



ECIV 3302
Engineering Geology

CHAPTER 2

MATTER & MINERALS

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The materials are mostly adapted from the presentation of Stan & Cindy Hatfield

Minerals: Building Blocks of Rocks

- **By definition a mineral is**
 - Naturally occurring
 - Inorganic solid
 - Ordered internal molecular structure
 - Definite chemical composition
- **Rock**
 - A solid aggregate of minerals

Composition of Minerals

- **Elements**

- Basic building blocks of minerals
- Over 115 are known (92 naturally occurring)
- A group of the same kind of atoms is called an element

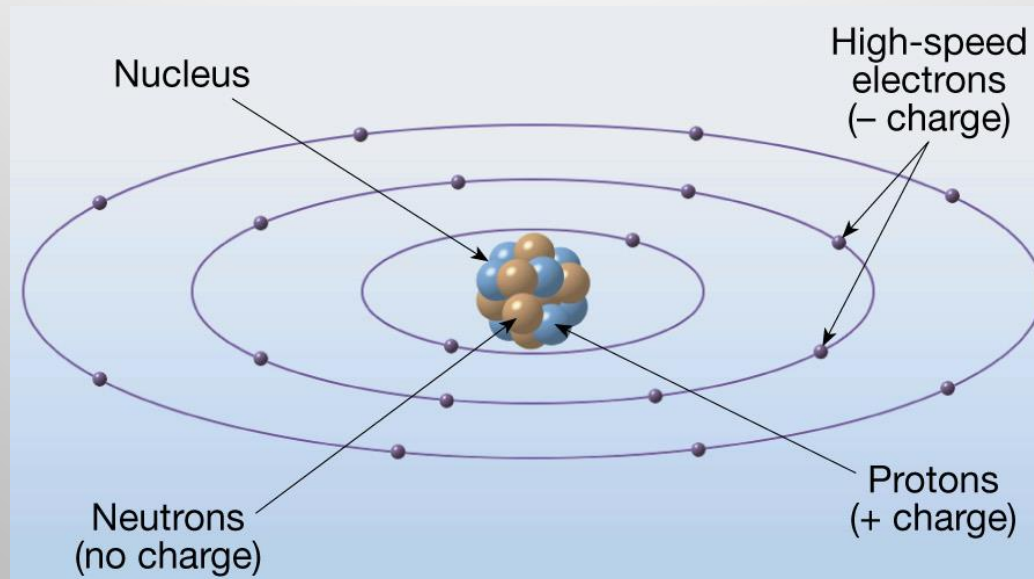
- **Atoms**

- Smallest particles of matter
- Retains all the characteristics of an element

Composition of Minerals

- **Atomic structure**

- Central region called the **nucleus**
 - Consists of **protons** (+ charges) and **neutrons** (0 charges)
- **Electrons** (- charges)
 - Negatively charged particles that surround the nucleus
 - Located in discrete energy levels called **shells**



Composition of Minerals

- **Chemical bonding**

Formation of a compound by combining two or more elements and three types:

- a. **Ionic bonding**

- Atoms gain or lose outermost electrons to form ions
- Ionic compounds consist of an orderly arrangement of oppositely charged ions

Halite (NaCl) – An example of ionic bonding

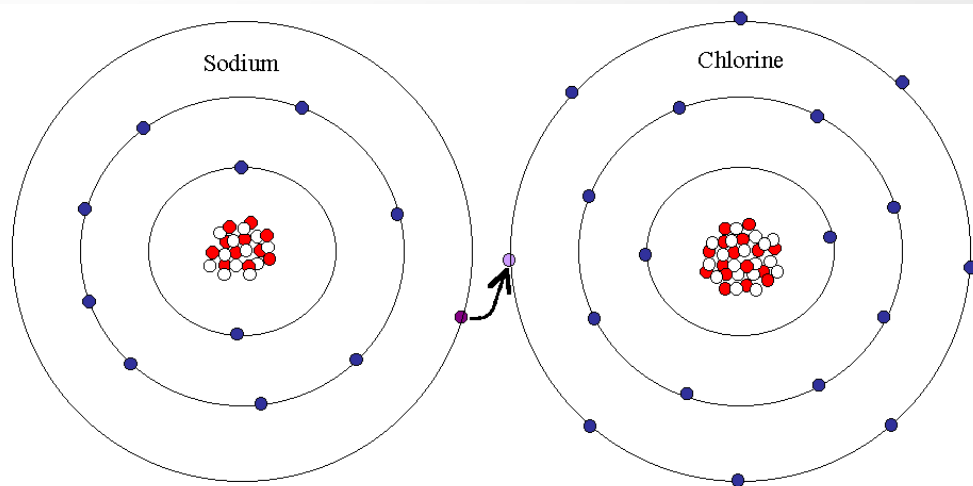
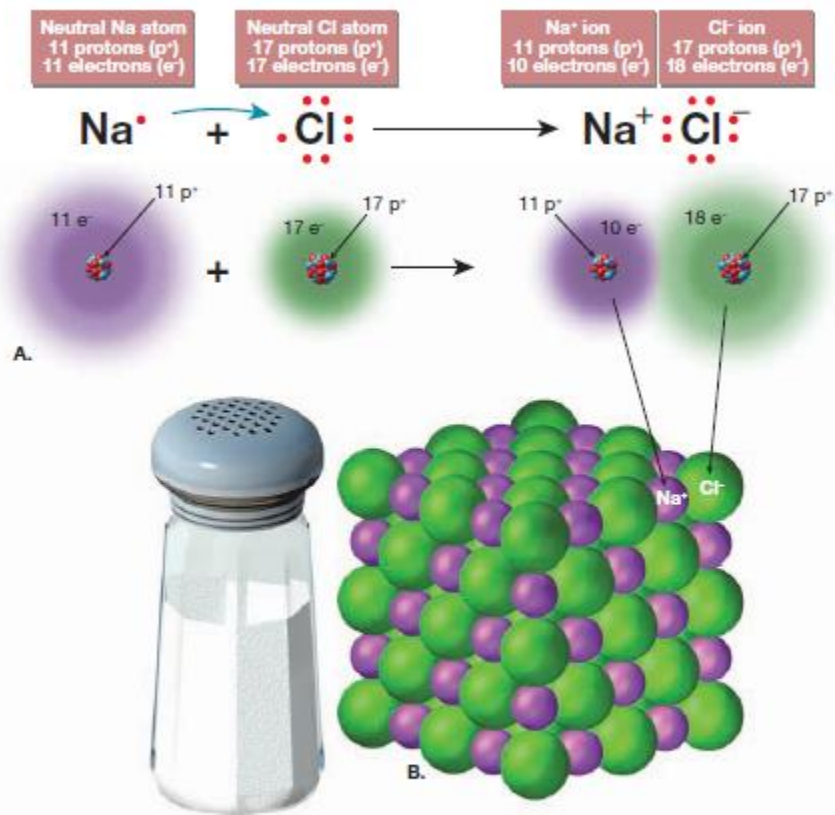


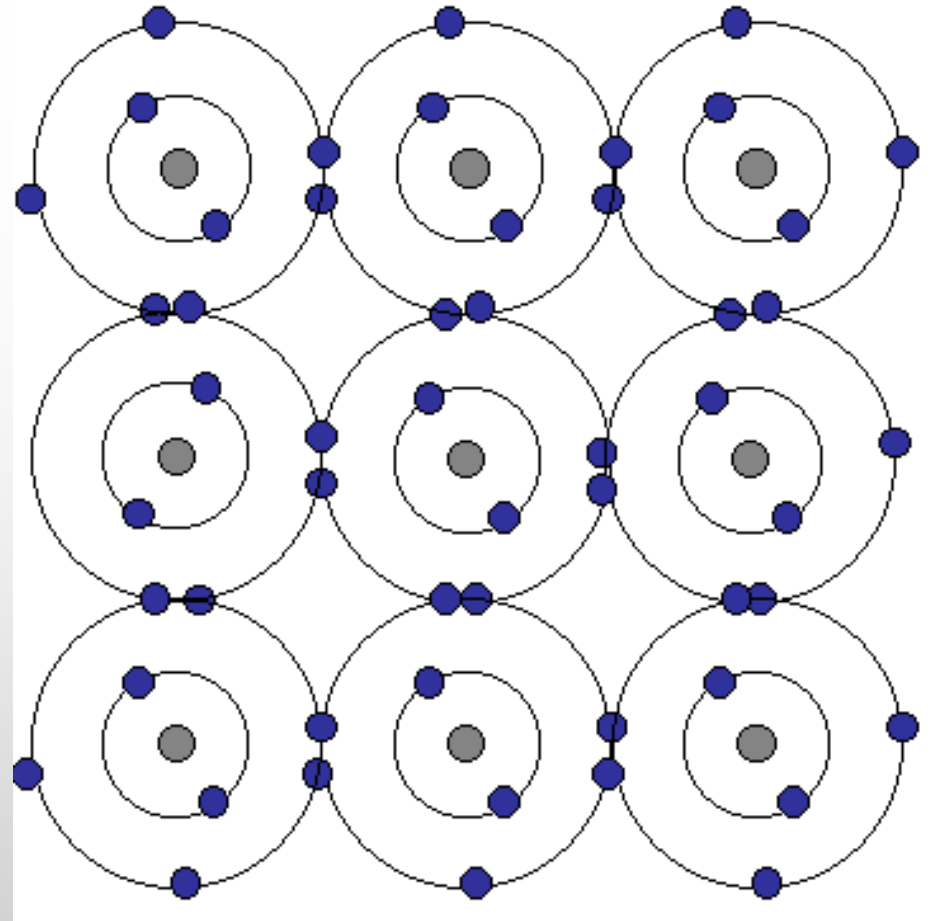
FIGURE 2.7 Chemical bonding of sodium chloride (table salt). **A.** Through the transfer of one electron in the outer shell of a sodium atom to a chlorine atom, sodium becomes a positive ion and chlorine a negative ion. **B.** Diagram illustrating the arrangement (packing) of sodium and chlorine ions in table salt.

Composition of Minerals

6
C
12.011
Carbon

b. Covalent bonding

- Atoms share electrons to achieve electrical neutrality
- Generally stronger than ionic bonds
- Both ionic and covalent bonds typically occur in the same compound



Diamonds are made of pure carbon and its the hardest substance

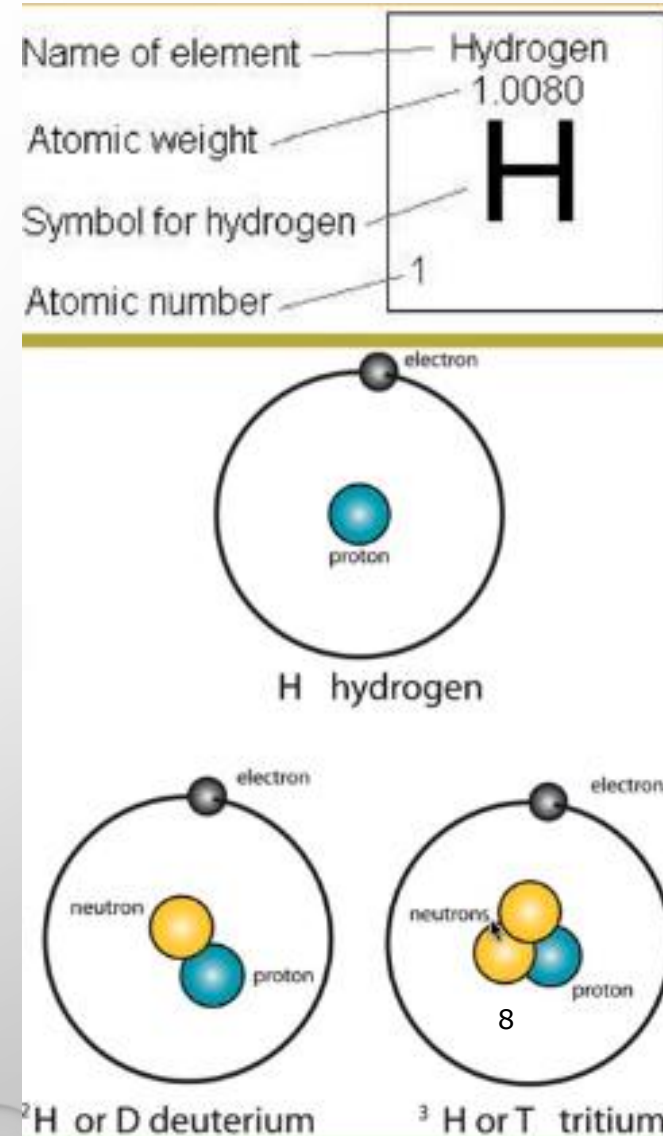
Composition of Minerals

c. Metallic bonding

- Electrons are free to migrate among atoms
- Weaker and less common than other bonds

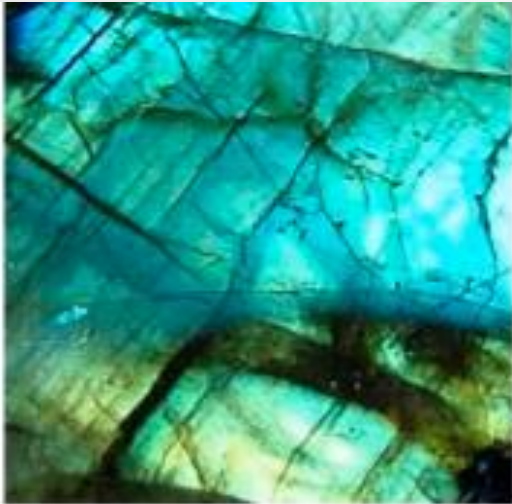
• Isotopes

- **Mass number** = sum of neutrons + protons in an atom
- Atoms of same element with different # of neutrons
- **Isotope** = atom that exhibits variation in its mass number



Structure of Minerals

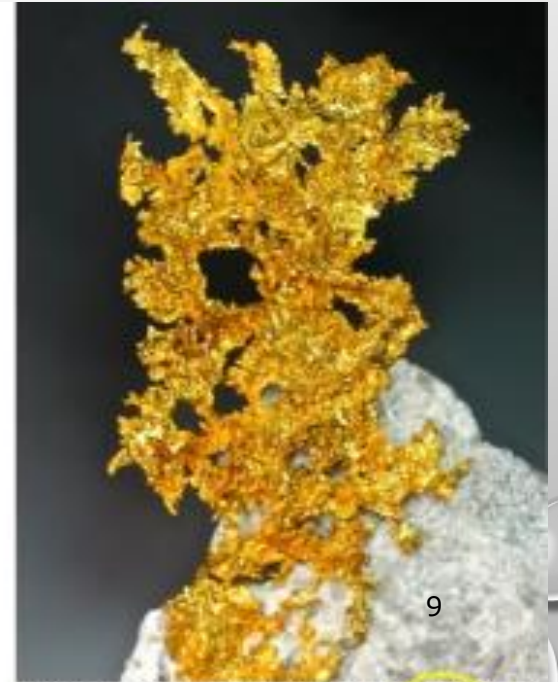
- Minerals consist of an orderly array of atoms chemically bonded to form a particular crystalline structure
- Internal atomic arrangement in ionic compounds is determined by ionic size



Labradorite Plagioclase
 $((\text{Ca}, \text{Na})(\text{Al}, \text{Si})_4\text{O}_8)$



Elbaite
 $(\text{Na}(\text{Li}_{1.5}\text{Al}_{1.5})\text{Al}_6\text{Si}_6\text{O}_{18}(\text{BO}_3)_3(\text{OH})_4)$



Gold (Au) on Quartz (SiO_2)

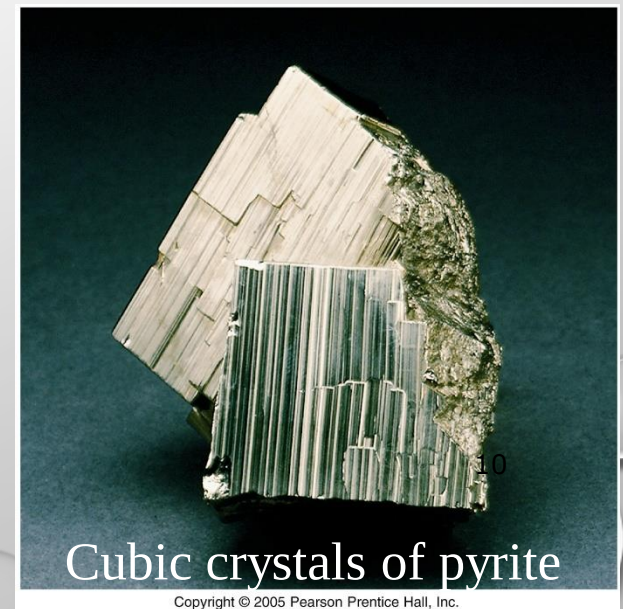
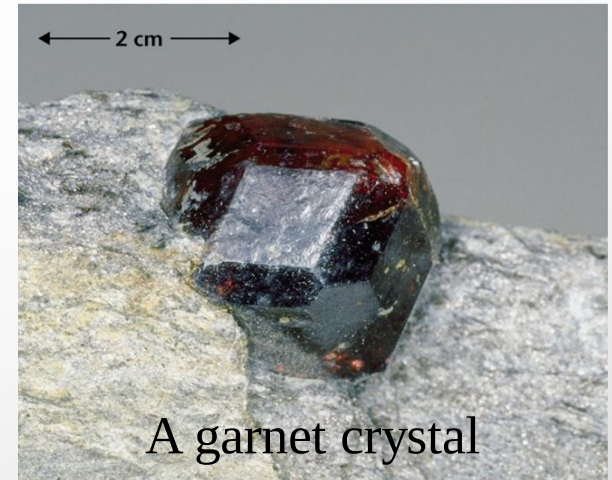
Physical Properties of Minerals

- **Primary diagnostic properties**

- Determined by observation or performing a simple test
- Several physical properties are used to identify hand samples of minerals

1. **Crystal form**

- External expression of a mineral's internal structure
- Often interrupted due to competition for space and rapid loss of heat



Physical Properties of Minerals

2. Luster

- Appearance of a mineral in reflected light
- Two basic categories
 - Metallic
 - Nonmetallic
- Other descriptive terms include vitreous, silky, or earthy

FIGURE 2.9 The freshly broken sample of galena (right) displays a metallic luster, while the sample on the left is tarnished and has a submetallic luster. (Photo courtesy of E. J. Tarbuck)



Galena (PbS) displays metallic luster

Physical Properties of Minerals

3. Color

- Generally unreliable for mineral identification
- Often highly variable due to slight changes in mineral chemistry
- Exotic colorations of certain minerals produce gemstones

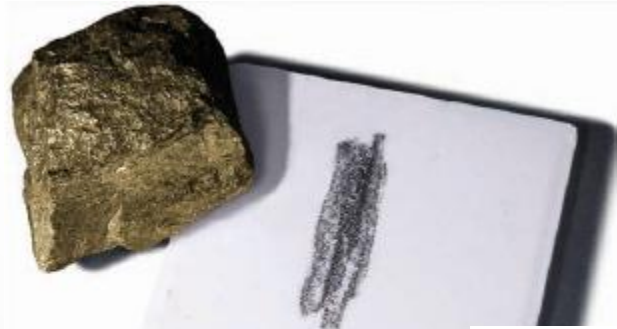


Quartz (SiO₂) exhibits a variety of colors

Physical Properties of Minerals

4. Streak

- Color of a mineral in its powdered form

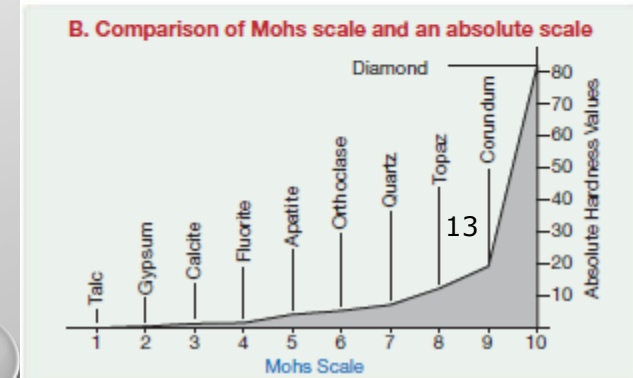
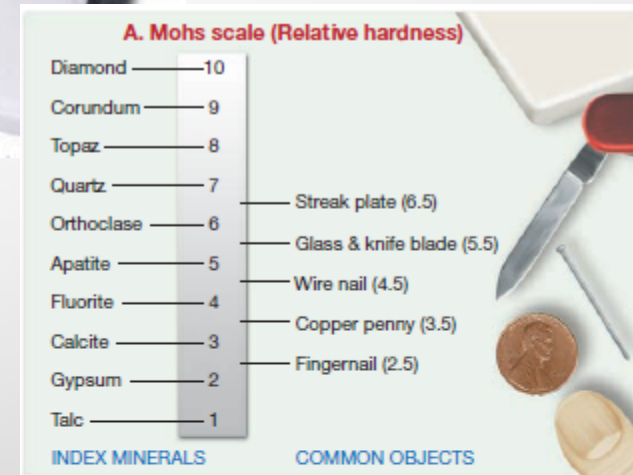


Streak is obtained on an unglazed porcelain plate

Mohs scale of hardness

5. Hardness

- Resistance of a mineral to abrasion or scratching
- All minerals are compared to a standard scale called the Mohs scale of hardness



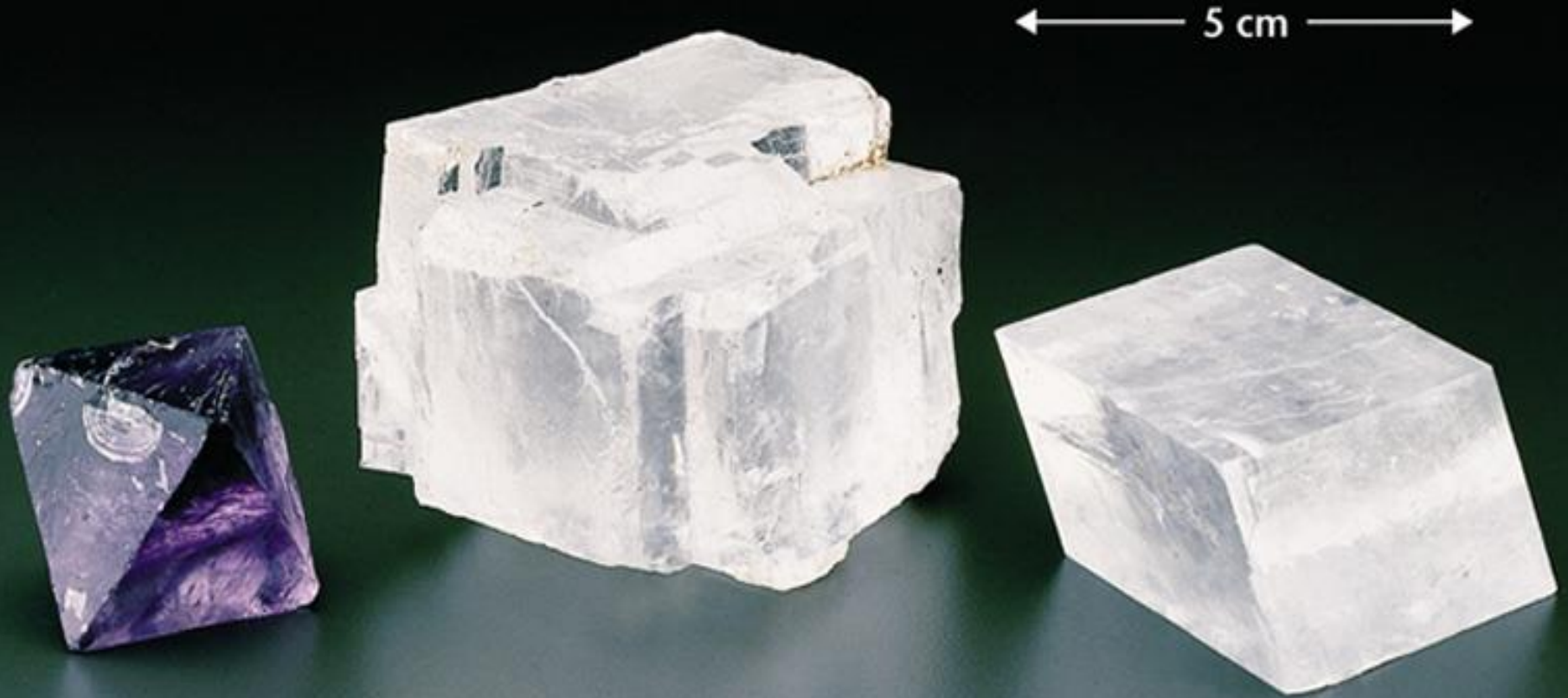
Physical Properties of Minerals

6. 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

Number of Cleavage Directions	Shape	Sketch	Directions of Cleavage	Sample
1	Flat sheets			 Muscovite
2 at 90°	Elongated form with rectangle cross section (prism)			 Feldspar
2 not at 90°	Elongated form with parallelogram cross section (prism)			 Hornblende
3 at 90°	Cube			 Halite
3 not at 90°	Rhombohedron			 Calcite
4	Octahedron			 Fluorite

Fluorite, halite, and calcite all exhibit perfect cleavage



Physical Properties of Minerals

7. Fracture

- Absence of cleavage when a mineral is broken

8. Specific Gravity

- Weight of a mineral / weight of an equal volume of water
- Average value = 2.7



Conchoidal Fracture

Physical Properties of Minerals

9. Other properties

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

Mineral Groups

- Nearly 4000 minerals have been named
- 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

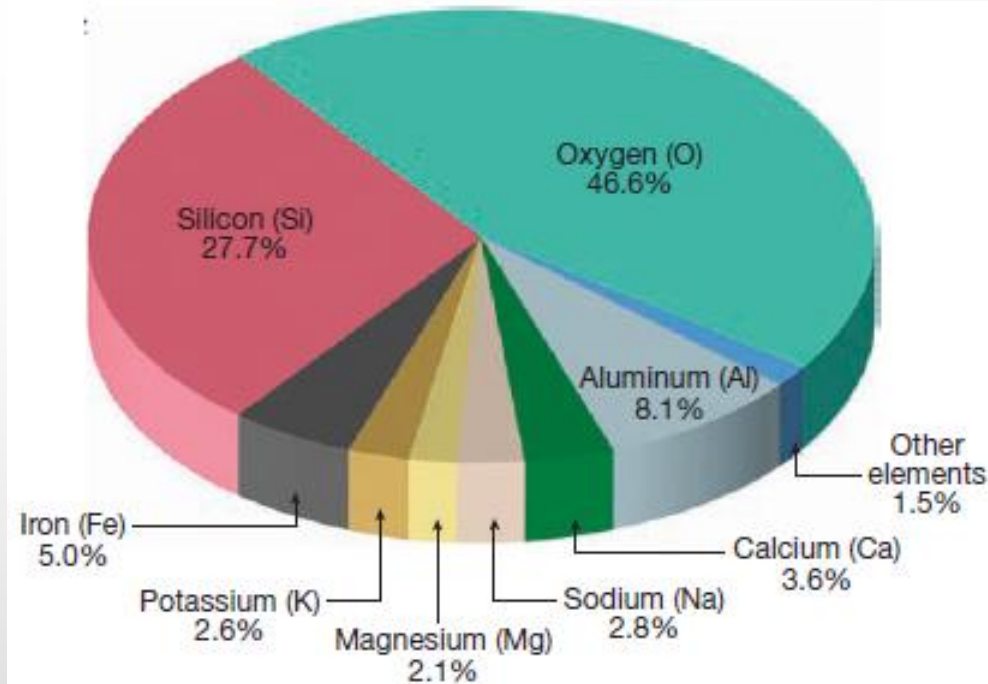
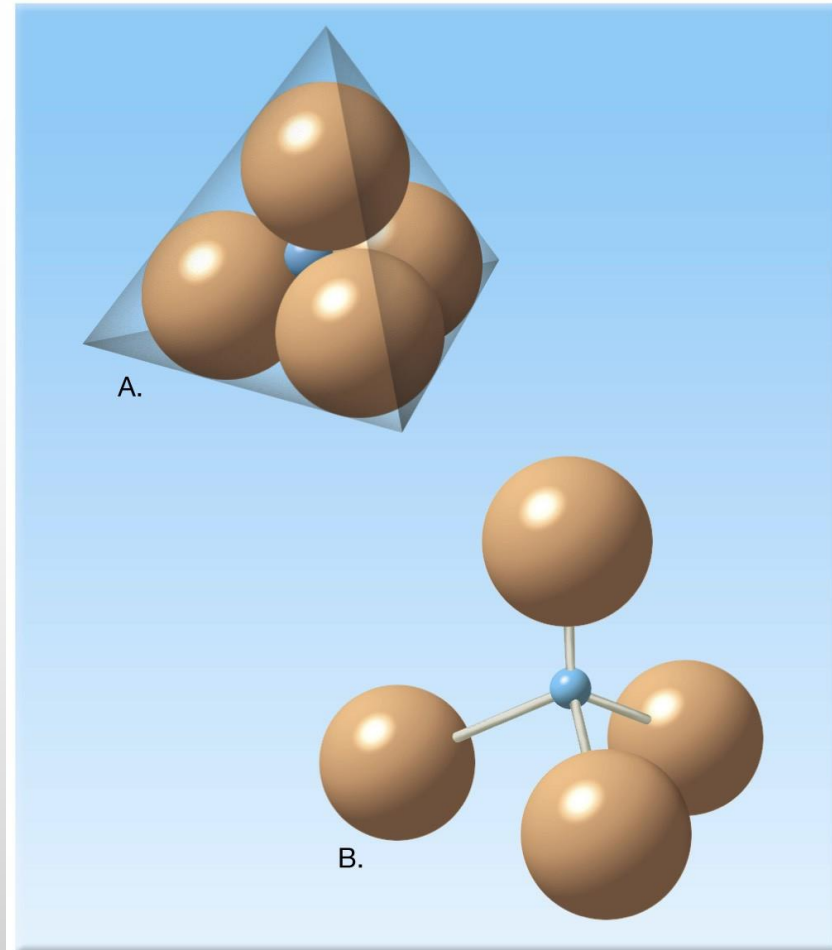


FIGURE 2.20 Relative abundance of the eight most abundant elements in the continental crust.

Mineral Groups

- **Silicates**

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



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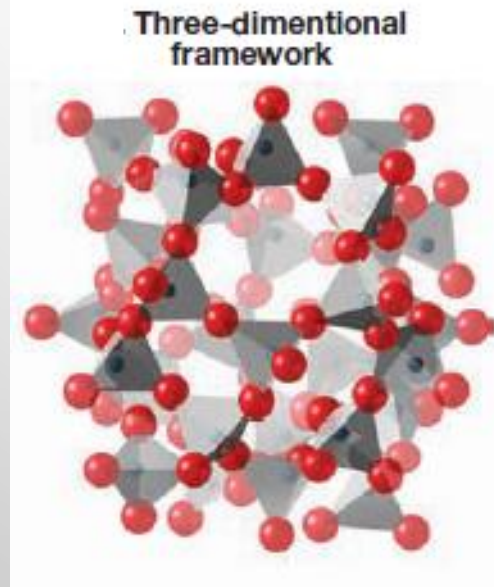
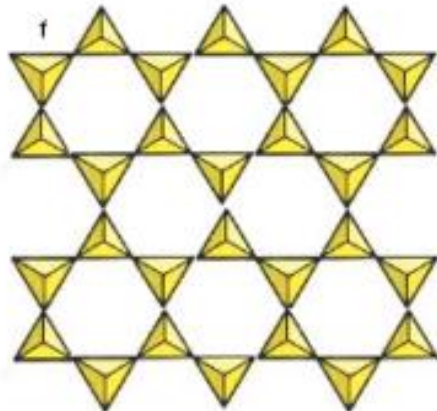
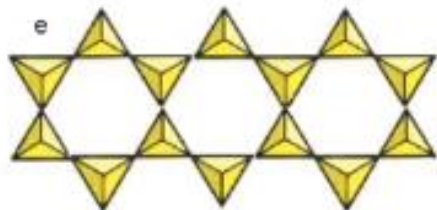
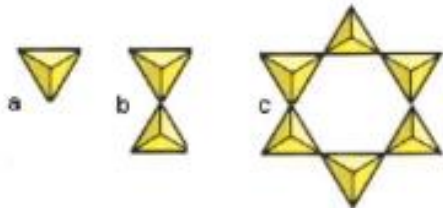
Two illustrations of the
Si–O tetrahedron

Mineral Groups

• Joining silicate structures

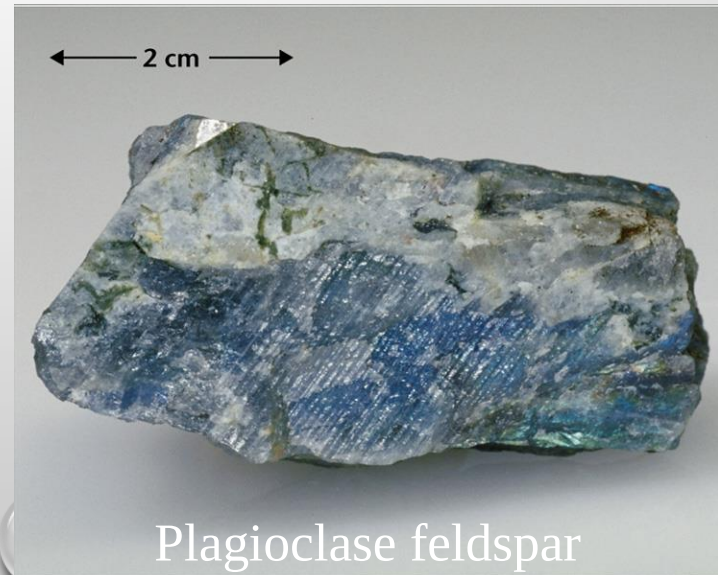
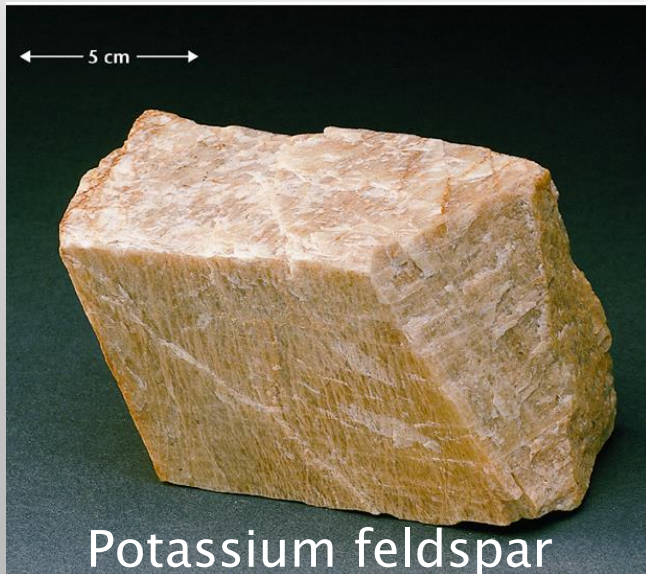
Single tetrahedra are linked together to form various structures:

- Isolated tetrahedra (a)
- Tetrahedra pairs (b)
- Ring structures (c)
- Single and double chain structures (d, e)
- Sheet or layered structures (f)
- Complex 3-dimensional structures



Mineral Groups

- Common **silicate** minerals
 - **Light silicates: Feldspar group**
 - Most common mineral group
 - Exhibit two directions of perfect cleavage at 90 degrees
 - Orthoclase (potassium feldspar) and Plagioclase (sodium and calcium feldspar) are the two most common members



Mineral Groups

- Common **silicate** minerals

- **Light silicates: Quartz**

- Only common silicate composed entirely of oxygen & silicon
 - Hard and resistant to weathering
 - Conchoidal fracture
 - Often forms hexagonal crystals



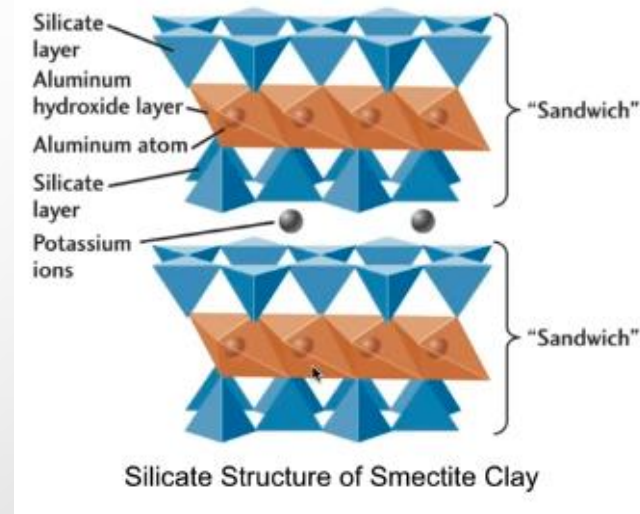
- **Light silicates: Muscovite**

- Common member of the mica family
 - Excellent cleavage in one direction
 - Produces the “glimmering” brilliance often seen in beach sand



Mineral Groups

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

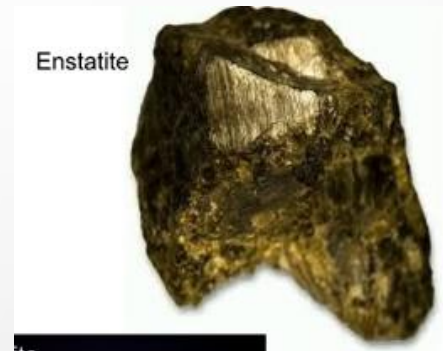


Mineral Groups

- Common **silicate** minerals

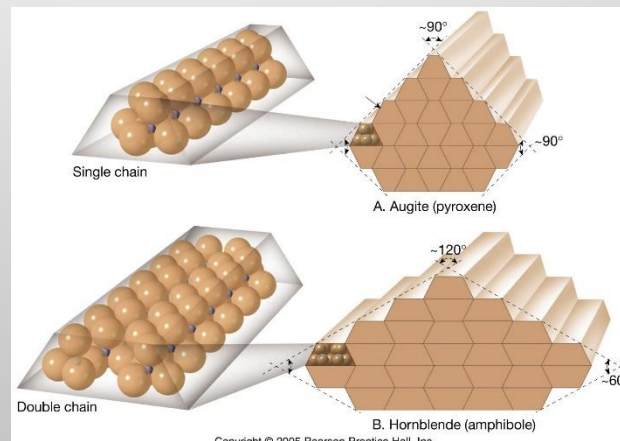
- **Dark silicates: Pyroxene group**

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



- **Dark silicates: 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 amphibole group



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Cleavage angles for
augite and hornblende

Mineral Groups

- Important **non-silicate** minerals
 - Typically divided into classes based on anions
 - Comprise only 8% of Earth's crust
 - Often occur as constituents in sedimentary rocks

TABLE 2.1

Common Nonsilicate Mineral Groups

Mineral Groups [key ion(s) or element(s)]	Mineral Name	Chemical Formula	Economic Use
Carbonates (CO_3^{2-})	Calcite	CaCO_3	Portland cement, lime
	Dolomite	$\text{CaMg}(\text{CO}_3)_2$	Portland cement, lime
Halides (Cl^{1-} , F^{1-} , Br^{1-})	Halite	NaCl	Common salt
	Fluorite	CaF_2	Used in steelmaking
	Sylvite	KCl	Fertilizer
Oxides (O^{2-})	Hematite	Fe_2O_3	Ore of iron, pigment
	Magnetite	Fe_3O_4	Ore of iron
	Corundum	Al_2O_3	Gemstone, abrasive
	Ice	H_2O	Solid form of water
Sulfides (S^{2-})	Galena	PbS	Ore of lead
	Sphalerite	ZnS	Ore of zinc
	Pyrite	FeS_2	Sulfuric acid production
	Chalcopyrite	CuFeS_2	Ore of copper
	Cinnabar	HgS	Ore of mercury
Sulfates (SO_4^{2-})	Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	Plaster
	Anhydrite	CaSO_4	Plaster
	Barite	BaSO_4	Drilling mud
Native elements (single elements)	Gold	Au	Trade, jewelry
	Copper	Cu	Electrical conductor
	Diamond	C	Gemstone, abrasive
	Sulfur	S	Sulfuric acid, chemicals
	Graphite	C	Pencil lead, dry lubricant
	Silver	Ag	Jewelry, photography
	Platinum	Pt	Catalyst

Mineral Groups

- Important non-silicate minerals
 - Carbonates
 - Primary constituents in limestone and dolostone
 - Calcite (CaCO_3) and dolomite $\text{CaMg}(\text{CO}_3)_2$ are the two most important carbonate minerals
 - Many non-silicate 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)

