Chapter - 5 Mineralogy

Highlights :

- Nomenclature and classification of minerals.
- Characteristic features of minerals.
- Physical properties for mineral identification.

Introduction :

Rocks are fundamental units of the Earth's crust and study of Earth begins with the study of rocks. A close examination of rocks reveals that they are made up of smaller units known as minerals. Minerals may vary in colour, hardness, density, crystal form, crystal size, transparency, composition, occurrence and abundance.

Some minerals are radioactive (Uraninite) while others are magnetic (Magnetite) (Fig. 5.1).

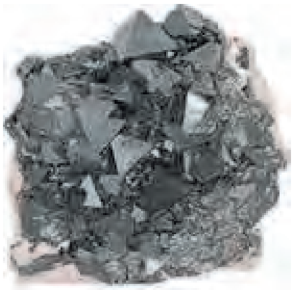


Fig. 5.1 : Uraninite Magnetite

Minerals such as fluorite glow with a vibrant luminescence after exposure to ultraviolet light. Feldspar and quartz are most abundant minerals found in the Earth's crust. Mankind has a desire for many minerals and gemstones due to their strikingly beautiful colors. Some specimens of opal exhibit rainbow-like colors while some specimens of the gemstone, tourmaline show progressions of watermelon like green to pink colours (Fig. 5.2).

Fig. 5.2 : Opal Tourmaline

Few minerals are deceiving and many amateur prospectors have been tricked into thinking that they have found gold but have instead found pyrite (Iron disulphide) otherwise known as "Fools Gold" (Fig. 5.3 A) due to its uncanny resemblance to the precious metal.

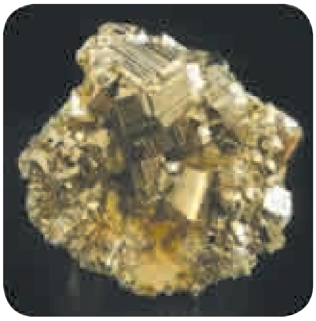


Fig. 5.3 : A) Pyrite (fool's gold) B) Diamond

Diamond, the hardest natural substance found on Earth, has long been priced as the most desirable of all minerals due to its spectacular interaction with light. Majority of diamonds are impure and not suitable as gemstones. They, however, can be used in the industry as cutting tools (Fig. 5.3 B).

5.1 Mineral nomenclature :

Name of any mineral is its identity. The names of many minerals are derived from antiquity. Most of the earlier mineral names were based on their physical properties like colour, density, etc. Later with the discovery of new elements, many new minerals were named. A set of guidelines formulated by the Commission on New Minerals and Mineral Names (CNMMN) under the International Mineralogical Association (IMA) are followed in naming minerals. The master list of minerals prepared by CNMMN in November 2018 has 5,389 minerals.

Many minerals are named after famous personalities or scientists who discovered or analysed them. Moreover, there are names of minerals that convey information about the region where they have been found. Some are quite specific about the location. Some mineral names convey useful information about the mineral itself and are based on the chemical composition, colour, crystal form, hardness, lustre or other properties. Majority of mineral names end in 'ite' which is derived from the Greek word lithos (from its adjective form-ites) meaning rock or stone.

5.1.1 Minerals named after person :

The first mineral which was named after a person is Prehnite. It was named after Col. von Prehn in 1790. Since then, the naming of minerals after people became a common practice. Few other commonly occurring minerals which have been named after persons are Biotite (French mineralogist Jean-Baptise Biot), Dolomite (French mineralogist, D.de Dolomieu), Heulandite (German mineral collector and dealer John Henry Heuland).

People who have two minerals named after them :

1) **Marie Sklodowska Curie :**
   a) Sklodowskite
   b) Curite (named after Marie and her French physicist husband Pierre).
2) **Neil Alden Armstrong :** American, astronaut, first human being to land on the moon's surface.
   a) Armstrongite
   b) Armalcolite (named after Neil Armstrong and other Apollo 11 crew members Aldrin and Collins).

Minerals named after persons of Indian origin :

1) **Radhakrishnaite :** Named after Bangalore Puttaiya Radhakrishnan (1918 - 2012) Indian Mineralogist, who was Director Mysore Geological Department.
   A mineral found in Kolar Gold field, Karnataka.
2) **Rustumite :** Named after Rustum Roy (1924 - 2010) B.Sc and M.Sc in Chemistry from Patna University and Ph.D in ceramic science and Professor at Pennsylvania University, specialist in crystal chemistry of minerals and synthetic materials.

5.1.2 Minerals named after a place :

Common minerals named after the place from where they were first reported from or are abundantly found are Amazonite (named after area near the Amazon River), Labradorite (named after Labrador province, Canada) and Muscovite (named after the Russian province Muscovy).

5.1.3 Minerals named after their chemical composition :

Common mineral names derived from their chemical composition are Calcite (derived from the Greek word 'Chalx' which means burnt lime), Cavansite (named after its elemental contents of Calcium, Vanadium and Silicon), Halite (Greek word 'hals' which means salt).

5.1.4 Minerals named after physical properties :

1) **Colour :** Some of the common minerals named after their color are Beryl (Greek word 'beryllos' which means a green stone), Hematite (after Greek word haimetites, meaning blood-like), Kyanite (Greek word 'kyanos' meaning blue).
2) **Lustre :** Stilbite-Named after German word 'stilbein' which means 'to shine' because of its brilliant lustre. It is a member of the zeolite group of minerals, commonly found as a secondary mineral in basalt.
3) **Cleavage :** Orthoclase-Named after the Greek words 'ortho' and 'klao' meaning 'straight' and 'cleave'. It breaks due to two cleavages meeting at right angles.
4) **Hardness :** Diamond-Named after the Greek word 'adamas' which means 'invincible' because of its hardness.
5) **Sp. gravity :** Barite-Named after the Greek word 'barys' which means 'heavy' because of its high specific gravity. It is also known as heavy spar.
6) **Magnetism :** Magnetite-Named for its strong magnetic property. It is an important ore of Iron.

5.1.5 Minerals named after Sanskrit word :

1) **Corundum :** Named after the Sanskrit word 'Kuruvind' which means 'ruby'.
2) **Opal :** Named after Sanskrit word 'Upala' which means 'gem'.

5.1.6 Mineral names from antiquity :

Many mineral names have been in existence from antiquity like Quartz, Galena, Gypsum etc.

5.2 History of Mineralogy :

The history of mineralogy goes back to Aristotle the Greek philosopher (384 - 322 BCE) who was one of the first to write about minerals and their properties in the western tradition.

Theophrastus, the Greek philosopher (372 - 287 BCE) is known for the first written work on minerals. He wrote a book on mineralogy called 'Conerning Stones'. Pliny the Elder, Roman naturalist (23 - 79 CE) recorded the mineralogical ideas of his time. He wrote an encyclopaedic work 'Natural History'. Agricola Georgius, a German scholar and scientist (1494-1555) was a town physician and considered as the 'Father of Mineralogy'. His book 'De re metallica' published in 1556, is about the mining practices and metallurgy techniques of his time.

5.3 Mineralogy - Salient points :

1) Elements are the building blocks of minerals while minerals are the building blocks of rocks.
2) There are more than 5000 mineral species approved by the International Mineralogical Association (IMA)
3) Silicate minerals compose over 95% of the Earth's crust. Silicon (27.7%) and Oxygen (46.6%) constitute approximately 75% of the Earth's crust.
4) Eight elements account for most of the key components of minerals due to their abundance in the crust. These eight elements constitute more than 98% of the crust by weight. These eight elements in decreasing order of abundance are Oxygen, Silicon, Aluminium, Iron, Magnesium, Calcium, Sodium and Potassium.
5) Differences in crystal structure and chemistry greatly influence the physical properties of minerals. The carbon allotropes diamond and graphite have vastly different properties.

5.4 Mineral characteristics :

Five criteria essential for classifying a substance as a mineral are as follows :

1) **A mineral has to occur naturally :** Substances produced artificially by humans are not considered as minerals. With the help of modern technology, many compounds can be produced in the laboratory by artificially simulating the conditions under which they are formed in nature, e.g. precious and semi-precious stones such as topaz, corundum and even diamond can be produced synthetically. Cubic Zirconia also known as American diamond is a synthetic gem variety and does not qualify as a mineral.
2) **A mineral has to be formed by inorganic processes :** Substances originating from plants (amber, rudraksha etc) or animal (ivory, pearls, corals etc) cannot be termed as minerals. Calcite or aragonite which is formed inorganically due to the processes of evaporation or crystallization are minerals, but the same substances deposited by the activity of organisms (mollusk shells) do not qualify as minerals.
3) **A mineral has to be in a solid state :** Accordingly, water which is in liquid form is not a mineral while ice which is in solid form, is termed as a mineral. Therefore mercury, petroleum etc. also cannot be considered as minerals.

Do you know?

Natural oil (Petroleum) although occurs naturally, is liquid in nature and is formed by organic processes, is dealt with separately and not in mineralogy.

4) **A mineral must have a definite chemical composition or a definite range of chemical composition :** Quartz crystals collected from any part of the Earth will always have the same chemical composition i.e SiO_2. Many minerals may exhibit a range of chemical composition, for e.g. plagioclase feldspars form a wide

range of minerals from Na rich (albite) to Ca rich (anorthite) varieties.

5) **A mineral must possess an ordered internal atomic structure :** Definite physical and chemical characters will be exhibited by a substance if its atoms are orderly arranged in a geometric pattern. Such substances qualify as minerals. For example natural glass which is formed by faster cooling of lava is not a mineral because it lacks an ordered internal atomic structure.

Activity :

Using the above significant characteristics of minerals, derive a holistic definition for a mineral.

5.5 Physical properties of minerals :

The physical properties vary from mineral to mineral depending on their chemical composition and crystal structure. Minerals possess widely different physical properties such as form, colour, streak, lustre, fracture, cleavage, hardness, specific gravity etc. The study of these physical properties is the first step in identification of minerals. Some properties like radioactivity, specific gravity, magnetism, electrical and thermal properties may need instruments for measurement.

Some of the original properties of the minerals may be partly or completely altered due to their exposure to air and water which causes corrosion or rusting. Hence, whenever geological studies are to be carried out, it is important to obtain fresh, *in-situ* sample.

5.5.1 Characters depending upon light :

1) Colour : Colour is the first property one notices in a mineral. It is also one of the big reasons that attracts people to minerals, especially to gem stones. However, colour is not a very reliable property to be used in the identification of minerals. It usually confuses an inexperienced collector into making an incorrect identification. It is important to know what causes colour in minerals in order to understand this mineral property.

Colour is determined by its wavelength. When pure white light (containing all wavelengths of visible light) enters a mineral, some of the wavelengths might be absorbed while other wavelengths are emitted. If this happens, then the light that is transmitted through the mineral will no longer be white but will have some colour. Colour in minerals is caused by the absorption or lack of absorption of various wavelengths of light.

Colourless minerals (transparent and translucent) like quartz, calcite, fluorite can exhibit certain colours due to the presence of transition elements. These transition elements cause a mineral to exhibit a certain colour if they are part of the chemistry of the mineral. The most common chromophoric (colour causing) transition elements with unfilled electron shells are Ti, V, Cr, Mn, Fe, Co, Ni, Cu. However, if there is just a trace of these elements, they still can strongly influence the colour of the mineral. Copper usually produces green and blue colours. Iron is known for the red and yellow colours that it typically produces. However, almost any element can be responsible for a characteristic colour. Thus, minerals of same composition can exhibit different colours e.g. quartz (Fig. 5.4), calcite (Fig. 5.5), fluorite (Fig. 5.6) etc. Minerals of different compositions can also exhibit the same colour e.g. calcite (Fig. 5.7 A), natrolite, (Fig. 5.7 B) and milky quartz (Fig. 5.7 C) all exhibit white colour. Hence, colour cannot be considered as the most diagnostic property for identifying minerals.

Quartz varies widely in colour, due to minor (parts per billion) impurities and even defects in its crystalline structure. Pure quartz has no colour. Varieties of quartz, shown in figure 5.4 include : amethyst (purple), smoky quartz (brown to black), citrine (yellow), rosy quartz (pink), rock crystal (clear).

Amethyst

Smoky quartz

Citrine

Rosy quartz

Rock crystal

Fig. 5.4 : Varieties of quartz showing different colours due to presence of chromophoric elements

Fig. 5.5 : Variety of colours exhibited by Calcite

Fig. 5.6 :Variety of colours exhibited by Fluorite (CaF_2)

A) Calcite ($CaCO_3$)

B) Natrolite ($Na_2Al_2Si_3O_{10}\cdot 2H_2O$)

C) Milky quartz (SiO_2)

Fig. 5.7 : Minerals with different chemical composition showing white colour

Do you know?

V^{+3} in grossular garnet (variety of garnet) causes the green colour.

Cr^{+3} causes green colour in emerald (variety of beryl)

Mn^{+3} causes red colour in muscovite mica

Cu^{+2} usually produces blue and green colours in minerals such as azurite and malachite.

2) Streak : Streak refers to the colour of a mineral's powder left behind after it is rubbed across a porcelain streak plate. This property is studied only for coloured (not white) minerals. Minerals with hardness less than 6.5 are tested with the help of the porcelain plate, while those with higher hardness are checked with other streak plates, e.g corundum plate. Streak of a mineral may be different from the colour of the mineral e.g. pyrite, which shows golden colour has a pencil lead grey streak (Fig. 5.8).

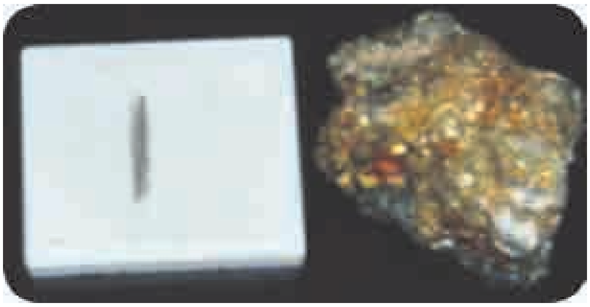
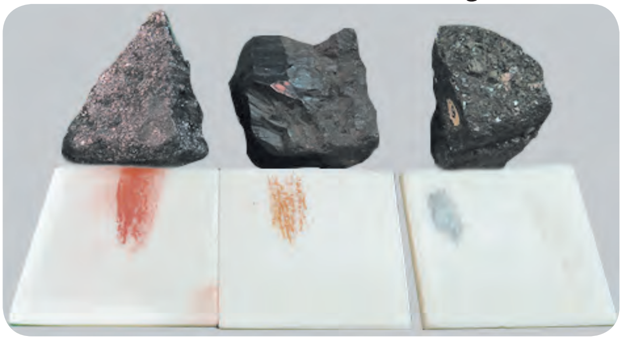


Fig. 5.8 : The streak of golden coloured mineral pyrite is pencil lead grey

Hematite Limonite Magnetite



Brick red Yellow brown Black

Fig. 5.9 : Streak of different dark coloured Fe-bearing minerals appears brick red, yellowish brown and black

Streak of the mineral is a more reliable identification characteristic than the colour of the mineral.

Do you know?

Application of streak in identifying gold

Kasauti stone/touch stone is a small piece of fine grained black stone which is used by goldsmiths for testing the purity of gold.

A piece of gold to be tested is scratched on the 'Kasauti' stone, which leaves a streak on it. This is compared with the streak obtained from piece of gold of known purity.

3) Lustre : Lustre describes the appearance of a mineral when light is reflected from its surface. It is the degree of reflected light and directly related to optical properties (mainly refractive index) and surface conditions.

Lustre of minerals is mainly classified as Metallic and Non-metallic :

i) Metallic lustre : Strictly belongs to opaque minerals, where light is completely reflected from the surface. Most ore minerals having high content of metals exhibit metallic lustre, e.g., galena, magnetite, pyrite (Fig. 5.10), etc.

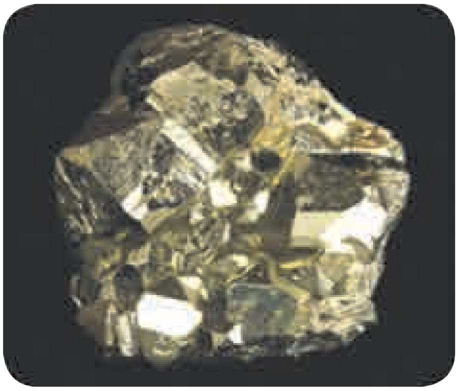


Fig. 5.10 : Metallic lustre in pyrite

ii) Submetallic lustre : Some minerals have lustre similar to that of a metal, but are dull and less reflective. Submetallic lustre often occurs in near-opaque minerals with very high refractive indices, such as hematite, chromite (Fig. 5.11) etc.

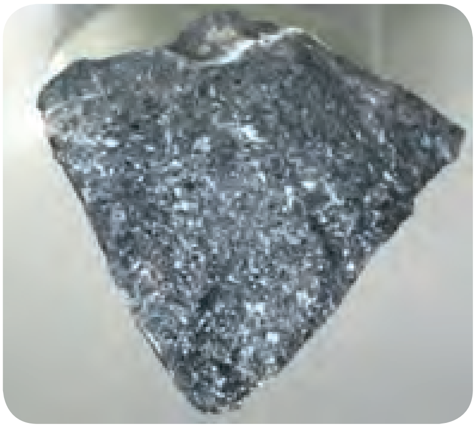


Fig. 5.11 : Sub-metallic lustre in Chromite

iii) Non-metallic lustres : Other lustre types are collectively known as non-metallic lustres. They may be brilliant or faint where reflection is poor due to scattering of light from the mineral surface. The different types of non-metallic lustres are:

a) Adamantine lustre : An exceptionally brilliant lustre exhibited by minerals having very high refractive index, e.g. diamond (Fig. 5.12), zircon, corundum (ruby, sapphire). These minerals are used as precious gem stones.

Fig. 5.12 Adamantine lustre in Diamond

b) Dull / Earthy lustre : Dull lustre is also known as 'earthy' and is used to describe minerals that have poor reflectivity. The surface of minerals with dull lustre is coarse and porous, e.g., kaolinite (Fig. 5.13), limonite, bauxite.

Fig. 5.13 : Dull / Earthy lustre in Kaolinite

c) Greasy / Waxy / Oily lustre : It results from light scattered by a microscopically rough surface, e.g. chalcedony (Fig. 5.14), opal etc.

Fig. 5.14 : Waxy lustre in Chalcedony

d) Pearly lustre : It results due to reflection from successive layers, such as cleavage surfaces, e.g. talc (Fig. 5.15), muscovite, gypsum.

Fig. 5.15 : Pearly lustre in Talc

e) Resinous lustre : Minerals have the appearance of resin, chewing gum or (smooth-surfaced) plastic, eg., amber (Fig. 5.16) which is a form of fossilised resin.

Fig. 5.16 : Resinous lustre in Amber

f) Silky lustre : It is due to the reflection from minerals having parallel arrangement of extremely fine fibres, e.g. gypsum (satin spar) (Fig. 5.17), asbestos, malachite.

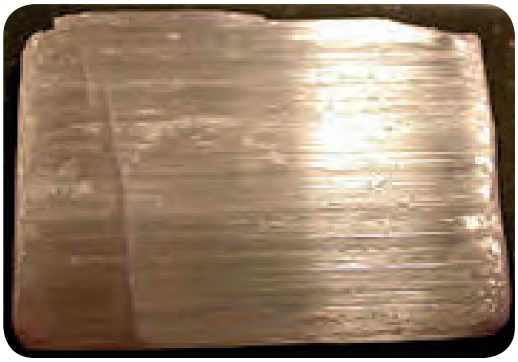


Fig. 5.17 : Silky lustre in Gypsum (Satin spar)

g) Vitreous lustre : It is generally shown by broken glass. This type of lustre is one of the most commonly observed lustres and occurs in transparent or translucent minerals with relatively low refractive indices. Common examples include quartz (Fig. 5.18), fluorite etc.

Fig. 5.18 : Vitreous lustre in Quartz

Subvitreous lustre : When the minerals exhibit feebly developed vitreous lustre, they are said to show subvitreous lustre, e.g milky quartz, calcite (Fig. 5.19), etc.

Fig. 5.19 : Subvitreous lustre in Calcite

5.5.2 Characters depending upon crystal aggregate habits :

4) Form : Most minerals are formed within the spaces in between other minerals and may grow into shapeless masses. However, if they are formed freely in a hole or a cavity within a rock, the mineral takes the form of a crystal. These crystal-lined cavities are called geodes, vugs or pockets.

Form is the natural mode of occurrence of a mineral or the common geometric morphology of the mineral. Various forms are identified as follows :

Degree of crystallisation :

i) **Crystallised :** The minerals occur in the form of well developed crystals, e.g. quartz (Fig. 5.20).

Fig. 5.20 : Crystallised form in Quartz

ii) **Crystalline :** The minerals occur in the form of aggregates of imperfectly developed crystals, e.g. quartz (Fig. 5.21).

Fig. 5.21 : Crystalline form in Quartz

iii) **Cryptocrystalline :** The minerals occur as partly crystalline and partly amorphous and lack a perfect shape, e.g. agate, chalcedony (Fig. 5.22).

Fig. 5.22 : Cryptocrystalline form in Chalcedony

iv) **Amorphous :** The minerals are formed in nature as solids without development of internal atomic structure, e.g. opal (Fig. 5.23)

Fig. 5.23 : Amorphous form in Opal

Growth dominantly in one direction :

Minerals of this category exhibit slender forms and are described as :

i) **Acicular :** The minerals are needle-like and may occur individually or in aggregates, e.g. actinolite (Fig. 5.24).

Fig. 5.24 : Acicular form in green coloured needles of Actinolite

ii) **Columnar :** Such minerals occur as columns of varying sizes e.g., beryl (Fig. 5.25).

Fig. 5.25 : Columnar form in Beryl (Aquamarine)

iii) **Fibrous :** Minerals are made up of thin hair-like separable fibres or crystals, e.g. asbestos (Fig. 5.26).

Fig. 5.26 : Fibrous form in Asbestos (Serpentine)

iv) **Radiating or Divergent :** The minerals appear as diverging needles from central nucleus e.g. natrolite (Fig. 5.27).

Fig. 5.27 : Radiating form in Natrolite

v) **Wiry :** Some minerals occur in nature in the form of thin wires, which may be twisted or stretched in different directions, e.g. native copper or native silver (Fig. 5.28).

Fig. 5.28 : Wiry form in Native Silver

Growth in two dimensions :

Minerals of this category are described as :

i) **Bladed :** The mineral appears like a flat blade of a knife, e.g. kyanite (Fig. 5.29).

Fig. 5.29 : Bladed form in Kyanite

ii) **Foliated :** Mineral occurs as flakes or plates which are separable and can split into sheets or lamellae, e.g., muscovite and biotite (Fig. 5.30).

Fig. 5.30 : Foliated form in Biotite

iii) **Tabular :** Mineral occurs in the form of a flattened rectangular shape, resembling a table, e.g. barite (Fig. 5.31), plagioclase etc.

Fig. 5.31 : Tabular form in Barite

Growth in three dimensions :

i) **Equidimensional :** Minerals grow equally in three dimensions and appear as stubby crystals, e.g. garnet, pyrite (Fig. 5.32).

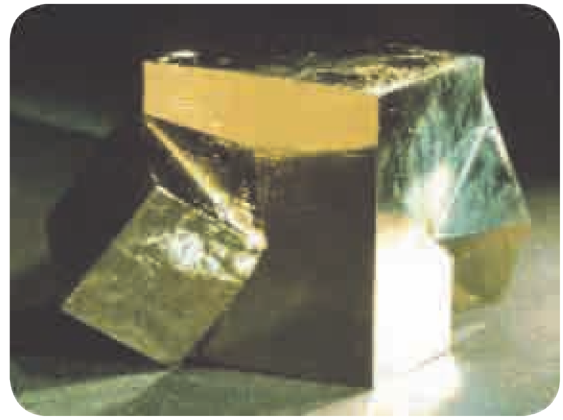


Fig. 5.32 : Equidimensional form in Pyrite

Growth with curved surfaces :

i) **Botryoidal :** Crystals occur in spheroid aggregates resembling a bunch of grapes, e.g., chalcedony, agate (Fig. 5.33).

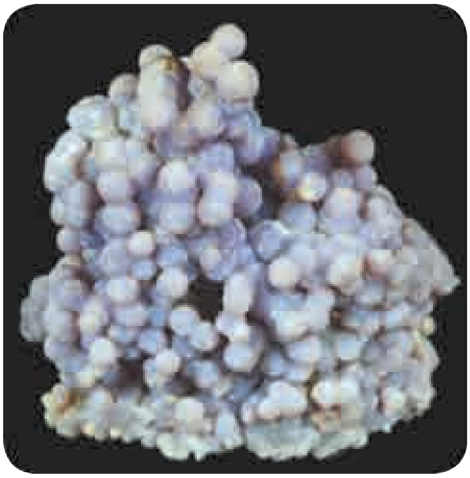


Fig. 5.33 : Botryoidal form in Agate

ii) **Granular :** Mineral occurs as distinct grains resembling a lump of sugar, e.g., olivine (Fig. 5.34).

Fig. 5.34 : Granular form in Olivine

iii) **Oolitic :** These minerals appear like small spherical growths, resembling eggs of fish, e.g. bauxite (Fig. 5.35).

Fig. 5.35 : Oolitic form in Bauxite

iv) **Pisolitic :** Mineral grains resemble pea-sized spheroids, coarser than oolites, e.g., bauxite (Fig. 5.36).

Fig. 5.36 : Pisolitic Bauxite

v) **Reniform :** Mineral is circular or roughly circular, resembling the shape of a kidney, e.g., hematite (Fig.5.37), psilomelane etc.

Fig. 5.37 : Reniform form in Hematite

Growth in miscellaneous manner :

i) **Dendritic :** Minerals show branch-like growth in different directions, e.g. native copper (Fig. 5.38).

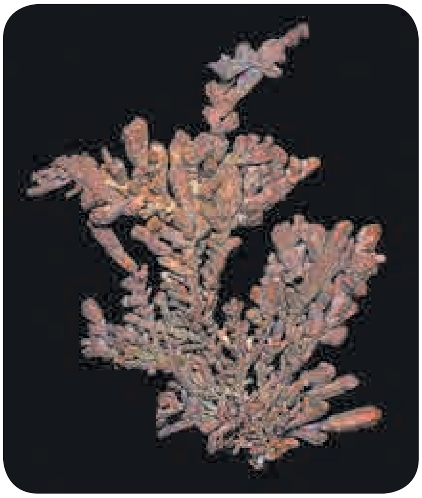


Fig. 5.38 : Dendritic form in Native Copper

ii) **Massive / Compact :** The minerals cannot be individually identified with the naked eye as they form a compact mass exhibiting an irregular shape, e.g. rosy quartz (Fig. 5.39).

Fig. 5.39 : Massive form in Rosy Quartz

5.5.3 Characters depending upon cohesion and elasticity :

Cohesion : It is the force of attraction existing between molecules. It shows resistance to any external influence that tends to separate them, Cohesion force is related to bonding force.

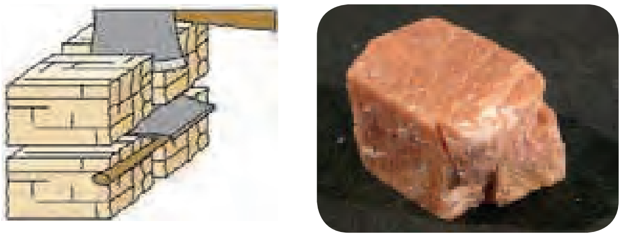
Elasticity : It is the force that tends to restore the molecules of a body into their original position from which they have been disturbed.

The result of cohesion and elasticity in a mineral appears as cleavage, fracture and hardness.

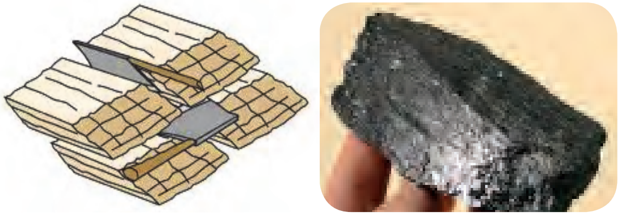
5) Cleavage : The manner in which a mineral breaks is determined by the arrangement of its atoms and the strength of the chemical bonds holding them together. As this property is unique to the mineral, careful observation can aid in mineral identification (Fig. 5.40).

The word cleavage is derived from 'cleave' meaning to break or split. Cleavage is therefore, a plane of weakness along which mineral splits easily. Only crystalline minerals can show cleavage, though every crystalline mineral may not possess cleavage (e.g. quartz). Amorphous minerals (limonite, opal etc.) do not show cleavage. Cleavage, if present, occurs as numerous parallel planes along which the mineral is equally weak. Hence, all such weaker planes along a single direction are referred to as 'sets of cleavage'. Depending upon their atomic structure, crystalline minerals will exhibit one set of cleavage (e.g. mica, Fig. 5.40 A), two sets of cleavage (e.g. feldspars Fig. 5.40 B, amphiboles Fig. 5.40 C), three sets of cleavage (e.g. galena Fig. 5.40 D, calcite, Fig. 5.40 E) or four sets of cleavage (e.g. fluorite, Fig. 5.40 F).

A) Biotite and muscovite micas exhibit one set of cleavage.

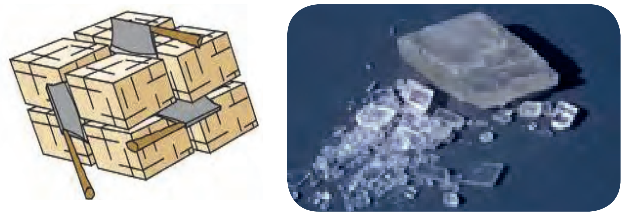


B) Orthoclase and plagioclase fedspars exhibit two sets of cleavage at approximetely 90° from each other.

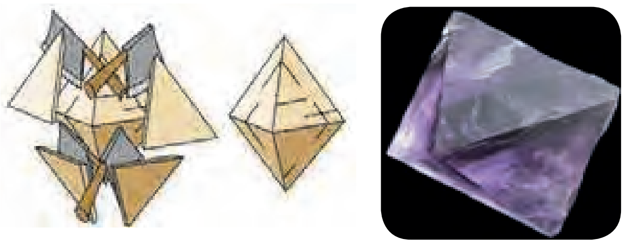


C) Hornblende (an amphibole) has two sets of cleavage at 124°. from each other.

D) Galena has three sets of cleavage that form two 90° angles (cubic cleavage)



E) Calcite has three sets of cleavage - 105° in one plane and 75° in another



F) Fluorite has four sets of cleavage (octahedral cleavage)

Fig. 5.40 : Minerals and their cleavages

Quality of cleavage can be categorised into :

- **Perfect :** Minerals with perfect cleavage split without leaving any rough surface. A full, smooth plane is formed where the crystal breaks, e.g. calcite.
- **Good :** Minerals with good cleavage also leave smooth surfaces, but often leave minor residual rough surfaces e.g. feldspars.
- **Poor :** Smooth crystal edge is not visible in minerals with poor cleavage, since the rough surface is dominant, e.g. barite and apatite.
- **Indistinct :** If a mineral exhibits cleavage, but it is so poor that it can hardly be distinguished, it is indistinct cleavage e.g. beryl.
- **None :** Some minerals never exhibit any cleavage. Thus, broken surfaces are fractured and are rough, e.g. quartz.

Do you know?

Six cleavage planes can give a 12-sided form e.g., sphalerite.

Number of cleavages and their directions	Name and description of how the mineral breaks
6 cleavages intersect at 60° and 120°	**Dodecahedral cleavage** Shapes made of dodecahedrons and parts of dodecahedrons

Shape of broken pieces (cleavage directions are numbered)	Illustration of cleavage directions
 Sphalerite	

6) Fracture : The appearance of broken surface of the mineral is expressed by the term fracture. It is the irregular breaking of a mineral along a surface which is not parallel to the cleavage or to the parting planes. The fracture planes are not related to the atomic structure of the mineral. These are simply ruptures which are devoid of any systematic and regular placement of planes. The different types of fractures are described as follows :

i) Conchoidal : Broken surface shows concentric rings or concavities which may be deep in character, e.g., obsidian (Fig. 5.41 A). When the broken surface shows faint concentric rings, it is subconchoidal fracture. e.g. rock crystal, flint (Fig. 5.41 B)

A)

B)

Fig. 5.41 : A) Conchoidal, B) Subconchoidal fracture

ii) **Earthy :** Fractured surface is soft and smooth resembling the broken surface of chalk, e.g. bauxite, limonite (Fig. 5.42).

Fig. 5.42 : Earthy fracture in Limonite

iii) **Hackly :** Broken surface is highly irregular and exhibits sharp, pinching projections. e.g. asbestos, native copper (Fig. 5.43).

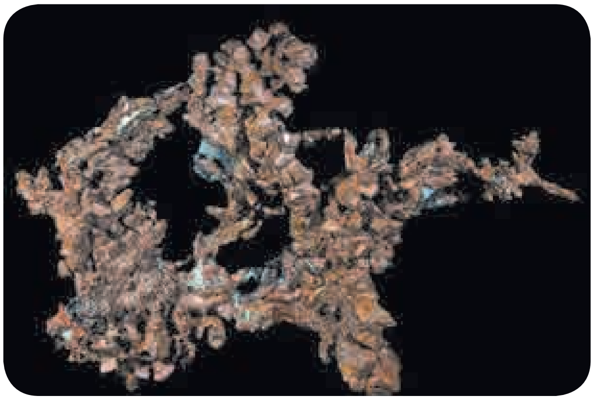


Fig. 5.43 : Hackly fracture in Native Copper

iv) **Splintery :** The mineral breaks with a rough woody fracture, e.g. kyanite, serpentine (Fig. 5.44).

Fig. 5.44 : Splintery fracture in Serpentine

v) **Uneven :** Broken surface is rough and irregular with a rugged appearance, e.g., orthoclase, magnetite (Fig. 5.45).

Fig. 5.45 : Uneven fracture in Magnetite

7) Hardness : Hardness of mineral is a measure of its resistance to abrasion or scratching.

The degree of hardness is determined by observing the comparative ease or difficulty with which one mineral is scratched by another. Hardness of a mineral depends upon its atomic structure, hence it is considered to be a reliable property in mineral identification.

In 1822, an Austrian mineralogist Friedrich Mohs devised a hardness scale, (Table 5.1) based on one mineral's ability to scratch another mineral. He placed 10 minerals in order, from softest to hardest, giving a relative hardness value of 1 to the softest mineral i.e. talc and 10 to the hardest i.e. diamond. Each mineral on the scale scratches the one below it (the lower number), but not the one above it (the higher number). This is known as Mohs' scale of hardness, and is one of the best practical methods of estimating a mineral's hardness :

Note : It must be noted that Mohs' scale is arbitrary and non-linear (Fig. 5.46), i.e. the steps between relative hardness values are not necessarily equal. Rather, it is a method of gauging the relative hardness of minerals. If a mineral cannot be scratched by a knife blade but can be scratched by quartz then its hardness is between 5 and 7 (stated as 5-7) on Mohs' scale. A relative hardness value of 6.5 means, that the mineral could scratch orthoclase (feldspar) but not quartz.

Table 5.1 : Mohs' hardness scale with objects of equivalent hardness

	Mineral Name	Scale Number	Common Object
Increasing Hardness	Diamond	10	
	Corundum	9	
	Topaz	8	Masonry Drill Bit (8.5)
	Quartz	7	
	Orthoclase	6	Steel Nail (6.5)
	Apatite	5	Knife/Glass Plate (5.5)
	Fluorite	4	
	Calcite	3	Copper Penny (3.5)
	Gypsum	2	Finger nail (2.5)
	Talc	1	

Test : Using moderate pressure, drag a sharp edge over the smooth surface of a mineral. If the surface of the mineral is scratched, then it is softer than the material used to scratch it, if not then it is harder.

Terminology :

Soft : can be scratched by a fingernail (1-2 Mohs').

Medium : can be scratched by a knife or nail (3-5 Mohs').

Hard : cannot be scratched by a knife, but it can scratch glass (6-9 Mohs').

Diamond is the hardest known mineral (10 Mohs').

Do you know?

Hardness is measure of the strength of the structure of the mineral relative to the strength of its chemical bonds. It is not the same as brittleness, which is another measure of strength that is purely related to the structure of the mineral. Minerals with small atoms, packed tightly together with strong covalent bonds throughout, tend to be hardest minerals. The soft minerals have metallic bonds or even weaker Van der Waals bonds as important components of their structure. Hardness is generally consistent with the chemistry of minerals.

Minerals exhibiting hardness more than 7 can be cut and polished as gemstones, e.g. crystalline varieties of quartz, corundum, beryl, etc. Any mineral with hardness less than 7 cannot be used as a gemstone, but can be used in making sculptures or artifacts, e.g. jade, chalcedony, malachite, turquoise, etc.

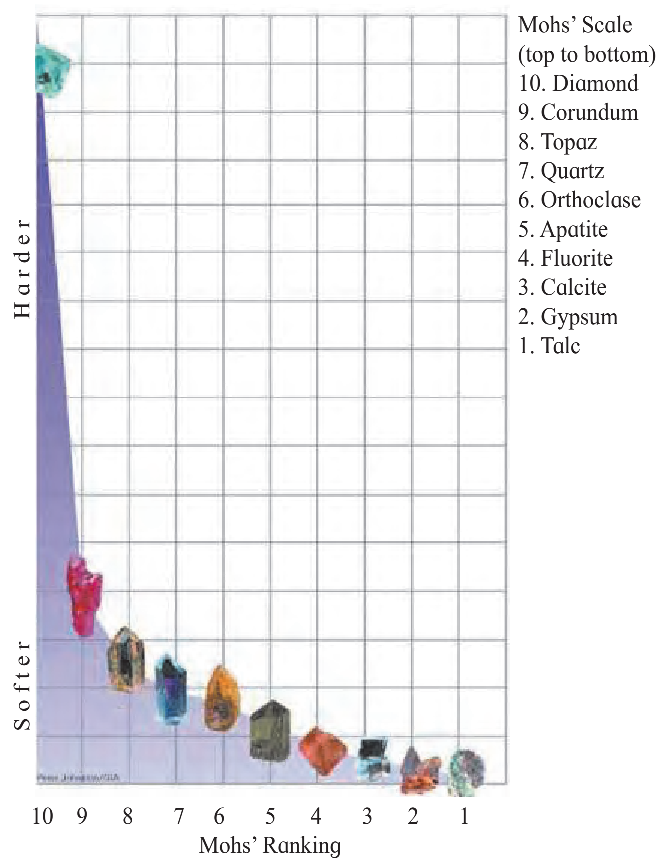


Fig. 5.46 : Non-linear relationship between Mohs' scale and hardness of minerals

8) Specific Gravity : Specific gravity of a mineral is defined as a number that expresses the ratio of the weight of the mineral in air to the weight of an equal volume of water displaced by it at normal temperature and pressure (NTP) conditions. The specific gravity of a mineral depends upon the atomic arrangement, crystal structure, chemical composition. It varies with temperature and pressure. For a mineral of variable composition crystallising in specific structure, the variation in specific gravity will depend on the atomic weight of the individual atoms, e.g., in olivine, specific gravity varies from 3.2 for pure forsterite (Mg_2SiO_4) to 4.4 for pure fayalite (Fe_2SiO_4). The atomic weight of Mg is 24.3 and Fe is 55.8.

The common rock forming minerals have specific gravity that ranges between 2.5 and 3.5 while the average specific gravity for metallic minerals is about 5.0. Ore minerals have specific gravity around 3.0.

The specific gravity of minerals can be determined in the laboratory by two methods i.e. Walker's steelyard balance and Jolly's spring balance.

Do you know?

Minerals like galena (7.5), barite (4.25) and hematite (5.26) having high specific gravity are commonly used to increase the weight of drilling muds for oil- well drilling especially to avoid blow-out. Gravity separation technique depends on the difference in specific gravity of minerals. This method is environment friendly and used for the separation of high specific gravity minerals and metallurgical waste.

Classification of Minerals :

On the basis of chemical composition and internal structure, minerals are classified as follows :

Oxides : Oxides are minerals that consist of metal cations (atoms with a positive charge) bonded to oxygen anions. An anion is an atomic structure that has a net negative charge, e.g. haematite (Fe_2O_3) and magnetite (Fe_3O_4).

Sulphides : Sulphides consist of metal cations bonded to a sulphide anion, e.g. pyrite (FeS_2) and galena (PbS).

Sulphates : Sulphates are minerals that consist of metal cations bonded to a sulphate (SO_4^{-2}) anion. e.g. gypsum ($CaSO_4.2H_2O$).

Halides : Halides are minerals that consist of metal cations bonded to halide anions. Halide refers to the elements chlorine, fluorine, iodine, e.g. fluorite (CaF_2).

Carbonates : Carbonates are minerals that contain metal cations bonded to the carbonate (CO_3^{-2}) anion, e.g. calcite ($CaCO_3$).

Native Elements : Minerals that consist of one single element belong to this group, e.g. copper, gold and silver.

Silicates : Silicates make up over 95% of the Earth's crust and about 97% of the mantle. They are the most common minerals on Earth. Silicates are minerals that contain the fundamental silicon tetrahedra (SiO_4) (Fig. 5.47). A tetrahedra is a geometric shape similar to a four-sided pyramid. The silica tetrahedra is composed of one silicon atom (Si^{+4}) surrounded by four oxygen atoms (O^{-2}).

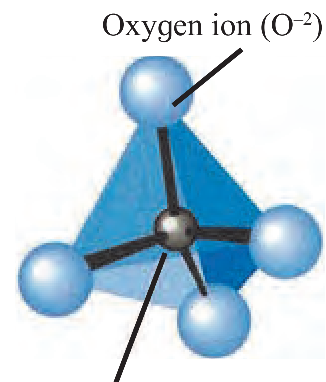


Fig. 5.47 : Silicon tetrahedra

Classification based on structure of silicates :

SiO_4 tetrahedra is the fundamental unit of all silicate minerals. This unit can either occur alone or in different combinations (along with other cations) in the mineral structure. Different groups of silicate structures of rock forming minerals are as follows :

i) **Nesosilicates :** In this group, SiO_4 tetrahedra occur as independent units, (Fig. 5.48) e.g., olivine, garnet, kyanite etc.

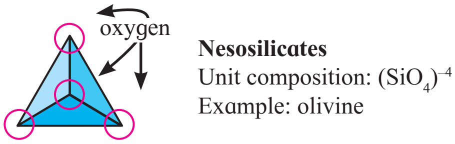


Fig. 5.48 : Nesosilicates

ii) **Sorosilicates :** SiO_4 tetrahedra occur in pairs, (Fig. 5.49) e.g., epidote etc.

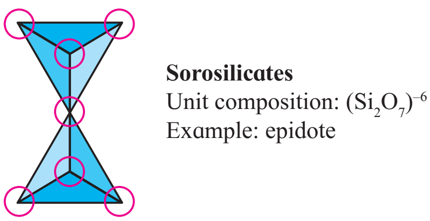


Fig. 5.49 : Sorosilicates

iii) **Inosilicates :** These are also called as 'chain silicates'. In this group of minerals SiO_4 teterahedra occur as chains resulting in preferential growth of mineral along one direction. Two varieties of Inosilicates occur in nature. They are single chain silicates (Fig. 5.50 A) e.g. pyroxenes and double chain silicates (Fig. 5.50 B) e.g. amphiboles.

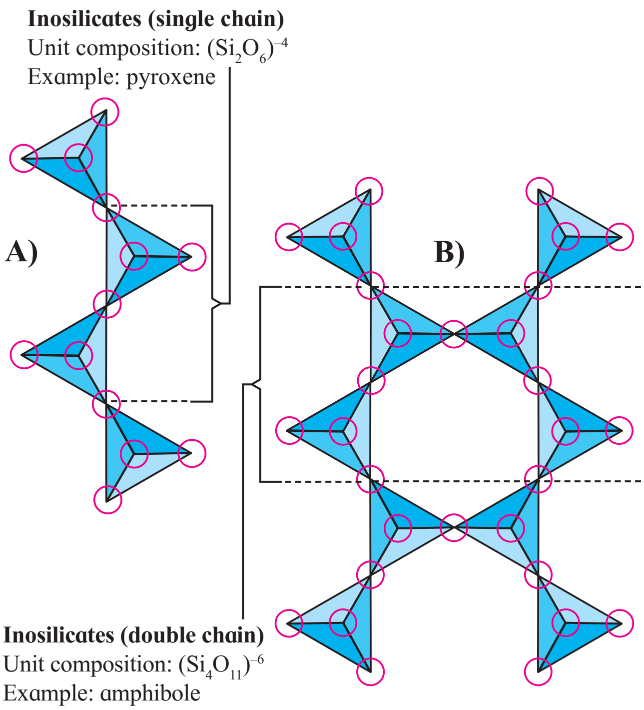


Fig. 5.50 : Inosilicates

iv) **Cyclosilicates :** These are known as 'ring silicates'. In this group of minerals, 3 or 4 or 6 SiO_4 teterahedra occur in the form of a ring (Fig.5.51) e.g., beryl, tourmaline.

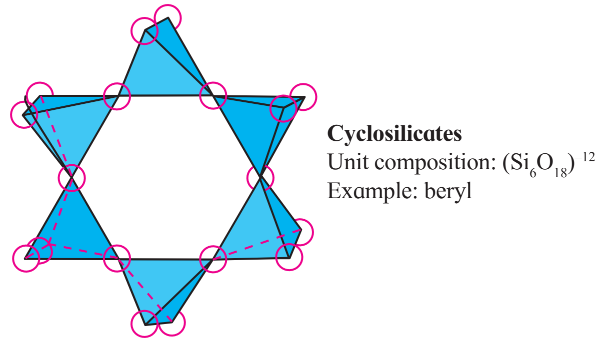


Fig. 5.51 : Cyclosilicates

v) **Phyllosilicates :** These are 'sheet silicates'. In this group, SiO_4 teterahedra occur as sheets, resulting in preferred growth along two directions of a mineral (Fig. 5.52) e.g., micas, talc, serpentine.

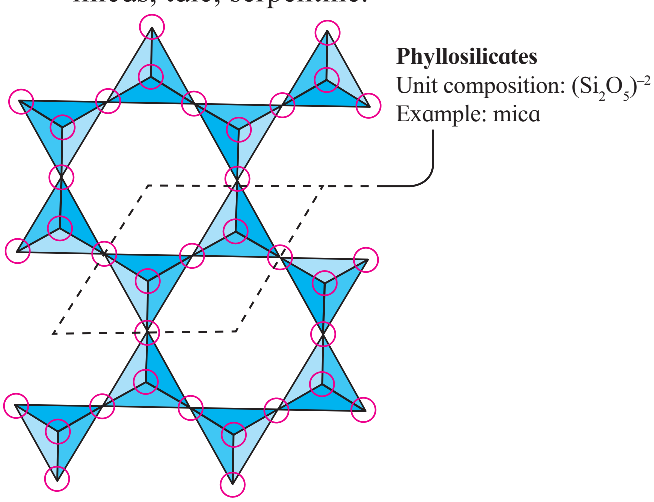


Fig. 5.52 : Cyclosilicates

vi) **Tectosilicates :** In this group, SiO_4 tetrahedra occur in a three-dimensional framework resulting in equidimensional growth of minerals (Fig. 5.53) e.g., quartz, feldspars, zeolites.

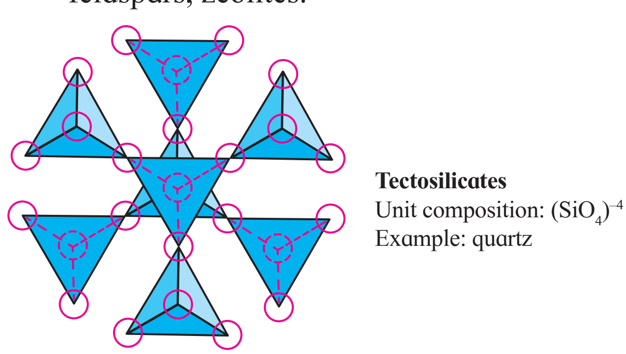


Fig. 5.53 : Tectosilicates

Rock forming mineral groups :

Rocks are composed of minerals. Only a few of the minerals are rock forming. Most rocks however, are a combination of commonly occurring minerals such as feldspars, quartz, micas, olivine, pyroxene and amphiboles.

Feldspar group :

Feldspar is one of the most abundant mineral found in the continental crust. This group constitutes over 50% of the Earth's crust.

The name feldspar is derived from the German word 'Feldspat'. 'Feld' meaning field and 'Spat' meaning a rock (that does not contain ore).

Silicate structure : All feldspars are tectosilicates. Ca, Na, K cations also occur in tectosilicates.

Chemical composition : It is expressed as $X(AlSiO)_4O_8$,where X is Ca, Na, K and Ba.

Varieties : This group is sub-divided on the basis of chemical composition and isomorphism into :

i) Alkali feldspars ii) Calc-alkali feldspars

i) Alkali feldspars or Potassium Sodium feldspars. e.g. orthoclase and microcline.

Albite ($NaAlSi_3O_8$) to Orthoclase ($KAlSi_3O_8$) isomorphous minerals. It is a substitution of sodium by potassium.

Orthoclase : Name has its origin in the Greek words- 'Orthos' meaning right, 'Clase' meaning to cleave (cleavages are at right angles) (Fig. 5.54).

Fig. 5.54 : Orthoclase

Microcline : 'Micro' meaning small or little, 'Cline' meaning to incline or to lean (Fig. 5.55).

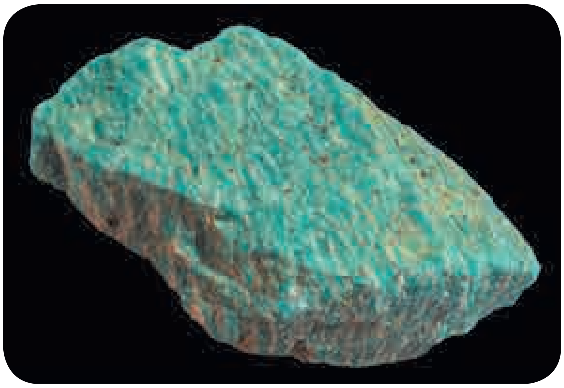


Fig. 5.55 : Microcline

Table 5.2 : Varieties of feldspar group of minerals can be given as follows:

Alkali feldspar

Potash feldspar ($KAlSi_3O_8$) — Barium feldspar ($BaAl_2Si_2O_6$)

Orthoclase .... Hyalophane .... Celsian.

Microcline

Soda Orthoclase

Soda Microcline

Albite ----- Oligoclase --- Andesine --- Labradorite --- Bytownite --- Anorthite.

($NaAlSi_3O_8$) Soda feldspar — ($CaAl_2Si_2O_8$) Lime feldspar

Plagioclase or Lime soda feldspar

ii) Calc-alkali feldspars - Plagioclase series of feldspars or lime soda feldspars, e.g. plagioclase (Fig. 5.56) and labradorite (Fig. 5.57).

Fig. 5.56 : Plagioclase

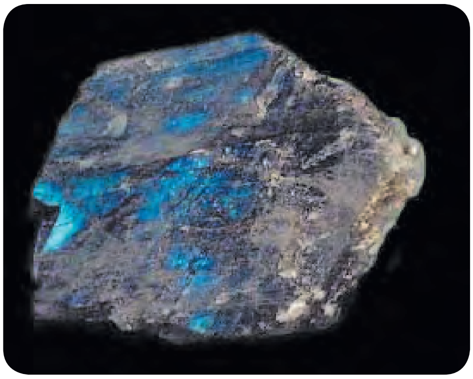


Fig. 5.57 : Labradorite

Plagioclase feldspars : Plagioclase series of feldspar minerals are a homogeneous mixture of albite and anorthite. In this series Na-Si is replaced by Ca-Al. The minerals so formed are called isomorphs. The two boundary minerals albite and anorthite are called end members.

Albite (Ab) $\rightleftharpoons$ Anorthite (An).

Table 5.3 : Plagioclase minerals and their composition :

Names	Ab content (%)	An content (%)
1. Albite	100-90	0-10
2. Oligoclase	90-70	10-30
3. Andesine	70-50	30-50
4. Labradorite	50-30	50-70
5. Bytownite	30-10	70-90
6. Anorthite	10-0	90-100

Physical properties of feldspar group :

Colour : Blue, orange, pink, white, green and gray.

Streak : White or pale shade of body colour.

Lustre : Vitreous to subvitreous

Form : Tabular

Cleavage : Two sets, at right angles

Fracture : Conchoidal to uneven

Hardness : 6 - 6.5

Specific gravity : 2.55 - 2.76

Occurrence : Feldspars are found in igneous rocks (e.g., granite, syenite, pegmatite), sedimentary rocks (e.g., arkose a variety of sandstone containing atleast 25% feldspar) and metamorphic rocks (e.g., gneiss).

Uses : Feldspars are used in the manufacture of glass, porcelain, sanitary ware and as filler in paints, plastic, rubber and adhesive industries. Feldspars are also used as gemstones e.g., orthoclase as moonstone, labradorite as sunstone and microcline as amazonite.

Silica group :

Quartz or 'Gargoti' was used during the stone age. The word quartz is derived from the German word 'Quarz' which came from the Polish dialect term 'Kwardy', corresponding to the Czech term 'Tvrdy' meaning hard. Quartz is the second most abundant mineral in the Earth's crust.

Silica group constitutes 12% to 15% of all rock forming minerals. This group includes crystalline, cryptocrystalline and amorphous minerals.

Silicate structure : Silica minerals are tectosilicates.

Chemical composition : The minerals of this group are characterised by same chemical composition i.e. SiO_2. Crystalline quartz is most abundant.

The composition varies from crystalline to cryptocrystalline silica, i.e. from SiO_2 to $SiO_2 \cdot nH_2O$. Varieties of cryptocrystalline silica are mixtures of cryptocrystalline silica (chalcedony) and hydrous silica (opal).

Varieties : Several varieties of silica can be recognised on the basis of their forms :

1) Crystalline silica (SiO_2) :

Well defined crystals are absent, but a marked tendency towards crystallisation is exhibited.

Rock crystal : Colourless and transparent (Fig. 5.58).

Fig. 5.58 : Rock crystal

Amethyst : Violet or purple coloured (Fig. 5.59), colour resulting from trace amounts of Fe impurity.

Fig. 5.59 : Amethyst

Rosy quartz : Pink colour (Fig. 5.60), resulting from traces of Ti impurity.

Fig. 5.60 : Rosy quartz

Milky quartz : Milky white coloured (Fig. 5.61), colour due to numerous air cavities.

Fig. 5.61 : Milky quartz

2) Cryptocrystalline silica (SiO_2+SiO_2nH_2O) :

Crystals are partially developed. Some faces of the crystals are developed and remaining faces are not (amorphous).

Chalcedony : A fibrous variety of quartz, (Fig. 5.62), white, brown or gray in colour, shows waxy lustre and is found as cavity fillings. Name derived from the town of 'Chalcedon', a district in Istanbul, Turkey.

Fig. 5.62 : Chalcedony

Agate : A variety of chalcedony, exhibits alternate curving layers of different colours (Fig. 5.63). Name is derived from the occurrence of the stone along the shoreline of river Achates (now called Dirillo), in south western Sicily.

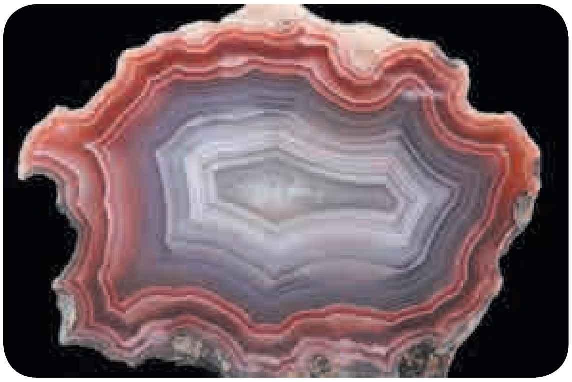


Fig. 5.63 : Agate

Onyx : Also a variety of chalcedony, exhibits alternate, parallel white and black or dark brown layers (Fig. 5.64).

Fig. 5.64 : Onyx

Jasper : An impure, opaque variety, red, brown, (Fig. 5.65) or yellow in colour. Name has its origin in the Latin word 'Gasper' from the Biblical Hebrew word 'Gizbar' meaning treasurer.

Fig. 5.65 : Jasper

Flint : Usually black or in shades of gray, found as nodules and breaks with sharp edges (Fig. 5.66). Name has been derived from Proto-Indo-European word 'Splind' meaning to split or cleave.

Fig. 5.66 : Flint

3) Amorphous silica (SiO_2nH_2O) :

There is total absence of crystallanity, not a single crystal face developed.

Opal : An amorphous variety of silica. Name derived from Sanskrit word 'Upala' meaning precious stone (Fig. 5.67).

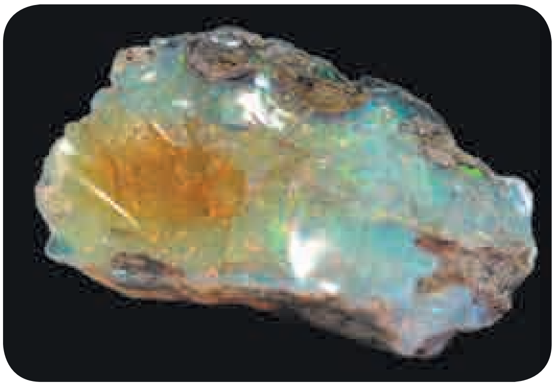


Fig. 5.67 : Opal

Physical properties of silica group :

Colour : Colourless or white, also shows variety of colours.

Streak : White.

Lustre : Vitreous, subvitreous, waxy.

Form : Prismatic, botryoidal , massive.

Cleavage : Absent.

Fracture : Conchoidal to subconchoidal, uneven.

Hardness : 5.5 - 7 (variable depending upon silica variety)

Specific gravity : about 2.65

Occurrence : It occurs in igneous rocks like granite, pegmatite; as secondary mineral within cavities of basalts; in sedimentary rocks such as sandstone and in metamorphic rocks like quartzite, schist and gneiss.

Uses : In glass, ceramics, abrasive and refractory industries, piezoelectric crystal plates used in quartz watches and also used as decorative and semi-precious stone.

Flint was used in the manufacture of tools as it has the property of splitting into thin, sharp splinters when struck by another hard object.

Amphibole group :

The name 'Amphibole' is derived from Greek word 'Amphibolus' meaning ambiguous.

Amphibole is an important group of rock forming minerals which are basically dark coloured (mafic).

Silicate structure : Amphiboles are double-chain inosilicates.

Chemical composition : These minerals are complex silicates of Mg, Fe, Ca and Al with a hydroxyl group (OH radical) present.

Varieties : Amphiboles include hornblende, tremolite and actinolite.

Hornblende : Hornblende is the most common mineral. Name is derived from German terms 'Horn' referring to its colour and 'Blende' meaning to deceive, owing to its similarity in appearance to metal-bearing ore minerals (Fig. 5.68).

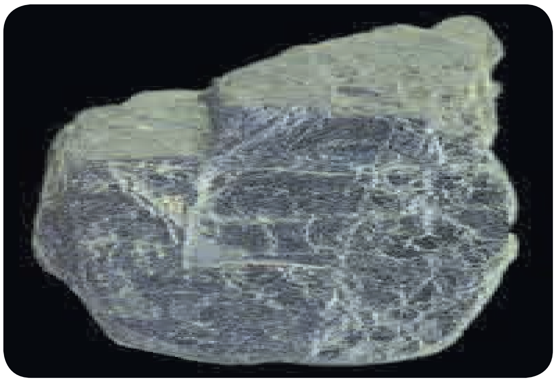


Fig. 5.68 : Hornblende

Tremolite : Name has been derived from Tremola Valley, Switzerland (Fig. 5.69).

Fig. 5.69 : Tremolite

Actinolite : Name has been derived from the Greek words 'Aktim' for ray and 'Lithos' for stone, meaning fibrous in nature (Fig. 5.70).

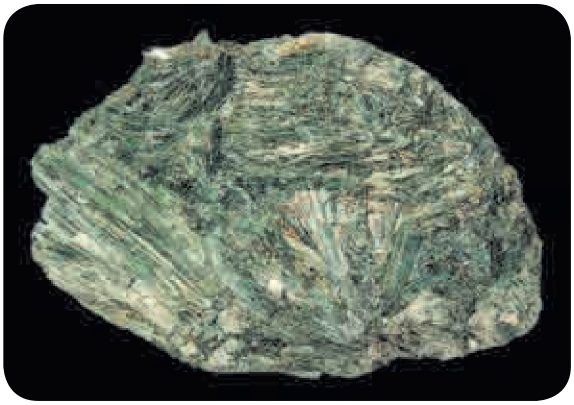


Fig. 5.70 : Actinolite

Physical properties of amphibole group :

Colour : Black, dark green, dark brown

Streak : White, colourless.

Lustre : Vitreous, silky, dull.

Form : Prismatic, acicular, fibrous, bladed, columnar and massive

Cleavage : 2 sets, prismatic, at 124^0 and 56^0.

Fracture : Uneven.

Hardness : 5 - 6

Specific gravity : 2.9 - 3.4

Occurrence : Hornblende is an important constituent of many igneous rocks such as granite, syenite, diorite and andesite. Amphiboles are common in metamorphic rocks e.g. schist and gneiss.

Uses : 'Nephrite', a variety of amphibole is fibrous aggregate of actinolite and tremolite. It is used as a gemstone, in sculptures, jewellery, tools, etc.

Pyroxene group :

The name 'Pyroxene' has its origin in the Greek words- 'Pyro' meaning fire and 'Xenox' meaning stranger.

Pyroxene is an important rock forming mineral group, which is similar to amphibole group, except for different atomic structure and the absence of hydroxyl group (OH radical).

Silicate structure : All pyroxenes are single chain inosilicates.

Chemical composition : Pyroxenes are complex silicates of Mg, Fe, Ca and Al.

Varieties : Pyroxenes are a group of allied minerals. The common members of this group are augite and hypersthene.

Augite : $(Ca, Na, Mg, Fe, Mn, Ti, Al)_2(Al, Si)_2O_6$ is a common brownish black variety.

Name has been derived from the Greek word 'Auge' meaning shine or lustre, in allusion to the appearance of its cleavage surface (Fig. 5.71).

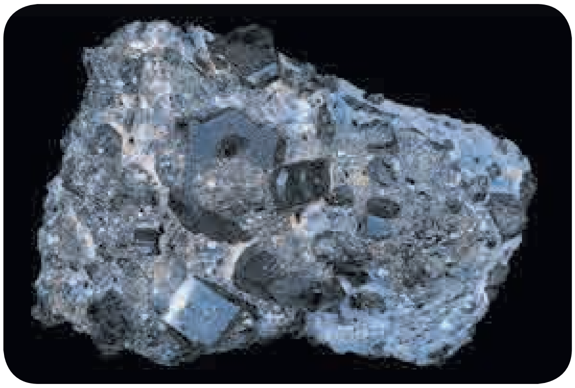


Fig. 5.71 : Augite

Hypersthene : $(Mg,Fe)SiO_3$

It is gray or greenish black in colour with metallic lustre.

Name has its origin from the Greek words 'Hyper' meaning exceeding, 'Sthenos' meaning strength (Fig. 5.72).

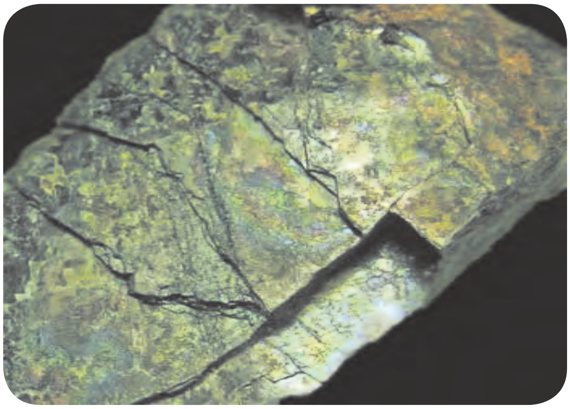


Fig. 5.72 : Hypersthene

Physical properties of pyroxene group :

Colour : Gray, greenish brown, brownish black.

Streak : White or pale body colour

Lustre : Vitreous, subvitreous.

Form : Prismatic, granular, massive.

Cleavage : Two sets, at nearly 90^0.

Fracture : Uneven

Hardness : 5 - 6

Specific gravity : 3.22 - 3.56 (increases with Fe content)

Occurrence : Pyroxenes are found in basic and ultrabasic igneous rocks like gabbro, dolerite, basalt and peridotite.

Augite is found in metamorphic rocks like schist and gneiss and hypersthene is found in charnockites and granulites.

Uses : Used in ceramics. Jadeite is used as a gemstone.

Do you know?

Nephrite (an amphibole) and Jadeite (a pyroxene) are two different minerals which together form mineral Jade.

Mica group :

Micas are important rock forming minerals. They can be cleaved into thin elastic plates.

Name Mica has its origin in the Latin word 'Micare' meaning to flash or glisten.

Silicate structure : All micas are phyllosilicates.

Chemical composition : Micas are silicates of Al and K with Mg or Fe. Some varieties contain Na, Li or Ti. Hydroxyl group is present in micas and is partially replaced by fluorine.

Varieties :

Muscovite : Hydrated silicate of Aluminium and Potassium with Fluorine, silvery white in colour. Name Muscovite originated from 'Muscovy glass' because it came from Muscovy province of Russia (Fig. 5.73).

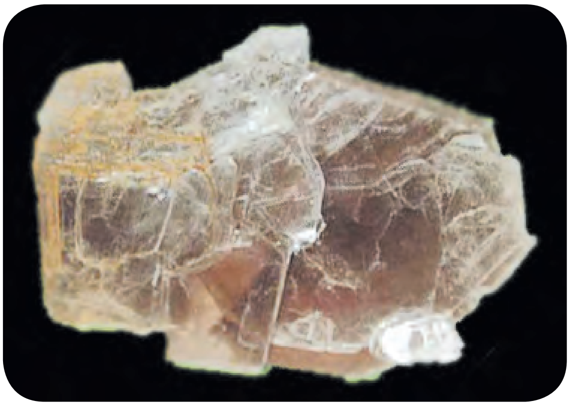


Fig. 5.73 : Muscovite

Biotite : Hydrated silicate of Mg, Fe, Al, and K with F, black to brown in colour (Fig. 5.74).

Fig. 5.74 : Biotite

Physical properties of mica group :

Colour : Colourless, silvery white, dark green, brown, black.

Streak : White, colourless.

Lustre : Pearly, silky.

Form : Foliated, flaky, lamellar

Cleavage : One set, perfect

Fracture : Uneven.

Hardness : 2 - 3

Specific gravity : 2.76 - 3.1

Occurrence : In igneous rocks, it occurs in pegmatite and granite; in sedimentary rocks such as sandstone and in metamorphic rocks like schist and gneiss.

Uses : As insulator in electrical industries, as filler in rubber, in lubricants and paints, has wide applications in ayurvedic medicines.

> **Do you know?**
>
> Mica is a good electrical insulator that can withstand extremely high temperatures. It is commonly used in equipments like toasters, electric irons and hair dryers where the heating elements are sandwiched between mica sheets.

Olivine group :

Like amphiboles and pyroxenes, olivines are also mafic i.e., dark coloured minerals.

Silicate structure : Olivines are nesosilicates.

Chemical composition : Olivine is chemically $(Mg,Fe)_2SiO_4$ with two end members, forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4).

Varieties : The olivine group consists of an isomorphous series between forsterite and fayalite.

Forsterite : It is green, yellow, yellowish green, white.

Fayalite : It is greenish yellow, yellowish brown or brown.

Olivine : It has been named after its typical olive green colour (Fig. 5.75).

Fig. 5.75 : Olivine

Physical properties of olivine group :

Colour : Usually olive green.

Streak : White.

Lustre : Vitreous, but often shows dull lustre due to alteration by weathering.

Form : Granular, massive.

Cleavage : Absent

Fracture : Conchoidal to uneven.

Hardness : 6.5 - 7

Specific gravity : 3.2 - 4.3 (depending on Fe content)

Occurrence : It occurs in monomineralic ultrabasic igneous rocks like dunite. It also occurs in rocks like peridotite (olivine and pyroxene), basalt, dolerite and gabbro.

Uses : Olivine is used in the manufacture of refractory bricks and its variety Peridot is used as a gemstone.

Zeolite group :

The term 'Zeolite' was originally coined by Swedish mineralogist Axel Fredrick Cronstedt, who observed that rapid heating of the mineral produced large amounts of steam from water that had been adsorbed by the mineral. Based on this, he named the mineral as Zeolite, from the Greek word 'Zein' meaning to boil.

Silicate structure : Zeolites are tectosilicates.

Chemical composition : Zeolites are aluminosilicates of alkali and alkaline earth metals.

Do you know?

Zeolites belong to the family of solids known as 'molecular sieves'. Molecular sieves are crystalline metal aluminosilicates having a three dimensional interconnecting network of silica and alumina tetrahedra. Natural water of hydration is removed from this network by heating, to produce uniform cavities which selectively adsorb molecules of a specific size.

Varieties :

Heulandite : Named after John Henry Heuland, a British mineral collector and dealer (1778-1856). It shows tabular form and vitreous to pearly lustre (Fig. 5.76).

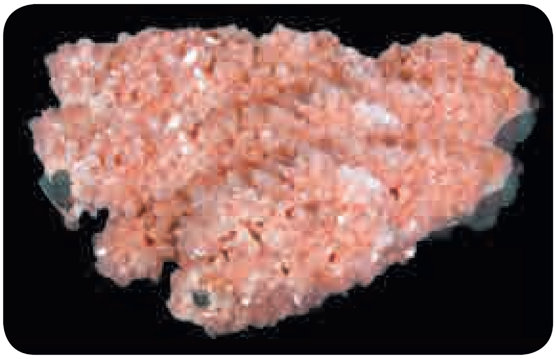


Fig. 5.76 : Heulandite

Stilbite : Originated from the Greek word 'Stilbein' meaning to glitter or shine or 'Stilbe' a mirror, alluding to its pearly or vitreous lustre. It shows unique 'bowtie' form (Fig. 5.77).

Fig. 5.77 : Stilbite

Scolecite : Named from the Greek word 'Skolex' which means worm, with reference to the mineral's reaction to a blowpipe flame. Crystals radiate out from a centre without producing stellar forms (Fig. 5.78).

Fig. 5.78 : Scolecite

Mesolite : Originated from the Greek word 'Meso' meaning middle and 'Lithos' meaning stone, due to its chemical composition being in between that of Natrolite and Scolecite. It shows cotton-ball cluster of acicular white crystals (Fig. 5.79).

Fig. 5.79 : Mesolite

Physical properties of zeolite group :

Colour : White, red, pink, yellow, brown.

Streak : White

Lustre : Pearly to vitreous.

Form : Crystals are usually thin and delicate, acicular or may occur as sheaf-like aggregates.

Cleavage : Perfect, one or two sets.

Fracture : Subconchoidal to uneven.

Hardness : 3.5 - 5.0

Specific gravity : 2.1 - 2.4

Occurrence : They usually occur in cavities and veins of volcanic basic rocks such as basalts (Deccan trap), also in acid igneous rocks like rhyolite. Few zeolite minerals occur in tuffaceous sediments.

Uses : Zeolites are mainly used in domestic and commercial water softening and purification.

5.8 : Rock forming minerals :

Apophyllite :

Apophyllite, according to recent studies, is the name of a group of minerals and is not a specific mineral title.

It is generally found along with zeolites and has very high water content.

The name apophyllite has been derived from Greek words 'Apo' meaning away from and 'Phyll' meaning leaf, referring to its tendency to exfoliate (i.e. flake apart like a leaf) when heated due to loss of water.

Silicate structure : Apophyllite is a phyllosilicate.

Chemical composition :
$(K,Na)Ca_4Si_8O_{20}(F,OH).8H_2O$

Varieties : On the basis of variable ratio of fluorine and hydroxyl group, apophyllites can be differentiated into the following mineral species :

i) **Fluorapophyllite :** White, colourless, yellow, green, (F > OH); (Fig. 5.80).

Fig. 5.80 : Fluorapophyllite

ii) **Hydroxyapophyllite :** White, colourless, (OH > F); (Fig. 5.81).

Fig. 5.81 : Hydroxyapophyllite

iii) Natroapophyllite : Brown, yellow, colourless, (K replaced by Na) (Fig. 5.82).

Fig. 5.82 : Natroapophyllite

Physical properties of apophyllite :

Colour : Usually white, green, yellow, also blue, brown, pink, violet.

Streak : White

Lustre : Vitreous, pearly

Form : Prismatic, tabular, massive

Cleavage : Perfect, one set.

Fracture : Uneven

Hardness : 4.5 - 5

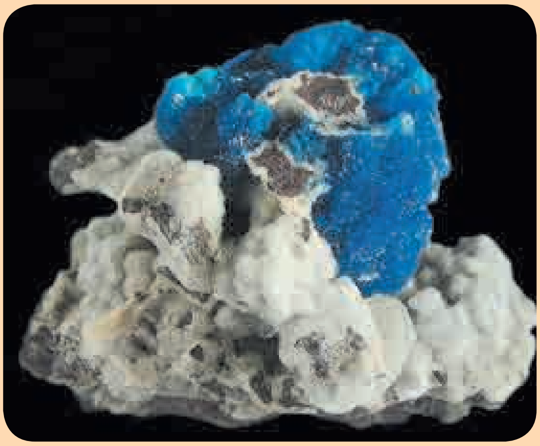
Specific gravity : 2.3 - 2.4

Occurrence : Apophyllite is a secondary mineral which occurs as cavity fillings in vesicles of volcanic igneous rocks like basalt.

Uses : As a decorative mineral and as an ornamental stone.

Do you know?

Cavansite is also found along with zeolites and apophyllite. It is found in many regions of the world, but it is generally accepted that the ones from Wagholi Dist, Pune, Maharashtra excel in quality and quantity to those found in other countries.



A cluster of cavansite mineral crystals shown on a bed of microcrystalline stilbite, quarried in Wagholi, Pune, Maharashtra.

Talc :

Mineral talc (Fig. 5.83) is a soft, non-metallic mineral.

The name has been derived from Arabic word 'Talq', due to the pure colour of its powder.

Silicate structure : Talc is a phyllosilicate.

Chemical composition : Talc is hydrated magnesium silicate, $Mg_3Si_4O_{10}(OH)_2$.

Varieties :

i) **Soapstone or Steatite (Talc schist) :** It is a metamorphic rock composed predominantly of talc which has a soft texture and soapy feel.

ii) **Pot stone :** It is impure Steatite, hard, grey or black coloured, used especially in prehistoric times to make cooking vessels.

iii) **French chalk :** It is a kind of Steatite used for marking cloth and removing grease, also used in powder form as a dry lubricant.

Fig. 5.83 : Talc

Physical properties of talc :

Colour : White, pale green, brown, gray, yellowish white, brownish white.

Streak : White

Lustre : Vitreous, pearly, greasy, waxy.

Form : Foliated, fibrous.

Cleavage : One set, perfect.

Fracture : Uneven

Hardness : 1 (Mohs' scale), very soft and easily scratched by finger nail.

Specific gravity : 2.7 - 2.8

Occurrence : Talc commonly occurs in metamorphic rocks like talc schists.

Uses : Talc is used in paint, paper, ceramics, plastics, cosmetics and talcum powders. Soapstone is used to make ornamental objects, sculptures, bowls, countertops, sinks, etc.

Do you know?

During Stone age, the people of Scandinavia used soapstone carved moulds to cast metal objects such as knife blades and spear heads.

Seals of Mohenjodaro and Harappan civilization were made from soapstone (steatite).

Gypsum :

Name 'Gypsum' originated from the Greek word 'Gypsos' meaning plaster. Mineral gypsum found in abundance near Paris is called Plaster of Paris.

Gypsum is the most common sulphate mineral found on the Earth's crust, extracted, processed and used by man in construction or decoration in the form of plaster and alabaster since 9000 BCE.

It is an indefinitely recyclable raw material which can be reused because the chemical composition of the raw material in the final product remains unchanged.

Silicate structure : Gypsum is a non-silicate mineral belonging to sulphate group i.e. it lacks silicon.

Chemical composition : Hydrated calcium sulphate, ($CaSO_4 2H_2O$).

Varieties :

i) **Alabaster gypsum :** Fine grained and off white coloured (Fig. 5.84).

Fig. 5.84 : Alabaster gypsum

ii) **Selenite gypsum :** Transparent and bladed (Fig. 5.85).

Fig. 5.85 : Selenite gypsum

iii) **Satinspar gypsum :** Pearly and fibrous (Fig. 5.86).

Fig. 5.86 : Satinspar gypsum

Physical properties of gypsum :

Colour : Colourless, milky white, grayish, yellowish, red or brown

Streak : White

Lustre : Vitreous, pearly, silky.

Form : Elongated and generally as prismatic crystals, granular, lamellar, fibrous.

Cleavage : Perfect, 2 sets.

Fracture : Hackly, brittle.

Hardness : 2 (Mohs' scale)

Specific gravity : 2.31 - 2.33

Occurrence : As an evaporite mineral and as a hydration product of anhydrite, in bedded deposits associated with limestones, shales and salt deposits, also formed by precipitation from natural waters.

Uses : In the manufacture of plaster of paris, blackboard chalk, wallboard, in cement industry to control the setting or hardening time of cement, as a fertilizer for plant growth in soils with deficiency of Ca and S.

Calcite :

Calcite is one of the most common minerals on the surface of the Earth. It is the crystalline form of $CaCO_3$, occuring as chalk, limestone and marble (Fig. 5.87).

Silicate structure : It is a non-silicate mineral belonging to the carbonate group.

Chemical composition : Calcite is calcium carbonate ($CaCO_3$).

Varieties : Iceland spar : Pure, transparent and colourless showing double refraction (Fig. 5.88).

Fig. 5.87 : Calcite

Fig. 5.88 : Iceland spar

Physical properties of calcite :

Colour : Colourless, white, gray, black, brown, yellow, red, blue, green

Streak : White.

Lustre : Vitreous, pearly, resinous, dull.

Form : Crystalline (rhombohedral), massive

Cleavage : Perfect, 3 sets.

Fracture : Uneven, conchoidal (rarely observed due to perfect cleavage).

Hardness : 3 (Mohs' scale)

Specific gravity : 2.71 - 2.94

Occurrence : Calcite occurs in sedimentary rocks like limestone and metamorphic rocks such as marble, as vein and cavity fillings in igneous rocks like basalt and as deposits in limestone caves.

Uses : The pure variety of calcite i.e. Iceland spar is used in the manufacture of optical lenses, optical instruments and Nicol's prism. Calcite is used in cement industry, in manufacture of soap, paints, paper, abrasive, in soil treatment as a conditioner and also in medicines (Fig. 5.88).

Do you know?

We can differentiate between the minerals Gypsum and Calcite with an acid test. Calcite ($CaCO_3$) gives effervescence of CO_2 even when cold weak acids such as vinegar are placed on the specimen, whereas Gypsum ($CaSO_4.2H_2O$) shows no reaction.

$$CaCO_3 + 2H^{(+1)} \rightarrow Ca^{(+2)} + H_2O + CO_2 \uparrow$$

Fluorite :

The name Fluorite (Fig. 5.89) was derived from Latin word 'Fluere' meaning to flow. In the mining industry, it is often called Fluorspar.

Silicate structure : Fluorite is a non-silicate mineral belonging to halide group.

Chemical composition : Calcium fluoride (CaF_2)

Fig. 5.89 : Fluorite

Physical properties of fluorite :

Colour : Colourless, deeply coloured due to impurities.

Streak : White

Lustre : Vitreous, dull

Form : Crystalline (octahedral), massive

Cleavage : Four sets, often cleaves into perfect octahedrons.

Fracture : Subconchoidal, uneven.

Hardness : 4 (Mohs' scale)

Specific gravity : 3.18 - 3.56

Occurrence : It is a very common rock forming mineral. It often occurs as a gangue mineral associated with metallic ores deposited in veins by hydrothermal processes. It is also found in fractures and cavities of some sedimentary rocks such as limestones and dolomites.

Uses : Fluorite is an important industrial mineral used in chemical, metallurgical and ceramic industries. It is also used as a gemstone and ornamental stone.

Do you know?

The Smithsonian National Museum of Natural History is the world's largest museum and research complex located in Washington D.C. It opened in 1910 and today houses about 3,75,000 mineral specimens from around the world. It is one of the largest collections of its kind with great value to the scientific community. The purpose of the collection is to support scientific research.

Summary :

- Minerals are identified and described by observation and analytical methods There are about 5,389 mineral species recognised.
- Minerals derive their names after their founders, localities where they were found irst or from their chemical composition and physical properties.
- Depending upon chemical composition and atomic structure, minerals exhibit different physical properties like colour, streak, lustre, form, cleavage, fracture, hardness and specific gravity. These are readily used to identify and differentiate minerals.
- Based on chemical composition, minerals are classified as oxides, sulphates, halides, carbonates and silicates. Silicates are most abundant and are classified according to their structures as nesosilicates, sorosilicates, cyclosilicates, phyllosilicates and tectosilicates.
- Rocks are aggregates of minerals which give us clues to the rock forming processes.

EXERCISE

Q.1. Fill in the blanks :

1) Silicates make up over .... % of the Earth's crust.
2) Mohs' scale is .... and ....

Q. 2. Match the correct pairs :

1)

Minerals	**Characters**
a) Amethyst	i) Numerous air cavities
b) Rose Quartz	ii) Fe impurity
c) Milky Quartz	iii) Ti impurity
d) Onyx	iv) Alternate, parallel white and black layers

1) a-ii, b-iii, c-i, d-iv
2) a-iii, b-iv, c-ii, d-i
3) a-i b-ii, c-iii, d-iv
4) a-iv b-i, c-iii, d-ii

2)

Silicate structure	**Mineral**
a) Nesosilicates	i) Olivine
b) Sorosilicates	ii) Beryl
c) Cyclosilicates	iii) Mica
d) Phyllosilicates	iv) Epidote

1) a-i, b-ii, c-i, d-iv
2) a-i, b-iv, c-ii, d-iii
3) a-iv, b-i, c-iii, d-ii
4) a-iii, b-iv, c-i, d-iv

Q. 3. Complete the series :

1) Complete the plagioclase series:-
   Albite, ..., ..., ..., ..., ...
   a) Albite, Oligoclase, Andesine, Labradorite, Bytownite, Anorthite
   b) Albite, Anorthite, Bytownite, Andesine, Labradorite, Oligoclase
   c) Albite, Andesine, Anorthite, Bytownite, Labradorite, Oligoclase
   d) Albite, Oligoclase, Labradorite, Bytownite, Anorthite, Andesine
2) Write the Hardness scale in the ascending order.
   Talc, ..., ..., ..., ..., ...
   a) gypsum, corundum, diamond, fluorite, quartz
   b) corundum, gypsum, fluorite, diamond, quartz
   c) diamond, quartz, corundum, gypsum, fluorite
   d) gypsum, fluorite, quartz, corundum, diamond

Q. 4. Identify the odd one out :

1) Agate, onyx, jasper, flint, opal
2) Heulandite, stilbite, mesolite, scolecite, forsterite
3) Sorosilicate, cyclosilicate, inosilicate, nesosilicate, phyllosilicate

Q. 5. Give geological terms :

1) Flat blade-like form exhibited by mineral kyanite.
2) Exceptionally brilliant lustre exhibited by minerals having very high refractive index.
3) Highly irregular broken surface with sharp projections.

Q. 6. Choose the correct alternative :

1) Minerals which glow after being exposed to ultraviolet light are said to be ....
   a) fluorescent   b) Radioactive
   c) Iridescent   d) Opalescent
2) Amphiboles are .... silicates
   a) Hydrous ferromagnesian
   b) Ferromagnesian
   c) Potassium - aluminium
   d) Hydrated alumino

Q.7. Distinguish between :

1) Mica and Apophyllite
2) Calcite and Fluorite

Q. 8. State whether the statement is True or False and correct the False statement :

1) Fluorite and calcite are silicates in composition.
2) Cubic Zirconia is considered as a mineral.

Q. 9. Give geological reasons :

1) Minerals of the same composition exhibit different colours.
2) Opal is classified as amorphous silicate.

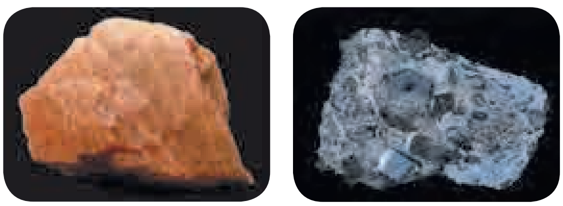
Q. 10. Explain the concept :

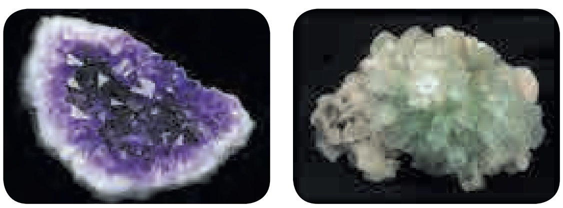
1) Lustre and hardness.
2) Degree of cooling and crystallization in silica.
3) Streak and hardness.

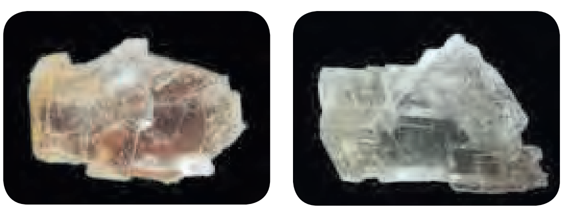
Q. 11. Long answer questions :

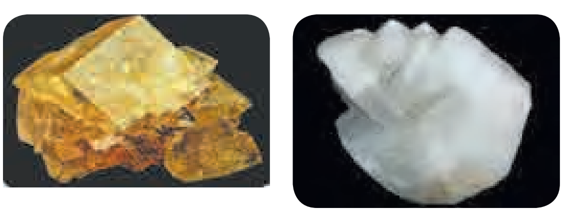
1) Discuss in detail the criteria for classifying a substance as a mineral.
2) Give the interdependence of cleavage, hardness and lustre citing suitable examples.
3) Enumerate and describe the forms dependant on the degree of crystallization. Give suitable examples.
4) Describe with examples, forms independent of the degree of crystallization.

Activity no. 1 : Observe the photographs, identify and distinguish between the following pairs :

A) 

B) 

C) 

D) 

Activity no. 2 : Crossword

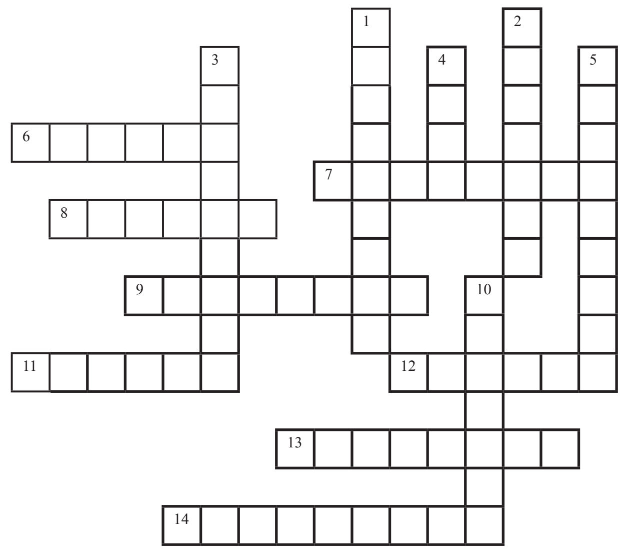
Name the common minerals, using the given information.

DOWN :

1) a naturally magnetic mineral
2) a bright blue copper carbonate
3) metamorphic quartz sandstone
4) a silicate mineral known for its perfect cleavage resulting in thin sheets
5) strontium sulphate its name means celestial
10) a common carbonate mineral often a replacement mineral in fossils

ACROSS :

6) the main source of lead
7) an iron ore, sometimes used in jewellery
8) sometimes called fool's gold
9) sulphide mineral, long metallic slender bladed crystals
11) a very heavy sulphate mineral
12) rock salt
13) calcium fluoride
14) a bright green copper carbonate



Activity no. 3 : Observe the back cover of your text book and answer the following question :

1) Name the 'Father of Mineralogy'.
2) Classify the stamps into their mineral classes.
3) List the minerals found within the state of Maharashtra.
4) Ice is considered as a mineral - Justify.
5) Identify and name the native elements depicted in the stamps.
6) Sort the minerals containing (OH) group in their chemical composition.
7) Categorise the minerals having 'Water of Crystallisation' in their chemical composition.
8) Find and name all the minerals with 'Ca' in their chemical composition.
9) List all the minerals which are oxides.
10) Enumerate all the carbonate minerals.

Activity no. 4 : Collect the information on minerals museums in the state of Maharashtra/India.