CHAPTER 111

QUARTZ

3.1 Historical review

There is so much of literature available on quartz that it is difficult to describe, even briefly, characteristics of quartz. However, an effort is made in this direction in what follows. Quartz is very hard - even harder than steel - and hence is an useful tool and weapon. Even ten thousand years ago quartz family minerals were used. Its ornamental value, as a semi-precious stone, was known first to sumereans. They had mastered the art of cutting, polishing and preparing ornaments from quartz family minerals.

For many centuries India has supplied this rich minerals. Cambay is also a source of this semi-precious stone. In 3500 B.C., the Egyptians undertook the mining of quartz systematically. Mention of quartz as a gem, has been made even in Bible. A full understanding of quartz minerals is truly a prerequisite to the study of minerology and geological sciences.

Properties of quartz have been described in details by Sosman (1927), Davey (1934), Heising (1945), Mason (1949) and Vigoureux and Booth (1950). Quartz was the first mineral to be studied seriously. It received more attention and Steno (1669), established the "Law of constancy of angles" with the help of quartz. Its crystallography was fully investigated as early as 1885.
3.2 Occurrence

Silicon occurs as free silica and silicon dioxide, in the form of quartz. It is one of the most abundant mineral on earth. It is found in Scotland, Ireland, North Wales and other parts of the world. In Brazil, transparent, colourless, beautiful pieces of quartz are available in huge quantities. They are also found in Madagascar.

It has been reported at Calavers (U.S.A.) that a single crystal weighing a ton has been found. Transparent quartz crystals are also available at Dauphine, Savoy, Abzer, Alps, Tintagel in Cornwall, Pantala Hills (India) etc. From Herkimer county in New York clear, brilliant well developed quartz crystals have been obtained. They are known as "Herkimer Diamonds".

3.3 Symmetry, form and habit

Quartz is prismatic (having six prism faces) and is terminated by six rhombohedral faces at either of its two ends. Horizontal striations are the characteristics of the prism faces while rhombohedral faces are covered by triangular growth layers. On account of unequal developments of different faces, a variety of shapes of quartz crystals are available. The trigonal pyramids appear as small faces, truncating the corners between rhombohedral and prism faces. Trapezohedral faces generally appear with combination with trigonal pyramids, revealing the edges between pyramidal and prism faces (figures 11 c and 11 d). In figures 11 a, b, c and d faces marked "m" are prism faces.
Having the form \(\{10\overline{1}0\}\). The major rhombohedral faces are more developed than the minor rhombohedral faces and these two types are alternate. The major rhombohedral faces are bright and are symbolised by "\(\gamma\)", while the minor rhombohedral ones are symbolised by "\(z\)". They are of the forms \(\{10\overline{1}1\}\) and \(\{0\overline{1}11\}\) respectively. Crystals in which small trapezohedral faces are situated at the lower right hand of the major rhombohedral faces, the crystal is a right-handed quartz, while if the former are at the lower left hand of the latter it is a left-handed quartz. These trapezohedral faces are symbolised by "\(x\)" and have the form \(\{51\overline{6}1\}\) and \(\{6\overline{1}51\}\) for the right- and left-handed quartz respectively. Some quartz crystals have small trigonal bipyramidal faces at right or left corners of the major rhombohedral faces. They are symbolised by "\(g\)" and have the form \(\{11\overline{2}1\}\) for right-handed and the form \(\{2\overline{1}11\}\) for the left-handed crystals. From the position of the "\(x\)" face or from the direction of striations on the "\(g\)" face or from the direction zone "\(z, x, s, m\)", the right- or left-handed nature of the crystal can be attributed. \(\alpha\)-quartz has three molecules per un-twinned crystals. It has one triad, which coincides with the vertical C-axis. It has three dipoles which pass through the pairs of opposite prism edges, but has no plane of symmetry and centre of symmetry. Quartz belongs to the trigonal trapezohedral class \(\langle 32 \rangle\) of the hexagonal symmetry. In \(\alpha\)-quartz the three horizontal axes are polar, and it belongs to the trigonal trapezohedral class \(\langle 32 \rangle\) of the hexagonal system.
β-quartz belongs to the hexagonal trapezohedral class of the hexagonal system. It has one triad and six diads perpendicular thereto, and separated by 30°; it has also no plane of symmetry and no center of symmetry.

Crystals growing in fissures have a great number of irregular and 'rare planes' than those which grow in closed cavities. Smoky quartz may have rare planes. The shape of a crystal is governed by two important factors, viz., the shape of the nucleus and the presence of impurities in the silica solutions.

3.4 Crystal structure

In figure 12 the structure of α-quartz is shown. Here SiO₂ is shown as SiO₄ tetrahedra with a small silicon atom at the centre of a group of four oxygens in tetrahedral co-ordination. Each tetrahedron shares a corner (oxygen) with an adjoining tetrahedron. For simplicity most of the tetrahedrons are shown without the circles representing oxygen. The screw axis symmetry (three-fold) of the C axis is shown by the dot-dash line, repeating each tetrahedron with a rotation of 120° and a translation of C/3. Two units of structures along C are shown.

Lord Kelvin, S.Nakamura, and S.Ichikawa studied the molecular structure of quartz. The X-radiogram of quartz has been investigated by W.H.Bragg. He refers the lattice to a set of hexagonal axes, because this gives the simplest explanation of the observed spectra. The value of a is 4.89 x 10⁻⁸ cm.,
and there are three molecules of silica, $\text{SiO}_2$, associated with each point of lattice as structural units or crystal molecules.

The quartz lattice is produced by three interpenetrating hexagonal lattices. These are so related that they can be derived from each other by a rotation of about $\frac{2}{3}\pi$, and a translation of $\frac{1}{3}c$ along an axis parallel to the direction of $c$, figure 13, where $a:c = 1:1.10$. Each hexagonal lattice locates the position of one-third the triplets. Each trigonal axis of the structure has points arranged spirally about it; and, since a spiral can be either left- or right-handed, the enantioformism of quartz follows. J. Beckenkamp assumed that the silicon atoms form a rhombohedral lattice instead of a three-point screw as in W. H. Bragg's structure. His lattice of ordinary quartz is in effect a third-fold trigonal prismatic lattice with the trigonal axis vertical, figure 14. The solid circles represent one layer of silicon atoms, the second circles another layer, and the open circles a third layer. The fourth layer is like the first, the fifth like the second, etc. The positions of the oxygen atoms represented by small circles in the diagram depend on whether the crystal is right- or left-handed. In the right-handed quartz, the oxygen atoms are situated as in the inset of figure 14, where the lowest layer of atoms is numbered 1, the next layer 2, the next 3, ......... The pairs of oxygen atoms 1 and 3, 4 and 6, 7 and 9, are associated respectively with the silicon atoms 2, 5 and 8. The series of nine atoms of three $\text{SiO}_2$-triplets
thus form a helix rotating to the right. The spiral structure appears only after the introduction of the oxygen atoms, the arrangement of the oxygen atoms is such that the orientation of the valency directions is the same in horizontal or vertical molecular layers.

3.5 **Physical properties**

The specific gravity of quartz varies from 2.5 to 2.6, that of the purest quartz is 2.65. Its melting point is 1750°C and on Mohs's scale its hardness is 7. Above 800°C, crystalline quartz is unstable. Under atmospheric pressure, below 573°C, quartz is known as α-quartz or low-quartz; above this temperature it is called β-quartz or high-quartz. This distinction was first introduced by MÜGGE in 1907. Beyond the temperature 573°C, rearrangement of the molecular or atomic structure takes place.

Quartz dissolves in hydrofluoric acid and in hot alkalis, but it is not attacked by other acids. At high pressures and elevated temperatures, it is soluble to some extent in water. It does not oxidise readily. Thermal conductivity of quartz is maximum along its c-axis. Although quartz, at ordinary temperatures, is a poor conductor of heat, it becomes a good conductor at temperatures near its melting point.

Quartz is piezoelectric having wide applications. It is doubly refracting and optically active, the c-axis being the direction of the optic axis. As a result of the study of the
origin and deposition of quartz; number of important conclusions have been arrived at in the fields of Geology, Mineralogy, etc.

3.6 Cleavage

Quartz has no distinct cleavage in any direction. It usually breaks with a conchoidal fracture. Quartz has a partial cleavage parallel to rhombohedral faces. When plane surfaces of separation are examined, they have nearly always been parallel to the primary positive or negative rhombohedron or to the hexagonal prism. Lehmann and Judd have suggested that the plane surfaces of separation may be only the result of glide planes. Separation parallel to the hexagonal prism or to the base is much less distinct than either the major or minor rhombohedron.

According to Japanese workers fracture surfaces sometime occur not only parallel to rhombohedron and hexagonal prism, but also to the common trigonal pyramid and trapezohedrons. Rarely an imperfect cleavage takes parallel to the second-order prism \( \{110\} \). The fracture of quartz perpendicular to the principal axis is more irregularly conchoidal than that in the other directions.

3.7 Quartz Crystallization

Spoeiu (1905) was the first to report about the successful attempt to grow quartz crystals hydrothermally. The term 'hydrothermal crystal growth' is restricted to mean a process in which an aqueous solution is held at high pressures and temperature in order to dissolve a material (the nutrient)
in one part of the system, transport it to another part of the system and there deposit it either on a seed, or on small crystals attached to the containing vessel by epitaxy. This process is usually carried out in a sealed vertical autoclave with a temperature difference (ΔT) established between the top and bottom of the vessel. Usually the nutrient is placed in the lower, hotter part of the autoclave, and the seeds are mounted in the upper cooler part. The seeds are single crystal plates properly oriented (see figure 15) and are mounted on a suitable wire frame. Figure 16, a schematic diagram shows this arrangement.

The conditions of Spezia's experiment are not known precisely, but the slow rate of growth of crystals discouraged further efforts in the matter. These attempts were further advanced by Nacken in Germany during the second world war. When his work was revealed several laboratories undertook this work of quartz crystal growth almost simultaneously. Spezia's process was modified by Hale (1948), who succeeded in growing quartz at a rate several times faster than the rate reported by Spezia. Buchler and Walker (1950) were able to achieve the growth of large, flawless crystals suitable for piezo-electric device, at a commercially fissible rate. The size and the quality of the crystals obtained in production may be seen in figure 17.

3.8 Uses of quartz:

Quartz is useful in the efficient sending of
electrical signals at a very rapid rate. It is also useful in detecting submarines in the sea. It has increased the use of radio to the maximum possible extent. Quartz crystal is really a boon to the telephone industry. Quartz crystal is so reliable, in this respect, that a large number of messages can be sent simultaneously from one place to the other, without any loss of quality. As the improvement of communication by tele-vision, radio and telephone grows everyday, so does the role of quartz. Its demand, both in the time of peace and war, is so large that it can only be kept up by the artificial growth of perfect crystals in the laboratories from the chips of quartz created in nature.