ENVIRONMENTAL GEOSCIENCES

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Lecture-20

Crystal Systems – Different Crystal Classes

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are covering module four, in which we have already covered the crystal and its characteristics in lecture one. Today we will discuss lecture two, which is the crystal system, and within the crystal system, we will discuss the different classes. Now, the crystal classes. The classification of crystals into classes depends upon the degree and nature of elements of symmetry.

There are, in all, only thirty-two crystal classes. In every system, the class that shows the highest degree of symmetry is known as the holohedral or normal class. Besides, according to the presence of symmetry elements, different classes are designated as hemihedral, hemimorphic, enantiomorphic, or tetrahedral classes. All the thirty-two classes of crystals are grouped under six cryptocrystalline systems. You can see in the table that the system, number of classes, and characteristic symmetry elements are given in different columns.

The first one is the isometric or cubic system, the number of classes is five, whereas the characteristic symmetry elements are four axes of 3-fold symmetry. Tetragonal system The number of classes is seven, with a unique four-fold axis or four-fold axis of inversion. Hexagonal, having two different divisions. In the hexagonal division, the number of classes is seven, with a unique six-fold axis or inversion.

Whereas, in the trigonal division, the number of classes is five, with a unique 3-fold axis or a 3-fold axis of inversion. Next is the orthorhombic system. In this, you can see the number of classes is three, with three axes of two-fold symmetry. Then comes the monoclinic system, where the number of classes is three, with one axis of two-fold symmetry. And in the triclinic system, the number of classes is two, with no axis or plane of symmetry.

These are the pieces of information related to the number of classes in the different crystallographic systems. The highest degree of symmetry is shown by the isometric system, and the lowest degree of symmetry is exhibited by the triclinic system. It has been observed from a statistical study of the mineral kingdom that more than 50% of the crystallized minerals belong to the monoclinic and orthorhombic systems. But in general, about 35 % of the minerals crystallize in the monoclinic system, about 27 % in the orthorhombic system, about 15 % in the cubic system, about 10 % in the hexagonal system, of which more than one-third belong to the trigonal division, and 9 % in the triclinic, and about 6 % in the tetragonal systems. In every system, the majority of minerals are crystallized in the respective normal classes.

Now, we will discuss each system one by one. So, the first one is the isometric or cubic system. Here, there are three axes which are of equal length, mutually perpendicular, and are interconvertible. The three axes are designated as the a-1, a-2, and a-3 axes. Two axes are horizontal.

A-one and a-2 are horizontal, and the third, a-3, is the vertical. Examples of this system are galena, garnet, magnetite, etc. These are good examples of the isometric system. Here in the diagram, you can see the a1 axis runs front to back and is positive at the front end, whereas the a-2 axis runs right to left and is positive at the right end, and the a-3 axis runs top to bottom and is positive at the top end. So, this is about the isometric or cubic system. In this cubic system, the unique features of the isometric system are the axial ratios, which are one is to one is to one. Each of its classes has four axes of threefold symmetry. Every form occurring in this system is a closed form and, therefore, it can exist as a real crystal.

The forms occurring in this system are unique to it, as forms like Pedian and Pinaquite, which occur in all other systems, do not occur in this system. It is the only system composed of classes containing more than one axis of n-fold symmetry, where n is greater than two. Now, classes included in the isometric or cubic system are the normal class, holohedral class, holosymmetric class, hexa-octahedral class. These are some of the classes which are included in the isometric system. It is also known as the galena type, after the name of the mineral galena, which crystallizes in this system. The next class is the gyroidal class or plaguohedral class, then the hexatetrahedral class, and tetrahedral class. The deploidal class or pyritohedral class and the tetartohedral class. These are some of the classes within the isometric system.

The details of these classes you can see in this table, in which the plane of symmetry, the axis of symmetry, and the center of symmetry have been mentioned. In which the plane of symmetry, axis of symmetry, and center of symmetry have been given. Here, for the normal class, the plane of symmetry is nine, the axis of symmetry is thirteen, and the center of symmetry is present. For the gyroidal class, the plane of symmetry is absent, the axis of symmetry is thirteen, and the center of symmetry is absent. For the hexatetrahedral class, the plane of symmetry is six, the axis of symmetry is seven, and the center of symmetry is absent.

Diploidal class, the plane of symmetry is three, the axis of symmetry is seven, and the center of symmetry is present. Tetartohedral class, the plane of symmetry is absent. The axis of symmetry is seven, and the center of symmetry is absent. Next system is the tetragonal system. In this system, there are three axes, of which two are of equal length and are horizontal, but both are at right angles to each other.

The three axes are designated as a-1, a-2, and c-axis. The third one is vertical, and it may be shorter or longer than that of the horizontal axis. A good example of this system is the mineral zircon. In the diagram, you can see a-1 is equal to a-2 but not equal to c-axis. Angle a, angle c is equal to 90°. So here you can see a-1 axis runs front to back and positive at the front end. a-2 axis runs right to left and positive at the right end, and c-axis runs top to bottom and positive at the top end. In this system, the different classes are normal class, di-tetragonal dipyramidal class or zircon type,

tetragonal trapezohedral class or trapezohedral class, di-tetragonal pyramidal or hemimorphic class, tetragonal dipyramidal or tripyramidal class, tetragonal scalenohedral class or sphenoidal class, tetragonal pyramidal or pyramidal hemimorphic class, and tetragonal disphenoidal or tetartohedral class. So these are the classes included in the tetragonal system. And the details about the plane of symmetry, axis of symmetry, and center of symmetry you can see in this table, where the normal class contains five planes of symmetry, five axes of symmetry, and the center of symmetry is present. In tetragonal trapezohedral class, the plane of symmetry is absent, the axis of symmetry remains five, and the center of symmetry is absent. Di-tetragonal pyramidal class, the plane of symmetry is four, the axis of symmetry is one, and the center of symmetry is absent.

Tetragonal dipyramidal class: the plane of symmetry is one, that is horizontal; the axis of symmetry is one of four-fold, and the center of symmetry is present. Tetragonal scalenohedral class: the plane of symmetry is two, whereas the axis of symmetry is three,

and the center of symmetry is absent. Tetragonal pyramidal class: the plane of symmetry is absent, the axis of symmetry is one, and the center of symmetry is absent. The tetragonal disphenoidal class: the plane of symmetry is absent, the axis of symmetry is one, and the center of symmetry is present. So these are the details about the planes of symmetry, axes of symmetry, and centers of symmetry. The next system is the hexagonal system. Here, there are two axes, of which three are in the horizontal plane, which are mutually inclined at 60°, but the angle between their positive ends is 120°. The three axes are designated as a-1, a-2, and a-3, which are horizontal axes, and the c-axis is the vertical axis.

Out of the four axes, the three axes are designated as a-one, a-2, and a-3, which are horizontal axes, and the fourth one, the c-axis, is the vertical axis. These horizontal axes are equal in length, and the fourth axis is vertical, which may be shorter or longer in length than the horizontal ones. The minerals Quartz and Beryl are good examples of the hexagonal system. And here, you can see in the diagram also: a-1 is equal to a-2, which is equal to a-three, but not equal to c, and the angle c is equal to 90°, where a-1, a-2, and a-3 are horizontal axes, which are mutually inclined at 60°, and the c-axis runs from top to bottom, with the positive at the top end. Classes included in the hexagonal system are twelve classes.

The system consists of the highest number of symmetric classes, which is twelve classes. They are conveniently grouped into two divisions: the hexagonal division and the trigonal division. Seven symmetric classes have been included in the hexagonal division, and five are grouped in the trigonal division. In the hexagonal division, the seven symmetric classes are included into different classes: the normal class or dihexagonal dipyramidal class, the hexagonal trapezoidal class, the dihexagonal pyramidal class, the ditrigonal dipyramidal class, the hexagonal dipyramidal class, the hexagonal pyramidal class, and the trigonal dipyramidal class. So these are the classes of the hexagonal division.

The details of the plane of symmetry, axis of symmetry, and center of symmetry will now be discussed. In the normal class, the plane of symmetry remains one, the axis of symmetry is seven, and the center of symmetry is present. In the hexagonal trapezoidal class, the plane of symmetry is absent, the axis of symmetry is seven, and the center of symmetry is absent. In the di-hexagonal pyramidal class, the plane of symmetry is six. The axis of symmetry is one, and the center of symmetry is absent.

In the di-trigonal di-pyramidal class, the plane of symmetry is four, the axis of symmetry is four, and the center of symmetry is present. In the hexagonal di-pyramidal class, the plane of symmetry is one, the axis of symmetry is one, and the center of symmetry remains present. In the hexagonal pyramidal class, the plane of symmetry is absent, the axis of symmetry is one, and the center of symmetry is absent. In the trigonal dipyramidal class, the plane of symmetry is one, the axis of symmetry is one, and the center of symmetry is absent. So, these are the details about the different classes.

Now, this is the second division of the hexagonal system, which is the trigonal division. All the crystals of the trigonal division are characterized by a vertical axis of threefold symmetry. This division includes five symmetric classes: rhombohedral or hexagonal, scalenohedral class, trigonal-trapezohedral class, ditrigonal pyramidal class, tri-rhombohedral class, trigonal-pyramidal class, or tetartohedral class. The details of the plane of symmetry, axis of symmetry, and center of symmetry will be as in the normal class. The plane of symmetry is three, the axis of symmetry is four, and the center of symmetry is present.

Whereas in the trigonal trapezoidal class, the plane of symmetry is absent, the axis of symmetry is four, and the center of symmetry is absent. In the ditrigonal pyramidal class, the plane of symmetry is three, the axis of symmetry is one, and the center of symmetry is absent. In the tri-rhombohedral class, the plane of symmetry is absent, the axis of symmetry is one, and the center of symmetry is present. Whereas in the trigonal pyramidal class, the plane of symmetry is absent, the axis of symmetry is one, and the center of symmetry is absent. So these are the details about the different classes of the trigonal region.

The next system is the orthorhombic system. It consists of three axes of unequal length that are mutually perpendicular. The three axes are designated as the a, b, and c axes, where the a axis is also known as the Brachy axis, and the b axis is also known as the Macro axis. A good example of a mineral in this system is Barite. Here in the diagram, you can see

a is not equal to b, b is not equal to c, and the angle a, angle b, and angle c are equal to 90°. This means that the a and b axes are horizontal axes that are mutually inclined at 90°, whereas the c axis runs from top to bottom and is positive at the top end. The classes included in the orthorhombic system are three symmetric classes: the normal class or orthorhombic dipyramidal class, the orthorhombic pyramidal class, and the orthorhombic

dysphenoidal class. The details of the plane of symmetry, axis of symmetry, and center of symmetry in these classes are: in the normal class, the plane of symmetry is three, the axis of symmetry is three, and the center of symmetry is present.

The orthorhombic pyramidal class has a plane of symmetry, two axes of symmetry, and no center of symmetry. Whereas in the orthorhombic disk pyramidal class, the plane of symmetry is absent, the axis of symmetry is three, and the center of symmetry is absent. So, this is the detail about the different classes of the orthorhombic system. The next system is the monoclinic system. In this system, there are three unequal axes which are denoted as a, b, and c. The axes a and b are lateral axes, and the axes a and b, and b and c make 90° with each other.

But the axes a and c make an oblique angle with each other. In this system, the a axis is also known as the clino axis, and the b axis is also known as the ortho axis. The mineral gypsum is a good example of the monoclinic system. In the diagram, you can see that a is not equal to b, b is not equal to c, a angle c is equal to 90°, and b angle c is equal to 90°. Whereas beta is an oblique angle between axes a and c. The classes included in this monoclinic system are the normal or prismatic class, the domatic class, and the sphenoidal class.

The details about the plane of symmetry, axis of symmetry, and center of symmetry of these classes are: in the normal class, the plane of symmetry is one, the axis of symmetry is one, and the center of symmetry is present. In the domatic or clinohedral class, the plane of symmetry is one, the axis of symmetry is absent, and the center of symmetry is absent. In the sphenoidal or hemimorphic class, the plane of symmetry is absent, the axis of symmetry is one, and the center of symmetry is absent. The next system is the triclinic system. Here, there are three unequal axes which are inclined to each other at an oblique angle.

In this system, the a and b axes are chosen so that the a axis becomes the shorter one and is known as the brachy axis, and the b axis is longer and is known as the macro axis. Here, a good example of this system is the mineral axinite. In the diagram, you can see that a is not equal to b, b is not equal to c, and the angle a, angle b, and angle c are not equal to 90°, whereas alpha, beta, and gamma are oblique angles between the three different axes. The details about the plane of symmetry, axial symmetry, and center of symmetry in this system are: There are two different classes: the normal or pinacoid class and the asymmetric or hemihedral or pedial class.

In the normal class, the plane of symmetry is absent, the axis of symmetry is absent, and the center of symmetry is present, whereas in the pedial class, the plane of symmetry is absent, the axis of symmetry is absent, and the center of symmetry is absent. So now, the summary of this lecture is: We have discussed the crystal system, first, in which we have seen the division of crystals based on the number of crystallographic axes, the relative length of the crystallographic axes, and the angular relationship existing between the crystallographic axes. Secondly, we have learned about the types of crystal systems, in which we have seen six major types. The first is the isometric or cubic system. A good example of this system is the Secondly, we have learned about the types of crystal systems: the isometric or cubic system, which includes minerals like galena, garnet, and magnetite. The tetragonal system includes the mineral zircon.

The hexagonal system includes minerals like quartz and beryl. The orthorhombic system includes the mineral barite. The monoclinic system includes the mineral gypsum, and the triclinic system includes axinite. So these are the types of crystal systems. Thirdly, we have learned about the different crystal classes.

We have learned a total of thirty-two crystal classes. These are divided into different crystal systems. Isometric or cubic system, the number of classes is five. Tetragonal system, the number of classes is seven. Hexagonal system, the number of classes is twelve.

Orthorhombic system, the number of classes is three. Monoclinic system, the number of classes is three. And the triclinic system, the number of classes is two. So these are all about the different types of crystal systems. Thank you very much to all.