Basics of Mineralogy

Geology 200
Geology for Environmental Scientists
Terms to Know:

• Atom
• Molecule
• Proton
• Neutron
• Electron
• Isotope
• Ion

• Bonding
  • ionic
  • covalent
  • metallic
Fig. 3.3  Periodic Table of the Elements
Ionic Bonding

Sodium atom loses 1 electron

Chlorine atom gains 1 electron

Sodium ion $\text{Na}^+$

Chlorine ion $\text{Cl}^-$

Compound sodium chloride forms by electrical attraction between $\text{Na}^+$ and $\text{Cl}^-$
Covalent Bonding

Reaction

Covalent bond forms by sharing electrons
Figure 3.5 -- The effects of temperature and pressure on the physical state of matter, in this case water.
The 6 Crystal Systems

- All have 3 axes, except for 4 axes in Hexagonal system
- **Isometric** -- all axes equal length, all angles 90°
- **Hexagonal** -- 3 of 4 axes equal length, three angles @ 90°, three @ 120°
- **Tetragonal** -- two axes equal length, all angles 90°
  
  *(not common in rock forming minerals)*
- **Orthorhombic** -- all axes unequal length, all angles 90°
- **Monoclinc** -- all axes unequal length, only two angles are 90°
- **Triclinic** -- all axes unequal length, no angles @ 90°
Pyrite -- an example of the isometric crystal system: cubes
Galena -- an example of the isometric crystal system: cubes
Fluorite -- an example of the isometric crystal system, octahedrons, and an example of variation in color
Garnet -- an example of the isometric crystal system: dodecahedrons
Garnet in schist, a metamorphic rock
Large masses of garnet -- a source for commercial abrasives
Quartz -- an example of the hexagonal crystal system.
Amethyst variety of quartz -- an example of color variation in a mineral. The purple color is caused by small amounts of iron.
Agate -- appears to be a noncrystalline variety of quartz but it has microscopic fibrous crystals deposited in layers by ground water.
Calcite crystals. Calcite is in the hexagonal crystal system.
Tourmaline crystals grown together like this are called “twins”. Tourmaline is in the hexagonal crystal system.
Andalusite -- an example of the orthorhombic crystal system
Olivine crystals in a nickel-iron matrix from a meteorite. Olivine is in the orthorhombic crystal system.
Gypsum crystals -- an example of the monoclinic system
A gypsum rose. An example of different crystal habits, sheets instead of blades, for the same mineral.
Orthoclase -- a K-feldspar, an example of the monoclinic system
Microcline -- a K-feldspar, an example of the triclinic system
Kyanite -- an example of the triclinic system
Bauxite -- an amorphous mineral (noncrystalline). Bauxite is aluminum ore that forms by tropical weathering of aluminum silicates.
Crystal systems and example minerals:

Isometric - diamond, garnet, halite, pyrite
Hexagonal - quartz, calcite, dolomite
Tetragonal - *not common in rock forming minerals*
Orthorhombic - anhydrite, olivine, staurolite
Monoclinic - orthoclase, biotite, muscovite, amphibole, pyroxene, gypsum, kaolinite
Triclinic - plagioclase (Na-Ca-feldspar), microcline, kyanite
Chemical Classification of minerals and some examples:

Native elements - gold, silver, copper
Sulfides - pyrite (FeS$_2$), galena (PbS)
Oxides - hematite, limonite (iron oxides)
Halides - rock salt or halite, fluorite
Carbonates - calcite, dolomite
Sulfates - gypsum, anhydrite
Silicates - quartz, biotite, K-feldspar, plagioclase, pyroxene, amphibole
Chemical Composition of Minerals

Many minerals have a precise chemical formula. Examples include:

quartz, SiO$_2$

calcite, CaCO$_3$

Other minerals have a variable formula because of ionic substitution, which does not change crystal structure. Examples include:

olivine (Mg, Fe)$_2$SiO$_4$

pyroxene (Mg, Fe)SiO$_3$

plagioclase NaAlSi$_3$O$_8$ or CaAl$_2$Si$_2$O$_8$
Figure 3.7 -- The relative size and electrical charge of ions.
Gold, a native element
Copper -- an example of a native element
Halite -- an example of a halide mineral
Anhydrite -- example of a sulfate mineral
Major Silicate Mineral Groups based on tetrahedral configurations:

Isolated: olivine, garnet, kyanite
Double: uncommon in rocks
Rings: uncommon in rocks
Single chains: pyroxenes
Double chains: amphiboles
Sheets: micas, chlorite, clay minerals
Framework: feldspars and quartz
Figure 3.18 -- The silicon-oxygen tetrahedron
Figure 3.19 -- Silicon-oxygen tetrahedral groups
Olivine -- isolated tetrahedra
Augite -- single-chain tetrahedra, a pyroxene mineral
Hornblende -- double-chain tetrahedra, an amphibole mineral
Plagioclase feldspar – framework tetrahedra; notice the twinning striations characteristic of this mineral.
These are the physical properties most useful for mineral identification:

Color (be careful, not always diagnostic)
Luster
Transparency or Opacity
Crystal System
Crystal Habit
Twinning of crystals
Cleavage
Fracture
Hardness: Table 3.1 in Textbook
Specific Gravity or density
Streak
Examples of cleavage

A: biotite -- one direction

B: calcite -- three directions
Moh’s Scale of Hardness,
Table 3.1

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<table>
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<tr>
<td>1</td>
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<tr>
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<td>Calcite</td>
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<td>8</td>
<td>Topaz</td>
</tr>
<tr>
<td>9</td>
<td>Corundum (ruby)</td>
</tr>
<tr>
<td>10</td>
<td>Diamond</td>
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</tbody>
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Conchoidal fracture in quartz. Also an example of vitreous or glassy luster.
Density -- some examples

- water 1 g/cm³
- quartz 2.65 g/cm³
- olivine 3.37-4.40 g/cm³
- lead 11 g/cm³
- gold 20 g/cm³
Rock Forming Minerals

• Sialic Minerals
• Mafic Minerals
• Clay Minerals
• Non-silicate Minerals
Sialic Minerals - rich in Si and Al

- Feldspars
  - K-feldspar: \( \text{KA}\text{lSi}_3\text{O}_8 \)
  - plagioclase: \( \text{NaAlSi}_3\text{O}_8 - \text{CaAl}_2\text{Si}_2\text{O}_8 \)
- Quartz: \( \text{SiO}_2 \)
- Muscovite: \( \text{KA}\text{l}_3\text{Si}_3\text{O}_{10}(\text{OH})_2 \)
Mafic Minerals - rich in Mg & Fe

- Olivine: \((\text{Mg,Fe})_2\text{SiO}_4\)
- Pyroxene: \((\text{Mg,Fe})\text{SiO}_3\)
- Amphibole: \(\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2\)
- Biotite: \(\text{K}(\text{Mg,Fe})_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2\)
Clay Minerals

• Form from weathering of silicate minerals; common in shale, mudstone, and soil.
• Kaolinite: $\text{Al}_4\text{Si}_4\text{O}_{10}(\text{OH})_8$
• Montmorillonite or bentonite: $\text{(Al, Mg)}_8(\text{Si}_4\text{O}_{10})_3(\text{OH})_{10} \cdot 12\text{H}_2\text{O}$
• Illite: more complex than montmorillonite
SEM photograph of clay minerals: Permian, Supai Group, Grand Canyon; x 20,900. Figure 05-D, U.S. Geological Survey Professional Paper 1173.
Non-Silicate, Sedimentary Minerals

- Calcite: $\text{CaCO}_3$
- Dolomite: $\text{CaMg}(\text{CO}_3)_2$
- Halite: $\text{NaCl}$
- Gypsum: $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$