# *Essentials of Geology, 8e*

**Frederick K. Lutgens &**
**Edward J. Tarbuck**

# *Matter and Minerals*
# *Chapter 2*

## *Essentials of Geology, 8e*

**Stan Hatfield and Ken Pinzke**

**Southwestern Illinois College**

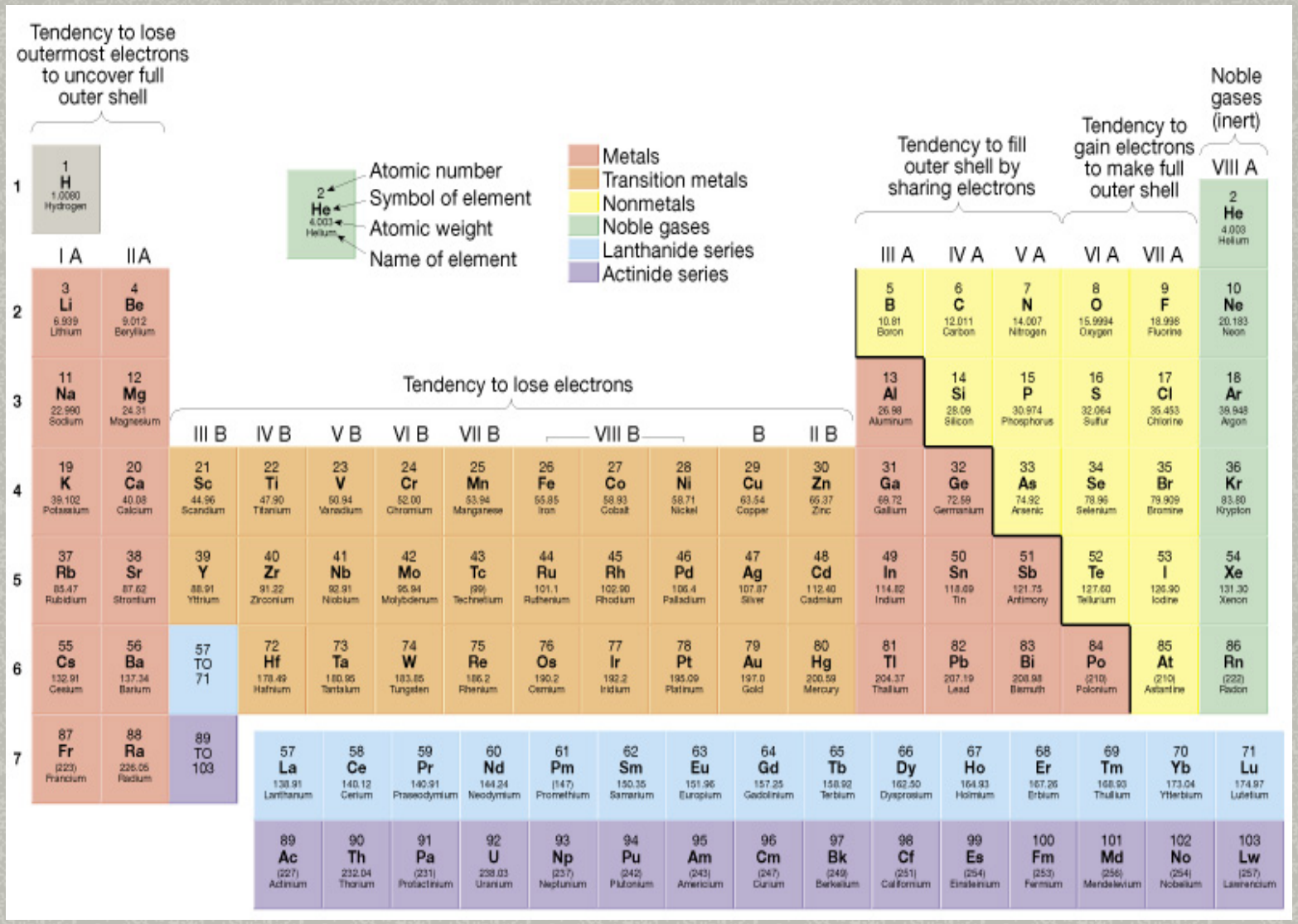
# *Minerals: Building blocks of rocks*

- Definition of a **mineral:**
  - Naturally occurring
  - Inorganic solid
  - Ordered internal molecular structure
  - Definite chemical composition
- Definition of a **rock:**
  - A solid aggregate or mass of minerals

# *Composition of minerals*

- **Elements**
  - **Basic building blocks of minerals**
  - **Over 100 are known (92 naturally occurring)**
- **Atoms**
  - **Smallest particles of matter**
  - **Retains all the characteristics of an element**

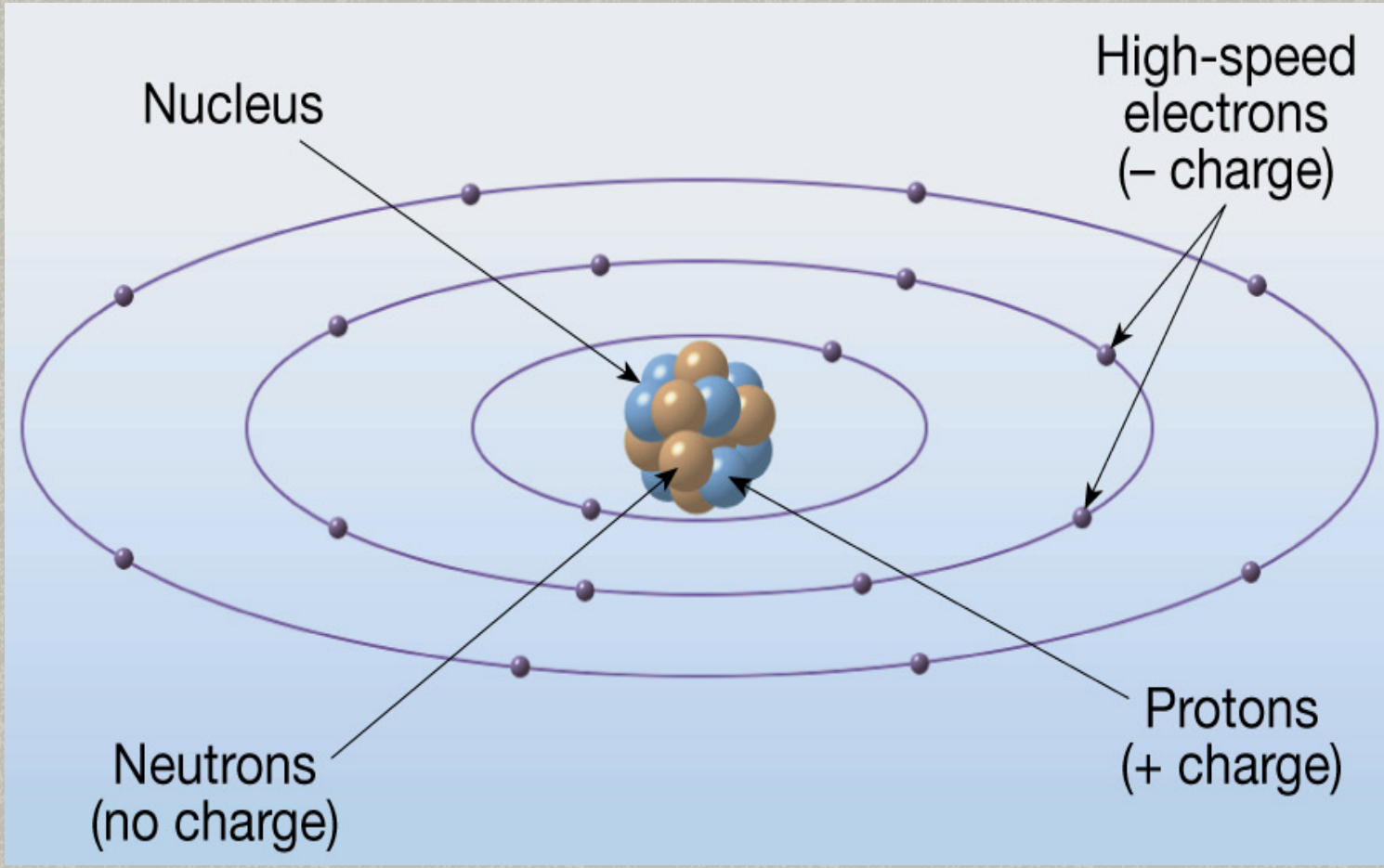
# *The periodic table*



# *Composition of minerals*

- **Atomic structure**
  - **Central region called the nucleus**
    - **Consists of protons (positive charges) and neutrons (neutral charges)**
  - **Electrons**
    - **Negatively charged particles that surround the nucleus**
    - **Located in discrete energy levels called shells**

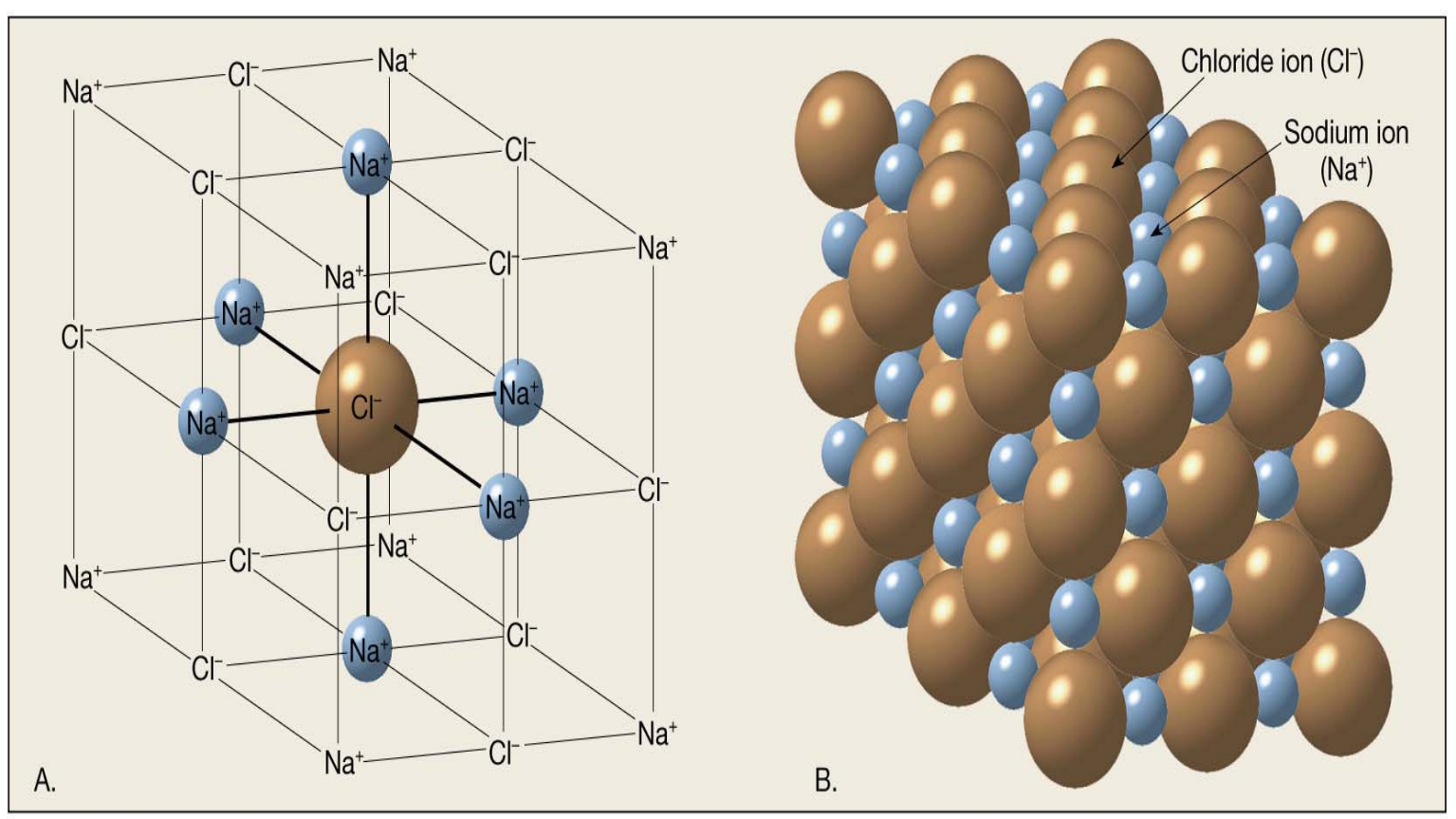
# *Idealized structure of an atom*



# *Composition of minerals*

- **Chemical bonding**
  - **Formation of a compound by combining two or more elements**
- **Ionic bonding**
  - **Atoms gain or lose outermost (valence) electrons to form ions**
  - **Ionic compounds consist of an orderly arrangement of oppositely charged ions**

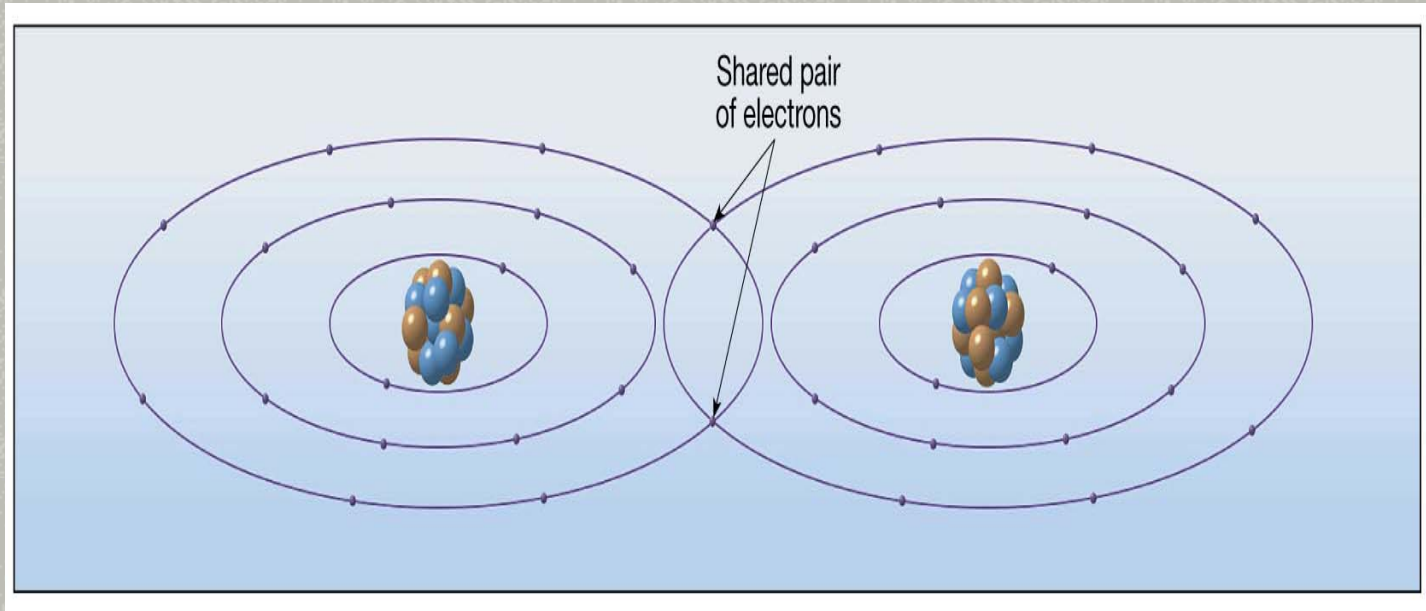
# *Halite (NaCl) – An example of ionic bonding*



# *Composition of minerals*

- **Covalent bonding**
  - **Atoms share electrons to achieve electrical neutrality**
  - **Covalent compounds are generally stronger than ionic bonds**
  - **Both ionic and covalent bonds typically occur in the same compound (bonds are seldom 100% ionic or covalent in character)**

# *Covalent bonding – sharing of valence electrons*



# *Composition of minerals*

- Other types of bonding
  - Metallic bonding
    - Valence electrons are free to migrate among atoms
    - Weaker and less common than ionic or covalent bonds

# *Composition of minerals*

- **Isotopes and radioactive decay**
  - **Mass number** is the sum of neutrons plus protons in an atom
  - An **isotope** is an atom that exhibits variation in its mass number
  - Some isotopes have unstable nuclei that emit particles and energy in a process known as **radioactive decay**

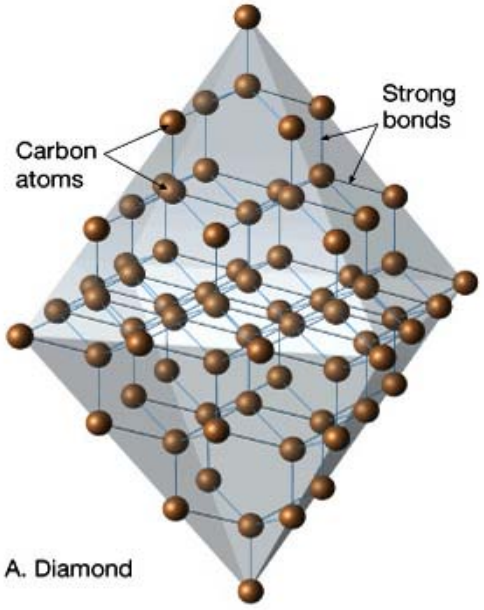
# *Structure of minerals*

- **Minerals consist of an orderly array of atoms chemically bonded to form a particular crystalline structure**
- **For ionic compounds, the internal atomic arrangement is primarily determined by the size of ions involved**

# *Structure of minerals*

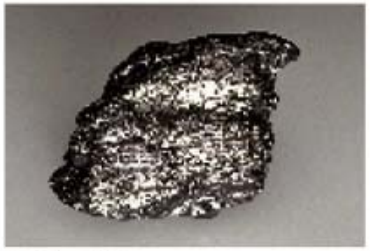
- **Polymorphs**
  - **Two or more minerals with the same chemical composition but different crystalline structures**
  - **Diamond and graphite are good examples of polymorphs**
    - **The transformation of one polymorph to another is called a phase change**

# *Diamond and graphite – polymorphs of carbon*

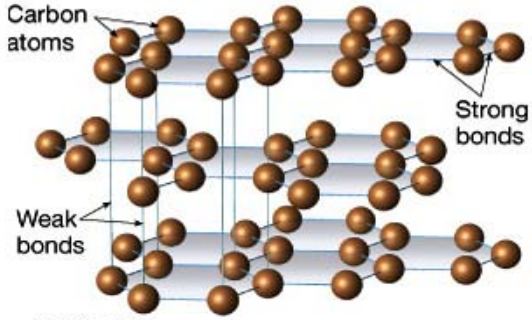



A. Diamond

**A.** Diamond



**B.** Graphite




B. Graphite

# *Physical properties of minerals*

- **Crystal Form**
  - **External expression of the orderly internal arrangement of atoms**
  - **Crystal growth is often interrupted because of competition for space and rapid loss of heat**

# The mineral quartz often exhibits good crystal form

# *Physical properties of minerals*

- **Luster**
  - **Appearance of a mineral in reflected light**
  - **Two basic categories**
    - **Metallic**
    - **Nonmetallic**
  - **Other terms are used to further describe luster such as vitreous, silky, or earthy**

# *Pyrite (fool's gold) displays metallic luster*

# *Physical properties of minerals*

- **Color**
  - **Generally an unreliable diagnostic property to use for mineral identification**
  - **Often highly variable for a given mineral due to slight changes in mineral chemistry**
  - **Exotic colorations of some minerals produce gemstones**

# *Quartz ($SiO_2$) exhibits a variety of colors*

# *Physical properties of minerals*

- **Streak**
  - **Color of a mineral in its powdered form**
  - **Helpful in distinguishing different forms of the same mineral**
- **Hardness**
  - **Resistance of a mineral to abrasion or scratching**
  - **All minerals are compared to a standard scale called the Mohs scale of hardness**

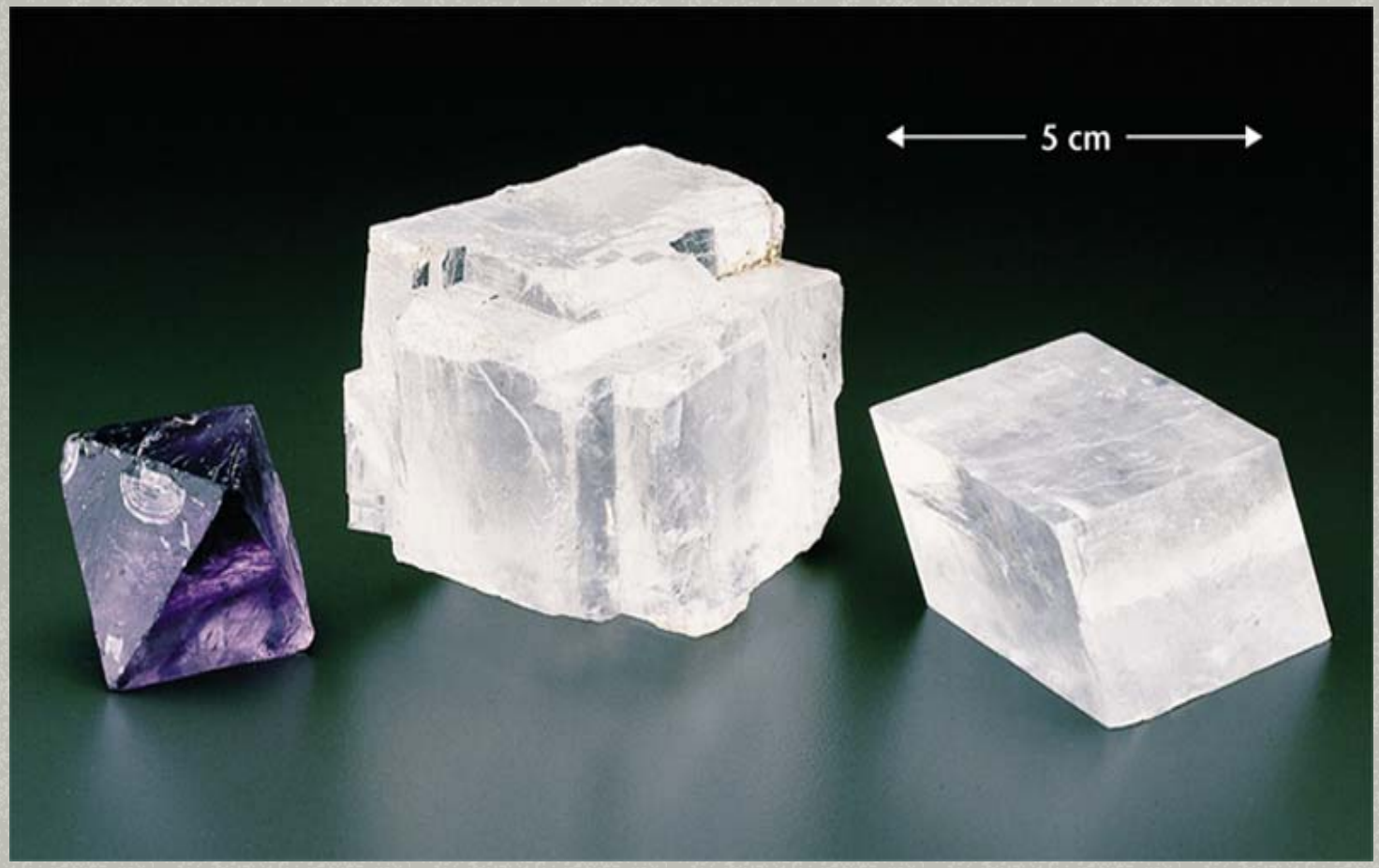
## TABLE 2.2 **Mohs Scale of Hardness**

| Relative Scale | | Mineral | Hardness of Some Common Objects |
|---|---|---|---|
| Hardest | 10 | Diamond | |
| | 9 | Corundum | |
| | 8 | Topaz | |
| | 7 | Quartz | |
| | 6 | Potassium Feldspar | |
| | 5 | Apatite | 5.5 Glass, Pocketknife |
| | 4 | Fluorite | |
| | 3 | Calcite | 3 Copper Penny |
| | 2 | Gypsum | 2.5 Fingernail |
| Softest | 1 | Talc | |

# *Physical properties of minerals*

- **Cleavage**
  - **Tendency to break along planes of weak bonding**
  - **Produces flat, shiny surfaces**
  - **Described by resulting geometric shapes**
    - **Number of planes**
    - **Angles between adjacent planes**

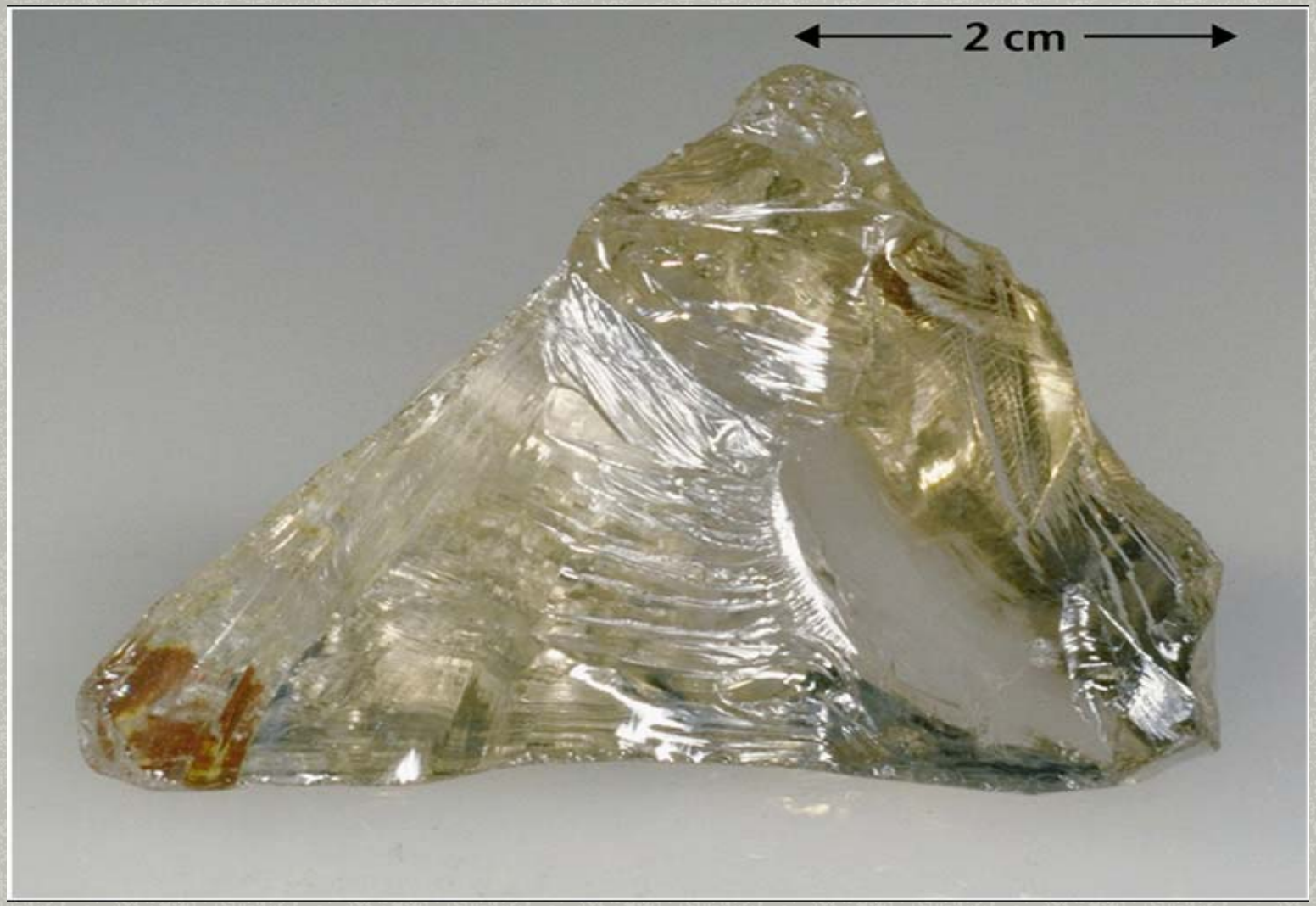
# *Three examples of perfect cleavage – fluorite, halite, and calcite*



# *Physical properties of minerals*

- **Fracture**
  - **Absence of cleavage when a mineral is broken**
- **Specific Gravity**
  - **Ratio of the weight of a mineral to the weight of an equal volume of water**
  - **Average value is approximately 2.7**

# *Conchoidal fracture*



# *Physical properties of minerals*

- **Other properties**
  - **Magnetism**
  - **Reaction to hydrochloric acid**
  - **Malleability**
  - **Double refraction**
  - **Taste**
  - **Smell**
  - **Elasticity**

# *Classification of Minerals*

- Nearly 4000 minerals have been identified on Earth
- Rock-forming minerals
  - Common minerals that make up most of the rocks of Earth's crust
  - Only a few dozen members
  - Composed mainly of the 8 elements that make up over 98% of the continental crust

**Table 2.3 Relative abundance of the most common elements in the continental crust**

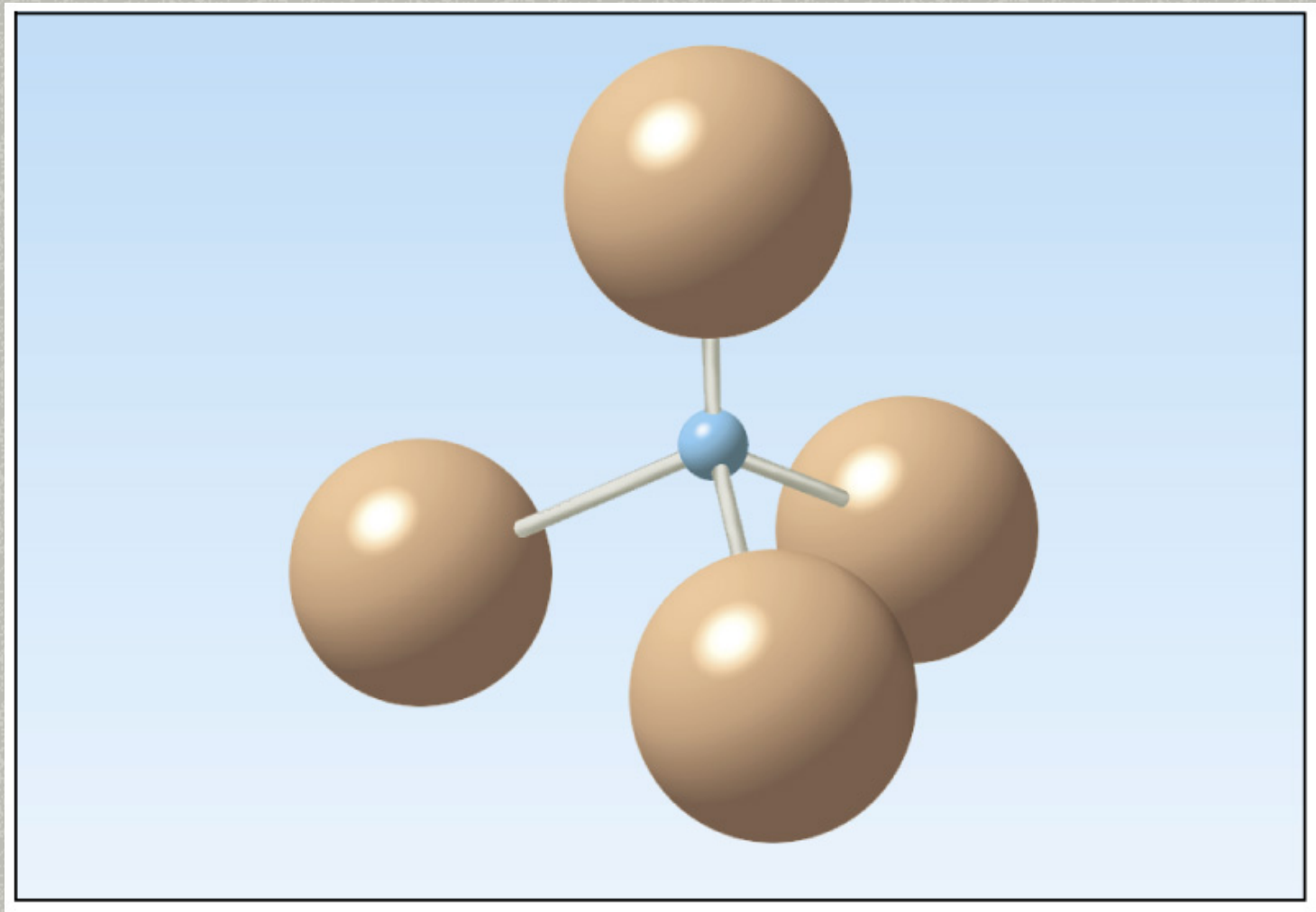
| Element | Approximate Percentage by Weight |
|---|---|
| Oxygen (O) | 46.6 |
| Silicon (Si) | 27.7 |
| Aluminum (Al) | 8.1 |
| Iron (Fe) | 5.0 |
| Calcium (Ca) | 3.6 |
| Sodium (Na) | 2.8 |
| Potassium (K) | 2.6 |
| Magnesium (Mg) | 2.1 |
| All others | 1.5 |
| Total | 100 |

*Source*: Data from Brian Mason.

# *Classification of Minerals*

- **Silicates**
  - **Most important mineral group**
    - **Comprise most of the rock-forming minerals**
    - **Very abundant due to large amounts of silicon and oxygen in Earth's crust**
  - **Basic building block is the silicon-oxygen tetrahedron molecule**
    - **Four oxygen ions surrounding a much smaller silicon ion**

# *The silicate $(SiO_4)^{-4}$ molecule*



# *Classification of Minerals*

- **Silicate structures**
  - **Single tetrahedra are linked together to form various structures including**
    - **Isolated tetrahedra**
    - **Ring structures**
    - **Single and double chain structures**
    - **Sheet or layered structures**
    - **Complex 3-dimensional structures**

# *Silicate structures*

| Mineral | | Idealized Formula | Cleavage | Silicate Structure |
|---|---|---|---|---|
| Olivine | | $(Mg, Fe)_2SiO_4$ | None | Single tetrahedron |
| Pyroxene group (Augite) | | $(Mg,Fe)SiO_3$ | Two planes at right angles | Single chains |
| Amphibole group (Hornblende) | | $Ca_2(Fe,Mg)_5Si_8O_{22}(OH)_2$ | Two planes at 60° and 120° | Double chains |
| Micas | Biotite | $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$ | One plane | Sheets |
| | Muscovite | $KAl_2(AlSi_3O_{10})(OH)_2$ | | |
| Feld-spars | Orthoclase (Potassium feldspar) | $KAlSi_3O_8$ | Two planes at 90° | Three-dimensional networks |
| | Plagioclase | $(Ca,Na)AlSi_3O_8$ | | |
| Quartz | | $SiO_2$ | None | |

# *Classification of Minerals*

- **Common Silicate minerals**
  - **Olivine**
    - **High temperature Fe-Mg silicate**
    - **Individual tetrahedra linked together by iron and magnesium ions**
    - **Forms small, rounded crystals with no cleavage**

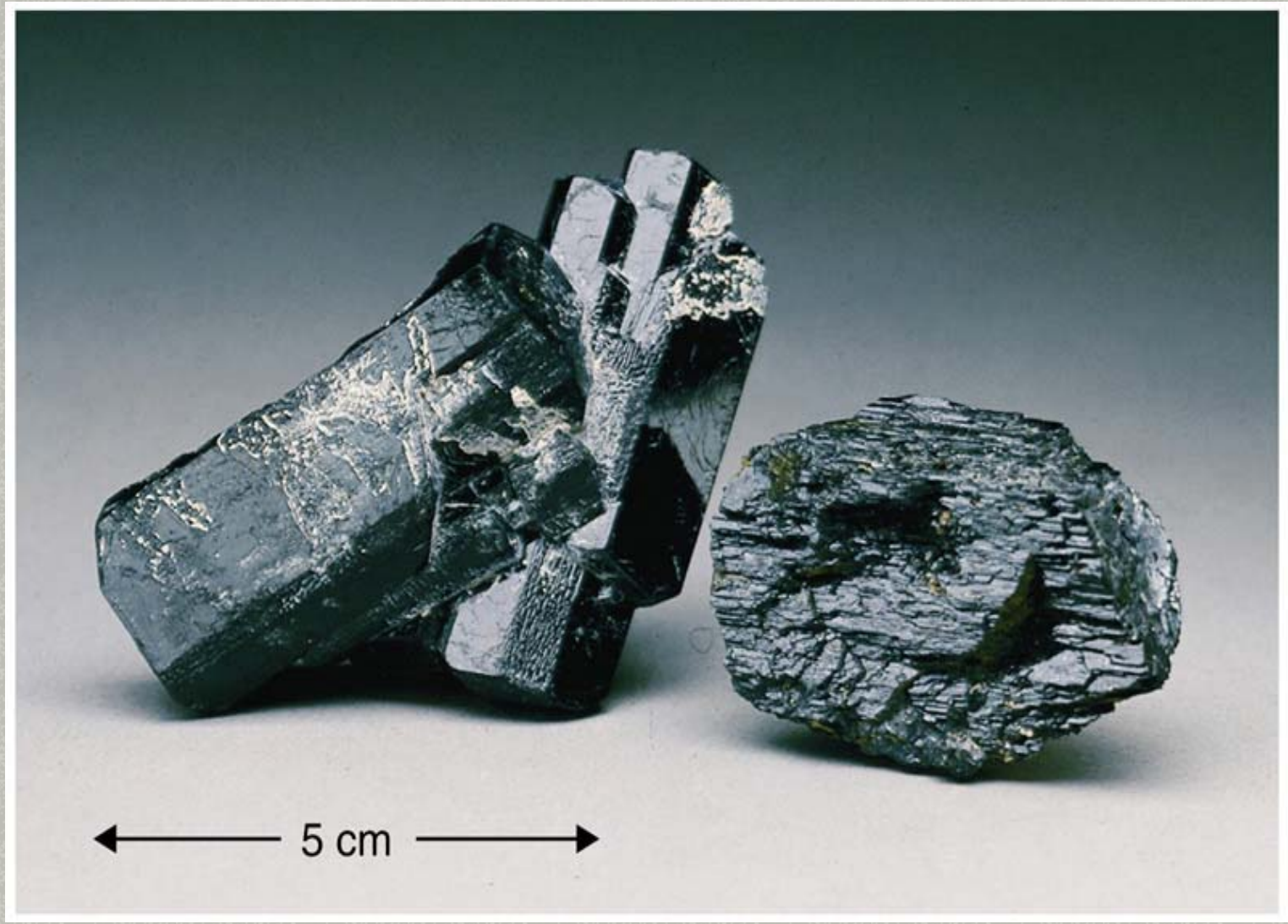
# *Classification of Minerals*

- Common Silicate minerals
  - Pyroxene Group
    - Single chain structures involving iron and magnesium
    - Two distinctive cleavages at nearly 90 degrees
    - Augite is the most common mineral in the pyroxene group

# *Classification of Minerals*

- **Common Silicate minerals**
  - **Amphibole Group**
    - **Double chain structures involving a variety of ions**
    - **Two perfect cleavages exhibiting angles of 124 and 56 degrees**
    - **Hornblende is the most common mineral in the amphibole group**

# *Hornblende crystals*



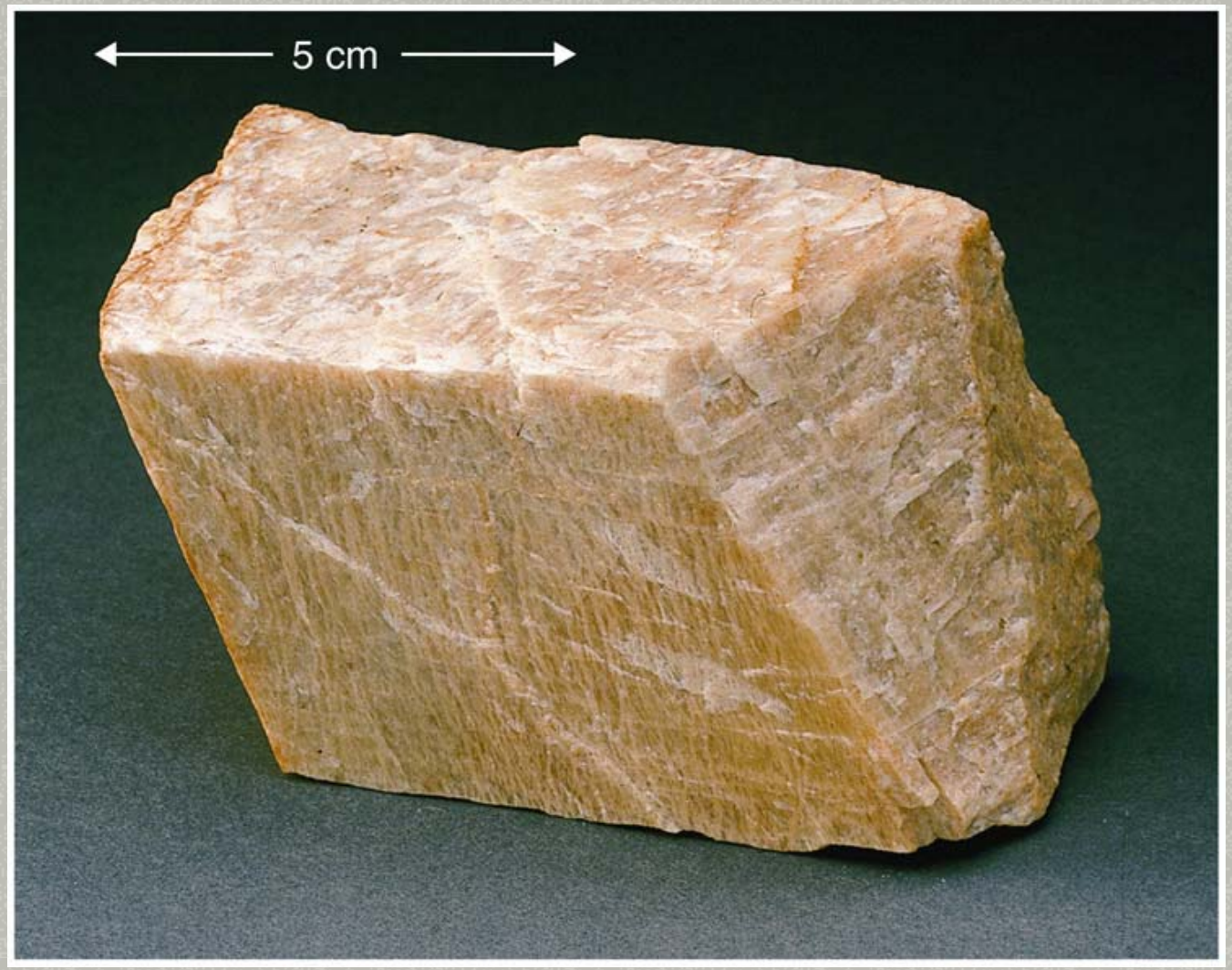
# *Classification of Minerals*

- **Common Silicate minerals**
  - **Mica Group**
    - **Sheet structures that result in one direction of perfect cleavage**
    - **Biotite is the common dark colored mica mineral**
    - **Muscovite is the common light colored mica mineral**

# *Classification of Minerals*

- **Common Silicate minerals**
  - **Feldspar Group**
    - **Most common mineral group**
    - **3-dimensional framework of tetrahedra exhibit two directions of perfect cleavage at 90 degrees**
    - **Orthoclase (potassium feldspar) and Plagioclase (sodium and calcium feldspar) are the two most common members**

# *Potassium feldspar*



# *Plagioclase feldspar*

# *Classification of Minerals*

- **Common Silicate minerals**
  - **Clay minerals**
    - **Clay is a general term used to describe a variety of complex minerals**
    - **Clay minerals all have a sheet or layered structure**
    - **Most originate as products of chemical weathering**

# *Classification of Minerals*

- **Important nonsilicate minerals**
  - **Several major groups exist including**
    - **Oxides**
    - **Sulfides**
    - **Sulfates**
    - **Native Elements**
    - **Carbonates**
    - **Halides**
    - **Phosphates**

# *Classification of Minerals*

- **Important nonsilicate minerals**
  - **Carbonates**
    - **Primary constituents in limestone and dolostone**
    - **Calcite (calcium carbonate) and Dolomite (calcium-magnesium carbonate) are the two most important carbonate minerals**

# *Classification of Minerals*

- **Important nonsilicate minerals**
  - **Many nonsilicate minerals have economic value**
  - **Examples**
    - **Hematite (oxide mined for iron ore)**
    - **Halite (halide mined for salt)**
    - **Sphalerite (sulfide mined for zinc ore)**
    - **Native Copper (native element mined for copper)**

# *Native Copper*

# *Mineral resources*

- **The endowment of useful minerals ultimately available commercially**
  - **Mineral resources include**
    - **Reserves – already identified deposits**
    - **Known deposits that are not yet economically or technologically recoverable**

# *Mineral resources*

- **Ore**
  - **A useful metallic mineral that can be mined at a profit**
  - **Must be concentrated above its average crustal abundance**
  - **Profitability may change because of economic changes**

# *End of Chapter 2*