, we will understand what is crystallography.

It is a branch of mineralogy which deals with the study of crystals, their internal structure and external shape. So, a crystal is a solid material whose atoms are arranged in a highly ordered repeating pattern that extends in all three spatial dimensions. Crystallization, it is defined as the crystals are formed by the solidification of minerals from the liquid states or from solutions under controlled conditions of temperature and pressure. You can see the diagram of hexagonal prism crystal and the square prism crystal. Now, what are the characteristics of crystals?

Crystals show the characteristics like, crystals are polyhedral bodies, first characteristic. Second, crystals are formed due to slow cooling. Third, It possesses a typical internal atomic structure and accordingly the faces of a crystal are arranged in a regular pattern. They are in a regular pattern and formed due to operation of interatomic forces. A crystal which possess both external form as well as internal atomic structure is generally called as a perfect crystal.

But if it possess only the internal atomic structure and without the development of the corresponding external form, then it is said to be crystalline. And when there is neither internal atomic structure nor external form, it will be known as amorphous substance. It is

important to know that within the mineral kingdom, 98% of the mineral are crystalline in nature. Now, we will discuss the elements of crystal forms in which we will know about the phases, edge, solid angle, interfacial angle, etc. Now, faces. These are the external expressions of the internal atomic planes of the crystal.

Faces are said to be light when they have similar properties and unlike when they are different characteristics. Edge, the line of intersections of two adjacent faces is known as an edge. Solid angle, it is a point where three or more faces meet. Interfacial angle, the interfacial angle between any two faces of a crystal is the angle subtended between the normal drawn on the two faces concerned. Here in the diagram we can see these like ABCD, CDGF, and BCFE.

These are the three crystal faces. AB, DC, AD, BC, GD, GF, FC, BE, and EF. These are the edges of the crystal. PR and QR are the normal on the two faces. Point C is the solid angle and angle PRQ is the interfacial angle. Now forms, it is a group of faces which have like position with respect to the crystallographic axis.

But this form is classified in three ways also. First way is to classify into simple form and the combination form. Simple form, when a crystal is made up of all like faces such as in cube, octahedron, etc., Combination form, when a crystal is made up of two or more simple forms, such as when it consists of basal pinnacoid and prism faces, each of which in itself is a simple form. Second category is the open form and closed form.

Open form are those forms whose faces cannot enclose space by all themselves as they do not have a great number of faces to do so and as a result occur only in combination with other forms like in pinnacoids and prisms. Closed form, it is an assemblage of faces which can enclose a volume of space and the best example is the pyramid. Third category is the general form, special form and restricted form. General form, it is one in which the indices are unrestricted in magnitude. Special form, here only one possible set of values exist for the indices.

Restricted form, when the forms are neither special nor general, part of their index is variable and part of it remain fixed.. And example is prism. Besides the above classification, forms have also been classified as holohedral forms, hemihedral forms, hemimorphic forms, tetatohedral forms, and enantiomorphic forms. One by one, we will understand these different types of forms. First is the holohedral forms. These forms exhibit the highest degree of symmetry possible in a system.

Octahedron is a holohedral form because it shows all the eight faces developed on the crystal. Hemihedral forms, these forms show half the number of faces required for the full symmetry of the system. Example is tetrahedron is a hemihedral form of octahedron. Hemimorphic forms, these forms have dissimilar faces about the two ends of an axis of symmetry, this axis is also called as polar axis. Hemimorphic forms have lack of center of symmetry. Just below you can see the different forms that is holohedral, hemihedral and hemimorphic form diagram also.

Next is the tetratohedral forms they show only a quarter of number of faces of the corresponding holohedral form. These forms have neither plane nor center of symmetry. Enantiomorphic forms, these forms do not have either plane or centre of symmetry and occur in two positions which are mirror images of each other. They cannot be converted into each other by any rotation whatsoever. So, these are about the different types of forms of the crystals. Now, after knowing this, we will just move for the some other different forms in crystallography that is pedian, it is represented by one face only. Pinacoid, it is an open form consisting of two faces which cuts one crystallographic axis and remains parallel to the remaining axis.

Prism, it is also an open form consisting of four faces, each face of which essentially parallel to the vertical axis and cuts one or more horizontal axis. Pyramids, it is a closed form having eight faces, each face of which cuts the vertical axis and cuts one or more horizontal axis at equal or unequal distances. Domes, it is an open form intermediate between a prism and a pyramid, whose faces cut the vertical axis and one of the horizontal axis. These are also known as horizontal prism. Diametral prisms, It is formed by the combination of three pinnacoids which together enclose space.

They occur only in the orthorhombic, monoclinic and triclinic systems in which all the pinnacoids occur. After this, we will know the elements of symmetry. This is very important because the geometric locus about which a group of repeating operations generally act is known as elements of symmetry. The symmetry developed in a crystal may be studied with reference to plane of symmetry, axis of symmetry or center of symmetry. First, we will discuss the plane of symmetry.

It is an imaginary plane which passes through the center of the crystal and divides it into two equal parts such that one part is the mirror image of the other part. These planes of symmetry may be diagonal, may be horizontal or it may be vertical. There are maximum nine planes of symmetry which is found in the normal class of isometric systems. Here

you can see the diagram also. In the diagram A, the hashed plane is a plane of symmetry of the crystal, whereas in diagram B, the nine planes of symmetry of a perfect cube have been shown by the dotted lines.

So this is about the plane of symmetry. Next is the axis of symmetry. It is an imaginary line about which if the crystal is allowed to rotate through an angle of 360°, similar faces, similar edges and solid angles will come to the space for more than once. If it comes twice, the axis is known as axis of two-fold symmetry. If it comes thrice, the axis is known as three-fold symmetry.

The maximum number of axis of symmetry is thirteen and it is found in the isometric system of the your crystal classes. In diagram also, it has been shown diagrammatically. Third is the center of symmetry. The point within a crystal through which straight lines can be drawn so that on either side and at the same distance from the center, similar faces, similar edges and solid angles are encountered. Then it is known as the center of symmetry. In other words, we can say a crystal is said to possess a center of symmetry when for each face, edge, corner, etc. on one side of the crystal, there is a similar face, edge or corner directly on the opposite side of the center point.

So this is about the center of symmetry. So after knowing the elements of symmetry, now we will discuss the laws of crystallography. Through studies of external forms and angular relationships between the crystal faces, some fundamental laws have been established which govern the whole crystallography. What are these laws? These laws are law of constancy of interfacial angle, law of rational indices, law of axial ratio, law of crystallographic axes and law of constancy of symmetry.

So one by one we will discuss in brief about these. Law of constancy of interfacial angle states that the interfacial angles of the crystals of the same mineral are constant regardless the size and the shape of the crystals. This law is valid for the crystals having identical chemical compositions and measurements are made at the same temperature. Contact goniometers and reflective goniometers are generally used in measuring the interfacial angles of the crystals. Second law, law of rational indices.

The law of rational indices states that the intercepts made by any crystal phase on the crystallographic axis are either infinite or small rotational multiples of the intercepts made by the unit phase. Third is the law of axial ratio. This law states that the ratio between the lengths of the axis of the crystals of a given substance is constant. This ratio

is termed as axial ratio. Axial ratio is the ratio of the lengths of the crystallographic axis expressed in terms of one of the horizontal axis, usually 'b' axis, as unity.

Fourth law is the law of crystallographic axes. The position of the crystallographic axes are more or less fixed by the symmetry of the crystals. In most crystals, they are symmetry axes or normal to symmetry plane. For example, all the crystals of Galena may be referred to three crystallographic axes which are of equal length, mutually perpendicular and are interconvertible and are designated as a1 front-back axis, a2 right-left axis and a3 top-bottom axis. Fifth law is the law of constancy of symmetry.

From X-ray studies of crystals, a general law regarding the symmetry has been propounded. This law states that the symmetry in all crystals of a particular species is constant, though they may not be similar in form. For example, the crystals of the mineral galena, whether it is octahedral, dodecahedral or cubic in shape, it shows the same symmetry elements like nine planes of symmetry, thirteen axes of symmetry and the center of symmetry. Similarly, all the crystals of mineral barite shows three planes of symmetry, three axes of two-fold symmetry and the presence of center of symmetry. So now the summary of the lecture is, the crystallography it is a branch of mineralogy which deals with the study of crystals.

Second, the crystals are polyhedral bodies. Crystals are formed due to slow-cooling. The faces of a crystal are arranged in a regular pattern. Within the mineral kingdom 98 % of the mineral are crystalline in nature. Elements of crystal forms, we have seen that faces, edge, solid angle, interfacial angle and forms, these are the elements of the crystal. Then classification of forms, we have already seen holohedral forms, hemihedral forms, hemimorphic forms, tetartohedral forms, enantiomorphic forms. Now the elements of symmetry, three important elements of symmetry, that is planes of symmetry, axis of symmetry and center of symmetry. And the law of crystallography we have seen that the law of constancy of interfacial angle is there, law of rational indices, law of axial ratio, law of crystallographic axes and law of constancy of symmetry.

Thank you very much to all.