Why study minerals?

• Minerals are the basic building blocks of rocks, which tell us the history of Earth. In order to understand how rocks form and evolve, we must understand the minerals of which they are made.
• Many minerals contain natural resources important to our everyday lives. Mineral exploration and mining are important—and sometimes deadly—global industries.

Important Point

• The study of minerals is a good example of the order and simplicity of nature.
  – Example: For all minerals, there are only four ways in which atoms commonly form chemical bonds!
  – Example: For the most abundant rock-forming minerals, there are only five fundamental geometric arrangements of atoms!

So, exactly what is a mineral?

• Naturally occurring (not man-made)
• Inorganic (composed of matter that is not primarily dead plant or animal)
• Solid
• Definite chemical composition (the ratios between atoms making up the mineral are constant)
• Crystalline atomic structure (consists of a geometric arrangement of atoms repeated throughout three-dimensional space)

Definitions to Know

• Element
  – Collection of atoms, all with the same number of protons
  • Nucleus
    – Protons (positive charge)
    – Neutrons (neutral charge)
  • Electrons (negative charge)

• Ion – atom with a net electrical charge
  – Cation – net positive electrical charge (electron deficiency)
  – Anion – net negative electrical charge (electron excess)
  – Valence (Ionic Charge) – number of electrons lost or gained when the atom becomes an ion

• Atomic Number = number of protons in nucleus
• Mass Number = protons + neutrons in nucleus
• Isotopes – atoms with same number of protons in nucleus, but varying number neutrons in nucleus
• Atomic Weight (Atomic Mass) = average of mass numbers of all isotopes of an element, weighted in accordance with the most abundant isotopes
THE PERIODIC TABLE (FIGURE 2.4)

Periodic Table
- **Period** – elements which occupy the same row
- **Group** – elements which occupy the same column
- **Alkali Elements** – occupy group 1A
- **Alkaline Earth Elements** – occupy group 11A
- **Halogens** – occupy group VIIA
- **Noble Gasses** – occupy group VIIIA
- **Transition Elements** – occupy central part of table (groups IIIB to 11B)

Four Common Chemical Bond Types in Minerals
- Ionic
- Covalent
- Metallic
- **van der Waals**

**Ionic Bond** – transfer of electrons

**Covalent Bond** – sharing of electrons

An ionically-bonded molecule
Metallic Bond – ‘sea’ of electrons

Van der Waals Bond
Weak attraction between ‘dipolar’ nuclei

Crystal - atoms are arranged in a simple geometric pattern which is repeated throughout space

Table 1.2 Relative abundance of the most common elements in Earth’s continental crust.

<table>
<thead>
<tr>
<th>Element</th>
<th>Approximate Percentage by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (O)</td>
<td>46.6</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>27.7</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>8.1</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>5.0</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>3.6</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>2.8</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>2.6</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>2.1</td>
</tr>
<tr>
<td>All others</td>
<td>1.7</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Data from USGS Museum

Silicate Mineral Group
- All contain Si$^{4+}$ and O$^{2-}$
- Si:O = 1:4
- $1 \text{Si}^{4+} + 4 \text{O}^{2-} = (\text{SiO}_4)^{4-}$
- Si and O arranged into the Silicon-Oxygen Tetrahedron

Blue = Si
Orange = O
Why is Si smaller than O?
Silicate Mineral Classification

- Classified on the basis of arrangement of Si-O tetrahedra & number of oxygens shared among tetrahedra.
  - Independent tetrahedra (olivine)
  - Single Chain of tetrahedra (pyroxene)
  - Double Chain of tetrahedra (amphibole)
  - Sheet of tetrahedra (mica)
  - Framework of tetrahedra (feldspar, quartz)

Independent Tetrahedra – Si-O tetrahedra are not bonded to other tetrahedra

Single Chain Silicates – each tetrahedron shares two oxygen with adjacent tetrahedra

Double Chain Silicates – two single chains are cross-linked by sharing of an additional oxygen

Sheet Silicates – Each tetrahedron shares three oxygens with adjacent tetrahedra

Framework Silicates – each tetrahedron shares four oxygen with adjacent tetrahedra
Important Points

• The color of a mineral is a function of its chemical composition. In general:
  -- High Si, K, Na results in light color
  -- High Fe, Mg, Ca results in dark color
• Independent tetrahedra exhibit the lowest amount of oxygen sharing among tetrahedra (no oxygens shared)
• Framework silicates exhibit the greatest amount of oxygen sharing among tetrahedra (four oxygens shared)

Non-Silicate Mineral Groups: use other atoms, ions or ionic groups as ‘building blocks’

- **Oxides** – all contain O\(^{2-}\) (hematite/iron ore, magnetite/iron ore, corundum/industrial abrasive, ice)
- **Sulfides** – all contain S\(^{2-}\) (galena/lead ore, sphalerite/zinc ore, pyrite/’fools gold’)
- **Sulfates** – all contain (SO\(_4\))\(^{2-}\) (gypsum/plaster)

Non-Silicate Mineral Groups

- **Native Elements** – elements found in the native state (gold, copper, diamond, sulfur, graphite, silver, platinum)
- **Halides** – all contain halogen ions, such as Cl\(^-\) and F\(^-\). Halogen elements are group VII on the Periodic Table of the Elements (halite/common table salt, fluorite/steel hardener)
- **Carbonates** – all contain (CO\(_3\))\(^{2-}\) (calcite/cement)

Mineral Formulas to Know

(see lecture notes)

- Quartz: SiO\(_2\)
- Calcite: CaCO\(_3\)
- Halite: NaCl
- Ice: H\(_2\)O
- Diamond: C
- Graphite: C
- Pyrite: FeS\(_2\)
- Magnetite: Fe\(_3\)O\(_4\)
- Hematite: Fe\(_2\)O\(_3\)

Tennessee Copper Basin
Physical Properties of Minerals

- Crystal Form
- Cleavage
- Fracture
- Hardness
- Specific Gravity
- Color
- Streak
- Luster
- Special Properties

Crystal Form – external expression of a mineral’s internal arrangement of atoms

Cleavage – the tendency of a mineral to break along a flat surface, which represents planes of weak atomic bonding

Muscovite – 1 direction cleavage

Halite – 3 directions cleavage; angle between cleavage planes = 90°
**Fracture** – The manner in which a mineral breaks other than along cleavage planes

- Obsidian (volcanic glass) – exhibits conchoidal fracture
- Quartz – has an irregular fracture

**Hardness** – The resistance of a mineral to scratching

<table>
<thead>
<tr>
<th>Mohs Hardness Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Talc</td>
</tr>
<tr>
<td>2. Gypsum</td>
</tr>
<tr>
<td>3. Calcite</td>
</tr>
<tr>
<td>4. Fluorite</td>
</tr>
<tr>
<td>5. Apatite</td>
</tr>
<tr>
<td>6. Stilbite</td>
</tr>
<tr>
<td>7. Quartz</td>
</tr>
<tr>
<td>8. Cleavelandite</td>
</tr>
<tr>
<td>9. Topaz</td>
</tr>
<tr>
<td>10. Corundum</td>
</tr>
<tr>
<td>11. Diamond</td>
</tr>
</tbody>
</table>

**Color** – reflection of the chemical composition of a mineral
- High concentrations of Ca, Fe, Mg = dark color
- High concentrations of Si, K, Na = light color

**Streak** – the color of a mineral when ground into a fine powder

- Hematite = Fe$_2$O$_3$
- Magnetite = Fe$_3$O$_4$

**Luster** – the manner in which a mineral reflects light

- Glassy
- Metallic
- Non-metallic
- Waxy/greasy/soapy
- Talc
Special Properties

- **Magnetism** – many Fe-bearing minerals are somewhat magnetic. Magnetite is well known for its magnetism.
- **Reaction with HCl** – Some carbonate minerals will react, especially calcite
- **Taste** – Halite
- **Fluorescence** – emission of light generated by excitation of ultraviolet light