QUARTZ GROUP OF MINERALS

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QUARTZ GROUP OF MINERALS

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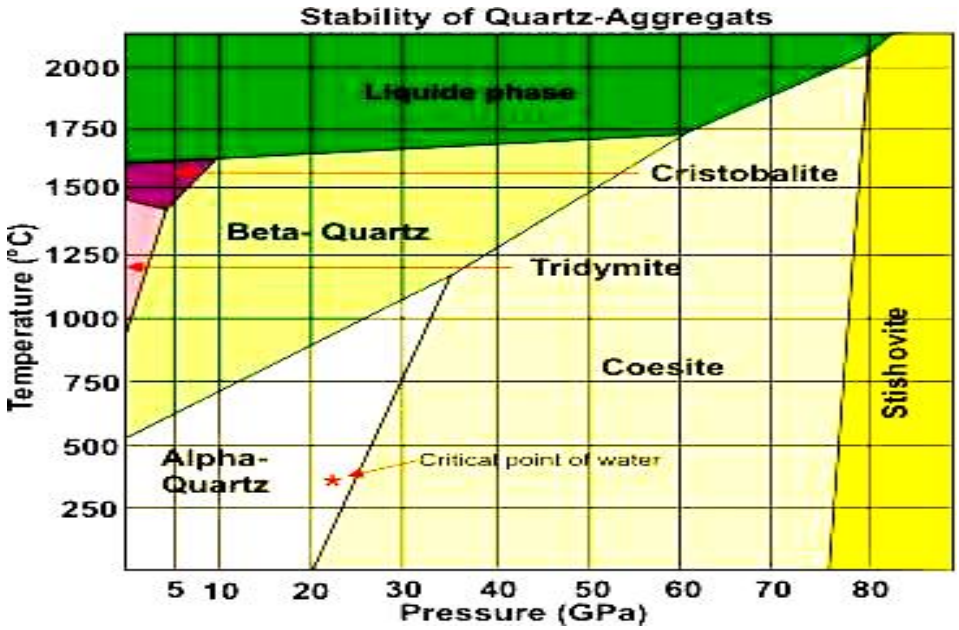


Introduction:

Minerals are valuable natural resources. Minerals are natural compounds formed through various geological processes. More than 2000 minerals have been identified so far in different geological environments. Minerals have unique physical properties, optical properties, crystal structure and chemical composition. Because of their uniqueness, it is easy to identify any of them and use them effectively. All the minerals are classified into different groups based on their chemical composition. Among the major mineral groups, the most abundant ones are the quartz group of minerals.

Quartz is found in almost every geological environment. It is a common constituent in most of the rock types and soil groups. Granite, sandstone, limestone, and most of the igneous, sedimentary, and metamorphic rocks contain quartz. Quartz contains mainly oxygen and silicon. These two constituents make upto 75 % of the earth's crust. An alternate name for the Quartz Group is the Silica Group.

In this module, the following aspects of quartz are highlighted:

1. Importance and uniqueness of quartz
2. Physical, chemical and optical properties
3. Varieties of quartz
4. Occurrence and crystallization of quartz
5. Uses of quartz

Importance and uniqueness of quartz

Quartz is ubiquitous, plentiful and durable. It is chemically inert in contact with most substances. Quartz occurs in hydrothermal veins and pegmatite. Well-formed crystals may reach several metres in length and weigh hundreds of kilograms. It has electrical properties and heat resistance that make it valuable in electronic products. Its luster, color and diaphaneity make it useful as a gemstone and also in the making of glass. It has a hexagonal crystal structure and is made of trigonal crystallized silica.

Some quartz crystal structures are piezoelectric and are used as oscillators in electronic devices such as quartz clocks and radios. An amorphous (glass) SiO_2, called Lechatelierite, is caused by lightning strikes in sand, distinct from typical window glass that is impure.

And it was Nicolas Steno's study of Quartz, that paved the way for modern crystallography. He discovered that no matter how distorted a quartz crystal is, the long prism faces always made a perfect 60 degree angle, when it is broken.

Quartz is highly resistant to both mechanical and chemical weathering. At surface temperatures and pressures, ordinary **quartz** is the most stable form of silicon dioxide. This durability makes it the dominant mineral of mountaintops and the primary constituent of beach, river and desert sand.

It will remain stable up to 573 degrees Celsius at 1 kilobar of pressure. As the pressure increases, the temperature at which quartz will lose its stability also increases. There are two types of quartz are recognized as alpha and beta quartz. Above 1300 degrees and at a pressure of approximately 35 kilobars, only beta quartz (also known as high quartz) is stable. Beta quartz is not the same as normal quartz which is actually called as alpha quartz. Beta quartz has higher symmetry, it is less dense and has a slightly lower specific gravity.

There are three polymorphs of SiO2 existing in nature, as quartz, tridymite and cristobalite.

Their temperature ranges of stability are also varied.
Let us see some of them.

(i) The first one is α- quartz . It is stable at atmospheric temperatures and upto 573°C.
(ii) The β-quartz is stable from 573°C to 870°C can exist metastably above 870°C.
(iii) The α- tridymite, which is also belonging to this group, can exist at atmospheric temperatures and upto 117°C. It is not a stable form in this range.
(iv) The β-tridymite can exist above 163°C and is the stable form from 870°C to 1470°C, above 1470°C it can exist but it is unstable; it melts at 1670°C.
(v) The α-Cristobalite; it can exist at atmospheric temperatures and upto 200°C-275°C by is not the stable form in this range.
(vi) β-Cristobalite: it can exist above 200°C-275°C and is stable from 1470°C to its melting point, 1713°C.

A few substances that contain SiO2 are classified as **mineraloids**. They are **opal**, SiO2 - n(H2O) and a very rare pure silica glass called **lechatelierite**, SiO2. Both of these are amorphous and therefore lack a true **crystal** structure.

The most important distinction between types of quartz is that of macrocrystalline and the microcrystalline or cryptocrystalline varieties. These are aggregates of crystals visible only under high magnification. Chalcedony is a generic term for cryptocrystalline quartz. The cryptocrystalline varieties are either translucent or mostly opaque, while the transparent varieties tend to be macrocrystalline.

Not all varieties of quartz are naturally occurring. Prasiolite , an olive coloured material, is produced by heat treatment. Although citrine occurs naturally, the majority is the result of heat-treated amethyst. Carnelian is widely heat-treated to deepen its colour. Because natural quartz is so often twinned , much quartz used in industry is synthesized. Large, flawless and untwinned crystals are produced in an autoclave via the hydrothermal process: emeralds are also synthesized in this fashion.

Physical, chemical and optical properties

Color of quartz is as variable as the spectrum. We also get some crystal clear quartz followed by white or cloudy / milky quartz. The Luster is glassy to vitreous as crystals, while cryptocrystalline forms are usually waxy to dull but can be vitreous. Quartz crystals are mostly transparent to translucent. The cryptocrystalline forms can be translucent or opaque. Quartz crystallizes in the trigonal Crystal System. Crystal Habits are again widely variable but the most common habit is the occurrence of hexagonal prisms of quartz, terminated with a six sided pyramid. These may actually look like two rhombohedrons.

The Cleavage of quartz is very weak in three directions (rhombohedral). The Fracture is conchoidal. The Hardness is 7. But it is less in cryptocrystalline forms. The Specific Gravity is 2.65 or less if cryptocrystalline. The Streak is white. Striations on prism faces run perpendicular to the C axis of the crystals. Quartz is piezoelectric . The index of refraction of quartz is 1.55.

Twinning of quartz is based on Common Dauphine law, Brazil law and Japan law. Tenacity-wise it is very Brittle. Quartz is Optically Uniaxial positive(+).

Many minerals are Associated with quartz. The commonly associated minerals are amazonite -a variety of microcline, tourmaline, wolframite, pyrite, rutile, zeolites, fluorite, calcite, gold, muscovite, topaz, beryl, hematite and spodumene.

The structure of quartz is built from SiO_4 tetrahedra which are linked by sharing each corner with another tetrahedron. In a three dimensional framework, every Si has four oxygen (O) and every 'O' has 2 Si as nearest neighbor. The chemical composition of quartz is nearly 100% SiO_2.

Varieties of quartz

Quartz group of minerals are divided into two varieties namely:

1. Crystalline varieties.
2. Crypto crystalline varieties.

The Crystalline varieties include:

1) Amethyst
2) Milky quartz
3) Rose quartz
4) Rock crystal
5) Aventurine quartz
6) Citrine
7) Smoky quartz
8) Blue quartz

Amethyst is the beautiful Violet colored quartz crystal. The color is due to the presence of the trace element of Ferric iron, which turns white when heated to 300°C (571°F), then to yellow (citrine) at 500°C (932°F), but becomes violet again if exposed to x-rays or bombarded with α-particles. There is a patchyness in the color distribution of these crystals. Due to this, Amethyst is often cut as brilliant round cuts to maximize the color effects. The color purple is traditionally the color of royalty and amethyst has been used since the dawn of history to adorn the rich and powerful monarchs and rulers. Today, amethyst is a lovely and affordable gemstone that is fortunately available in a wide variety of cut and uncut stones that we can all possess and admire.

Milky quartz is another crystalline variety of quartz found in pegmatites and hydrothermal veins. The color is generally caused by numerous bubble of gas and liquid in the crystal.

Rose quartz is one of the most desirable varieties of quartz. The rosy color of this mineral appears to be caused by traces of manganese or titanium present in it. It occurs in massive form in many pegmatites, but well-formed crystals are very rare. It loses its color when heated and turns black if exposed to radiation. Rose quartz is used as an ornamental stone and as a gemstone. It is also an alternate birthstone for the month of January. Rose quartz is associated with emotional balance and forgiveness.

Rock crystals are the most sought after crystals by mineral collectors. It is believed that the transparent, colorless rock crystal is like a petrified ice. It occurs mainly in Pegmatites, fissures and geodes in various rocks. It is used for optical and piezo-electrical purposes in the industries. Rock Crystal is the name given to all clear colorless quartz. It is widely used as a popular ornamental stone and is also used as a gemstone. Although it is one of the least expensive gemstones, cut rock crystal has been used as imitation diamonds. Rock crystal is widely used as a gemstone due to its beauty, affordability, availability, and ease of cutting. Rock crystal is used for many ornamental carvings from spheres (crystal balls) to pyramids and as many forms. There are also many fine chandeliers that are outfitted with the rock crystal ornaments.

Aventurine quartz is another variety which contains scales of mica or goethite that gives a sparkling green or brownish-yellow appearance. It is also characterized by its translucency and the presence of platy mineral inclusions that give a shimmering or glistening effect.

Citrine is an Yellow or brown variety of quartz. The color is due the inclusions of colloidal iron hydrates in it. It turns white if heated and dark brown if exposed to x-rays. It is widely used as an imitation of the more expensive gemstone topaz. It is called as 'Brazilian topaz'.

Smoky quartz is the light or dark brown to black variety of quartz. It is also used as a gemstone. When heated, it turns to yellow and then to white. Smoky quartz is a popular variety of quartz. It has an unusual color for a gemstone and is easily recognized and is well known by the general public.

Blue quartz is a variety with blue color arising due to the presence of tiny rutile, tourmaline inclusions. These are common in metamorphic rocks.

The Cryptocrystalline varieties of quartz are those, which by nature , having a microscopic crystalline structure. They are:

1) Agate
2) Chalcedony
3) Carnelian
4) Jasper
5) Onyx
6) Tiger's eye
7) Rutilated quartz
8) Chrysoprase
9) Heliotrope
10) Flint or chert

Agate is a concentric, banded, fibrous variety of quartz formed by precipitation from watery solutions in rounded cavities of volcanic rocks (geodes) . It occurs with beautiful clusters of rock crystal or amethyst at the centre.

Chalcedony is a compact, microcrystalline variety of quartz which is usually banded. Bands of fibrous structure alternate with microgranular bands are seen in these varieties.

Carnelian is unvaryingly colored, light to dark-brown variety of chalcedony. The orange-red color is due to the presence of very fine particles of hematite or limonite. Traditionally used as seals.

Jasper is a massive, fine-grained quartz with large amounts of admixed material, especially iron oxides. The commonest forms are usually strong shades of red, but grayish-green, yellow or black also occur. Also a very common in sedimentary rocks.

Onyx is a variety of agate with alternating parallel layers of black and white lines. It also have red and white bands. Such onyx are often employed in cameo carving.

Tiger's eye contains fibers of crocidolite altered to a yellow color. It is a less common variety. It is also called as "falcon's eye".

Rutilated quartz is a cryptocrystalline variety of quartz containing acicular yellow and red rutile crystals.

Chrysoprase is a translucent, greenish-yellow or apple-green variety which contains traces of nickel.

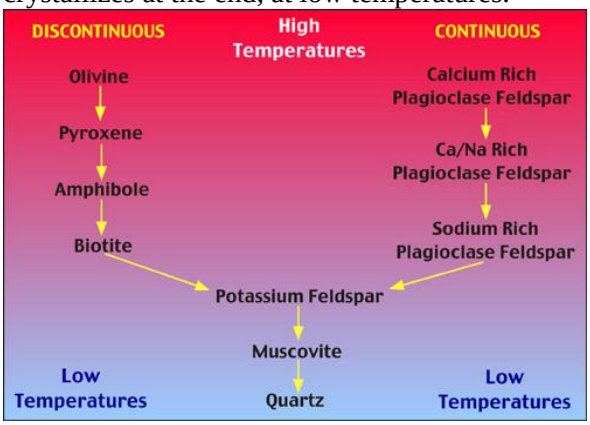
Heliotrope is an opaque green quartz with red markings, like drops of blood. Due to this appearance it is called as "bloodstone".. The red spots are caused by iron oxides.

Flint or Chert are siliceous nodules frequently found in chalk and limestone. Flint has a compact microcrystalline granular texture. It is dark grey to soot black in color.

Quartz is unattacked by acids other than HF.

If we look at the **occurrence and crystallization of quartz**, Quartz crystallizes directly from igneous magma. Hence, it is a major constituent of plutonic, hypabyssal and volcanic rocks. It is also a common constituent in sedimentary as well as metamorphic rocks.

As per Bowen's reaction series, which can show how crystallization happens in a magma, quartz crystallizes at the end, at low temperatures.



Quartz is stable under both low and high grade metamorphic conditions. Quartz is also stable in sedimentary conditions either as detrital material or as cement in consolidated rocks. As quartz is so common, it is impossible to enumerate all the places where it is found. It is a major constituent of sand and soil everywhere in the world.

Uses of quartz.

Uses of Quartz in Glass Making is a primary consumption. Highly pure silica sands are used in the glassmaking industry. Quartz sand is used in the production of container glass, flat plate glass, specialty glass and fiberglass. Quartz is an excellent abrasive material. Quartz sands and finely ground silica sand are used for sand blasting, scouring cleansers, grinding media, and grit for sanding and sawing.

Quartz is very resistant to both chemicals and heat. It is therefore often used as a foundry sand. With a melting temperature higher than most metals, it can be used for the molds and cores of common foundry work. Refractory bricks are often made of quartz sand, because of its high heat resistance.
Quartz sand is also used as a flux in the smelting of metals.

Quartz is used in the Petroleum Industry as sandy slurries in oil and gas wells. Quartz sand is used as a filler in the manufacture of rubber, paint and putty. Screened and washed, carefully sized quartz grains are used as filter media and roofing granules. Quartz sands are used for traction in the railroad and mining industries. These sands are also used in recreation on golf courses, volleyball courts, baseball fields, children's sand boxes and beaches.

High quality quartz crystals are normally single-crystal silica possessing good optical or electronic properties that make them useful for specialty purposes. In the industries, on an average , about ten

billion quartz crystals are used every year. Optical-grade crystals are used as lenses and windows in lasers and other specialized devices.

"Silica stone" is an industrial term for materials such as quartzite, novaculite and other microcrystalline quartz. These are used to produce abrasive tools, grinding stones and tube-mill liners.

Tripoli is a crystalline silica of an extremely fine grain size, may be less than ten micrometers. It is used for a variety of “mild abrasive” purposes which include: soaps, toothpastes, metal polishing compounds, jewelry polishing compounds and buffing compounds. Tripoli is also used in brake friction products, fillers in enamel, plastic, paint, rubber and refractories.

Quartz minerals show a strong piezo-electric effect perpendicularly to the prism axis. Applying pressure on a quartz crystal generates an electrical polarization along the pressure direction. Alternatively applying an electrical tension leads to a mechanical deformation of the crystal. During the 1970s, the "quartz watch" entered into the world market as the newest high-tech gadget. People wonder as why it is called as a quartz watch? Or why quartz watches are so much more accurate than wind-up watches?

There is an amazing electronic phenomenon existing in the quartz crystal . Due to which it is used in the heart of a quartz watch.

During 1970s, there was a necessity to Find a new timing element and designing an integrated circuit that would use very little power. It was also necessary to allow the watch to run on a tiny internal battery. This was the situation in the early 1960s. .

There was no problem with the choice of a timing element. The quartz crystal is possibly thousands of times better for timing than the tuning fork, and quartz crystals had been around for many years.

Only the type and the frequency of the crystal needed to be chosen. The difficulty was in the selection of the integrated circuit technology that would function at sufficiently low power.

Quartz crystals have been in regular use for many years to give an accurate frequency for all radio transmitters, radio receivers and computers.

Their accuracy comes from an amazing set of coincidences: Quartz -- which is silicon dioxide like most sand -- is unaffected by most solvents and remains crystalline to hundreds of degrees Fahrenheit.

The property that makes it an electronic miracle, is the fact that, when compressed or bent, it generates a charge or voltage on its surface. This is a fairly common phenomenon called the Piezoelectric effect.

In the same way, if a voltage is applied, quartz will bend or change its shape very slightly.

If a bell were shaped by grinding a single crystal of quartz, it would ring for minutes after being tapped. Almost no energy is lost in the material.

A quartz bell -- if shaped in the right direction to the crystalline axis -- will have an oscillating voltage on its surface, and the rate of oscillation is unaffected by temperature.

If the surface voltage on the crystal is picked off with plated electrodes and amplified by a transistor or integrated circuit, it can be re-applied to the bell to keep it ringing.

The best shapes are a **straight bar** or a **disk**. A quartz bar can be tiny and oscillate at a relatively low frequency -- 32 kilohertz (KHz). Modern quartz watches use a low-frequency bar or tuning-fork-shaped crystal.

Often, these crystals are made from thin sheets of quartz, plated like an integrated circuit and etched chemically to shape. Quartz is one of the most useful natural materials in the world. Its usefulness can be linked to its unique physical properties and chemical composition.