# MINERAL PROPERTIES, USES, and IDENTIFICATION

part 1

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# What are Minerals?

- A mineral is defined as:
  - a **solid**
  - that is **naturally occurring**
  - is **inorganic**
  - is **crystalline**
  - has a **specific chemical composition**
  - has **distinctive physical properties**

**Crystals of Halite (Table Salt)**
from the Bonneville Flats, Wendover, Utah

solid
naturally occurring
inorganic
crystalline (forms cubes)
has a specific chemical composition (NaCl)
has its distinctive physical properties

photo: © Alessandro Grippo

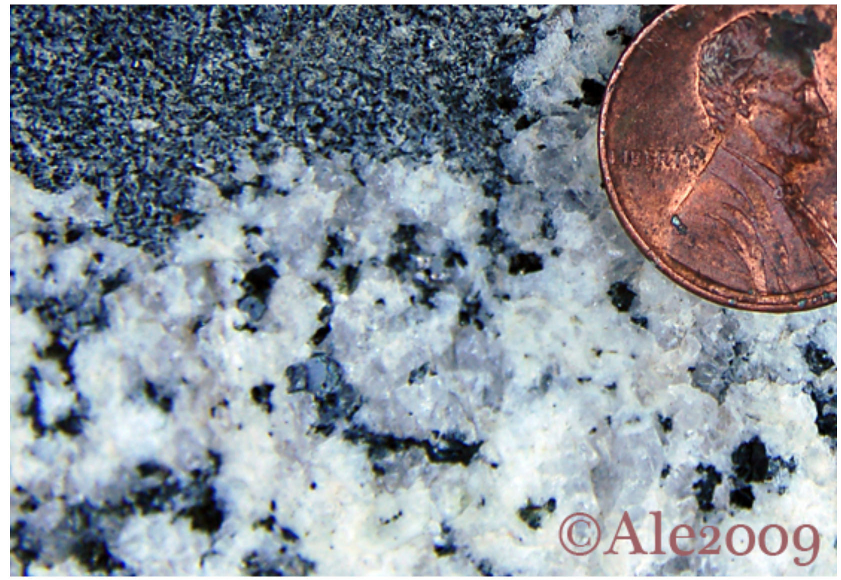
- **Solid**
  - if it is a gas or a liquid, it is not a mineral
- **Naturally occurring**
  - minerals form through natural geologic processes
- **Inorganic**
  - minerals are not hydrocarbon-based, like life forms are
- **Crystalline**
  - atoms are arranged in an orderly, repeating, 3-D pattern
- with a specific **Chemical Composition**
  - composition is described by a chemical formula
- with distinctive **Physical Properties**
  - specific gravity, density, magnetism, temperatures and pressures for change of state, and more

# Minerals vs. Rocks

- Rocks are defined as “naturally formed aggregates of minerals”
- A rock can be composed of a single mineral, or multiple minerals
- Some rocks are composed of non-mineral substances

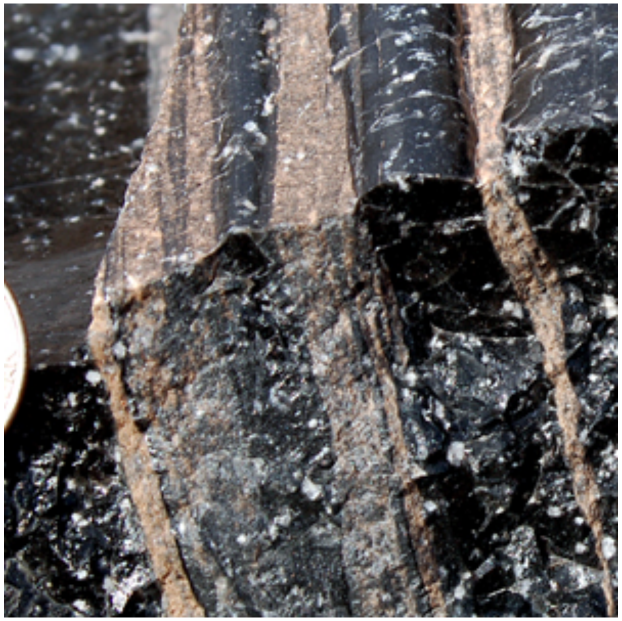

This rock is a LIMESTONE
It is made of multiple crystals of one, single mineral, called CALCITE $CaCO_3$

Kelbaker Road, San Bernardino County, California
photo: © Alessandro Grippo




This rock is a GRANITE
It is made of crystals of different minerals:
black is BIOTITE $K(Fe,Mg)_3AlSi_3O_{10}(OH)_2$
gray is QUARTZ $SiO_2$
white is ALBITE $NaAlSi_3O_8$

U.S. 395, Inyo County, California
photo: © Alessandro Grippo

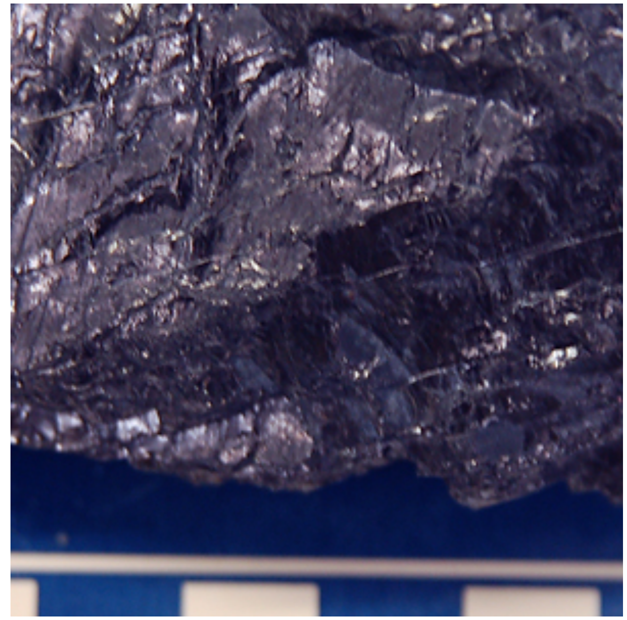


This rock is OBSIDIAN,
which is a volcanic glass.

Glass is not crystalline and as such it is not a mineral

Composition is Silica $SiO_2$

Lee Vining, California
photo: © Alessandro Grippo



This rock is COAL,
which is made of partially decomposed organic matter, which is not a mineral

Composition is Carbon $C$

Rock Collection
photo: © Alessandro Grippo

# Elements, minerals and rocks

- Rocks are composed of minerals

- Minerals are composed of atoms of elements bonded together in an orderly crystalline structure

- Example:
  - the rock LIMESTONE is made of the mineral CALCITE, which is made of one atom of Ca (Calcium), one atom of C (Carbon) and three atoms of O (Oxygen)
  - $CaCO_3$

- More than 4700 different kinds of minerals have been identified
- Only about 200 minerals are common
- Most rocks are formed by about 20 minerals
- 8 elements make up the bulk of those 20 minerals in Earth’s crust

# The 8 most common elements in Earth's crust

| ELEMENT | SYMBOL | VALENCE, or OXIDATION NUMBER | % BY WEIGHT | % BY VOLUME | % OF ATOMS |
|---|---|---|---|---|---|
| Oxygen | O | -2 | 46.6 | 93.8 | 60.5 |
| Silicon | Si | +4 | 27.7 | 0.9 | 20.5 |
| Aluminum | Al | +3 | 8.1 | 0.8 | 6.2 |
| Iron | Fe | +2 (+3) | 5.0 | 0.5 | 1.9 |
| Calcium | Ca | +2 | 3.6 | 1.0 | 1.9 |
| Sodium | Na | +1 | 2.8 | 1.2 | 2.5 |
| Potassium | K | +1 | 2.6 | 1.5 | 1.8 |
| Magnesium | Mg | +2 | 2.1 | 0.3 | 1.4 |
| all others | | | 1.5 | | 3.3 |

# How do minerals stay together?

- Minerals are made by atoms of elements
- Atoms are made by protons, neutrons, electrons (subatomic particles)
- Protons and neutrons reside in the nucleus
- Electrons orbit around the nucleus in “shells”
- Depending on how many electrons are found in shells, different kinds of chemical bonds occur (covalent, ionic, metallic)

# Chemical Bonds

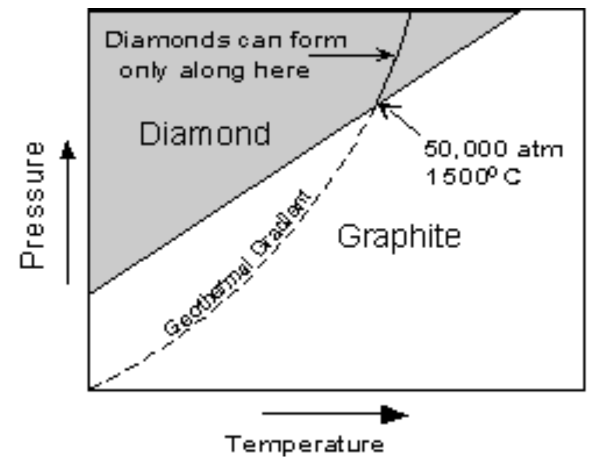
- **Covalent** Bond
  - when atoms share electrons
- **Ionic** Bond
  - when atoms exchange electrons
- **Metallic** Bond
  - electrons are free to move throughout the crystals
- **Van der Waals** Bond
  - weak electrostatic bond

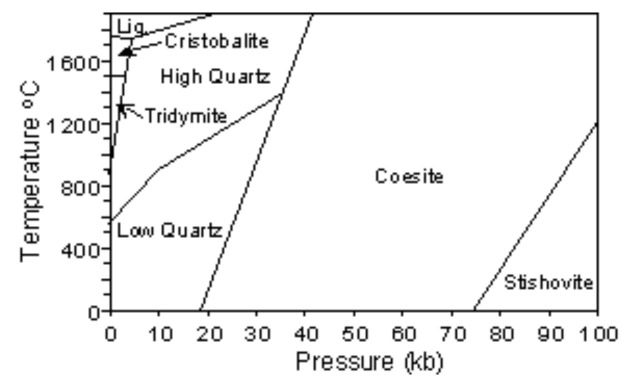
# Oxidation Number, or Valence

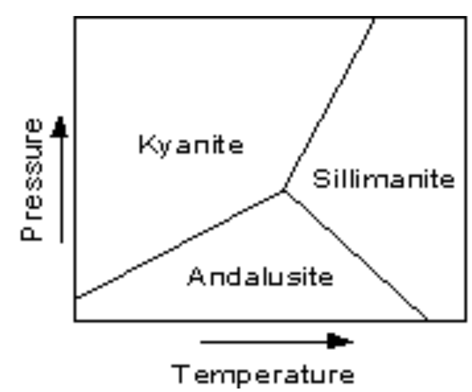
- The Oxidation Number of an atom represents how many electrons would be needed to have a complete, stable electronic structure
- It determines the kind of chemical bond
- It determines who is bonding with who
- In a mineral, the sum of oxidation number must be zero!

# Polymorphs

- Different crystal structures with the same composition
  - common examples:
    - Graphite and Diamond C
    - Calcite and Aragonite $CaCO_3$
    - Cristobalite, Tridymite, High Quartz, Low Quartz, Coesite, Stishovite (Quartz) $SiO_2$
    - Sanidine, Orthoclase, and Microcline (K-Feldspar) $KAlSi_3O_8$
    - Kyanite, Sillimanite, Andalusite $Al_2SiO_5$

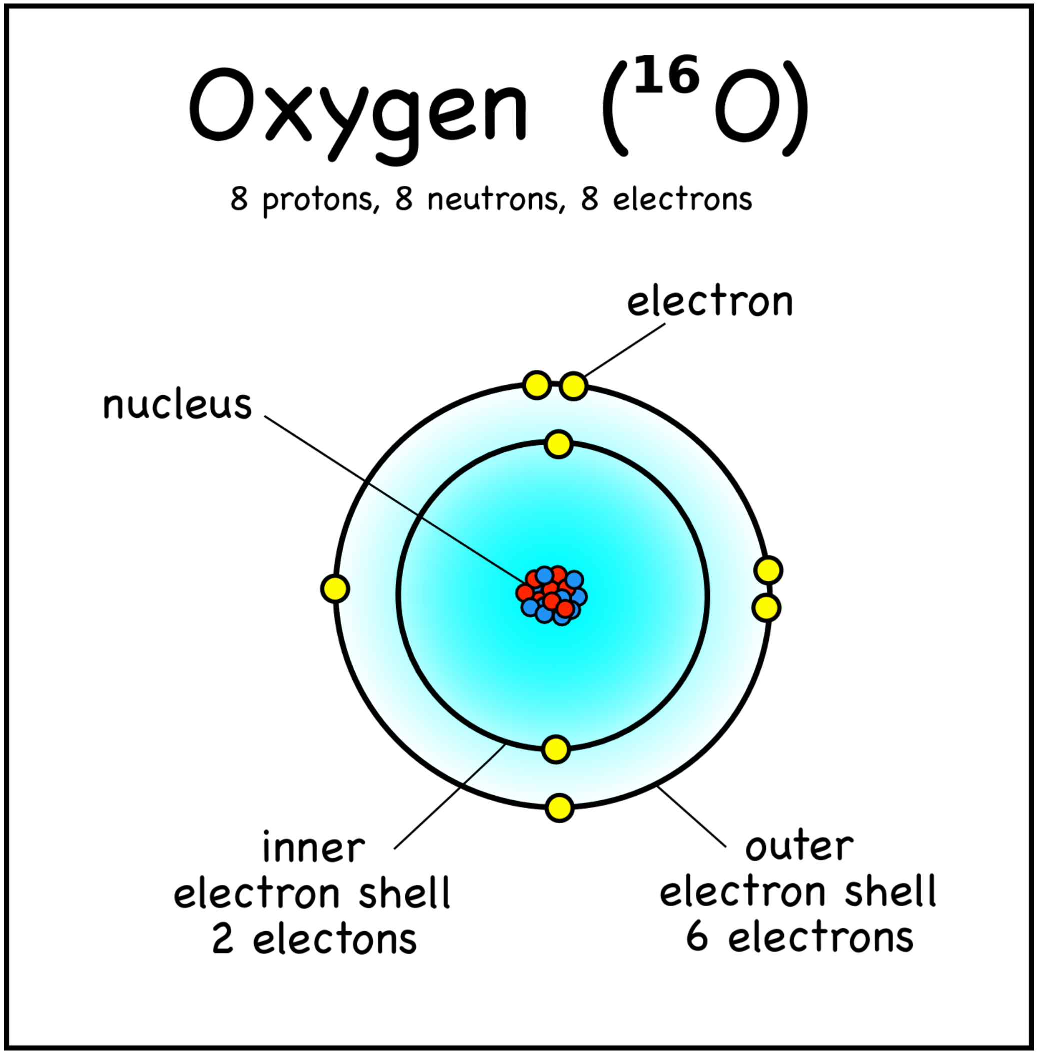



http://www.tulane.edu/~sanelson/eens211/twinning.htm

# Oxygen (-2):
# a negative oxidation number




The outer shell of an atom has space for 8 electrons.

Oxygen only has 6 electrons in the outer shell.

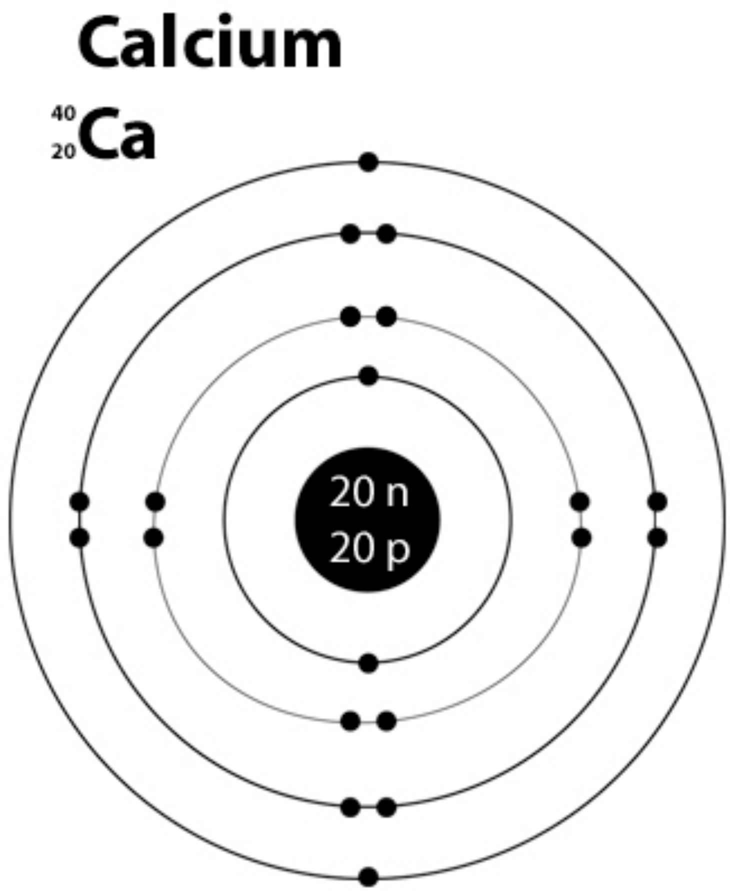
With two more electrons it would reach the stage of "full shell".

But, if we have two extra electrons, the atom would have a charge, and that is not possible, unless it bonds with one or more other atoms.

So, Oxygen would only bond with atoms that would provide it with two extra electrons.

That would imply that Oxygen is looking for two negative charges (-2), and that is how its Oxidation Number is calculated

# Calcium (+2): a positive oxidation number




http://www.micromountain.com/sci_diagrams/at_struct/at_struct_pages/calcium_lab_eng.htm

- Calcium only has 2 electrons in the outer shell.
- By losing those two more electrons it would reach the stage of “full shell”.
- But, if we lose two electrons, the atom would have a charge, and that is not possible, unless it bonds with one or more other atoms.
- So Calcium would only bond with atoms that would take from it those two extra electrons.
- That would imply that calcium is looking to give out two negative charges, leaving two positive charges (+2) uncovered, and that is how its Oxidation Number is calculated

# Minerals Groups

- Silicates
  - contain silica ($SiO_2$), O combined with Si
  - O and Si are the most common elements in the Crust
  - Silicates are the most common group of minerals in the Earth's Crust

•Carbonates

contain the carbonate ion $CO_3$

•Sulfates

contain the sulfate ion $SO_4$

•Sulfides

contain Sulfur (S) but not Oxygen (O) S

•Oxides

contain Oxygen, but not bonded to Si (silicates), C (carbonates), or S (sulfates) O

Chlorides

contain Cl

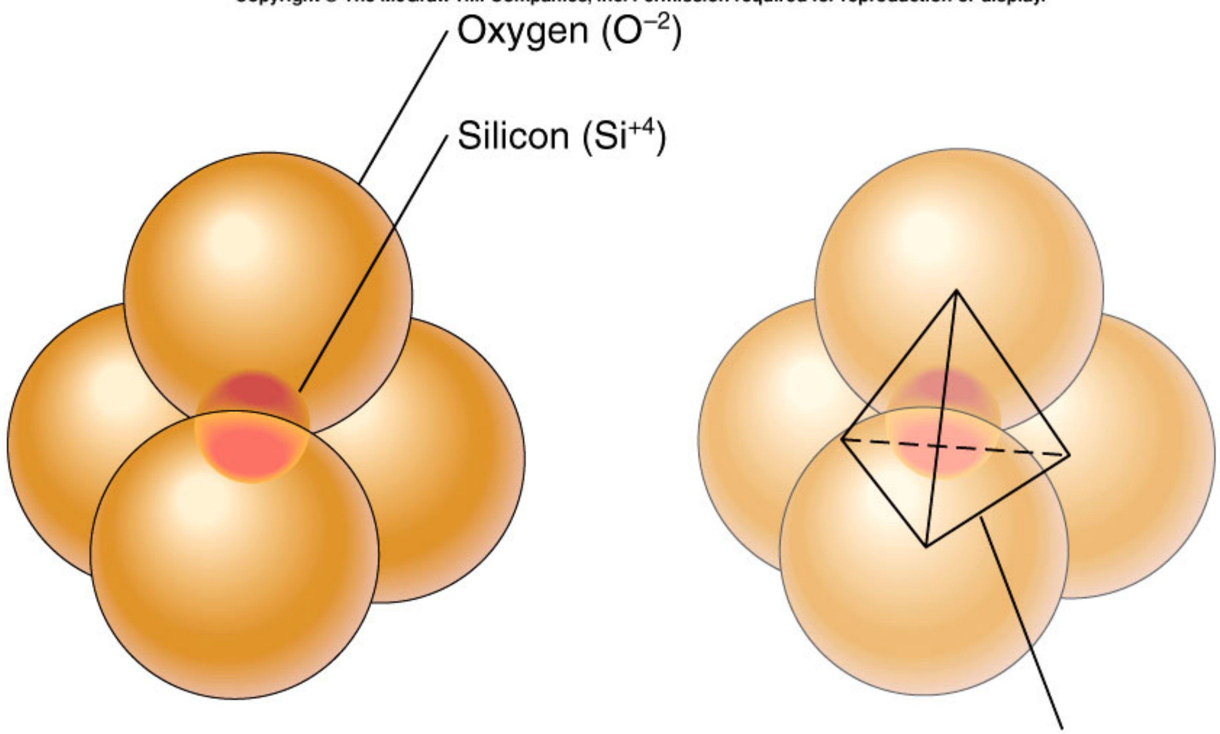
•Native Elements

only have one element in their formulas; examples: Gold (Au), Silver (Ag), Copper (Cu), Diamond (C), Lead (Pb), Zinc (Zn), Tin (Sn), Platinum (Pt) and many more

# Silicates

All different kinds of silicates are built with the same basic unit, which is the **Silicon Tetrahedron**



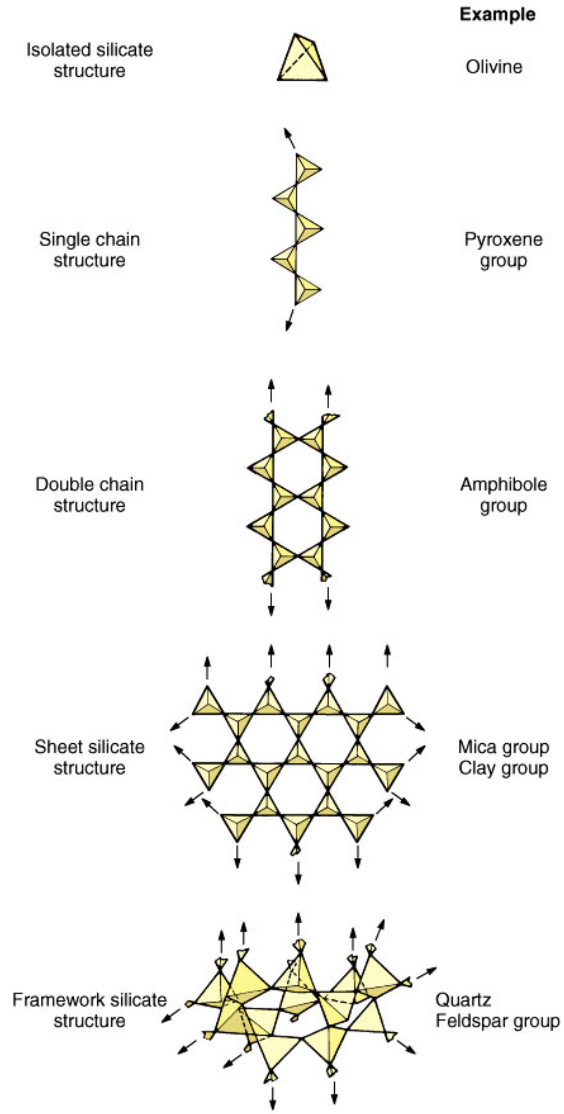



**A** Arrangement of atoms in silicon-oxygen tetrahedron

**B** Diagrammatic representation of a silicon-oxygen tetrahedron

# Types of Silicates

- Isolated Silicate Structure (tetrahedra are not connected)
  - **Olivines**
- Single Chain Silicates (tetrahedra connected to form single chains)
  - **Pyroxenes**
- Double Chain Silicates (tetrahedra connected to form double chains)
  - **Amphiboles**
- Sheet Silicates (tetrahedra connected to form flat sheets)
  - **Micas**
    - Biotite
    - Muscovite
  - **Clays**
- Framework Silicates (tetrahedra connected in all directions)
  - **Quartz**
  - **Feldspars**
    - Ca-Plagioclase
    - Na-Plagioclase
    - K-Feldspar


Example
Isolated silicate structure
Olivine
Single chain structure
Pyroxene group
Double chain structure
Amphibole group
Sheet silicate structure
Mica group
Clay group
Framework silicate structure
Quartz
Feldspar group

| Mineral Group | Mineral | Silicate Structure | Formula | Ratio O/Si | Color (and composition) |
|---|---|---|---|---|---|
| **Olivines** | (Forsterite, Fayalite)° | Isolated tetrahedra | $(FeMg)_2SiO_4$ | 4 | Green (mafic) |
| **Pyroxenes** | (Augite)* | single chains | *complex* | 3 | Black (mafic) |
| **Amphiboles** | (Hornblende)* | double chains | *complex* | 3 | Black / dark Green (mafic) |
| Micas | **Biotite** | sheet | *complex (Fe)* | 2.5 | Black (mafic) |
| Micas | **Muscovite** | sheet | *complex (no Fe)* | 2.5 | Silvery / Transparent (felsic) |
| Clay Minerals^ | several varieties | sheet | *complex* | 2.5 | Variable (n/a) |
| Feldspars | **Ca-Plagioclase** | framework | $CaAl_2Si_2O_8$ | 2 | Milky White (felsic) |
| Feldspars | **Na-Plagioclase** | framework | $NaAlSi_3O_8$ | 2 | Milky White (felsic) |
| Feldspars | **K-Feldspar** | framework | $KAlSi_3O_8$ | 2 | Pink / Orange (felsic) |
| | **Quartz** | framework | $SiO_2$ | 2 | White / Transparent (felsic) |

° Forsterite $Mg_2SiO_4$ and Fayalite $Fe_2SiO_4$ are the two end-members of a continuous olivine series

*Most common mineral within this group

^ Clay minerals are the only group listed here whose minerals do not form from magma or lava; they are sedimentary in origin. They are reported here because of their structure, but they are not found or formed within the crust

# Yes but..
# How do I identify my minerals?

- To identify an unknown mineral you should first determine its physical properties
- Then you should use a mineral identification chart
- In the next slide set we are going to describe the physical properties of minerals, the tools we use to determine them, and how to use the identification chart

to be continued …