

Non-Silicate Minerals

Non-silicate minerals are a diverse group of minerals that do not contain the silicate tetrahedron (SiO_4), which is the fundamental structural unit of silicate minerals. Although they constitute a smaller proportion, they are of major economic and industrial importance.

Classification of Non-Silicate Minerals

1. Native Elements: Minerals composed of a single element. These minerals are divided into:

a. Metals: Minerals with high heat and electrical conductance, malleability, ductility and a strong metallic bond, such as Au (gold), Ag (silver), Cu (copper), and Pt (platinum).

b. Semi-metals: Minerals with lesser conductivity but more brittle than metals and consist of a mixture of metallic and covalent bond types, such as Sb (antimony), Bi (bismuth), and As (arsenic).

c. Non-metals: Minerals which are non-conductors, very brittle and soft, and have a covalent type of bond, such as C (graphite) and S (sulfur).

Economic Importance: Native elements are highly valuable and widely used in industry and technology.

2. Sulfides: Minerals containing sulfur in the form of S^{2-} . Examples: FeS_2 (pyrite), CuFeS_2 (chalcopyrite), PbS (galena), ZnS (sphalerite), Fe_{1-x}S (pyrrhotite), As_2S_3 (orpiment), AsS (Realgar), and HgS (cinnabar).

Sulphides are of magmatic and hydrothermal origin. Most sulfides are deposited by hydrothermal solutions (e.g., galena, sphalerite, and chalcopyrite), and some of them are primary minerals in igneous and metamorphic rocks (e.g., pyrrhotite) and crystallize from the magma. Sulfides also may form in sediments under the reducing conditions resulting from the decay of organic matter.

Economic Importance: Primary sources of metals such as Pb, Zn, and Cu.

3. Oxides: Minerals composed of oxygen combined with one or more cations.

Classification: Oxides are classified into three main groups based on metal cation/oxygen ratios.

Hematite Group (X_2O_3) or (XO_3)

most phases hexagonal

Corundum $X=Al^{+3}$

Hematite $X=Fe^{+3}$

Ilmenite $X=Fe^{+2}, Ti^{+4}$ (solid solution)

Rutile Group (XO_2)

$x= +4$ cation

most phases tetragonal

Rutile $X=Ti^{+4}$

Pyrolusite $X=Mn^{+4}$

Cassiterite $X=Sn^{+4}$

Uraninite $X=U^{+4}$

Spinel Group (XY_2O_4)

$X= +2; Y= +3$ cation

most phases isometric or orthorhombic

Spinel $X=Mg, Y=Al^{+3}$

Magnetite $X=Fe^{+2}, Y=Fe^{+3}$

Chromite $X=Fe^{+2}, Y=Cr^{+3}$

Gahnite $X=Zn^{+2}, Y=Al^{+3}$

Chrysoberyl $X=Be, Y=Al^{+3}$

Ulvospinel $X=Ti^{+4}, Y=Fe^{+2}$

Economic Importance: Major ores of metals such as Fe, Al, Ti, Sn, Mn, and U.

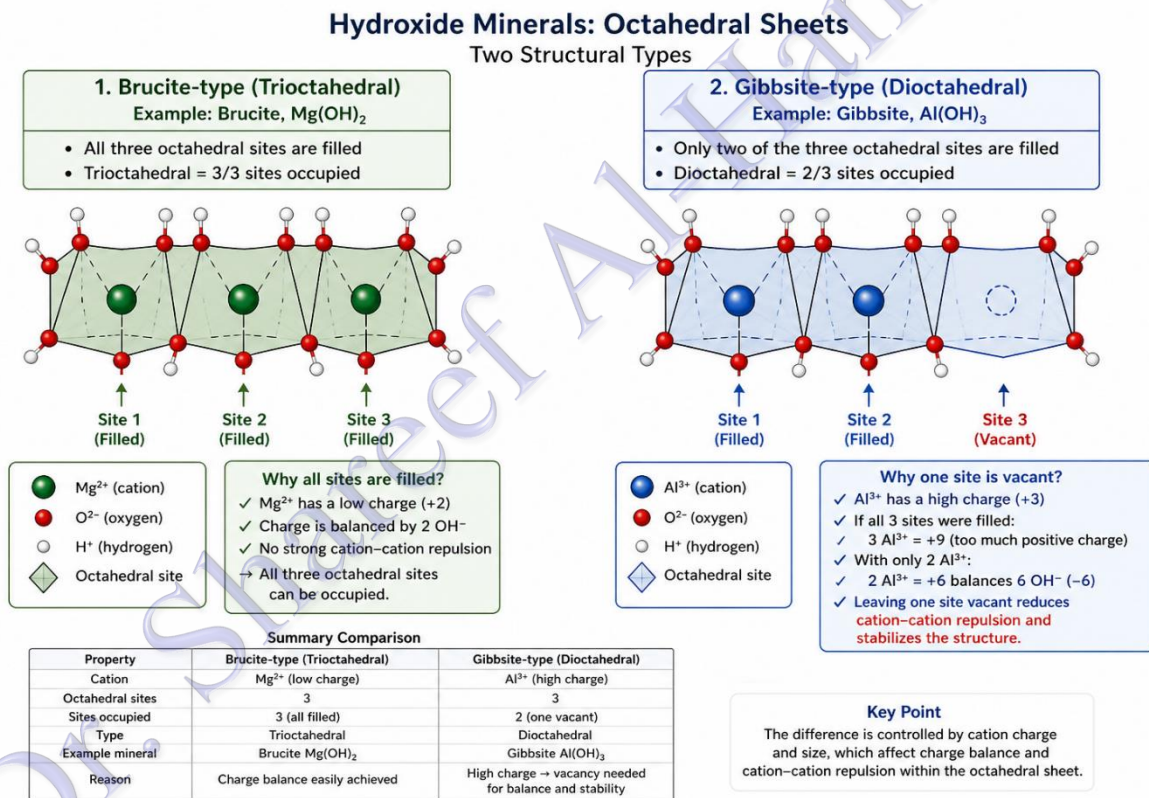
4. Hydroxides: Minerals that contain the hydroxyl ion (OH^-) as an essential structural component.

Hydroxide minerals are classified into two main types:

a. Layered hydroxides:

1. Brucite $\text{Mg}(\text{OH})_2$ trioctahedral sheets 3/3 (all octahedral cation sites are filled), such as brucite $\text{Mg}(\text{OH})_2$, $\text{Fe}(\text{OH})_2$, and $\text{Ni}(\text{OH})_2$.

2. Gibbsite $\text{Al}(\text{OH})_3$ dioctahedral sheets 2/3 (only two of three octahedral sites are filled), such as bauxite that is a mixture of gibbsite $\text{Al}(\text{OH})_3$, boehmite $\text{AlO}(\text{OH})$, and diaspore $\text{AlO}(\text{OH})$.



b. Non-layered Hydroxides:

1. Chain oxyhydroxides such as goethite $\text{FeO}(\text{OH})$ and manganite $\text{MnO}(\text{OH})$.

2. Other oxides/hydroxides such as Ferrihydrite ($\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$) and akaganeite ($\text{FeO}(\text{OH}, \text{Cl})$).

Hydroxide minerals typically form under:

- Weathering conditions (indicative of intense chemical weathering), particularly in warm and humid (tropical) climates.
- Oxidation zones of ore deposits
- Alteration processes affecting primary minerals

Economic Importance: Gibbsite is a major component of bauxite, the principal ore of aluminum. Goethite can serve as a secondary source of iron.

5. Halides: Minerals formed by the combination of halogen elements (Cl, F, Br, I) with metals. Examples: Halite (NaCl), Sylvite (KCl), and Fluorite (CaF₂). Halides are often soluble in water.

Formation Environment: Evaporite deposits.

6. Carbonates: Minerals containing the carbonate ion (CO₃²⁻). Carbonates react with dilute hydrochloric acid (HCl).

Carbonate minerals are classified into four main groups based on the crystallographic system:

- Trigonal group such as calcite (CaCO₃), siderite (FeCO₃), rhodochrosite (MnCO₃), and smithsonite (ZnCO₃).
- Orthorhombic group such as aragonite (CaCO₃) and witherite (BaCO₃).
- Hexagonal group such as dolomite (CaMg(CO₃)₂).
- Monoclinic group such as malachite (Cu₂CO₃(OH)₂) and azurite (Cu₃(CO₃)₂(OH)₂).

Calcite and aragonite have the same composition (CaCO₃) and different crystallographic systems. Aragonite is metastable compared with calcite and denser than calcite. Aragonite is the low-temperature and high-pressure polymorph.

Generally, carbonates are the major constituents of sedimentary rocks such as limestone.

7. Phosphates: Minerals containing the phosphate ion (PO₄³⁻). Example: Apatite (Ca₅(PO₄)₃(F, Cl, OH)), pyromorphite (Pb₅(PO₄)₃Cl), Monazite ((Ce,La,Y,Th)PO₄), and Wavellite (Al₃(PO₄)₂(OH)₃·5H₂O).

Economic Importance: Essential in fertilizer production.

8. Tungstates and Molybdates: Minerals containing tungsten (W) and molybdenum (Mo), such as wolframite ((Fe, Mn)WO₄), scheelite (CaWO₄), wulfenite (PbMoO₄), and molybdenite (MoS₂).

Tungstates are found in hydrothermal veins and associated with granite-related magmatic systems. Tungstates often occur with Sn, Cu, and quartz veins.

Economic importance of tungsten:

- Used in cemented carbides.
- Essential for cutting tools, drilling equipment, and high-temperature alloys.
- Important in military applications (armor-piercing materials).

Molybdates are found mainly in Cu–Mo deposits and associated with granitic intrusions and hydrothermal veins. Molybdates commonly occur with Cu, W, and Re.

Economic importance of molybdenum:

- Used in high-strength steel alloys.
 - Improves corrosion resistance and high-temperature stability.
 - Important in oil industry catalysts and chemical industry.
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9. Sulfates: Minerals containing the sulfate ion (SO₄²⁻). Examples: Barite (BaSO₄), anhydrite (CaSO₄), and gypsum (CaSO₄·2H₂O).

There are three variety types of gypsum:

- Satin spar is fibrous gypsum with the silky luster.
- Alabaster is the fine-grained massive variety of gypsum with pearly luster.
- Selenite is a variety of gypsum that is characterized by colorlessness, transparency, and cleavage.

Generally, sulfates occur in evaporitic environments.

Economic Importance of sulfates: Used in plaster and cement industries.
