Classification of Minerals

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Objectives

- After attending this module, the user would be able to know and explain the chemical classification of minerals and the types of minerals belonging to various classes and groups.
- The mineral kingdom is a very vast area in the subject of earth sciences. Mineralogy is a perfect physical science.

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Objectives

- About two thousand dominant minerals are popular and existing over the world, which are known for their unique properties.
- The study of the chemical classification of minerals is an essential topic in the subject of mineralogy.

Introduction

- Lithosphere is the solid layer of the planet earth. It is the rocky segment, holding all natural resources including the energy resources, water resources, mineral resources and the biotic resources. Everything is existing, on earth, for human survival.

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Introduction

- Earth's economic resources include thousands of minerals belonging to the Mineral Kingdom.
- Every segment of the human society uses the mineral resources, in one form or the other, everyday, directly or indirectly. There are many minerals which have commercial and industrial importance.

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Introduction

- While studying the minerals, the classification of minerals becomes a basic priority as there are numerous groups occurring in different parts of the world. There is a need to classify the minerals and study their properties. This module highlights the widely used chemical classification of minerals.

Crustal abundance of elements

The Earth's crust is dominated by eight abundant chemical elements. They are :

- Oxygen 47%
- Silicon 27%
- Aluminum 8 %
- Iron 5%
- Calcium 3.6%
- Sodium 2.8%
- Potassium 2.6 %
- Magnesium 2 % and all other elements about 1 %.

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Crustal abundance of elements

- Silicon and oxygen are the two most abundant elements present in the earth's crust. The other elements, following these two, are aluminium, iron, calcium, sodium, potassium, magnesium, hydrogen, phosphorous, barium, and strontium.

- It is to be noted that the metals like copper, lead, zinc, nickel, and tin which play an important role in all our modern technology, are present only in very small proportions.

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Crustal abundance of elements

- The most abundant minerals in the earth's crust are the silicates. Non-silicates constitute less than 10% of the Earth's crust.
- The most common non-silicates are the carbonates, the oxides, and the sulfides. There are also naturally occurring phosphates and salts.

The World of Minerals

- Minerals are naturally formed elements or compounds, having a definite chemical composition and, usually, a characteristic crystal form.
- Minerals are valuable resources for live support activities of the human population. Minerals are naturally occurring inorganic substances.

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The World of Minerals

- Every mineral can be identified by several of its physical properties and crystal chemistry.
- There are nearly 3700 minerals occurring on the earth, out of which about two dozen minerals are common, making upto 90% of the mineral constituents in the earth's crust.

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The World of Minerals

- Minerals may be composed of a single element, like gold (Au) or a combination of elements.
- Minerals which are composed of more than one element are bound together by chemical bonding. All minerals formed by more than one element are bound together by positive and negative ions.

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The World of Minerals

- Minerals are formed from various processes and source materials.
- Their growth are controlled by various physic-chemical conditions including the mass-balance, role of fluids, temperature, pressure, depth or other factors of the environment.

Classification of Minerals

- Of all the characters of minerals, the chemical constitution is the most fundamental, and it naturally takes an important position in any rational system of classification.
- Initially, grouping of minerals have been attempted according to their association in the field.

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Classification of Minerals

- Then the diversity of elements was considered.
- The crystallographers and mineralogists compared the salts that have similar crystalline structure and classified the minerals.
- An economic classification was also brought forward based on their utility point of view.

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Classification of Minerals

- Later, a comprehensive classification was proposed by arranging the minerals by the important fundamental element present in them.
- These elements were considered in the order of Mendeleev's periodic table. By this method, the ores of any one metal are kept together, while at the same time little violence is done to isomorphous groups.

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Classification of Minerals

- The silicates are complex in composition and form a very important a rock-forming group.
- They are best kept as a division by themselves. Inside this great division, if the whole range of the silicates is to be considered, the arrangement adopted in “Dana's System of Mineralogy" was found to be convenient.

The Structure of Classification

- In the field of Mineralogy, the organizational structure created by James Dwight Dana, aptly named as Dana's System of Mineralogy is the widely accepted classification system for the study of minerals.
- Dana was the first person to classify minerals into an arrangement by composition and structure.

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The Structure of Classification

- The first five editions of *A System of Mineralogy*, were published in 1837, 1844, 1850, 1854, and 1868, and were authored or revised by James Dwight Dana.
- Minerals are first separated into classes by anion.

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The Structure of Classification

- The main classes are Elements, Oxides, Halides, Sulfides, Carbonates, Phosphates, and Silicates. There are many subclasses still based on composition.
- Smaller groups that are chemically similar are often grouped together.

Chemical classification of minerals

The chemical classification of minerals broadly divides them into the following ten classes:

1. Native elements, Native metals and Alloys, Carbides, Silicides, Nitrides & Phosphides.
2. Sulfides, Sulfosalts, Sulfarsenates & Sulfantimonates
3. Halogenides, Oxyhalides & Hydroxyhalides.

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Chemical classification of minerals

4. Oxides and Hydroxides-Vanadates, Arsenites, Antimonites, Bismuthites, Sulfites, Iodates
5. Carbonates and Nitrates
6. Borates
7. Sulfates, Selenates, Chromates, Molybdates, Wolframates & Niobates
8. Phosphates, Arsenates, Vanadates & Polyvanadates
9. Silicates
10. Organic Compounds.

Class : Native elements, Native metals and Alloys, Carbides, Silicides, Nitrides, Phosphides

- The Native elements, as the name implies, are minerals containing individual or combined chemical elements.
- Native element minerals occur in nature in uncombined form with a distinct mineral structure.

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Class : Native elements, native metals and Alloys,

Carbides, Silicides, Nitrides, Phosphides

The elemental class includes four sub-classes as

- Metals and inter-metallic elements,
- Naturally occurring alloys,
- Semi-metals and
- Non-metals.

The Elements Class contains minerals that are composed of more than one element.

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Class : Native elements, native metals and Alloys, Carbides, Silicides, Nitrides, Phosphides

- These Elements, by the chemical definition are composed of all the same atoms; whereas substances composed of two or more elements are compounds.
- The Metals and their alloys and the Nonmetals belong to this group. Metal alloys are minerals that are composed of combinations of different metals in one mineral.

Sub-class: Native Metals and Alloys

The native metals include the following:

- Aluminum Al
- Cadmium Cd
- Chromium Cr
- Copper Cu
- Gold Au
- Indium In
- Iridium (Ir, Os, Ru)

(…Contd)

Sub-class: Native metals and Alloys

- Iron Fe
- Lead Pb
- Mercury Hg
- Nickel Ni
- Palladium Pd
- Platinum Pt
- Rhodium (Rh, Pt)
- Silver Ag
- Tellurium Te
- Tin Sn
- Titanium Ti
- Zinc Zn.

Metallic Alloys

- Metal alloys are the combinations of metals. Under this group, the following combination of elements lead to the formation of various minerals.
- The combination of Iron + Nickel is reflected in the minerals like Kamacite alpha, Taenite beta - and Tetrataenite.

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Metallic Alloys

- The combination of Copper + Zinc is reflected in the minerals like Brass (Cu_3Zn_2) and Danbaite ($CuZn_2$).
- The combination of Copper + Zinc + Aluminum is reflected in the minerals like Cupalite (Cu, Zn)Al.
- The combination of Copper + Mercury is reflected in the minerals like Belendorffite (Cu_7Hg_6).

(…Contd)

Metallic Alloys

- The combination of Copper + Gold is reflected in the minerals like Auricupride (Cu_3Au).
- The combination of Gold + Copper is reflected in the minerals like Tetra auricupride (AuCu).
- The combination of Gold+ Silver + Lead is reflected in the minerals like Hunchunite $(Au, Ag)_2Pb$.

(…Contd)

Metallic Alloys

- The combination of Iridium + iron is reflected in the minerals like Chengdeite (Ir_3Fe).
- The combination of Silver + Mercury is reflected in the minerals like Eugenite (Ag_9Hg_2).

Native Non-metals and Semi-metals

The Native Non-metals and Semi-metals include the following.

1. Antimony (Sb)
2. Arsenic (As)
3. Bismuth (Bi)
4. Diamond (C)
5. Graphite (C)

(…Contd)

Native Non-metals and Semi-metals

6. Selenium (Se)
7. Silicon (Si)
8. Sulfur (S)
9. Tellurium (Te)

Minerals with metallic and non-metallic elements include mostly Iron + Nickel in combination with non-metals like P, C, Si and N.

Class : Sulfides, Sulfosalts, Sulfarsenates, Sulfantimonates

- The sulphide class includes four categories of minerals as Sulfides, Sulfosalts, Sulfarsenates and Sulfantimonates.
- A group of minerals that are compounds of one or more metallic elements combined with the non-metallic element Sulfur.
- The Sulfides also occur as economically important class of minerals.

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Class : Sulfides, Sulfosalts, Sulfarsenates, Sulfantimonates

- Most major ores of important metals such as copper, lead and silver are all occurring as sulfide minerals in nature.
- This family includes, minerals of Sulphides & sulfosalts, Selenides, Telluride, Antimonide and Arsenides.

The Standard Sulfides

- Sulfur ions (S^{2-}) bind with a number of positive ions to form the sulfide minerals. Many of them are important ores for the ions to which they bind.

Antimony Sulfide	occurring as	Stibnite
Arsenic Sulfide	occurring as	Orpiment and Realgar
Bismuth Sulfide	occurring as	Bismuthinite
Cadmium Sulfide	occurring as	Greenockite
Cobalt Arsenic Sulfide	occurring as	Cobaltite

(…Contd)

The Standard Sulfides

▪ Copper Antimony Sulfide	occurring as	Famatinite
▪ Copper Iron Sulfide	occurring as	Bornite, Chalcopyrite and Cubanite
▪ Copper Iron Tin Sulfide	occurring as	Stannite
▪ Copper Sulfide	occurring as	Chalcocite, Covellite & Digenite

(…Contd)

The Standard Sulfides

▪ Iron Arsenic Sulfide	occurring as	Arsenopyrite
▪ Iron Nickel Sulfide	occurring as	Pentlandite
▪ Iron Sulfide	occurring as	Marcasite, Pyrite & Pyrrhotite
▪ Lead Sulfide	occurring as	Galena
▪ Manganese Sulfide	occurring as	Alabandite
▪ Mercury Sulfide	occurring as	Cinnabar

(…Contd)

The Standard Sulfides

▪ Mercury Sulfide	occurring as	Meta-cinnabar
▪ Molybdenum Sulfide	occurring as	Molybdenite
▪ Nickel Sulfide	occurring as	Millerite & Polydymite
▪ Silver Germanium Sulfide	occurring as	Argyrodite
▪ Silver Iron Sulfide	occurring as	Argentopyrite

(…Contd)

The Standard Sulfides

▪ Silver Iron Sulfide	occurring as	Sternbergite
▪ Silver Selenium Sulfide	occurring as	Aguilarite
▪ Silver Sulfide	occurring as	Argentite
▪ Tungsten Sulfide	occurring as	Tungstenite
▪ Vanadium Sulfide	occurring as	Patronite
▪ Zinc Iron Sulfide	occurring as	Sphalerite

Sulfosalts

- The sulfosalts are typical minerals occurring with the combinations of copper, iron, lead, silver, arsenic, bismuth, antimony and tin. The major minerals and their composition are as follows:

▪ Chalcostibite	containing	Copper Antimony Sulfide
▪ Enargite	containing	Copper Arsenic Sulfide
▪ Emplectite	containing	Copper Bismuth Sulfide
▪ Berthierite	containing	Iron Antimony Sulfide

(…Contd)

Sulfosalts

▪ Cylindrite	containing	Iron Lead Tin Antimony Sulfide
▪ Boulangerite	containing	Lead Antimony Sulfide
▪ Gratonite	containing	Lead Arsenic Sulfide
▪ Bournonite	containing	Lead Copper Antimony Sulfide
▪ Aikinite	containing	Lead Copper Bismuth Sulfide

(…Contd)

Sulfosalts

▪ Franckeite	containing	Lead Tin Iron Antimony Sulfide
▪ Miargyrite	containing	Silver Antimony Sulfide
▪ Proustite	containing	Silver Arsenic Sulfide
▪ Matildite	containing	Silver Bismuth Sulfide
▪ Polybasite	containing	Silver Copper Antimony Sulfide and
▪ Andorite	containing	Silver Lead Antimony Sulfide.

Class : Halogenides, Oxyhalides & Hydroxyhalides

- This class includes Halogenides, Oxyhalides and Hydroxyhalides. The Halides are a group of minerals whose principle anions are halogens.
- Most of the halides are very soft and easily dissolved in water. Halite and Fluorite are the well known examples of this group.
- The halogens that are found commonly in nature include Chlorine, Bromine, Iodine and Fluorine.

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Class : Halogenides, Oxyhalides & Hydroxyhalides

This group of minerals includes

a) Anhydrous Chlorides, Bromides, Iodides, and Fluorides.

b) Oxychlorides and Oxyfluorides

c) Hydrous Chlorides and Hydrous Fluorides.

The common minerals of Anhydrous Halides include Calomel – (horn quicksilver)- which Mercurous Chloride.

Halite group

Halite is commonly known as rock salt. It is the mineral form of sodium chloride (Na Cl). The halite group include the following minerals:

- Halite- NaCl- the common Rock salt.
  It is the salt which is used in our daily diet.
- Sylvite- KCl- potassium chloride.
- Sal Ammoniac- (NH4)Cl- ammonium chloride.
- Villiaumite – NaF – sodium fluoride.

Fluorite group

Fluorite which is also called fluorspar, is a halide mineral. It is composed of calcium fluoride, CaF_2.

This group include the following minerals:

- Fluorite (Fluor spar)- Calcium Fluoride
- Cryolite – Fluoride of Sodium and Aluminum

Oxychlorides and Oxyfluorides

- Oxychloride is a compound having oxygen and chlorine atoms bonded to another element.
- This group includes the mineral Atacamite. It is a Hydrated copper oxychloride.
- In addition, there are Hydrous Chlorides and Hydrous Flurides.

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Oxychlorides and Oxyfluorides

The major minerals of these groups include

- Carnallite, which is a hydrated potassium magnesium chloride and
- Prosopite which is a hydrated calcium aluminum fluoride.

Class : Oxides and Hydroxides

- The Class on Oxides and Hydroxides include a wide variety of minerals belonging to Vanadates, Arsenites, Antimonites, Bismuthites, Sulfites and Iodates. Oxygen is the most abundant element in the Earth's crust.
- It bonds readily with a number of metallic ions to form the oxides. These oxides form important ores for the metal resources.

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Class : Oxides and Hydroxides

- Most of the industrial minerals belong to this group. Important minerals of the Oxide Group are the following:
  - Oxides of Silicon
  - Oxides of semi-metals
  - Oxides of metals and
  - Intermediate oxides.

Oxides of Silicon

- Quartz is one the major mineral group present in almost all rocks of the earth due to its abundance. The major minerals are
- Quartz Group of minerals containing SiO_2 as their composition.
- Tridymite which is also a pure silica
- Opal which is a gem mineral containing Hydrous Silicate
- And Amethyst which is a Purple quartz.

Oxides of Semi-metals

- Oxides of semi-metals are typical mineral groups.
- They include minerals like
  - Arsenolite containing Arsenic Trioxide
  - Valentinite containing antimony trioxide
  - Tungstite containing Tungsten trioxide.

Oxides of metals

- The oxide mineral class includes those minerals in which the oxide anion (O^{2-}) is bonded to one or more metal ions. Cuprite is an oxide mineral composed of copper oxide Cu_2O, and is a minor ore of copper. This is a major mineral belonging to this group.
- There are two other groups of minerals belonging to the oxides of metals.
- They are Periclase Group and hematite group.

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Oxides of metals

- The minerals of these groups are as follows:

- Periclase Group with
  - Periclase containing Magnesia
  - Manganosite containing Manganese protoxide and
  - Zincite containing Zinc Oxide.

(…Contd)

Oxides of metals

- Hematite Group with
  - Corundum containing Al_2O_3
  - Hematite containing Fe_2O_3 and
  - Ilmenite containing $(Fe, Mg)O.TiO_2$.

Corundum is one of the dominant Aluminum Oxide belonging to this group. Corundum is the second hardest natural mineral known to science.

Intermediate oxides

The intermediate oxides comprise of three major mineral groups. They are spinel group, rutile group and hydrous oxides.

- The Spinel group is comprised of Aluminum Spinel called as Spinel

- Iron Spinel which forms a group including Magnetite, Jacobsite & Franklinite

- Chromium Spinel forming Chromite and finally Magnesium Aluminate.

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Intermediate oxides

- The Rutile group is comprised of four notable minerals. They are:
  - Cassiterite (SnO_2), Rutile (TiO_2)
  - Octahedrite – Titanium dioxide and Pyrolusite which is a Manganese dioxide.
- The Hydrous oxides group comprised of :
  - Diaspore, Goethite, Manganite, Limonite, Bauxite, Brucite, Gibbsite & Psilomelane.

Antimonides

- The minerals of this subclass include
  - Gold Antimonite,
  - Nickel Antimonite and
  - Silver Antimonite.
  - Aurostibite is a Gold Antimonide.

Arsenides

- The minerals of this subclass include

- Copper Arsenide,
- Nickel Arsenide, called as Nickeline,
- Cobalt Arsenide,
- Cobalt Nickel Arsenide called as Smaltite
- Platinum Arsenide and
- Cobalt Iron Arsenide called as Safflorite
- Iron arsenide called as Lollingite.

Class : Carbonates and Nitrates

- Carbonates and nitrates are very separate classes of minerals. The carbonate ion can bond with a variety of other ions to produce the carbonate minerals.
- The bonding with calcium to form the mineral calcite produces one of the most abundant of the non-silicate minerals.
- All carbonates have the property of dissolving easily in acidic water.

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Class : Carbonates and Nitrates

- Carbonates are further classified into two major classes as anhydrous Carbonates and Basic-hydrous carbonates.
- The Anhydrous Carbonates includes two groups as Calcite Group and Aragonite Group of Minerals.

Calcite Group

- The calcite group includes a variety of minerals with varying chemical composition.
- The notable minerals are :
  - Calcite which consists of Calcium carbonate.
  - Dolomite - which consists of Calcium Magnesium Carbonate.
  - Ankerite- which consists Calcium Magnesium Iron Carbonate.
  - Magnesite- which consists of Magnesium Carbonate.

(...Contd)

Calcite Group

- Siderite- which consists of Iron Carbonate
- Rhodochrosite- which consists of Manganse Carbonate
- Smithsonite- which consists of Zinc Carbonate
- Spaerocobaltite- which consists of Cobalt Carbonate.

Aragonite Group

- The aragonite group includes the following minerals:

- Aragonite - which consists of Calcium carbonate.
- Bromlite - which consists of Calcium Barium Carbonate.
- Strontianite - which consists of Strontium Carbonate.
- Cerussite - which consists of Lead Carbonate.

Basic and Hydrous carbonate

The basic and hydrous carbonates are yet another group of minerals. The minerals of this group are:

- Malachite – which consists of Basic cupric hydrous carbonate and
- Azurite - which consists of Basic cupric hydrous carbonate.

Nitrates

- Nitrates are soluble minerals. These minerals are few in number and with the exception of soda niter are of rare occurrence.
- Nitrates are similar to carbonates.
- Niter, specifically KNO3, is also known as "saltpeter".
- Nitrate Minerals include Sodium Nitrate, Calcium Nitrate, Barium Nitrate, Niter, and Nitratine.

(…Contd)

Nitrates

The Normal anhydrous and hydrated nitrates occurring as minerals are:

- soda niter, $NaNO_3$;
- niter, KNO_3:
- ammonia niter, NH_4NO_3;
- nitrobarite, $Ba(NO_3)_2$;
- nitrocalcite, $Ca(NO_3)_2 \cdot 4H_2O$; and
- nitromagnesite, $Mg(NO_3)_2 \cdot 6H_2O$.

(…Contd)

Nitrates

- The natural nitrates are for the most part readily soluble in water.
- Niter is one of the few nitrate minerals that is available on the mineral markets.
- In fact, some solid nitrate crystals will even become liquid by removing water from the moisture in the air, a process called deliquescence.

Class : Borates

- Borates are separate classes of minerals. Borate is a compound of the borate ion with metallic elements.
- The Borate minerals are more complex in their structures than typical carbonates.
- It is because of the scarcity and limited distribution of boron in the Earth's crust.
- There are more than 100 different borate minerals occurring in nature.

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Class : Borates

The most common Borate Minerals are the following:

- Kernite - $Na_2B_4O_7.4H_2O$; Kernite is a sodium borate hydrate
- Borax - $Na_2B_4O_7.10H_2O$; Borax is a sodium borate hydrate.
- Ulexite - $NaCaB_5O_9.8H_2O$; Ulexite is a sodium calcium borate hydrate
- Colemanite - $Ca_2B_5O_{11}.5H_2O$; Colemanite is a calcium borate hydrate,

(…Contd)

Class : Borates

- Boracite $Mg_3B_7O_{13}Cl$; Boracite is a Magnesium Borate Chloride
- Sussexite- HRBO3; Sussexite is the Magnesium Borate Hydroxide
- Hydroboracite Hydroboracite is the Hydrated Calcium Magnesium Borate Hydroxide.

Class: Sulfates, Selenates, Chromates, Molybdates, Wolframates & Niobates

- This Class includes many minerals belonging to Sulfates, Selenates, Chromates, Molybdates, Wolframates and Niobates.
- The Sulfates are an important mineral class and include some very interesting and attractive specimens. Although many minerals belong to this class, only barite, gypsum, Celestite, and anhydrite can be considered common.

Selenides

The minerals of the selenide subclass include

a) Copper Selenide,

b) Lead Selenide,

c) Silver Copper Selenide and

d) Mercury Selenide.

Tellurides

The minerals of the telluride subclass include

- Lead Telluride,
- Gold Telluride,
- Silver Telluride,
- Copper Gold Telluride,
- Nickel Telluride,
- Silver Gold Telluride ,
- Copper Telluride
- Gold Lead Antimony Iron Telluride and
- Mercury Telluride.

Notable telluride minerals are:

- (Silver Gold Telluride)
- Melonite (Nickel Telluride)
- Cala erite (Gold Telluride)
- Empressite (Silver Telluride)
- Petzite (Silver Gold Telluride)

Class: Phosphates, Arsenates, Vanadates & Polyvanadates

- This Class includes minerals belonging to Phosphates, Arsenates, Vanadates and Polyvanadates.
- Phosphorous in the form of phosphate ions (PO_4^{3-}) binds with positive ions to form the phosphate minerals.

Phosphates

- The Important minerals of phosphates are

- Xenotime
- Monazite
- Apatite
- Vanadinite
- Pyromorphite
- Mimetite
- Wagnerite
- Triplite
- Uraninite and
- Autunite.

Class : Silicates

- The Class on silicate includes a vast number of minerals belonging to the Silicates family.
- The Silicates are the largest, the most interesting, and the most complicated classes of minerals.
- Approximately, 30% of all minerals present on the earth are silicates.

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Class : Silicates

- Some geologists estimate that about 90% of the Earth's crust is made up of mainly silicates.
- Oxygen and silicon are the two most abundant elements in the earth's crust.
- Because of this the abundance of silicates is seen.
- The basic chemical unit of silicates is the Si O4 tetrahedron.

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Class : Silicates

- The Silicate tetrahedrons have more complicated structures.
- The silicate tetrahedrons combine each other and make the typical Silicate Class.
- They are the rock-forming silicates.

Classification of silicates

The Silicates are divided into the following six subclasses, not by their chemistries, but based on their structures:

- Nesosilicates (single tetrahedrons)
- Sorosilicates (double tetrahedrons)
- Inosilicates (single and double chains)
- Cyclosilicates (rings)
- Phyllosilicates (sheets)
- Tectoilicates (frameworks).

Nesosilicates

- The Nesosilicates are called as single tetrahedron silicates. These are also called as orthosilicates.
- They have an independent Si-O tetrahedral structure.
- These form separate groups of minerals.

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Nesosilicates

The major groups of minerals are

- Olivine group,
- Garnet group,
- Zircon group,
- Alumino-silicate group,
- Humite group,
- Titanite and chloritoid group of minerals.

(…Contd)

Nesosilicates

- The Olivine group includes major minerals like Forsterite and Fayalite.
- The Garnet group of minerals include Pyrope, Almandine, Spessartine, Grossular, Andradite & Uvarovite minerals.
- The Zircon group includes Zircon and Thorite.

(...Contd)

Nesosilicates

The Alumino-silicate group includes

- Andalustie
- Kyanite
- Sillimanite
- Topaz and
- Staurolite minerals.

The Humite group include Chondrodite and Humite.

Sorosilicates (double tetrahedrons)

- Sorosilicates are double tetrahedrons silicates. They posses two linked Si-O tetrahedra sharing one oxygen.
- They include epidote group of minerals as major groups. The notable ones are the epidote and vesuvianite groups. The Epidote group includes major minerals like Epidote, Zoisite and Allanite.
- The Vesuvinite group includes indocrase minerals.

Inosilicates (single and double chains)

- The Inosilicates occur as single and double chain structure of silicates.
- The most important mineral groups of Inosilicates are the pyroxenes and the amphiboles.
- Pyroxenes are the most important rock forming ferromagnesian silicate minerals.
- They occur in almost every type of igneous rocks.

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Inosilicates (single and double chains)

- These single-chain Inosilicates include the following mineral groups:-
- The Pyroxene group includes minerals like Enstatite & Ferrosilite, Diopside & Augite, Jadeite, Ageirine (Acmite) & Sodumene.
- The Pyroxenoid group includes minerals like Wollastonie, Rhodonite & Pectolite.

(…Contd)

Inosilicates (single and double chains)

- The pyroxenes can be further divided into two more groups based on chemistry and crystallography.
- The first one is the Orthorhombic Pyroxenes, Orthopyroxenes in short, which includes enstatite - $MgSiO_3$ and ferrosilite - $FeSiO_3$ and the second one is the Monoclinic Pyroxenes, Clinopyroxenes in short, which includes Diopside- Hedenbergite series.

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Inosilicates (single and double chains)

- In addition, we have the Sodic Pyroxenes comprising minerals like Jadeite ($NaAlSi_2O_6$) and Aegerine ($NaFe^{+3}Si_2O_6$), Augite and Pigeonite.

Double chain inosilicates

- These silicates show continuous chains of Si-O tetrahedra, sharing two oxygens. The amphibole group of minerals are double chain silicates, for example the tremolite - ferroactinolite series.

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Double chain inosilicates

- The Amphibole group of minerals include Anthophyllite, Cumingtonite series, Tremolite, Actinolite, and Hornoblende. It also includes Sodium amphibole minerals.

Cyclosilicates (rings)

- The Cyclosilicates show closed rings of linked Si-O tetrahedral, sharing two oxygens.
- The most common minerals based on this structure are Beryl, Cordierite, dioptase and Tourmaline.

Phyllosilicates(sheets)

- The Phyllosilicates are called as sheets silicates. These silicates show continuous sheets of Si-O tetrahedra sharing three oxygens.
- Many members of this class have a platy or flaky habit with one very prominent cleavage.
- Minerals are generally soft, low specific gravity, may even be flexible. Mostly hydroxyl-bearing minerals.

Phyllosilicates(sheets)

The phyllosilicates are an important group of minerals that includes the micas, chlorite, serpentine, talc, and the clay minerals. The major mineral groups are:

- Serpentine group
- Clay mineral group with Kaolinite, Illite & Montmorillonite
- Vermiculite & Talc
- Mica group including Biotite, Muscovite & Phlogopite and
- Chlorite group with Chlorite.

The Micas

- The micas can be divided into the dioctahedral micas and the trioctahedral micas. Muscovite, Paragonite, and Margarite are the white micas, and represent the dioctahedral group.
- Biotite and Clintonite (Xanthophyllite) are the black or brown micas representing the tri-octahedral group.
- Muscovite and Biotite are the most common micas.

Tectosilicates (frameworks)

- The Tectosilicates show continuous framework of Si-O tetrahedra sharing all four oxygens.
- All oxygen atoms are shared between two SiO4 tetrahedron.
- Quartz group with Quartz, Tridymite and Cristobalite belong to this class.

Tectosilicates (frameworks)

- In addition, the feldspar and feldspathoid minerals are also based on the tectosilicate framework. These silicates include the following groups of silicates:

- Feldspar family with Alkali-feldspars and Plagioclase feldspars
- Fildspathoid family with Nepheline and Sodalite
- Sacpolie group
- Zeolite group with Natrolite, Chabazite & Heulandite.

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Tectosilicates (frameworks)

- The structure of feldspar is similar to that of the SiO2 polymorphs, consisting of an infinite network of tetrahedral, inter-connected via bridging oxygen atoms.
- Among these, the Feldspars are the most common rock-forming minerals.

Class: Organic Compounds

- This class includes those organic compounds that are recognized and classified as minerals.
- Organic minerals are essential items which bring life to cells. These contain carbon, and their electrons spin clockwise, just like those of the human body.
- In fact, the body needs about 70 different minerals to carry out all the functions a body is required to do.

(...Contd)

Class: Organic Compounds

The Organic Minerals include the following:

- Salts of Organic Acids (Oxalates)
- Salts of Organic Acids (Mellitates, Citrates, Cyanates, and Acetates)
- Salts of Organic Acids (Hydrocarbons)
- Salts of Organic Acids with miscellaneous formulae.

Conclusion

- Mineralogy is a vast subject. More than 3000 minerals have been recognized so far.
- It is necessary to know the details about these minerals, their chemical formula, physical and chemical properties and the way in which they are used in different industries.

(…Contd)

Conclusion

- Systematic mineralogy is the subject which divides these minerals into different classes based on their chemical formulas. Many mineral collectors, collect or categorize their collections mainly based the mineral classes only.
- The chemical classification of minerals give an overall structure and composition of the minerals of the world.

Thank You