ENVIRONMENTAL GEOSCIENCES

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Lecture-21

Concept of Mineral and its Properties

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are continuing with module four. We have already covered the concepts of crystallography in lecture one and the different classes in lecture two. Today we will discuss lecture three, which is the concepts of minerals and their properties. In this lecture, important concepts will be covered, such as minerals, the types of minerals, physical properties of minerals, and the chemical properties of minerals.

We know minerals are naturally occurring inorganic substances with a definite chemical composition and a crystalline structure. They form the building blocks of rocks and are fundamental to the Earth's crust, mantle, and core. Minerals exhibit distinct physical and chemical properties that make them identifiable and useful in various scientific, industrial, and ornamental applications. The study of minerals is known as mineralogy, which helps us understand Earth's processes, resource distribution, and the development of materials essential to human life. Their properties, such as hardness, luster, color, and cleavage, make minerals valuable for identification and industrial use.

From gemstones to industrial ores, minerals play a critical role in shaping our daily lives. Now, types of minerals. Minerals can be classified based on their chemical composition and crystal structure into several categories. These include silicate minerals, carbonate minerals, oxide minerals, sulfide minerals, sulfate minerals, halide minerals, phosphate minerals, and native elements. Some of the silicate minerals, carbonate minerals, oxide minerals, sulfide minerals, sulfate minerals, and phosphate minerals have been shown through photographs as well.

Now, one by one, we will discuss these things. First are the silicate minerals. These minerals contain silicon and oxygen, often combined with other elements. Silicates are the most abundant minerals in Earth's crust. They are further divided into groups based on the arrangement of silicon-oxygen tetrahedra.

Some examples of important silicate minerals are quartz, feldspar, and mica. You can see in the picture also the different types of minerals have been shown. Now, the second type of mineral is the carbonate minerals. Carbonate minerals contain the carbonate ion. They typically form in sedimentary environments and are important for the formation of rocks like limestone.

Some important examples of carbonate minerals are calcite, dolomite, and magnesite. Now, the third category of minerals is the oxide minerals. These minerals are composed of oxygen and metal elements. They are important as ores for extracting metals. Some of the important oxide minerals are hematite, magnetite, and corundum.

The fourth category of minerals is the sulphide minerals. Sulphides consist of sulphur combined with metals or metalloids. These minerals are often found as metallic ores. Some of the important sulphide minerals are pyrite, galena, and chalcopyrite. Now, the fifth category of minerals is the sulphate minerals.

Sulphates contain the sulphate ion. They often form in evaporative environments. Examples of sulphate minerals are gypsum, barite, and anhydrite. Next are the halide minerals. Halides are minerals that contain a halogen element like fluorine, chlorine, bromine, or iodine, combined with another element, often a metal.

Examples of halide minerals are halite, fluorite, etc. Now, the next category is the phosphate minerals. These minerals contain the phosphate ion, often combined with metals. Phosphate minerals are crucial for agriculture and fertilizers. Examples of phosphate minerals are apatite, turquoise, etc.

Next up are the native elements. These are minerals composed of a single element. Native elements are rare and include some precious metals. Examples of native minerals are gold, silver, and copper. Now, we will learn about the physical properties of minerals.

Earlier, we learned about the types of minerals; now, we will learn about their physical properties. Minerals are naturally occurring substances that exhibit a wide range of physical properties. These properties are crucial for their identification and classification. So, the types of physical properties of minerals are: structure, color, streak, luster, diaphaneity, light-dependent phenomena, cleavage, fracture, tenacity, hardness, specific gravity, magnetic property, electrical property, and radioactivity. The structure of minerals. One by one, we will discuss the different physical properties.

First is the structure of minerals. The structure of minerals refers to the state of aggregation or the shape in which they occur. It reflects the arrangement of their constituent particles and is crucial for identifying and classifying the minerals. Structures vary widely from well-formed crystals to amorphous masses. Types of mineral structures are: Crystalline minerals, which appear as imperfectly developed crystals, often exhibiting a geometric shape, such as quartz. Amorphous or Massive, minerals without a definite crystalline structure, forming shapeless masses. Earthy, minerals forming as uniform aggregates of extremely fine particles, like china clay.

Next is the fibrous. Aggregates of fibers, either separable, for example, asbestos, or flattened prismatic crystals, for example, kyanite. Columnar, parallel prismatic crystals, for example, amphibole, or broad flat surfaces, for example, feldspar. Granular, composed of roughly equal-sized crystalline grains, a good example is chromite. Botryoidal, bunch-like aggregates resembling grapes or cylindrical forms, formed by dripping water. Next property is color,

It depends upon the absorption of some and reflection of others of the colored rays which constitute white light. Some minerals show distinctive colors like white color are shown by Calcite, Barite, Magnesite, Aragonite, Opal, Talc, Chalk, etc. Blue color, generally shown by azurite, sodalite, covellite, lazulite, lazurite, apatite, etc. Green color, fluorite, beryl, malachite, microcline, olivine, epidote, chlorite, etc. Yellow color, sulphur, marcasite, chalcopyrite, orpiment, citrine, siderite, etc.

Red color, realgar, jasper, orthoclase, pyrope, zircon, cinnabar, etc. Lead grey color, galena, graphite, molybdenite. Steel grey, hematite. Brass yellow, pyrite. Colorless, halite, quartz, calcite, zeolite, etc. Variation in color may be due to surface alteration, difference in composition, presence of impurities, inclusion of foreign matter, etc. Now the third property is the streak. It is the color of the powder of a mineral in small amount and sometimes it is quite different from the color of the mineral in mass.

For example, crocoite shows a streak color of yellow, chalcopyrite shows a streak color of black, and cinnabar shows a streak color of red. The fourth property is luster. It is the appearance of the surface of a mineral in reflected light. Luster also depends upon the absorption and reflection of light. The luster of minerals differs both in intensity and kind, depending upon the amount and manner of reflection, respectively.

Lusters are of different types. The first is metallic luster. Gold, silver, copper, galena, graphite, and molybdenite show metallic luster. Next is non-metallic luster. Different types of non-metallic lusters include vitreous luster, which is the luster of broken glass, as seen in quartz. Greasy luster, which is the luster of an oily glass, as seen in nepheline. Resinous luster, which is the luster of resin, as seen in sphalerite. Adamantine luster, which is the luster of a diamond.

Silky luster, which is shown by minerals possessing a fibrous structure, such as asbestos, fibrous gypsum, fibrous calcite, etc. Pearly luster, which is the luster of a pearl, as seen in talc, opal, gypsum, kyanite, etc. Earthy luster, which is a dull luster, as seen in kaolin, chalk, etc. When the degree of luster is more, the surface shines like a mirror, and it is known as splendid or brilliant luster. Next is diaphaneity, which is the degree of transparency of a mineral.

The different types are: first is transparent, when almost all light falling on the mineral is transmitted through it. Second is translucent, when light is transmitted through a mineral, but the objects are not seen through it. Opaque, when no light is transmitted through a mineral, it is said to be opaque. An example is also given here: Iceland spar, a variety of calcite, is transparent. Dogtooth spar on top of orpiment is translucent.

And molybdenumite on quartz is opaque. The next property is phenomena depending on light. Some minerals exhibit colors that are not in the minerals themselves but are produced by the effects of certain structures present in the minerals on white light. These are: play of color, a series of colors seen at various angles like a rainbow; change of color, a succession of colors produced when the mineral is turned about. Opalescence is a pearly reflection from the interior of a mineral. Iridescence is the brilliant color shown by copper and pyrite. Schillerization is a kind of metallic color shown by non-metallic hypersthene.

Fluorescence occurs when minerals exposed to ultraviolet light emit light; these are known as fluorescent. Phosphorescence is the property of continued emission of light after a substance has been subjected to rubbing, heating, or electric radiation, etc. Next is cleavage, a property that some minerals exhibit by breaking along definite smooth planes. The presence of these planes is a simple indication of the difference in the strength of bonds between atoms in the crystal. Thus, the property of cleavage is intimately connected with the atomic structure of minerals.

In number, there may be one or as many as six directions of cleavage. The atomic structure of minerals does not permit cleavage in five directions or in more than six directions. Types of cleavage are: Like pinnacoidal, parallel to the pinnacoidal faces, it is unidirectional. The 'a' pinnacoidal example is kyanite, 'b' pinnacoidal example is gypsum, 'c' pinnacoidal, also known as basal cleavage, example is mica, graphite, talc, etc.

In feldspar, there are 'b' pinnacoidal and 'c' pinnacoidal cleavages nearly at right angles. Prismatic, parallel to the prismatic faces, it is bidirectional, which may or may not be at right angles. Example is pyroxene and amphiboles. Cubic, it is tridirectional at right angles as in galena, halite, etc. Rhombohedral, it is tridirectional, parallel to the faces of rhombohedron as in the calcite group of minerals.

Octahedral, parallel to the faces of an octahedron, it is four-directional as in cases of diamond and fluorite. Pyramidal, it is four-directional, parallel to the pyramidal faces. Example is scheelite. Dodecahedral, parallel to the faces of dodecahedron, it is six-directional. Example is sphalerite.

Next is the fracture. Fractures are of different types. The first one is the conchoidal. When a mineral breaks with curved concavities, more or less deep as in broken glass, a good example is quartz. Even, when the fracture surface approximates to a plane. Uneven, when the fracture surface is rough. Hackly, when the surface is studded with jagged elevations and depressions. Splintery, when the mineral separates into fibers as in asbestos.

Fracture is thus the character of the surface obtained when a mineral is broken in a direction other than that of the cleavage. Next property is the tenacity. It is the behavior of a mineral under stress, and its different types are: first is brittle, when parts of a mineral separate into powder, an example is calcite. Next is sectile, when a mineral can be cut with a knife but the slices yield under pressure, examples are graphite, gypsum, etc. Third is malleable, when the mineral can be cut with a knife and flattens out under a hammer, an example is gold.

Flexible, when a mineral bends without breaking even when the force is removed, examples are micas, chlorite, etc. Elastic, when the mineral attains its previous position after the withdrawal of the force, an example is mica. Next example is the hardness. It is the resistance that a mineral offers to abrasion or scratching. A sclerometer is an instrument used for determining hardness.

Moh's scale of hardness generally ranges from one to ten for different minerals. The first is talc, second is gypsum, third is calcite, fourth is fluorite, fifth is apatite, sixth is feldspar, seventh is quartz, eighth is topaz, ninth is corundum, and tenth is diamond. The next property is specific gravity. It is the ratio of the weight of a mineral to the weight of an equal volume of water. It is determined by Walker's steel yard balance for large specimens, a specific gravity bottle or pycnometer for small mineral grains, and the chemical balance method for small fragments of minerals. The next property is magnetic property. A mineral capable of being attracted by a strong magnet is called magnetic.

Examples are magnetite and pyrrhotite. The next property is electricity. It is of three types: pyroelectricity, piezoelectricity, and photoelectricity. Pyroelectricity is the development of positive and negative charges of electricity on different parts of the same crystal when its temperature is suitably altered. An example is quartz.

Piezoelectricity is the property of development of an electric charge on a crystallized mineral by pressure or tension. Examples are tourmaline, quartz, etc. Photoelectricity occurs when some minerals are exposed to radiation and produce electricity. An example is fluorite. The next property is radioactivity.

Minerals containing elements of high atomic weights are called radioactive because of their emissions. The Geiger counter is an instrument used for the detection of radioactivity. Now, next are the chemical properties of minerals. Except for silicates and ferromagnesian minerals, most of the carbonate and sulfide minerals produce effervescence when they come in contact with acid. The chemical phenomena usually found with minerals are isomorphism and polymorphism.

First is isomorphism. Chemical compounds, which have an analogous composition and a closely related crystalline form, are said to be isomorphous. The members of an isomorphous series show a gradation in chemical composition, crystal forms, specific gravity, refractive index, etc., from one end to the other. The plagioclase feldspars constitute an excellent example of an isomorphous series. Now, polymorphism.

This is the phenomenon in which substances containing the same chemical composition differ from one another by some physical properties like the system of crystallization, hardness, density, etc. The polymorphic forms, in the case of elements, are known as allotropes. Its different types, based on the number of polymorphic forms, are first, dimorphic, when the chemical compound exists in two distinct forms, calcite, aragonite, pyrite, marcasite, etc. Trimorphic, when the chemical compound exists in three distinct polymorphic forms, examples are andalusite, kyanite, sillimanite, etc. Rutile, anatase, and brookite; orthoclase, microcline, and sanidine.

Trimorphic, when a chemical compound exists in three distinct polymorphic forms, examples include andalusite, kyanite, and sillimanite; then rutile, anatase, and brookite; and orthoclase, microcline, and sanidine, etc. Based on reversibility, the chemical composition of minerals can be categorized as enantiotropy and monotropy. First is enantiotropy. When polymorphic substances are interchangeable, it is called enantiotropy. Examples include diamond and graphite, and quartz and tridymite.

Monotropy occurs when the change is from one substance to another but not the reverse. An example is marcasite and pyrite. Additionally, it should be noted that high-temperature polymorphs have a higher degree of symmetry than their lower-temperature polymorphs, which have a lower degree of symmetry. Pseudomorphism occurs when a mineral falsely assumes the outer form of a different mineral crystallizing in another system. It is due to incrustation, infiltration, replacement, alteration, etc.

Homeomorphism occurs when some minerals closely resemble others in crystal habits, although they are different in chemical composition. If the geometry of the arrangement of similar ions is similar, the resulting crystal may appear alike. Examples include rutile and zircon, which are tetragonal but have different chemical compositions. Such minerals are called homeomorphs, and the phenomenon is known as homeomorphism. Paramorphism is the phenomenon in which a crystal's internal structure changes to that of a polymorphous form without any change in its external form.

Thus rutile changes to brookite and aragonite changes to calcite. Now, just summarizing lecture three of module four. First, we discussed the introduction to minerals. We have seen that minerals are naturally occurring inorganic substances with a definite chemical composition and crystalline structure. They form the building blocks of rocks and are vital for Earth's geological processes and human applications.

Then we discussed the types of minerals. We have seen that minerals are categorized based on chemical composition into different groups like silicates, carbonates, oxides, sulfides, native elements, etc. These classifications reflect their structural and compositional diversity. Then we discussed the physical properties of minerals, in which we have seen that minerals are identified by properties such as color, hardness, luster, streak, and cleavage, etc. These attributes depend on their internal atomic arrangement and are essential for classification and uses.

Lastly, we discussed the chemical properties of minerals, in which we have seen that minerals exhibit chemical behaviors such as reactions with acids and phenomena like isomorphism and polymorphism. These properties help understand their stability and transformations in different environments. Thank you very much to all.