MINERALS

I. What is a Mineral?

- An Earth material must meet several criteria in order to called a *mineral.*
- "Minerals" listed as nutritional components of food
  - have nothing to do with what geologists or chemists consider when they refer to minerals.

The "minerals" referred to by nutritionists . . .

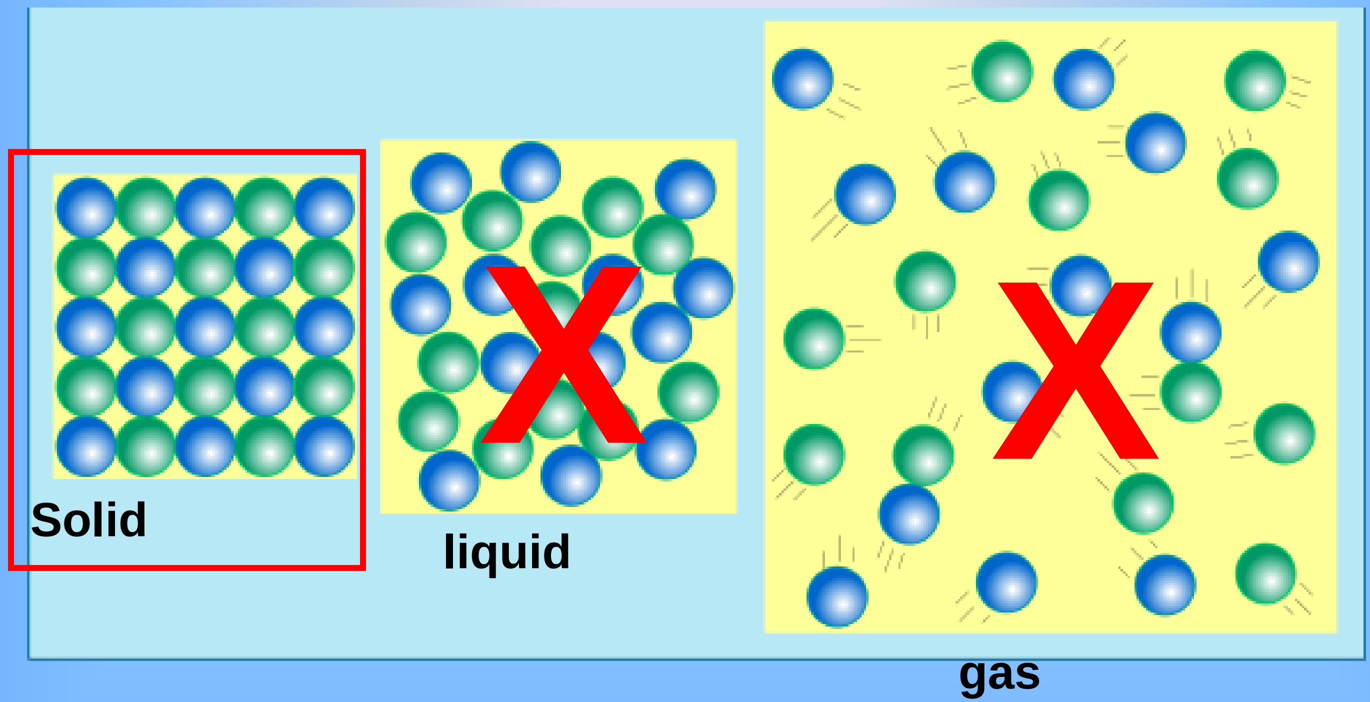
- Are single elements such as calcium or magnesium
  - Have dietary benefits
- Processing of "true" minerals yields these ingredients.
- Most "geological" minerals are complex assemblages of multiple elements.

To the geologist, a mineral . . .

A. Occurs **naturally** *,*

This means that any synthetic material is **<u>not</u>** considered to be a mineral

To the geologist, a mineral…



B. is a **solid**,

- Anything in the liquid or gas phase of matter
  - is not a mineral.

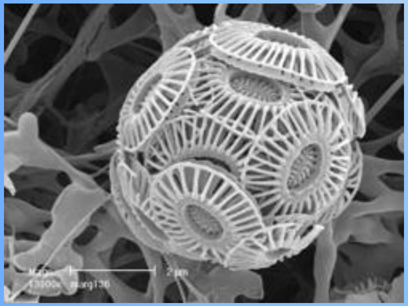
To the geologist, a mineral . . .

C. *is* <u>**inorganically formed**</u>

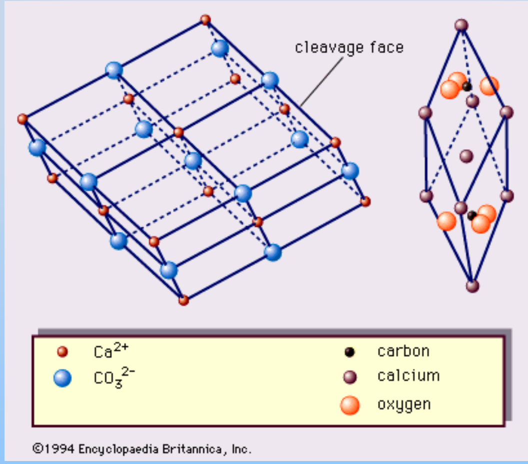
- They don’t consist of carbon-hydrogen molecules that also form crystalline substances through biological processes (such as sugars).
- Processes involving plants, animals, and other organisms don’t produce minerals.

To the geologist, a mineral . . .

Chalk



Calcite



Coral

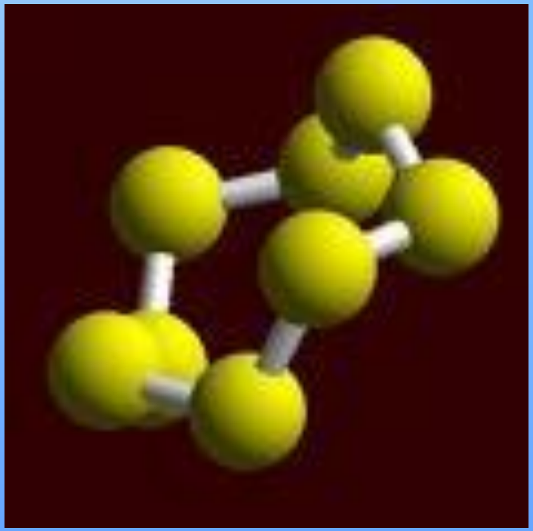
Shells

- Some organisms build shells or hard parts that are considered minerals.
  - Shells and the hard parts produced by corals are composed of the mineral *calcite*.
  - Chalk is made of microscopic platelets produced by yellow-green algae.

To the geologist, a mineral…

D. Has definite __chemical composition__

- Its elements are combined in definite proportions that can be expressed as a chemical formula
- The formula can be very simple as in native sulfur (S_8)



Or more complex as in muscovite mica

- Which has a formula of $KAl_{12}(AlSi)_3O_{10}(OH)_2$.

To the geologist, a mineral…

E. has atoms arranged in an __**orderly pattern**__, and Minerals are made of *crystals.*

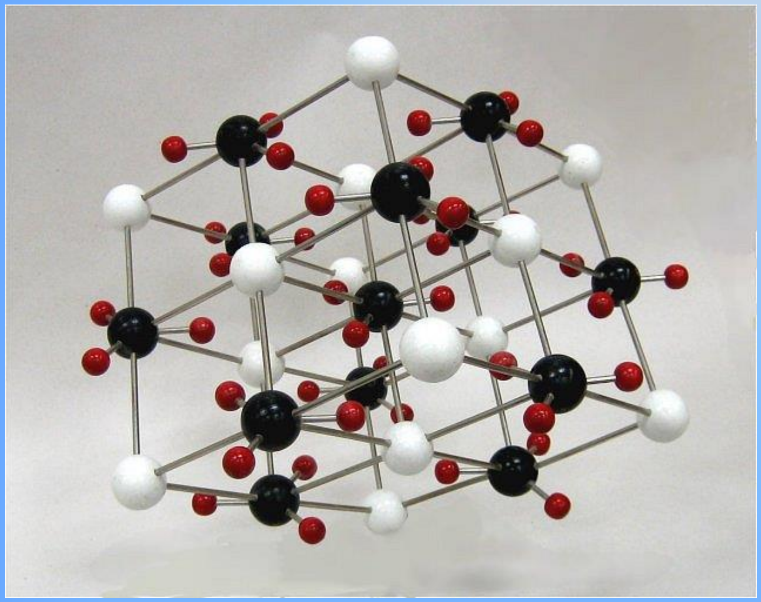
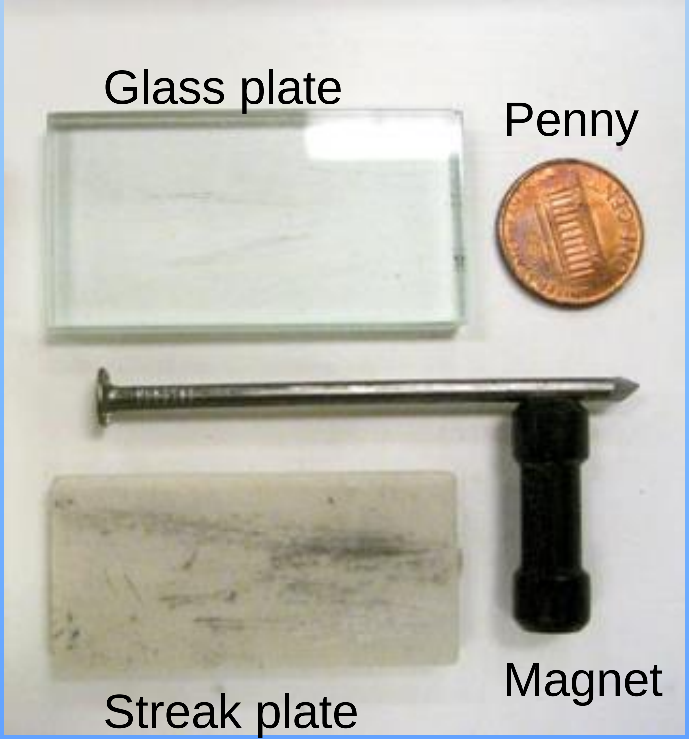


Photo by R.Weller/Cochise College

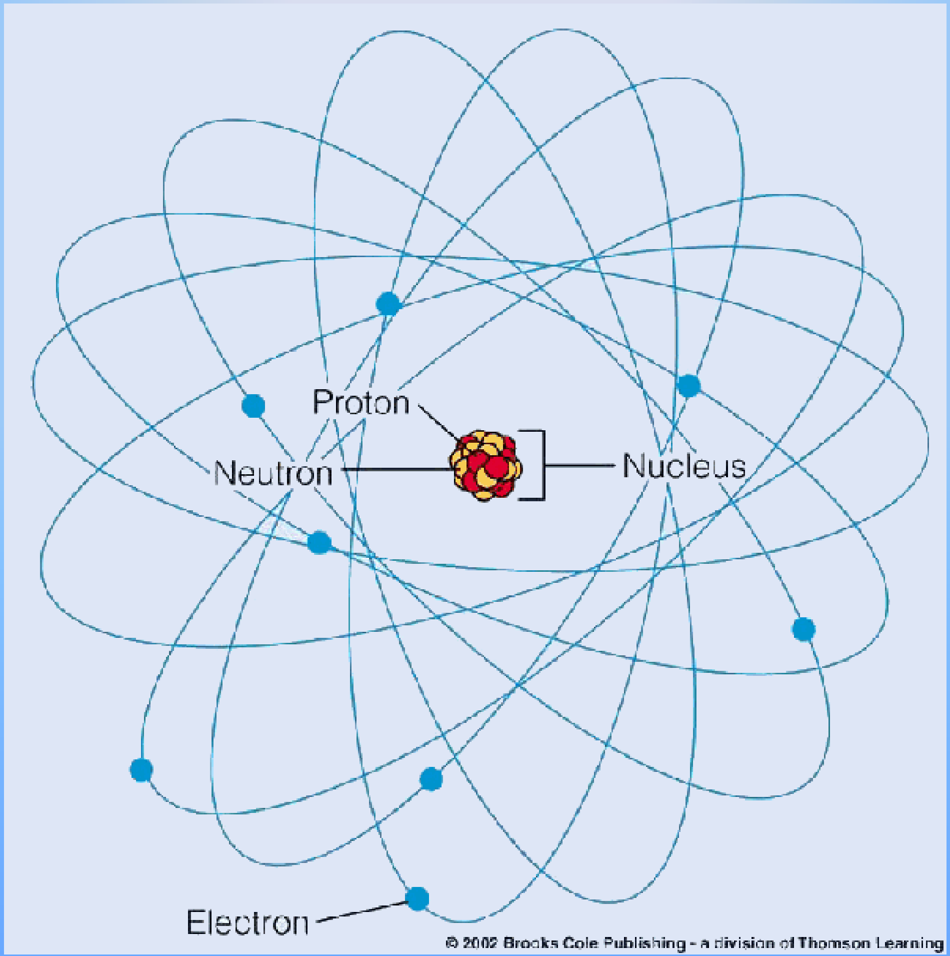
To the geologist, a mineral…

F. has physical properties such as color, hardness, shape, how it reflects light

- determined by composition and crystalline structure
- useful in identification



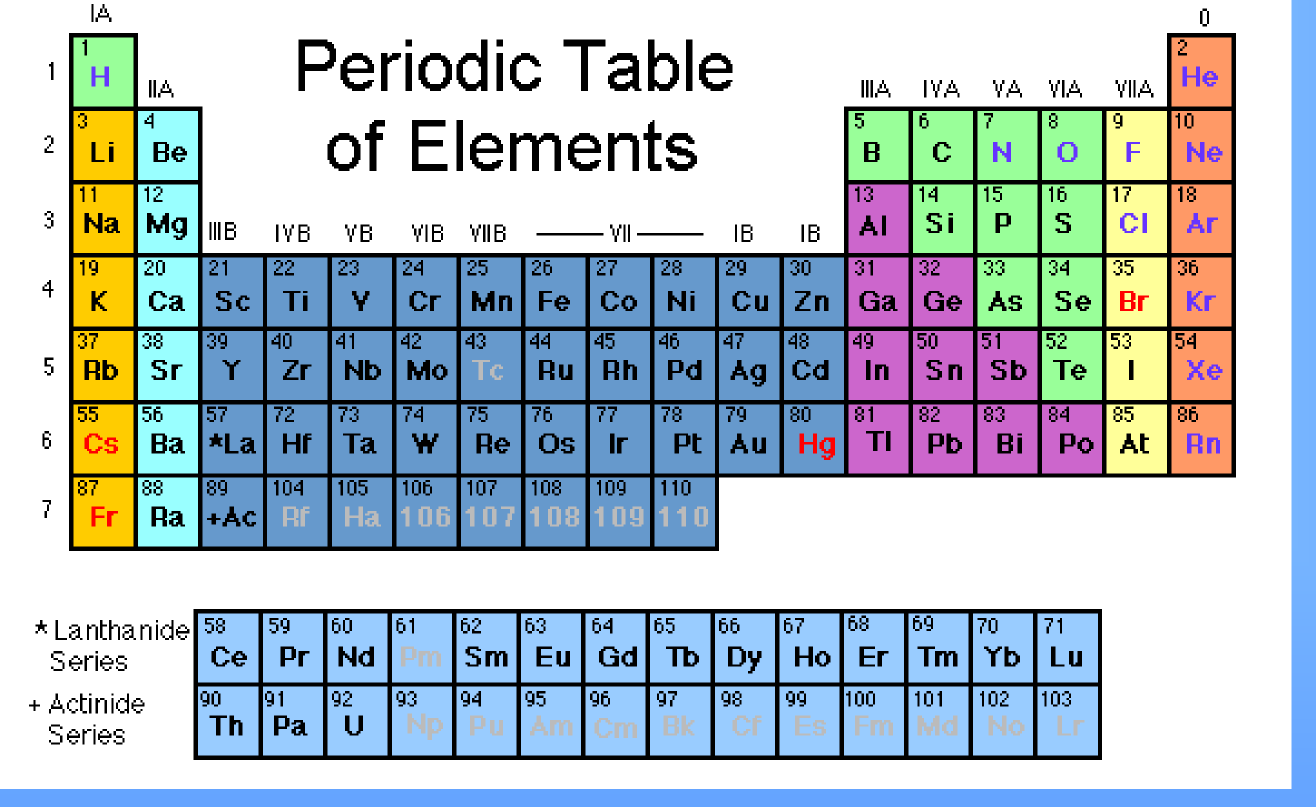
II. Mineral Chemistry



A. Chemical Activity

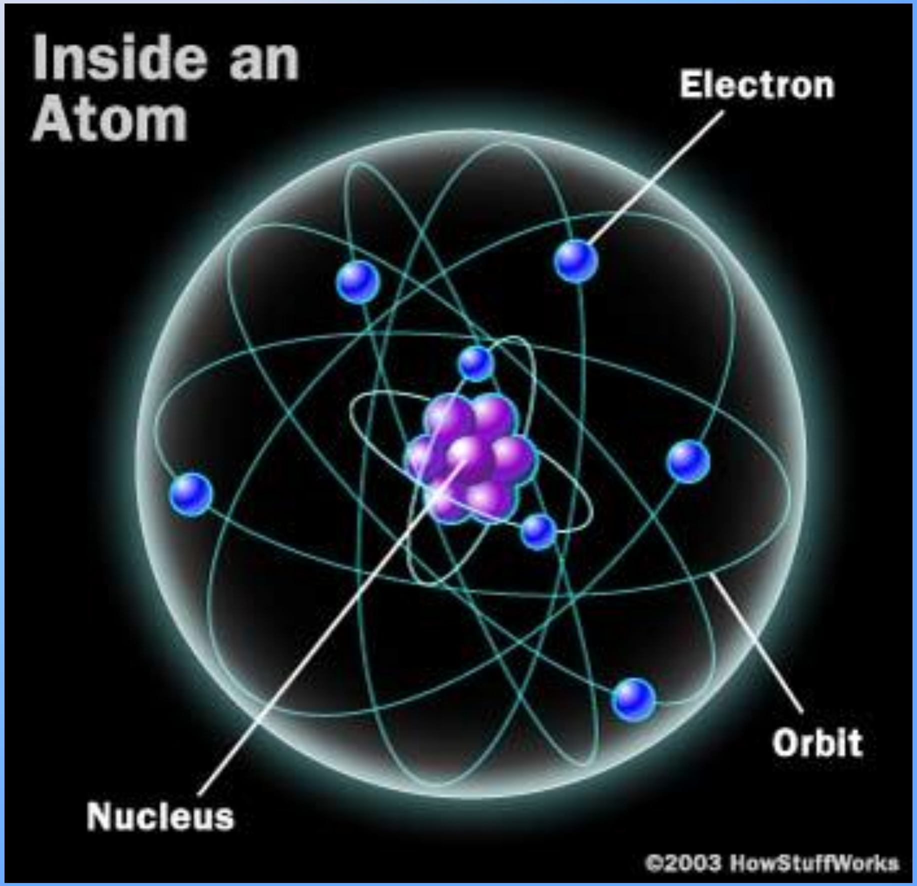
1. Elements and Atoms

   a. __Element__: A substance that cannot be broken into simpler substances by ordinary chemical means.



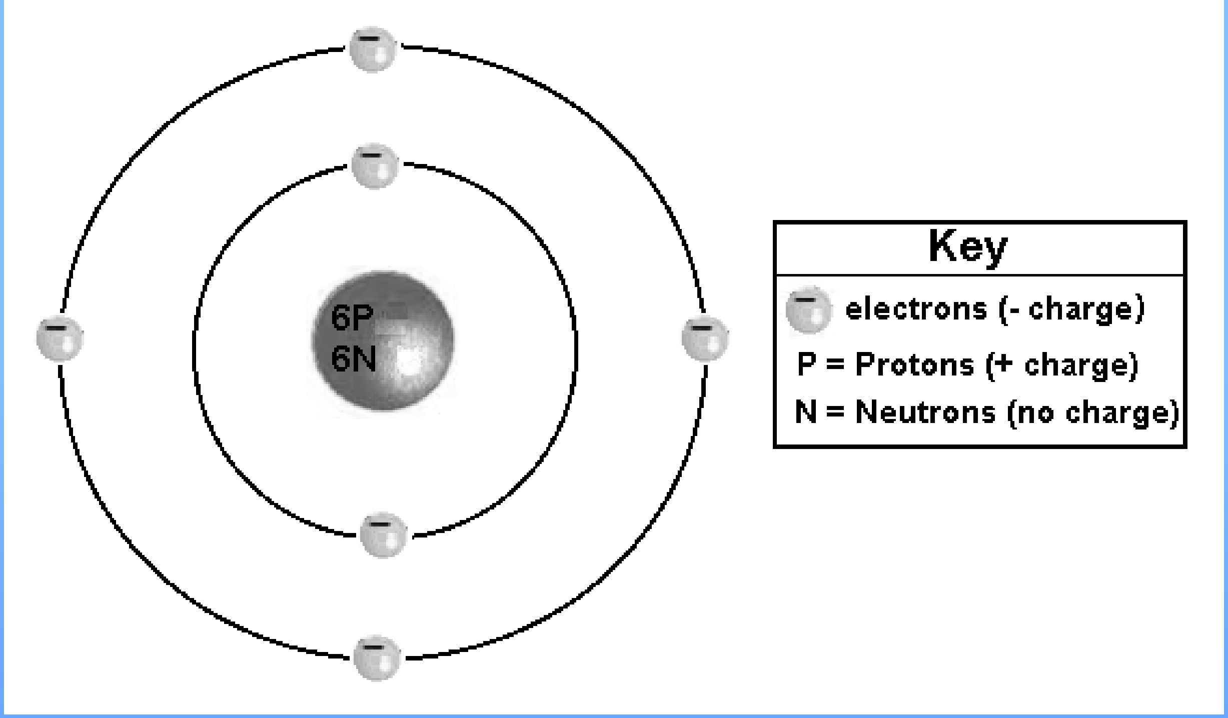
b. <u>Atom</u>

- Smallest particles of an element that can enter a chemical reaction
- The smallest chemically indivisible particle of an element.



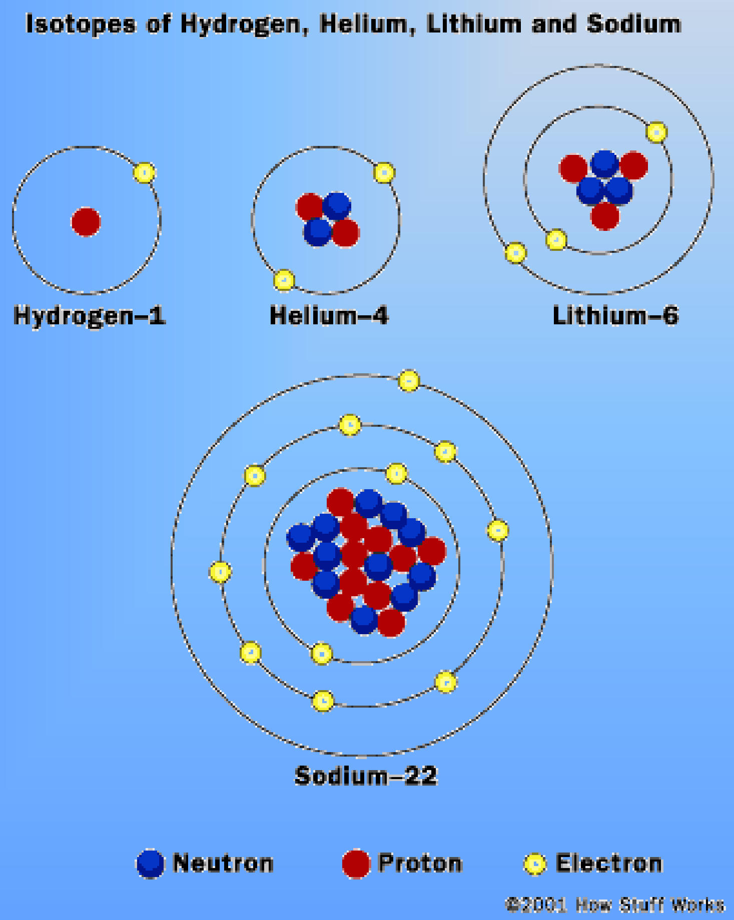
2. The Traditional Model of an Atom

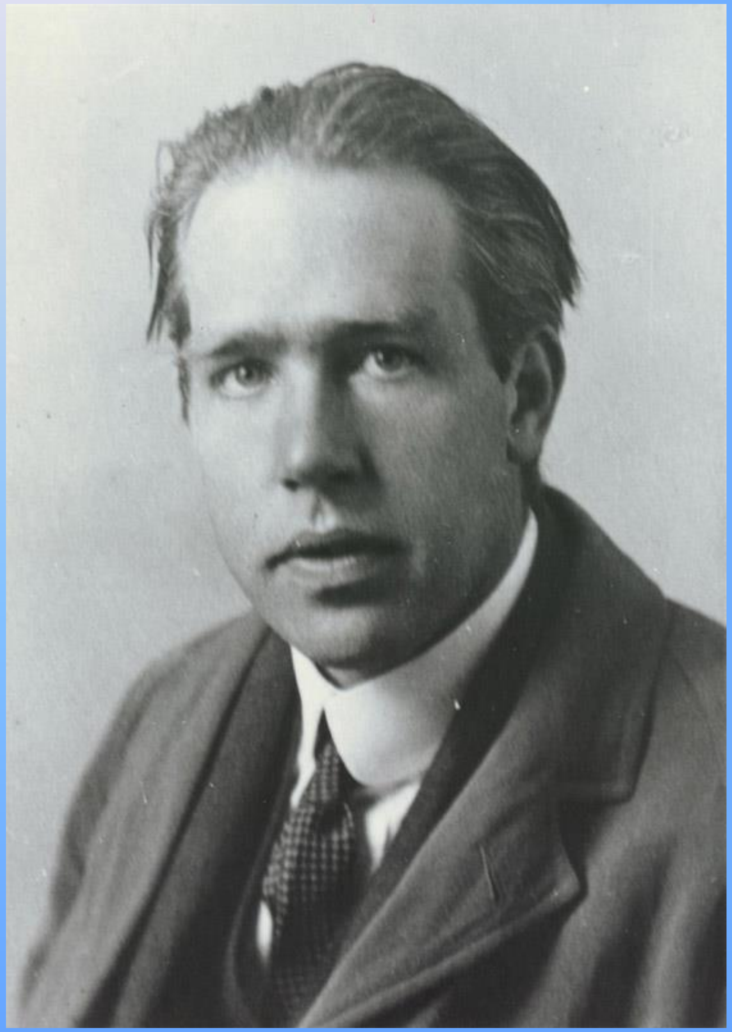
a. Central nucleus containing __**protons**__ and ____**neutrons**____.



b. Developed by Danish physicist Niels Bohr in 1913

- Referred to as the “Bohr Model” of the atom.

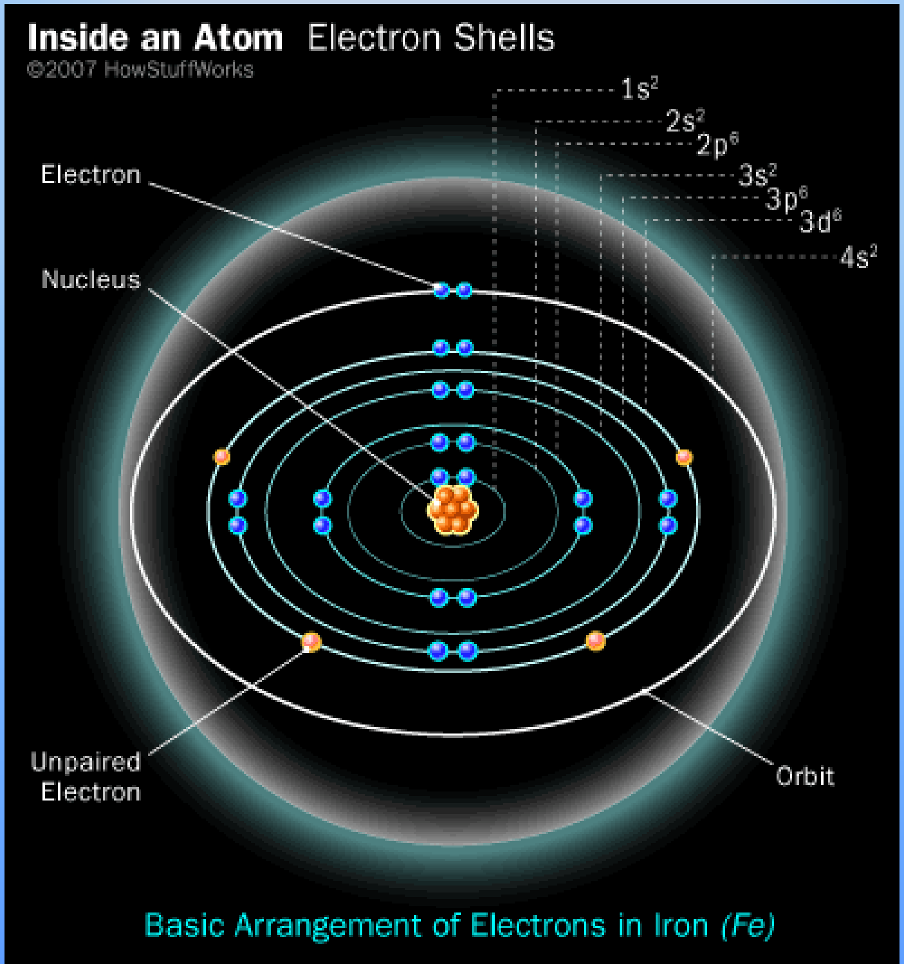




c. Electrons are in ___orbits___

i. Called shells

ii. Are specific distances from the nucleus.



3. The Modern Model of the Atom (Electron Cloud Model)

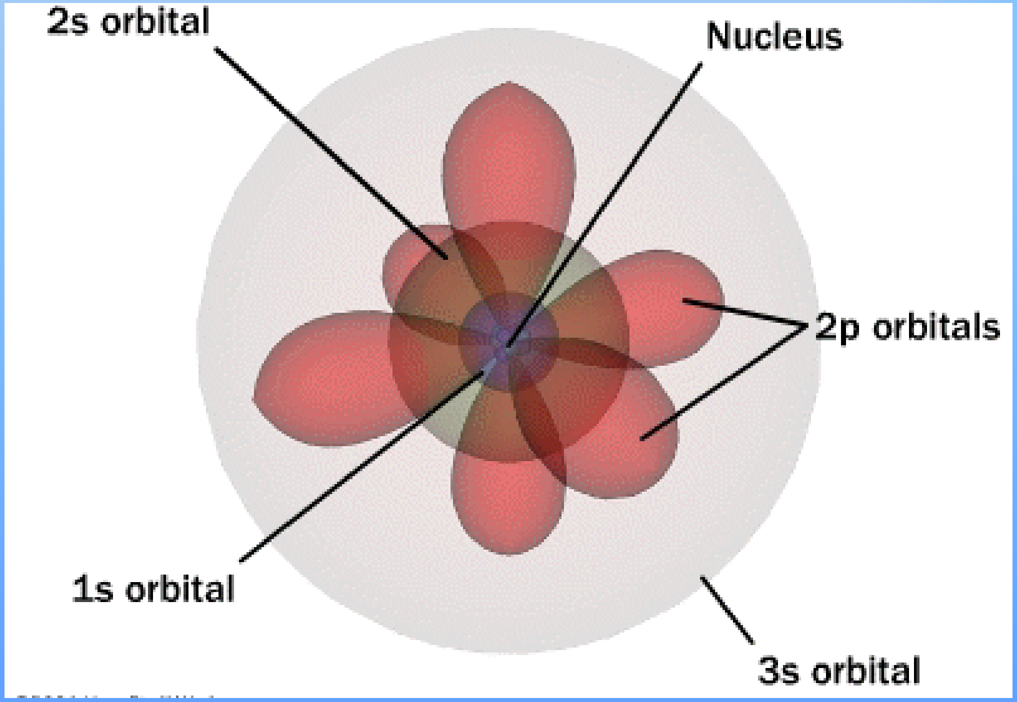
a. Electrons are in a cloud-like region around the nucleus

b. The shells are referred to as orbitals.

   i. Three-dimensional regions around the nucleus.

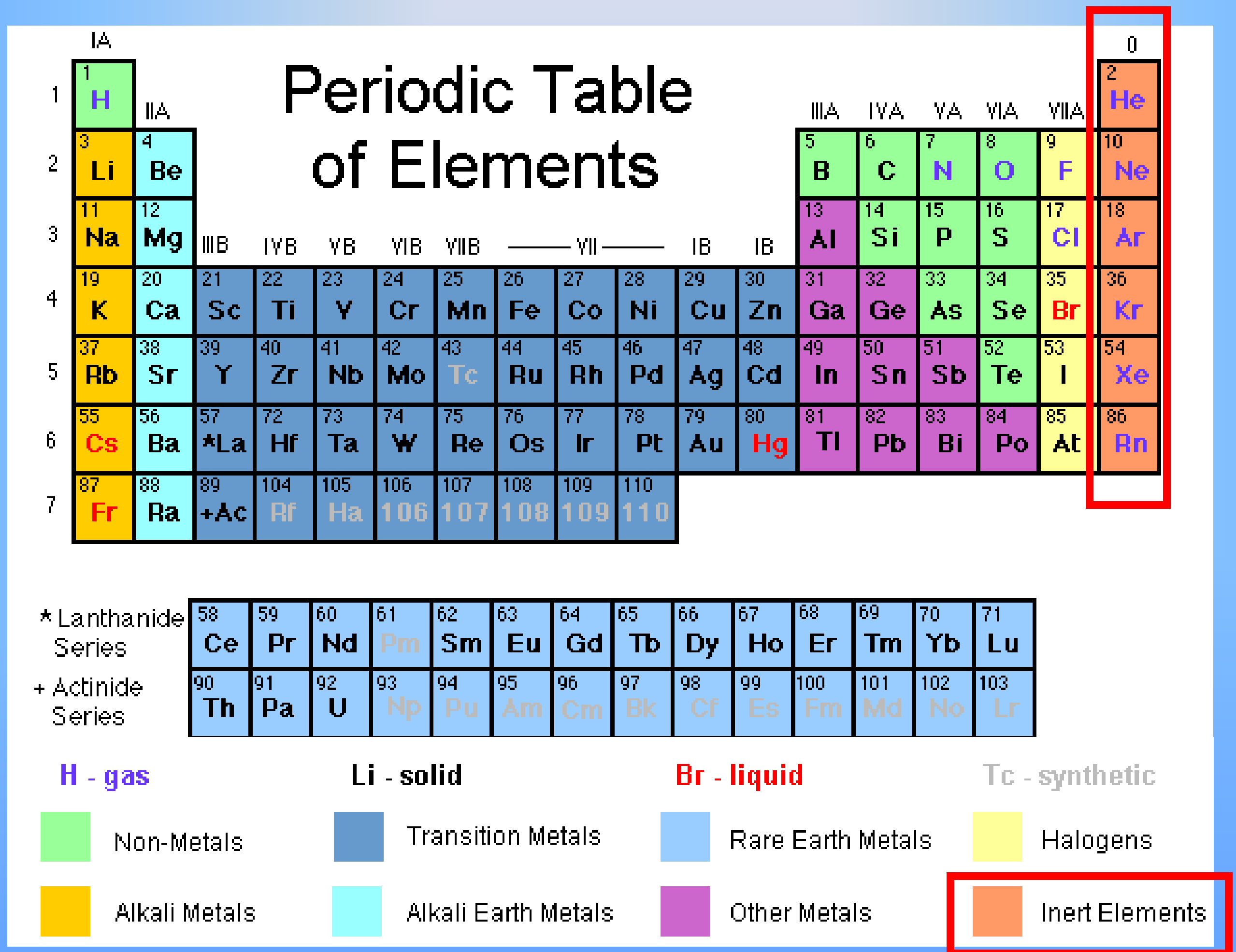
   ii. Each can hold a different number of electrons and has a different shape.

   iii. Most stable if the outermost shell has 8 electrons.



❑ Nobel Gases

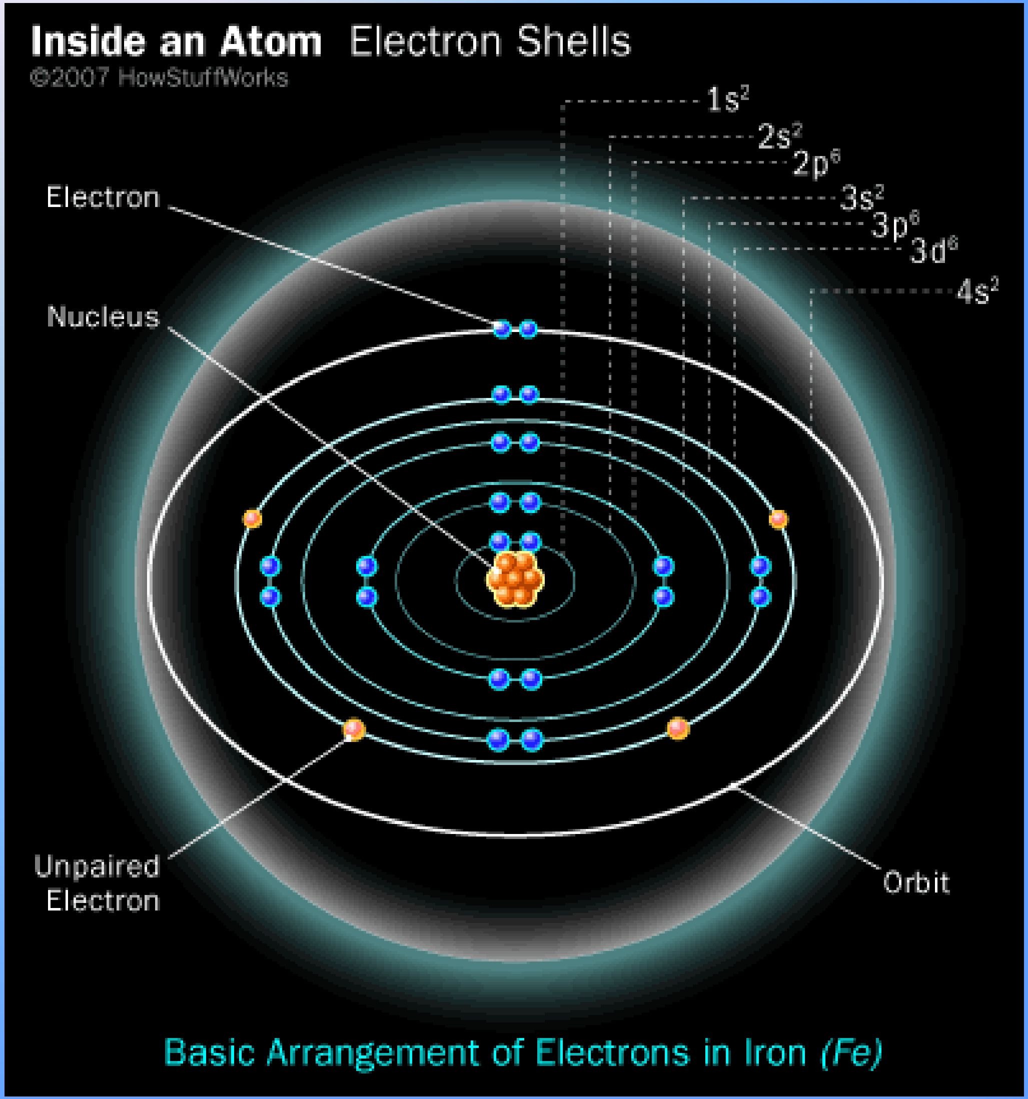
- Have 8 electrons and are inert (unreactive)



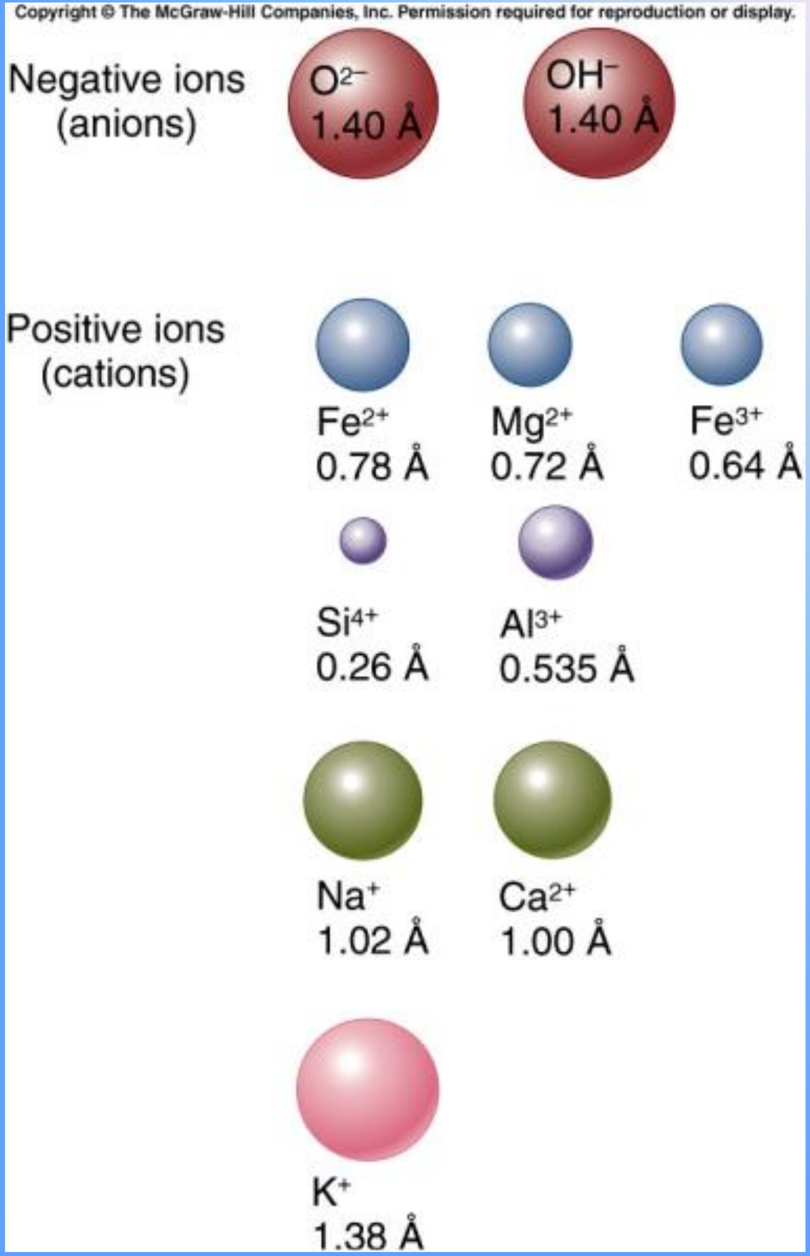
4. The Size of the Atom

a. An atom of iron is about 25 ten-millionths of a meter in diameter
   - Most of its volume is empty space.

b. Its nucleus has a diameter of about one-hundred-thousandths of the diameter of the space in which its electrons move.



Sizes of Most Common Ions in Minerals



- **Sizes are in angstroms.**
  - **One angstrom = 1.0 x 10^{-8} cm (one hundred millionth of a cm)**
- **Ions close in size are in the same row.**
- **Similar sized ions can replace one another in a crystal structure.**

5. Subatomic Particles

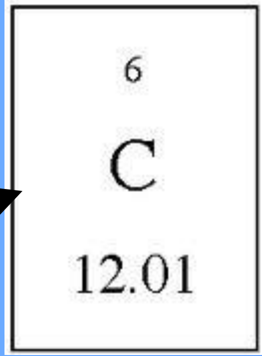
a. ___**Protons**___:Positively charged an equal to the unit charge of the electron. - - Protons are 1836 times heavier than electrons.

b. **Neutrons**_______:Electrically neutral and equal in mass to the proton.

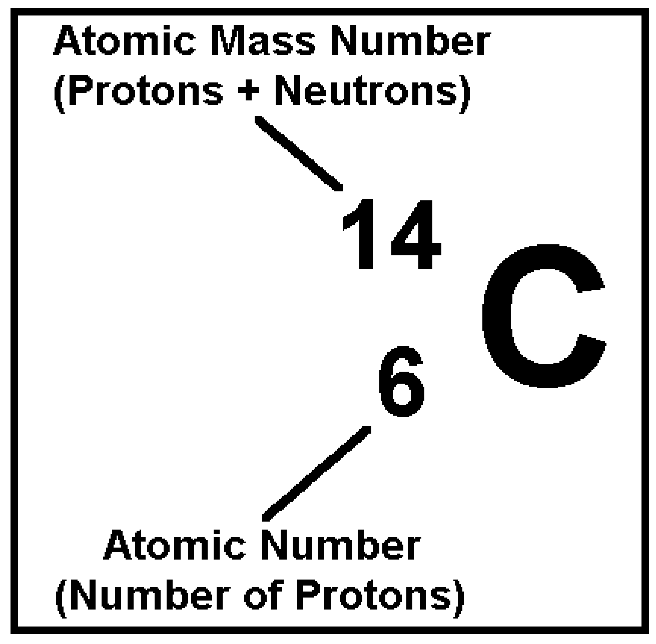
c. **Atomic Number**_: The number protons contained in the nucleus and identifies the atom.

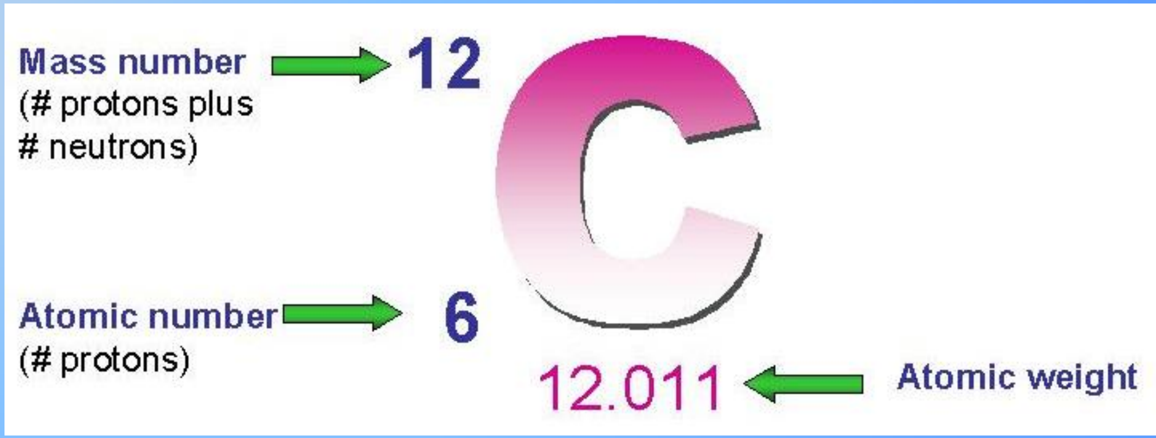
d. **Mass Number**_______: Sum of an atom's protons and neutrons.

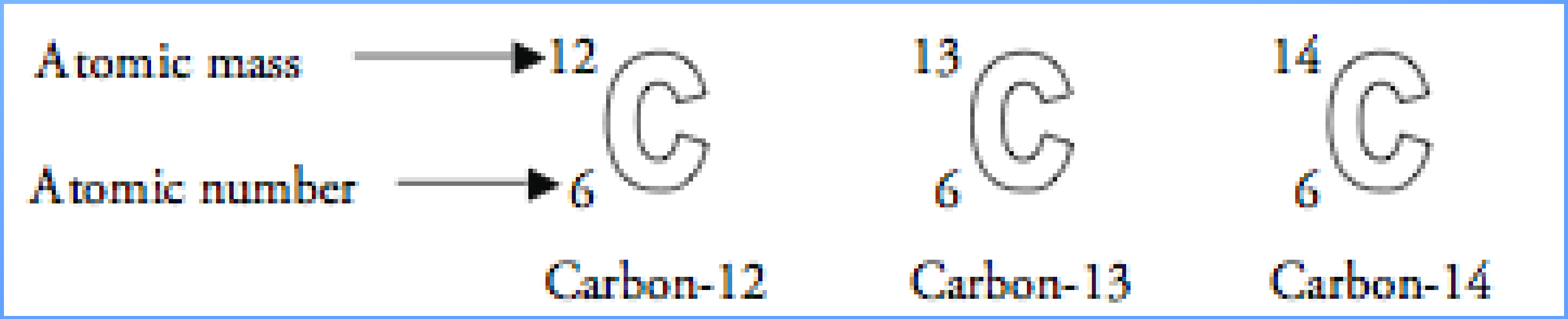
Plotting Information around the chemical symbol



On the Periodic Table of Elements:

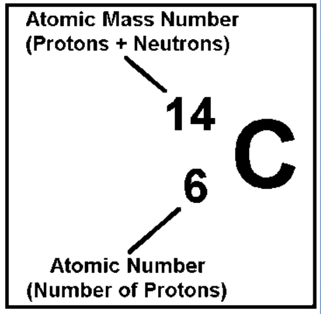






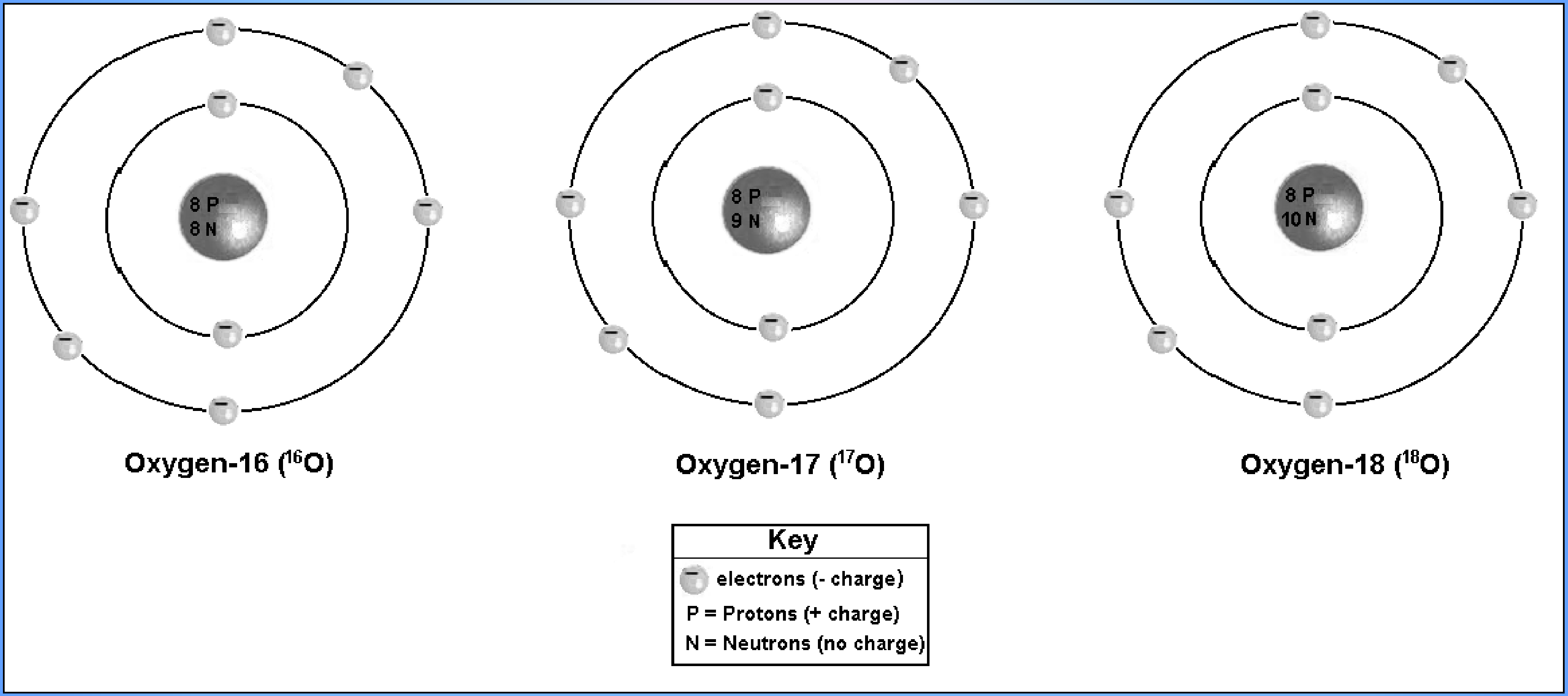
The Mass of an Atom

- Measured using a *mass spectrometer*
- Standard Mass is determined using
  - A neutral atom of carbon = **(1.99 X 10^{-27} kg)**
  - This number is set at exactly **12** (atomic) mass units (6P+6N)
  - 1 atomic mass unit (amu) = 1/12 of this mass (which is 1.66 X 10^{-26} kg.)
- So, the amu is based on the mass in grams of Carbon, therefore ….
  - All atomic masses for other minerals are set to this value
    - Only carbon-12 has a mass in amu that is exactly the same as its mass number (# protons + # neutrons).
    - For other atoms, it is not precisely the same as the mass of one proton and one neutron. For example . . .
      - **^{35}Cl has a mass of 34.969 amu**
      - **^{37}Cl has a mass of 36.966 amu**



e. ___**Isotopes**___: Atoms of the same element with the same number of protons but different numbers of neutrons.

Isotopes of Oxygen

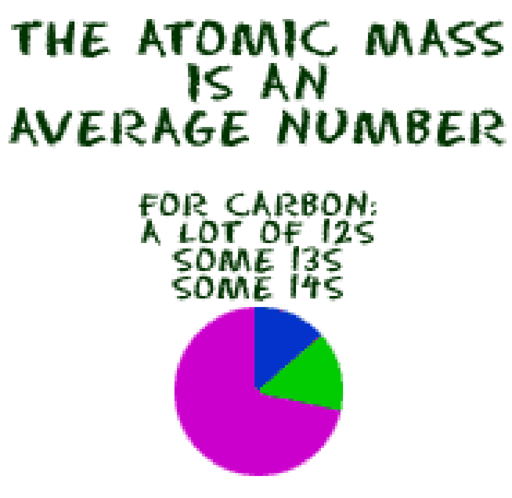


f. **Atomic Mass**: The average number of protons and neutrons in an atom

i. Also called atomic **weight**.

ii. Given in **atomic mass units** (amu)

iii. Also considers the **fractional abundance** of each isotope.

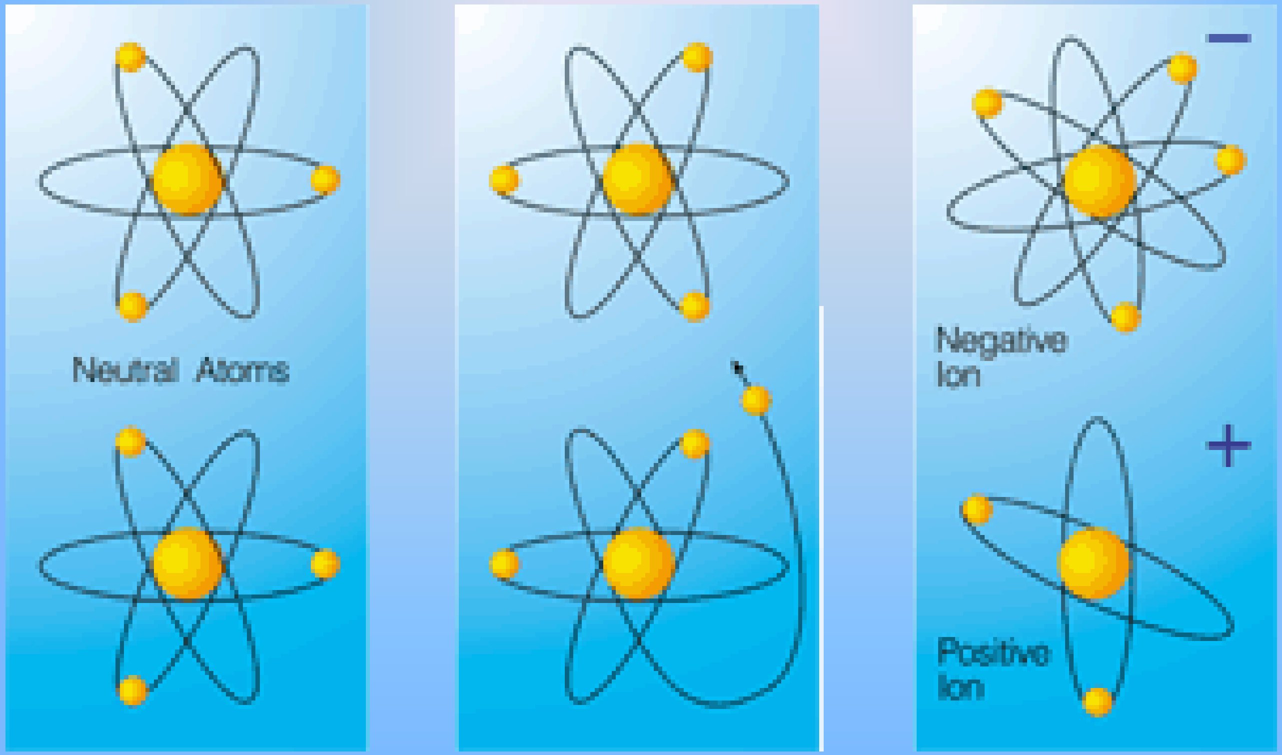


Example using chlorine:

- Of the two isotopes of Cl,
  ~75% (75.53%) are the lighter isotope ^{35}Cl
  ~25% (24.47%) are ^{37}Cl
- Finding the atomic mass
  (34.969 amu x .7553) + (36.966 amu x .2447) =

35.45 amu

6. __Ion__: A charged atom



a. Atoms that gain electrons are __negatively__ charged.

b. Atoms that lose electrons are __positively__ charged.

7. ___**Compounds**___

a. A substance consisting of ___**two**___ or more ___**elements**___ chemically combined.

b. A compound has new properties unlike those of the elements of which it is composed.

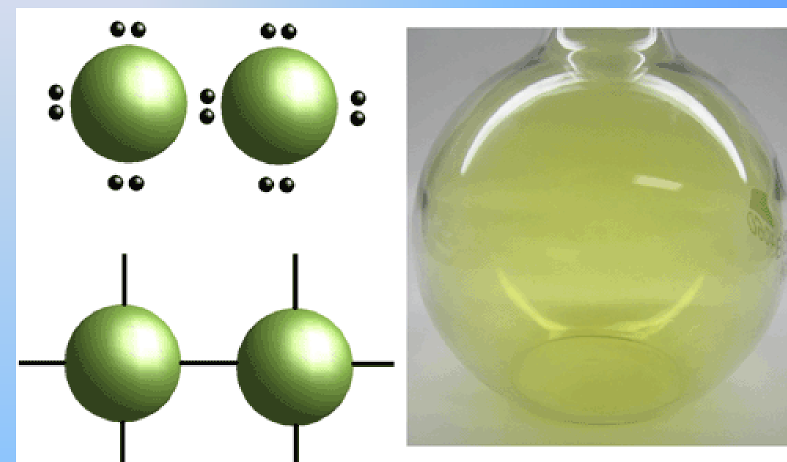
c. When atoms combine they will do so:

   i. in a manner that achieves ___**eight**___ electrons in the outer shell and

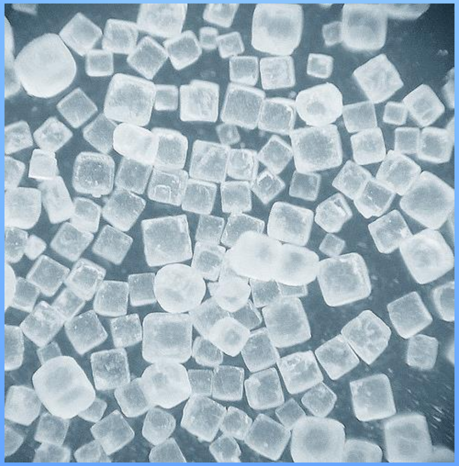
   ii. With the ___**smallest**___ possible change.

Sodium combines with Chlorine to form . . .

+



Common Table Salt
(The mineral halite)



8. How Compounds Form (Bonding)

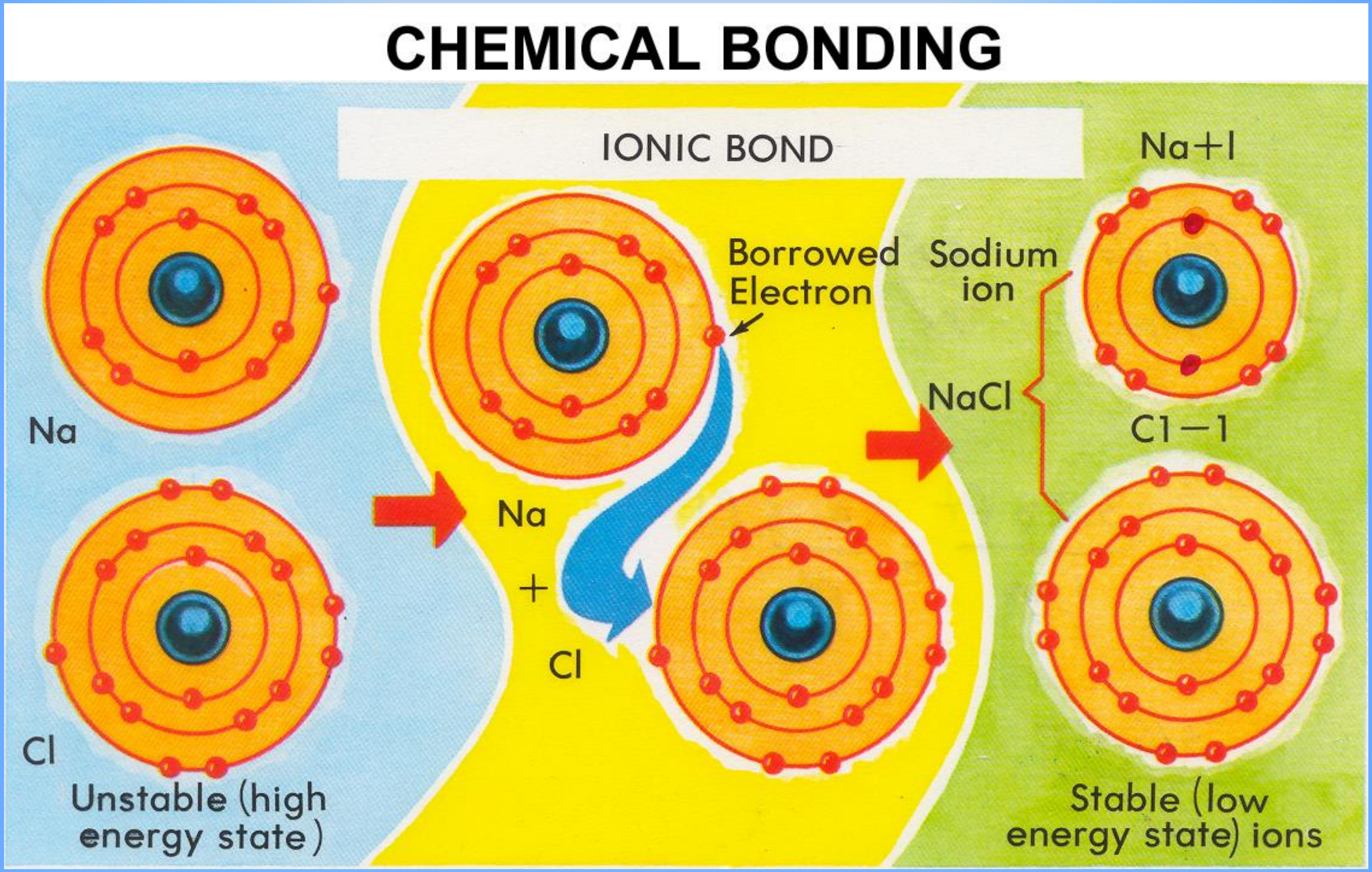
a. Ionic Bonding

i. The most common type of bonding in minerals.

ii. Atoms are fixed in place by their attraction to each other.

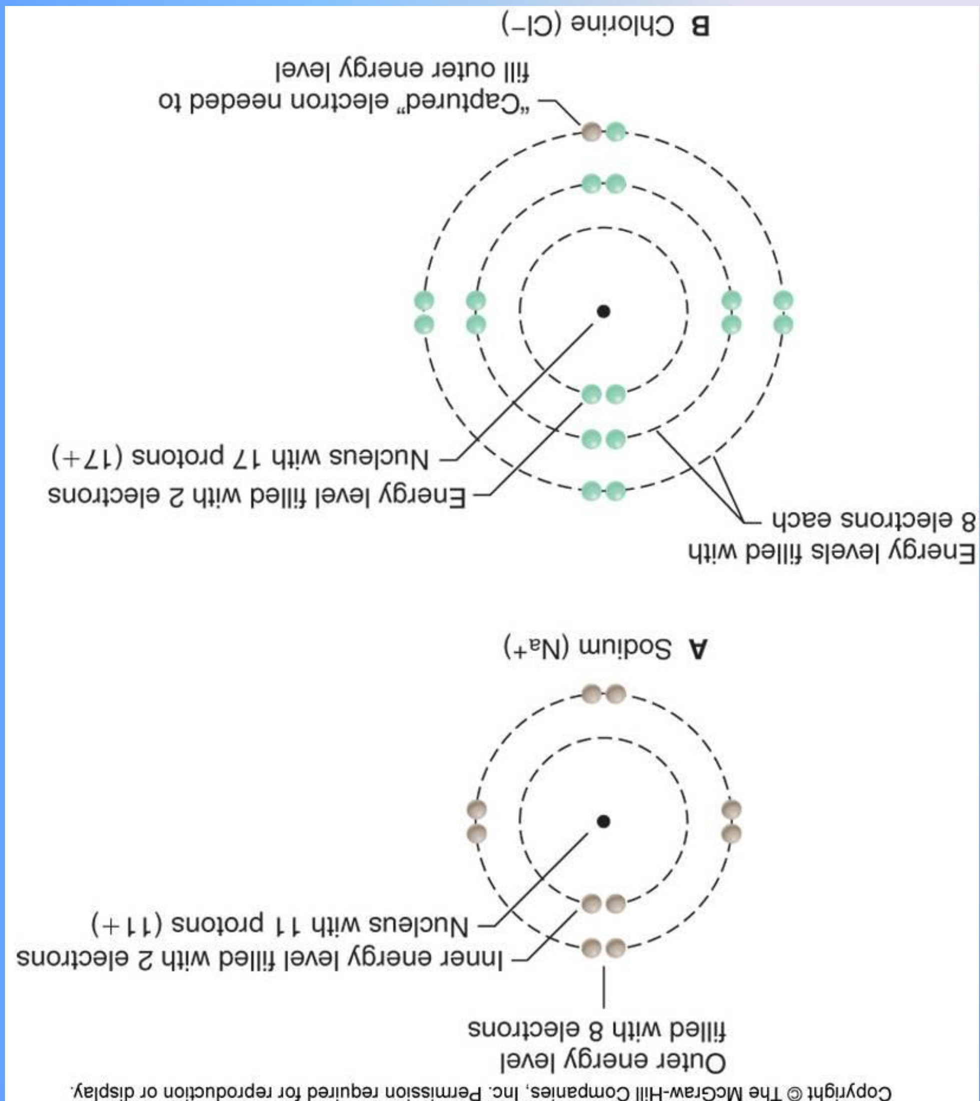
iii. Ions of opposite charge are attracted to each other.

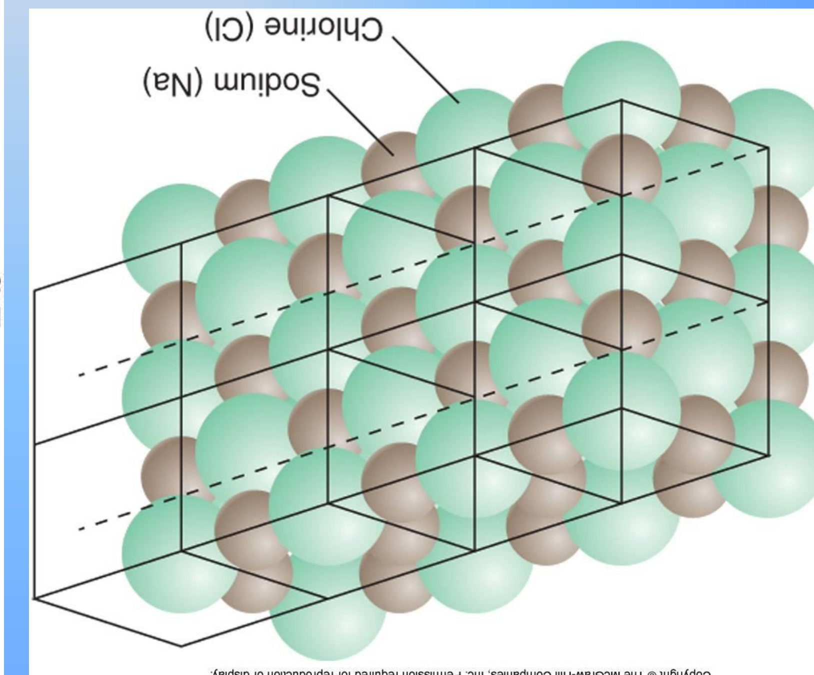
iv. Example: Formation of salt



- Chlorine (Cl) borrows a e- (becoming negatively charged) from sodium (Na) making it positively charged.
- NaCl (sodium chloride) forms.

Formation of NaCl





b. Covalent Bonding

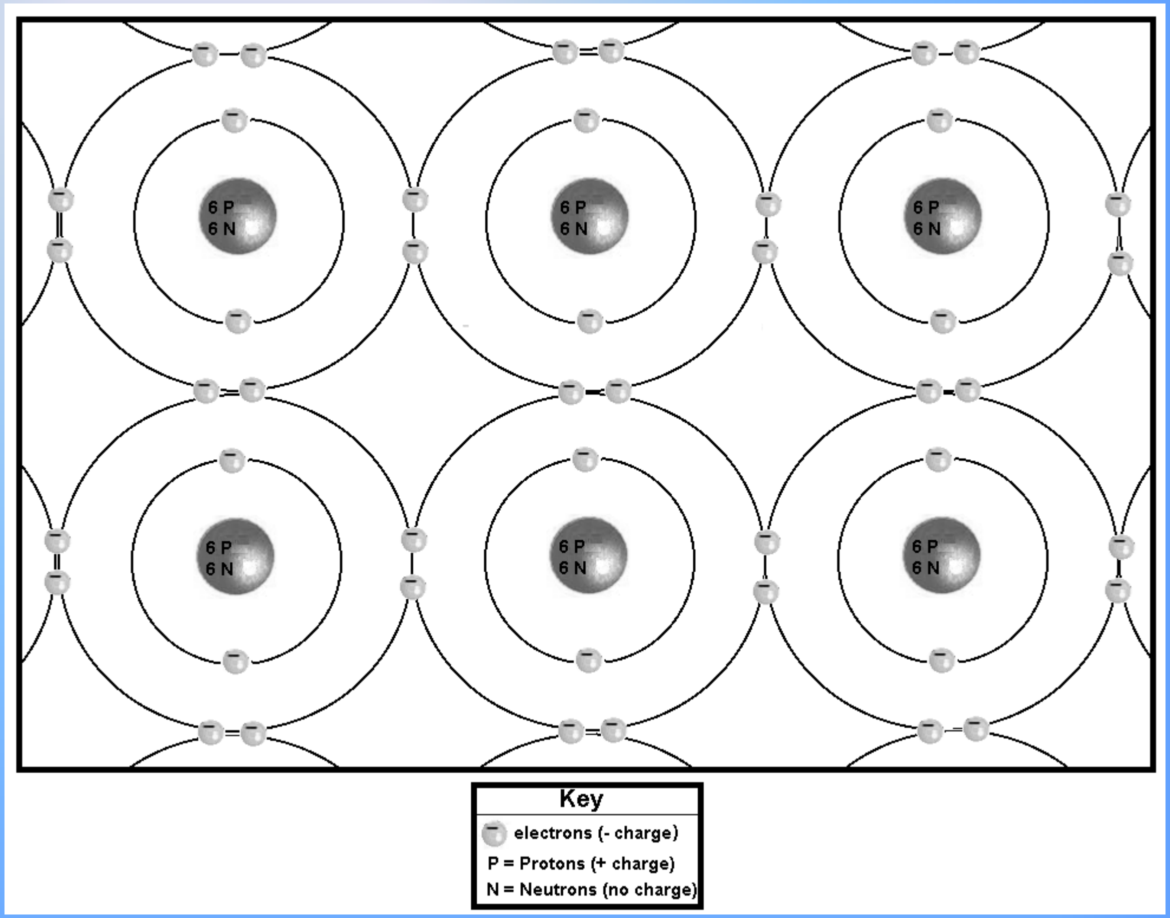
i. Common between nonmetal elements. Quartz is an example.

ii. Become stable by sharing pairs of electrons that serve both atoms simultaneously.

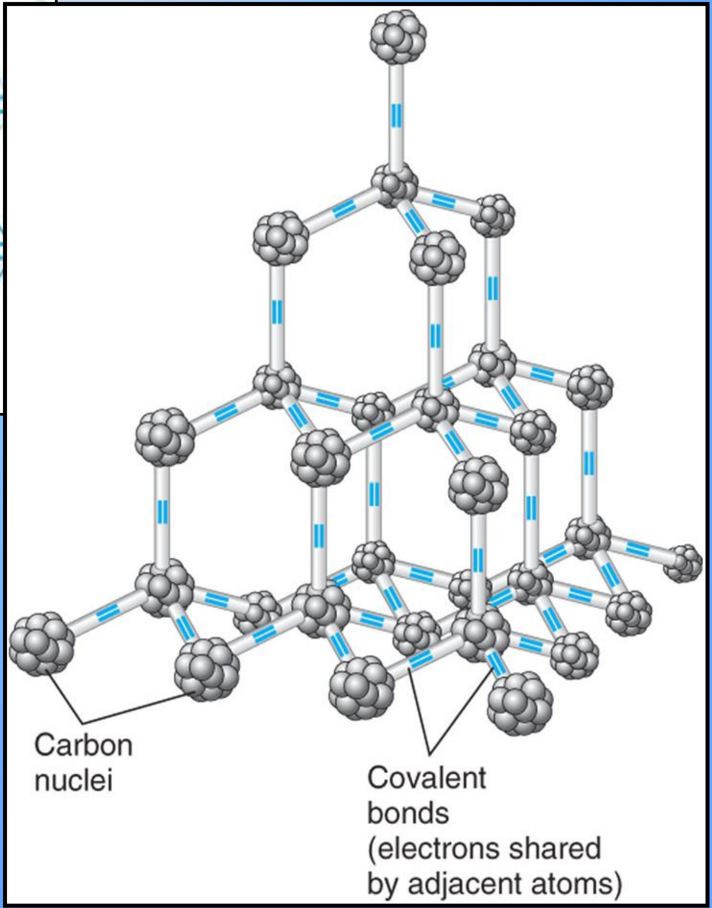
iii. Such elements have half of, or nearly half of, the required electrons in the outer shell.

iv. Ions are not formed.

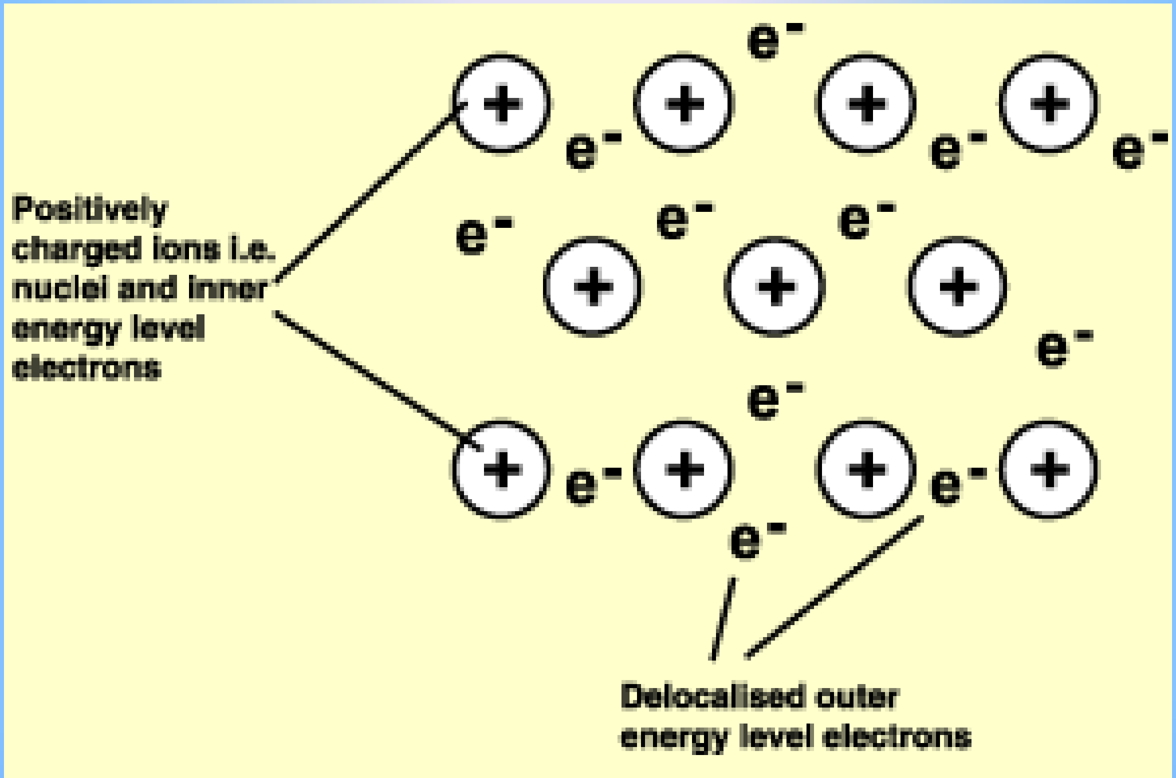
v. Act as electrical insulators.



Covalent Bonding - Diamonds



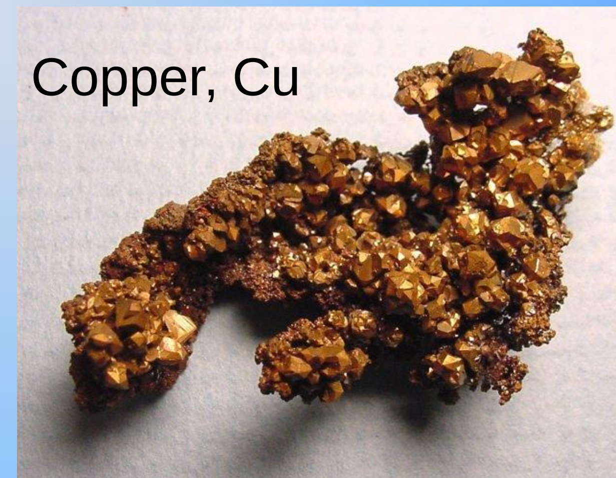
c. <u>**Metallic**</u> Bonding



i. Responsible for the cohesion of a metal.
ii. These elements readily lose their outer electrons.
iii. Crystal structure is determined by packing of positively charged atoms.
iv. Detached electrons are dispersed among the atoms and are freely mobile.
v. Responsible for good <u>**thermal and electrical conductivity**</u>

9. __Native Minerals__ (Also called native elements.)

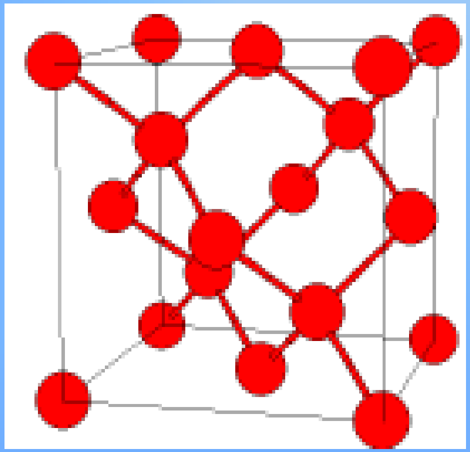
a. Comprised of one __element__ only
b. Examples include:

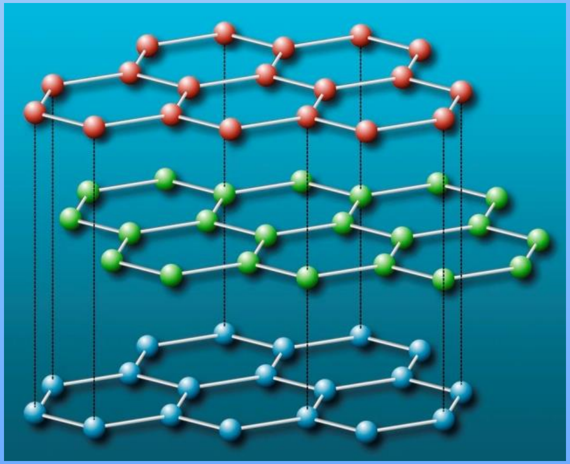


Sulfur, S

Silver, Ag

Native Elements

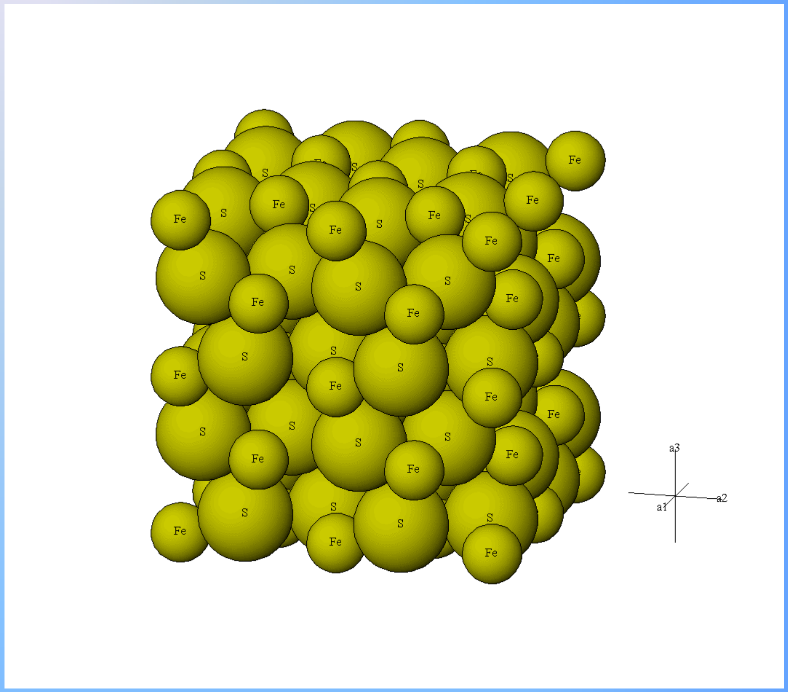




Diamond, C

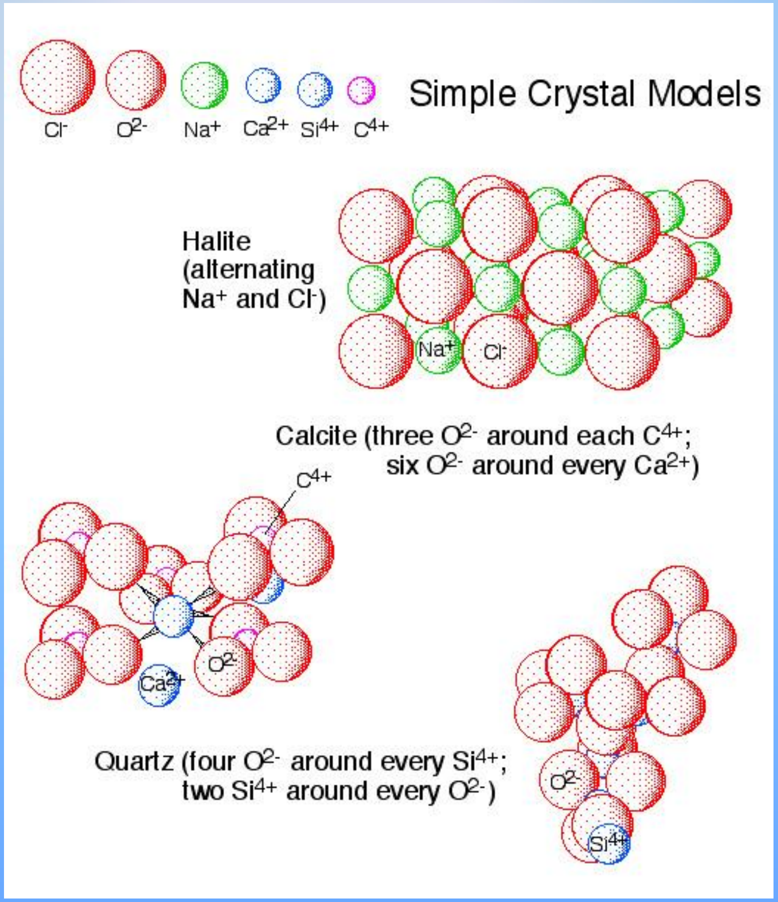
Graphite, C

B. Crystallinity



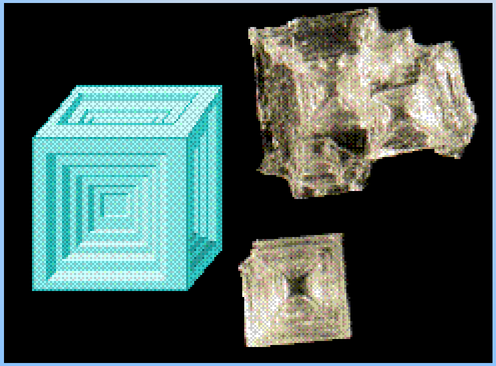
1. A ___Crystalline Substance___ is a solid substance in which the atoms are arranged in a ___3-dimensional___, orderly pattern.

2. Crystals are found in nature wherever constituent atoms are free to come together in the correct proportions to form a certain mineral.

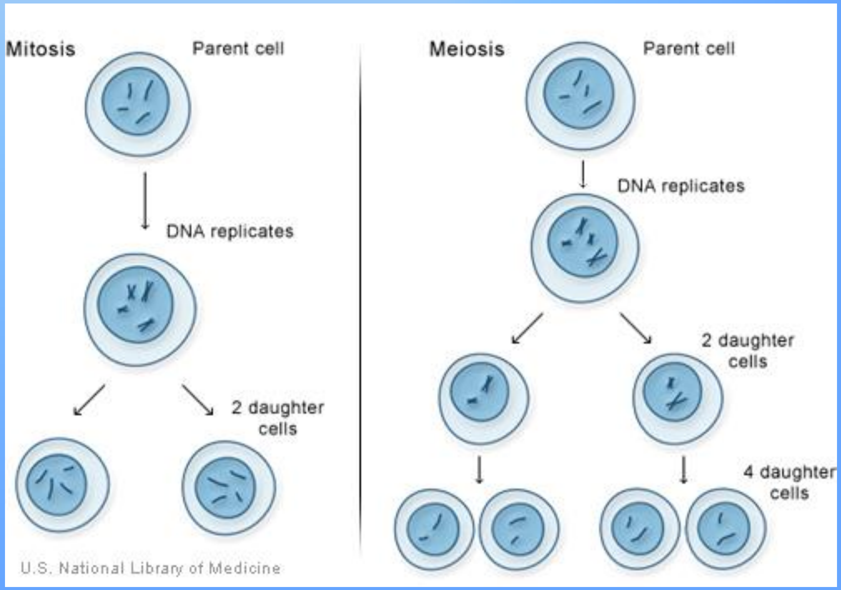


3. Mineral "Growth"

- Not the same as how a living organism grows
- Atoms are added as a mineral crystal grows (gets larger)

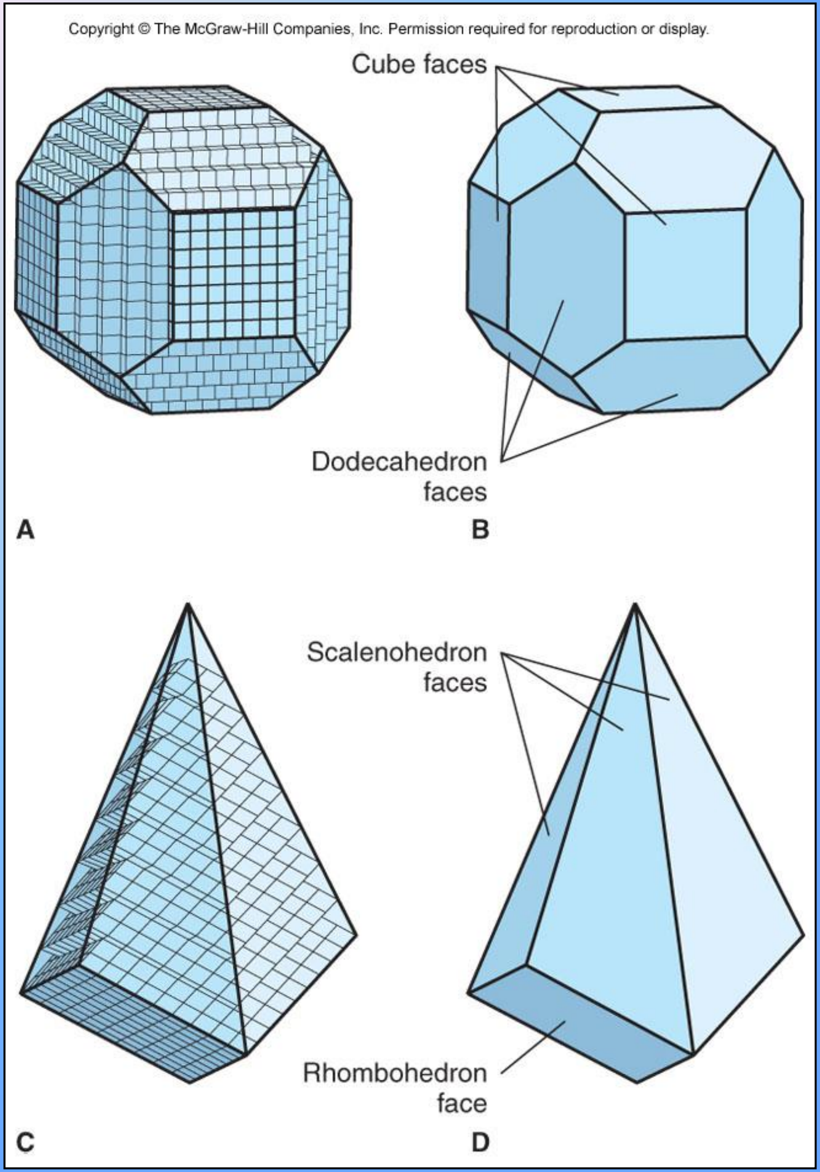


- Living things grow by cell division



4. The <u>Unit Cell</u>

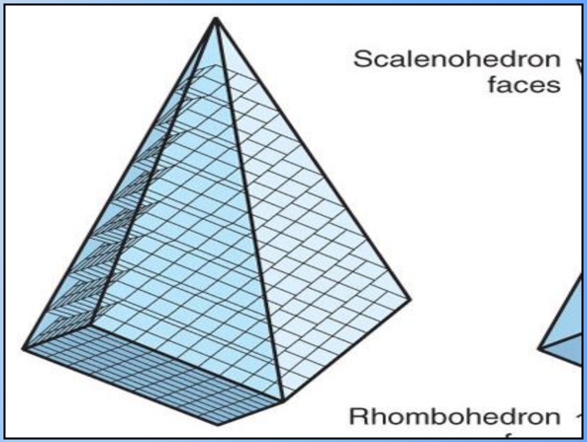
a. The basic building block for a crystal.
b. Analogous to a brick in a wall created by stacking bricks directly upon one another.
c. The unit cell's shape is described in terms of the lengths of its edges and the angles between them.
d. The crystal is composed of many tiny unit cells.
e. The geometric shape is determined by how they are put together.



5. Crystal **Faces**

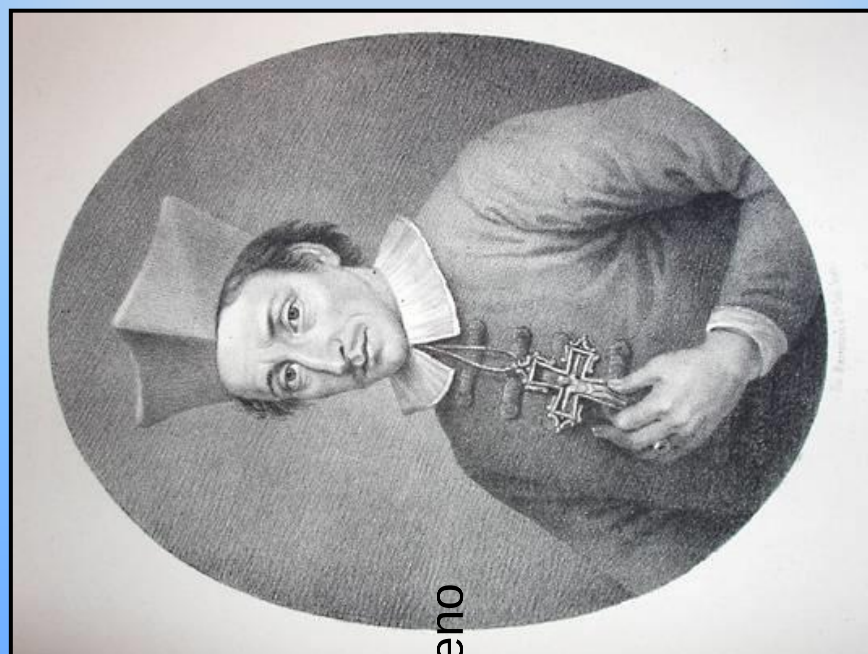
a. **External** *flat surfaces* that are determined by the internal arrangements of atoms (unit cells).

b. Have a definite geometric relationship to one another



6. Law of Constancy of Interfacial Angles

a. Recognized by the Danish naturalist Steno in the 17th century



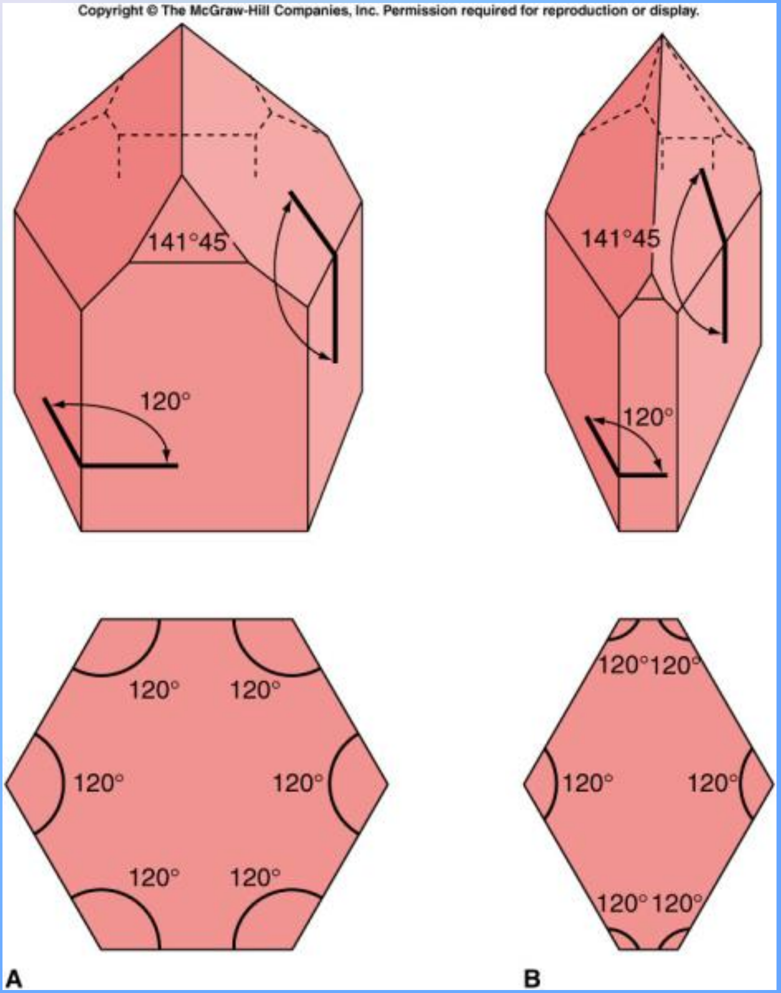
Nicholas Steno

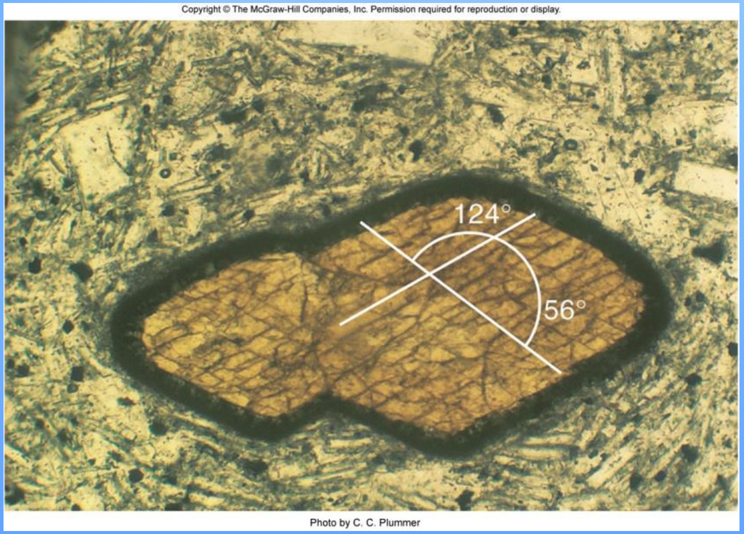
6. Law of Constancy of Interfacial Angles

b. Noted that the angle between two adjacent faces of quartz is always **the same** .

c. Crystals of other minerals were also found to have sets of angles for adjacent faces.

d. Also called "Steno's Law."

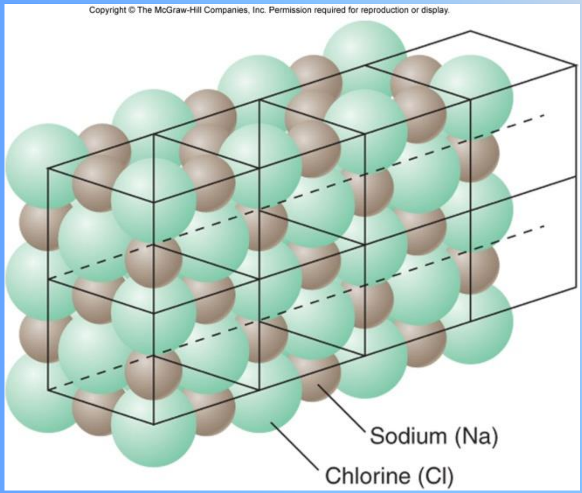


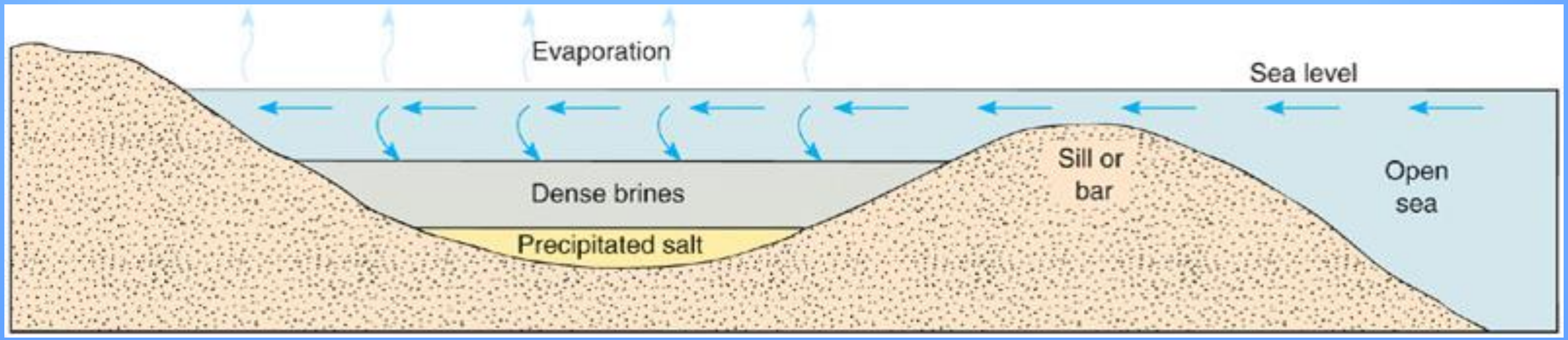


7. Development of Crystal Form

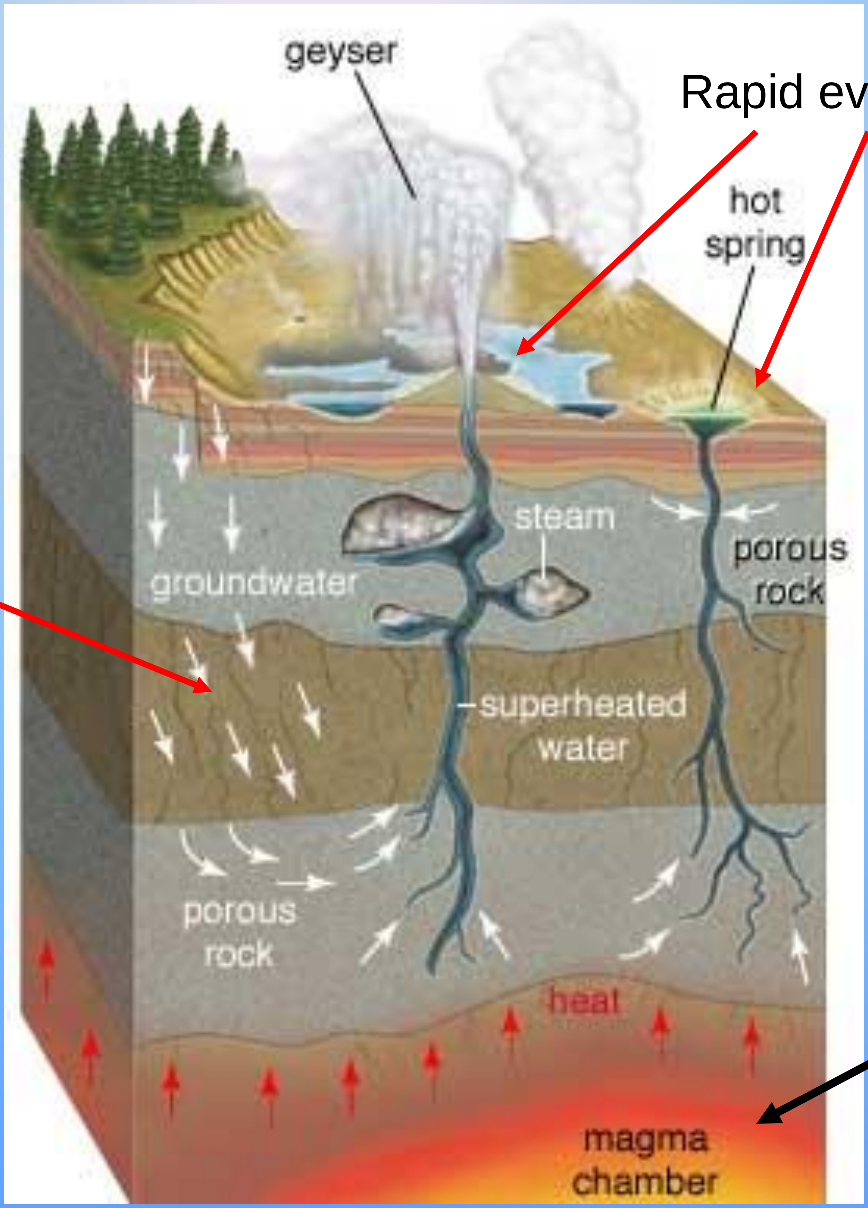
1. Most minerals do _**not**_ develop visible faces
   a. They grow while competing for space with other minerals
   b. Crystal faces develop if they are surrounded by a _**fluid**_______.
      - This can be easily displaced as the crystal forms
   c. Environments that promote crystal growth include . . .

Rapidly Evaporating Water (Evaporites)





More Environments Promoting Crystal Formation



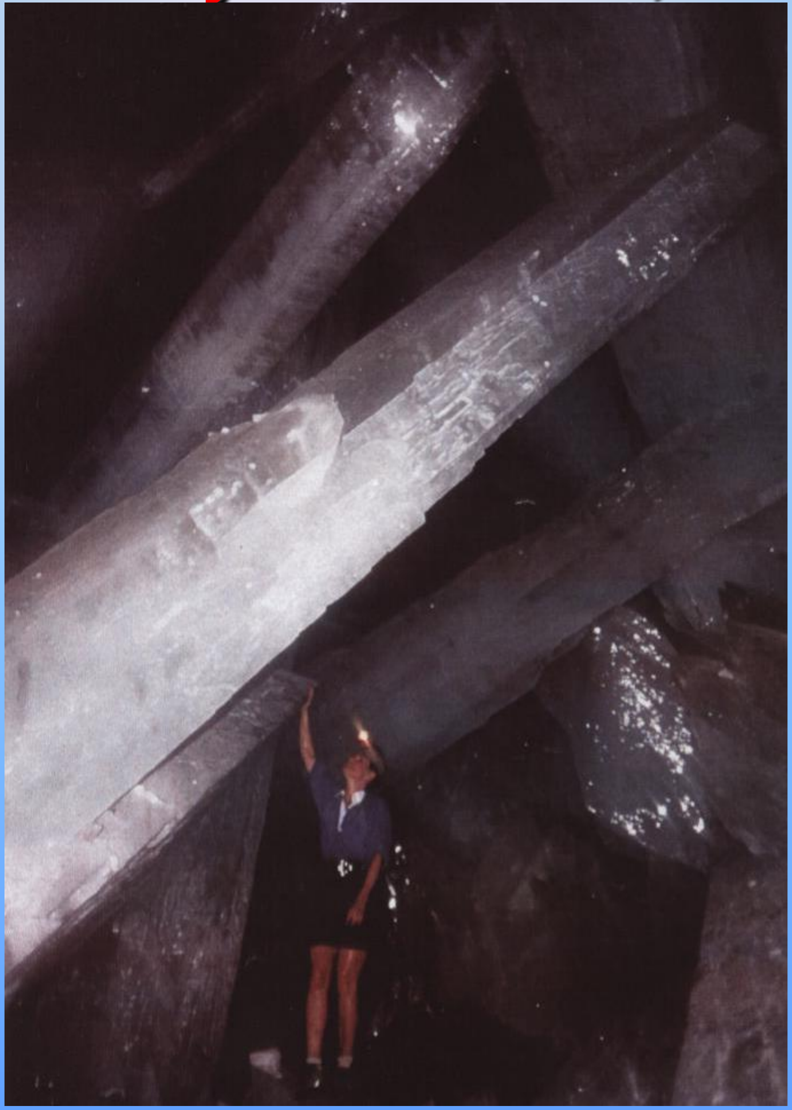
Rapid evaporation

Precipitation from solution

Slow cooling from molten rock

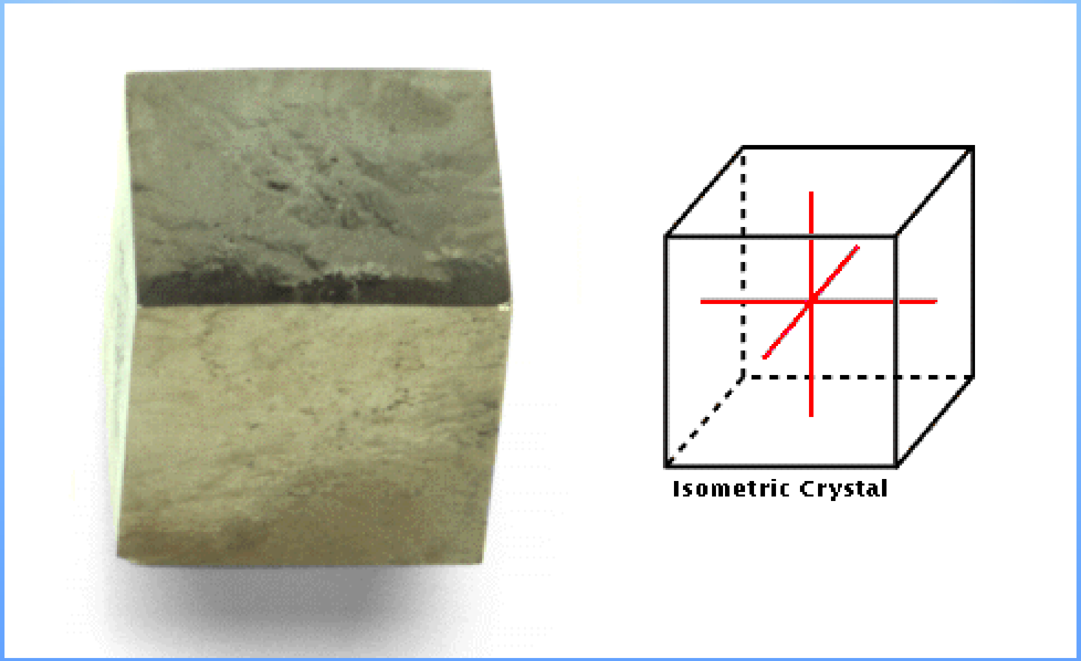
Giant Crystals

Selenite Crystal Caves, Mexico

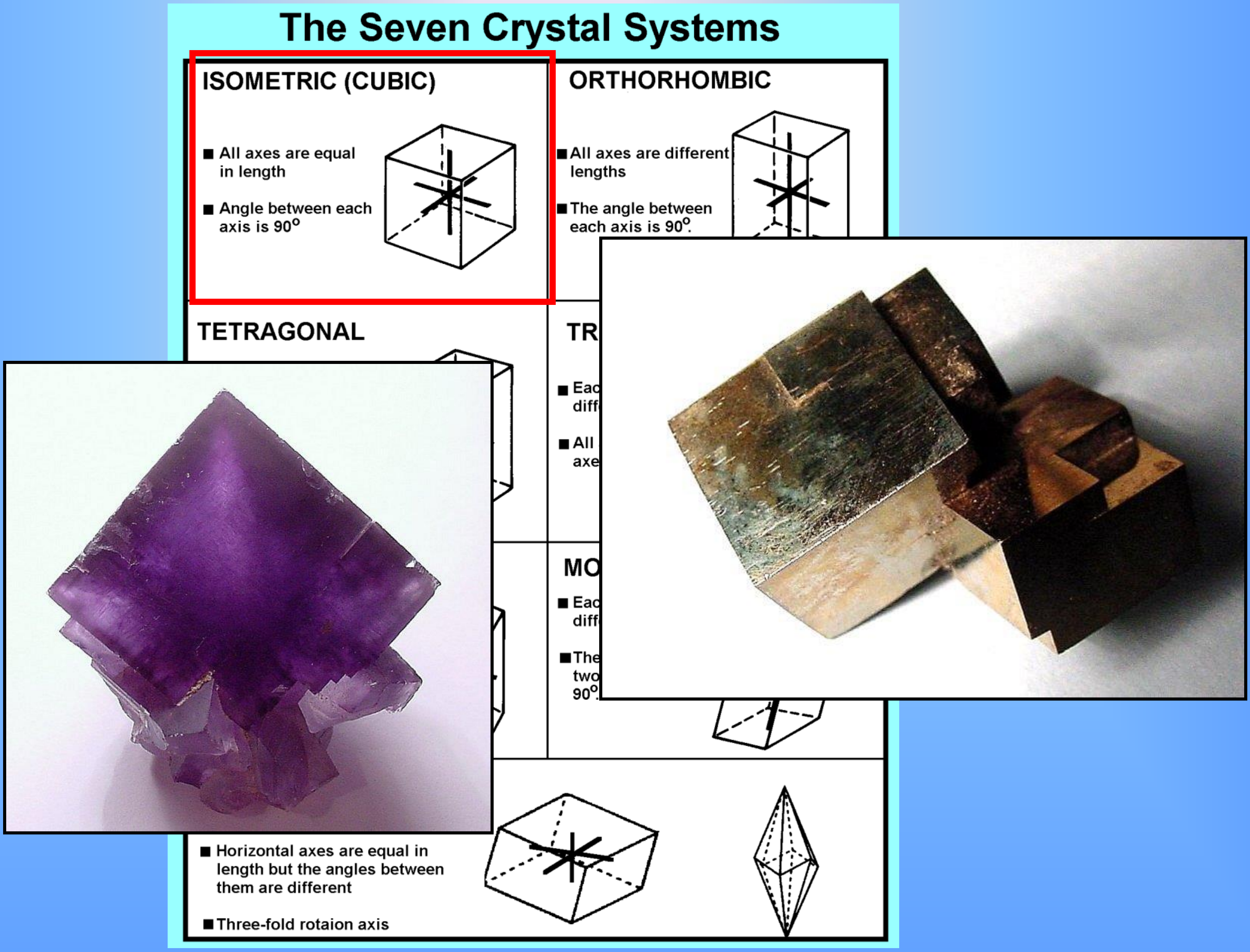


8. Crystal Systems

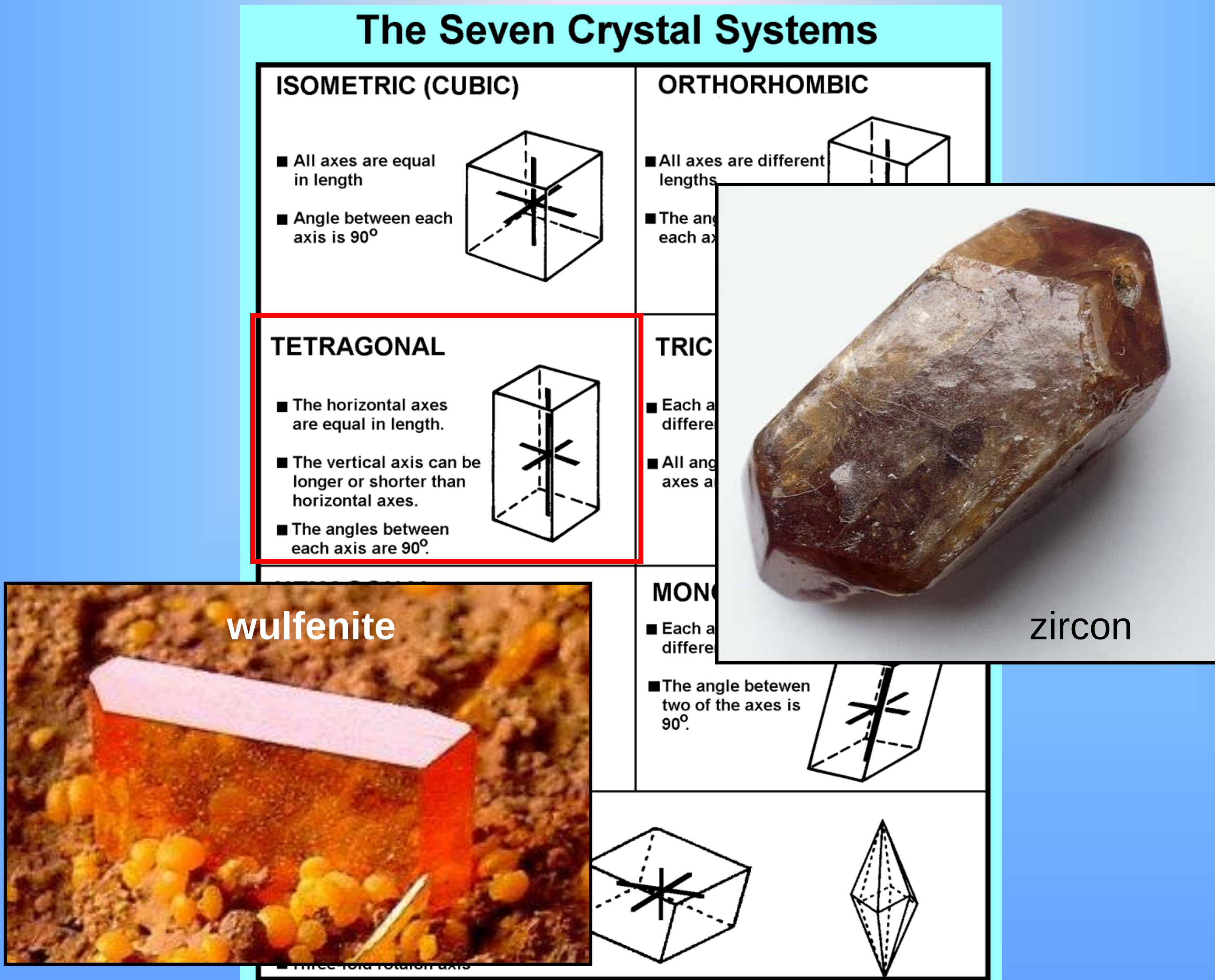
- Crystals are classified into seven *Crystal Systems*
- Classified based on the orientation of their *axes of reference.*
  - A mathematical method of relating planes to certain imaginary lines in space.
  - The position of any plane is uniquely fixed by the intercepts it makes on three intersecting lines.



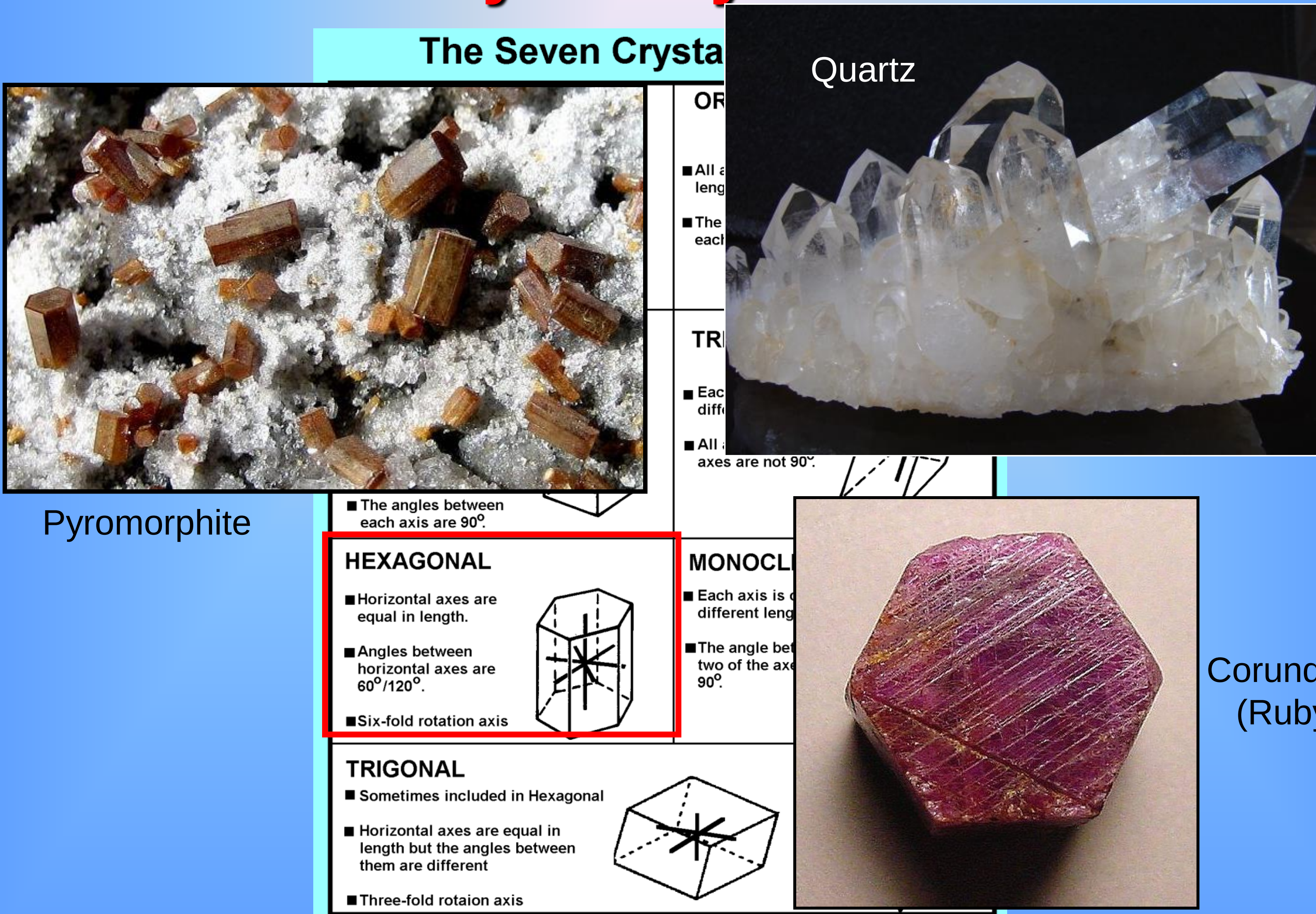
Crystal Systems



Crystal Systems



Crystal Systems

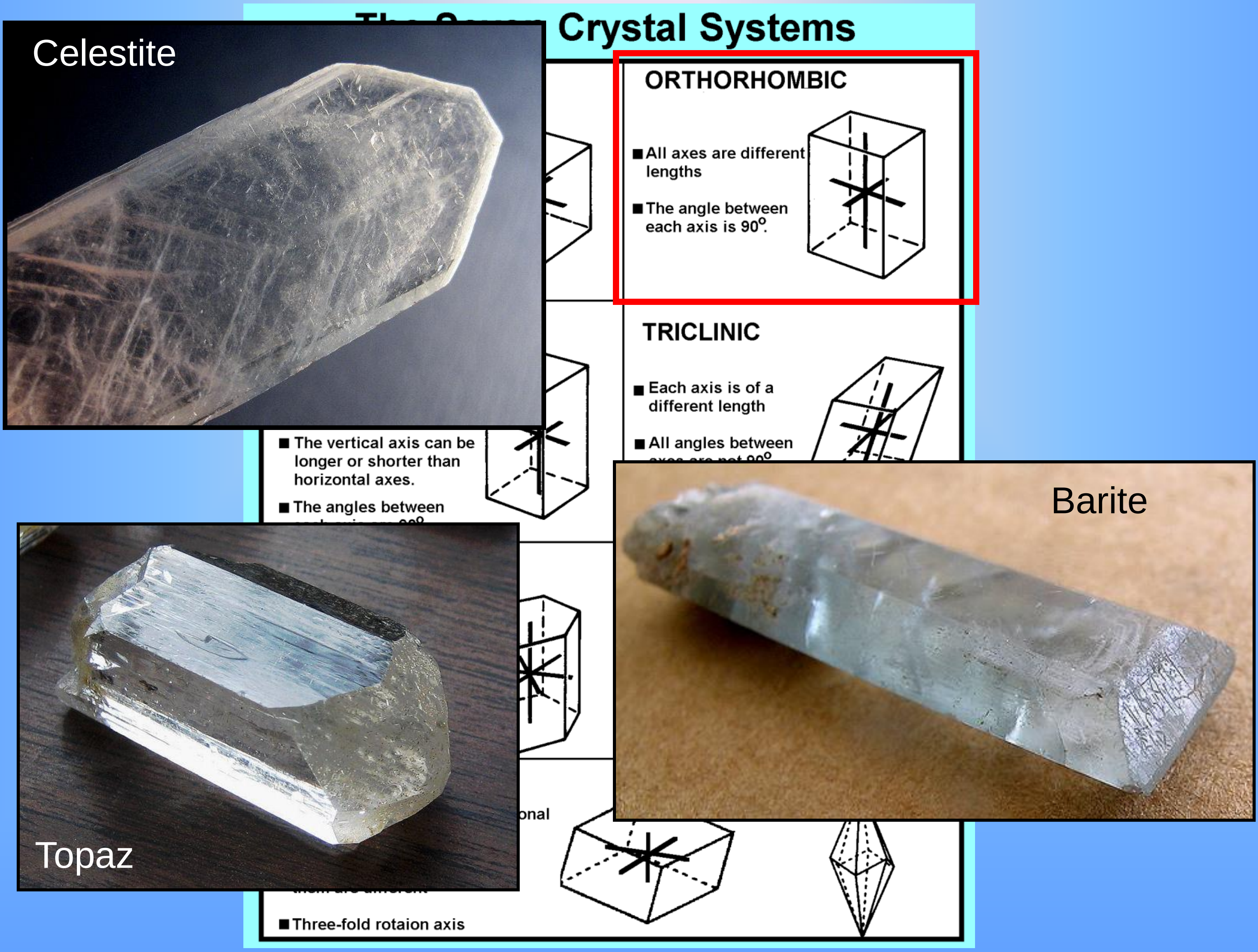


Quartz

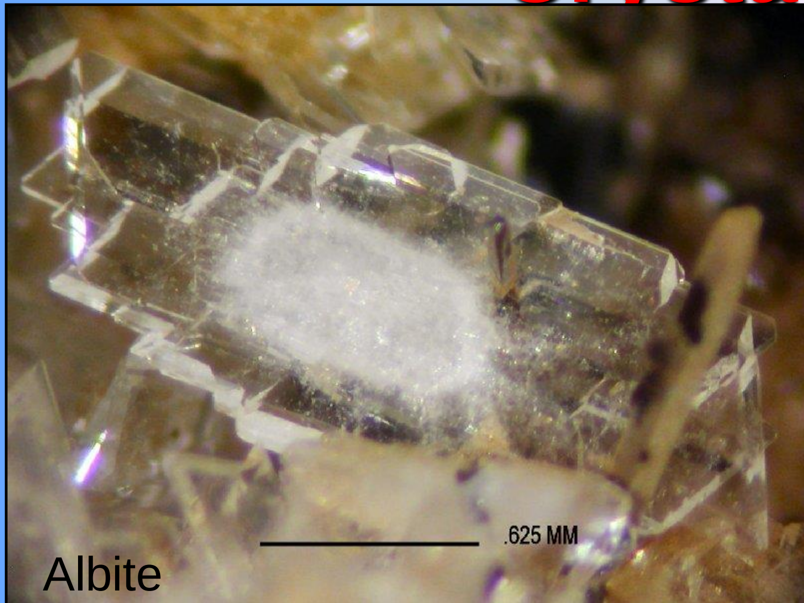
Pyromorphite

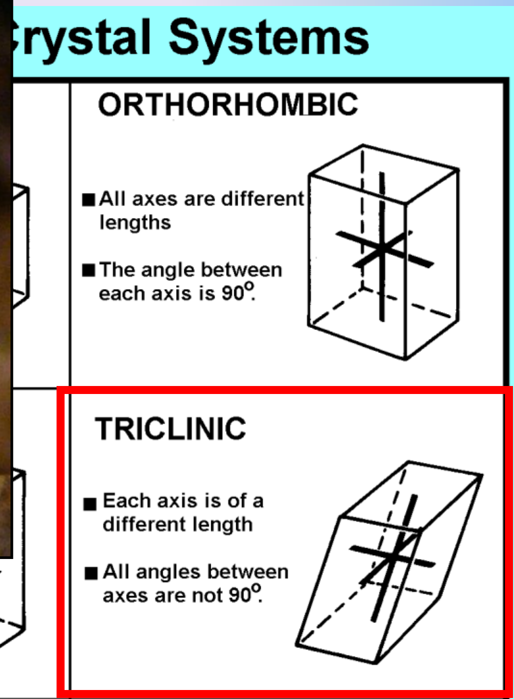
Corundum
(Ruby)

Crystal Systems

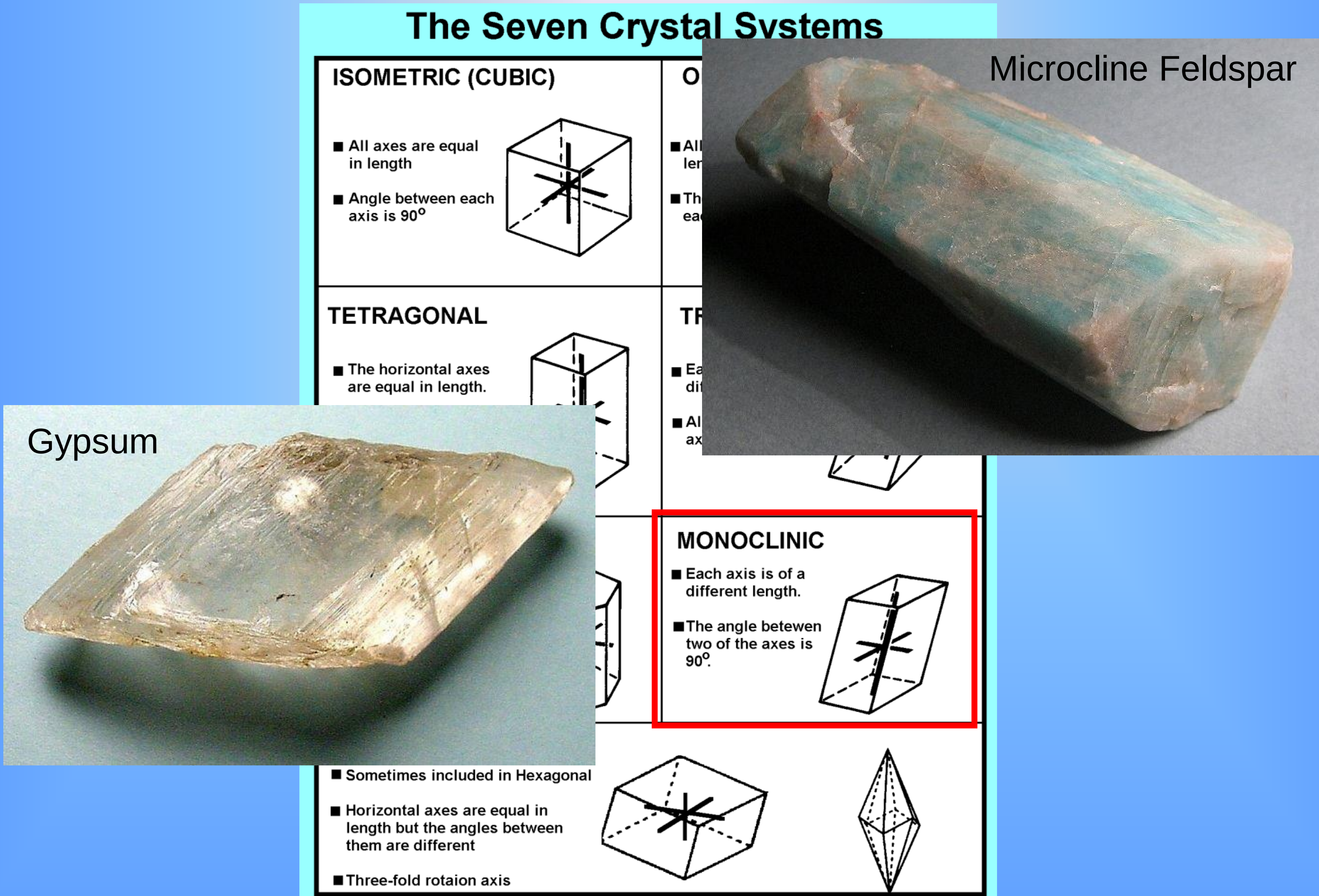


Crystal Systems

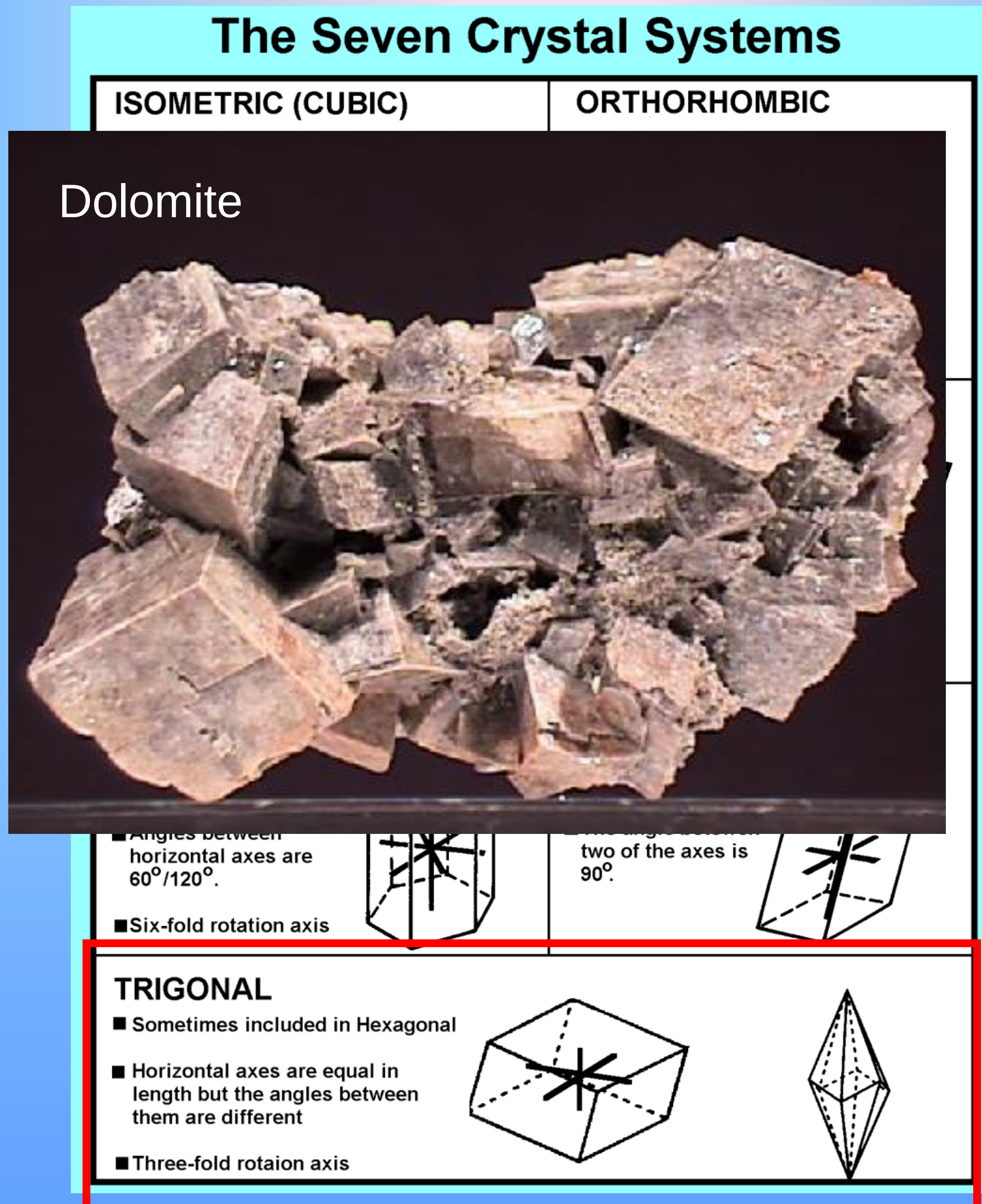




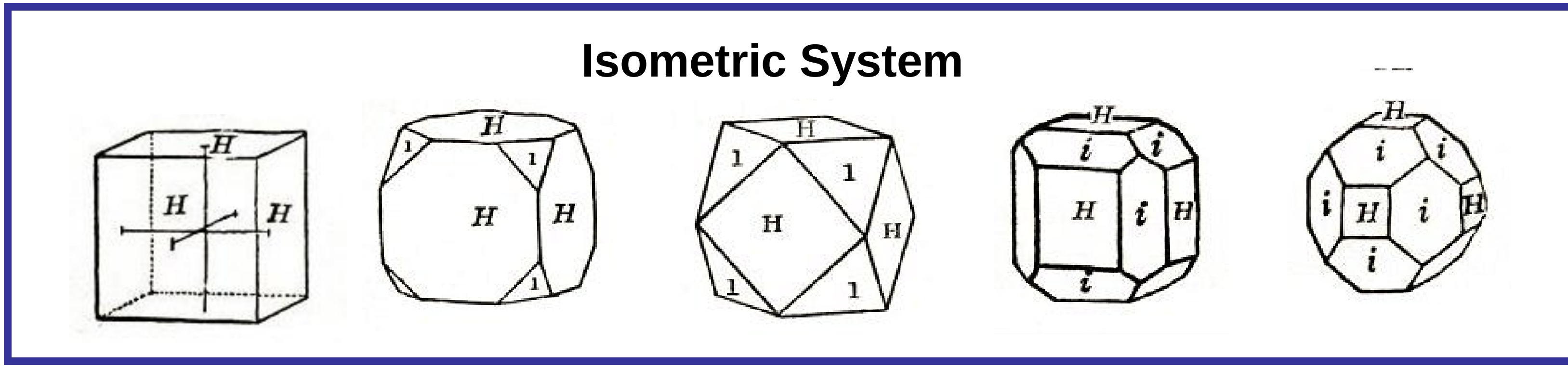
Crystal Systems

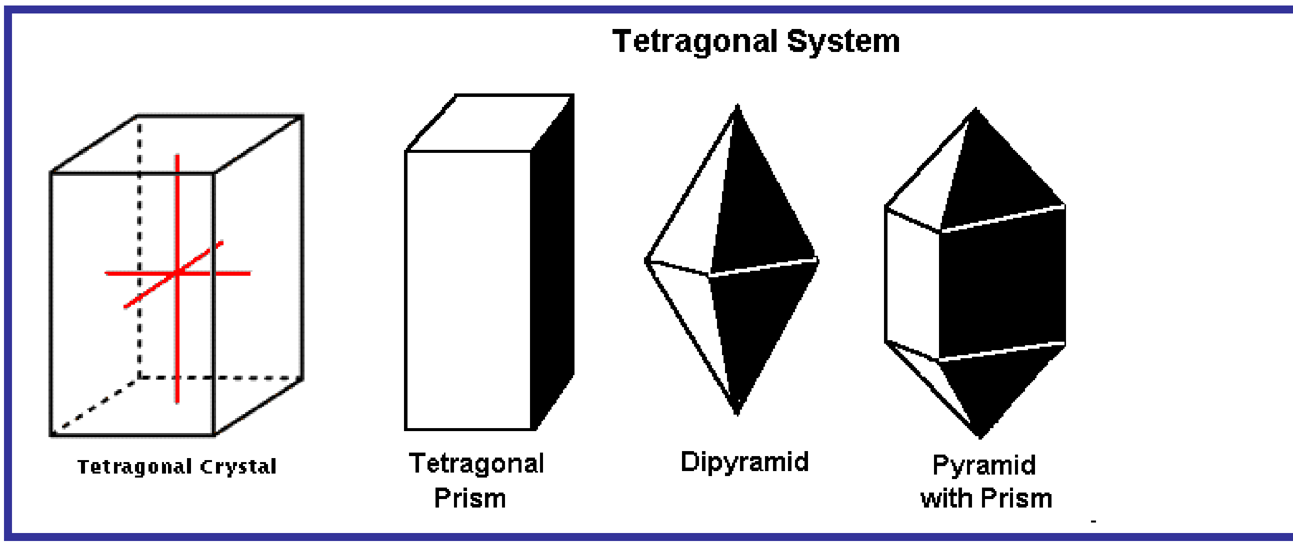


Crystal Systems



Crystals of the same substance may differ in appearance but . . .





9. **Mineraloids** Non-crystalline (no crystals) solids

a. A few natural occurring solids are not crystalline, but are generally considered as minerals.

   i. Their atoms are randomly arranged but are fixed in place.

   ii. **Glass** is a non-crystalline solid.

b. Kinds of Mineraloids

i. **Metamict**___________

- Originally formed as crystalline compounds and the crystalline structure was later destroyed.
- Breakdown of crystal structure results from bombardment by alpha particles ejected from disintegrating radioactive elements and therefore are always radioactive (ex. Ziron).

Fulgurites

- Variety of Lechatelierite
- Fused quartz resulting from lighting striking quartz sand



ii. ___**Amorphous**___: Originally formed in the non-crystalline state. (Means "without form")

- Rapid cooling from the molten state

Pele's Hair

Pele's Hair is formed when small gas pockets rise to the top of a lava flow. When the bubbles reach the surface, they "pop" sending streamers of lava into the air. This lava cools quickly to form long, slender, golden strands of obsidian.

Obsidian –
"Volcanic Glass"

ii. **Amorphous**: Originally formed in the non-crystalline state. (Means “without form”)

- Slow hardening of gelatinous material (a “gel”).
  - Example: Opal
    - Weathered silica carried in water.

III. Chemical Composition of Earth's Crust

A. ___Oxygen_________:

1. The most ___abundant_____ element in Earth's crust.
2. _46.6_ % by weight
3. Takes up _~94_% of the volume of an average rock.
4. Not to be confused with O_2 in the air
   - In minerals, it is strongly bonded to other elements.

BOX 2.2 ■ TABLE 1

Crustal Abundance of Elements

Element	Symbol	Percentage by Weight	Percentage by Volume	Percentage of Atoms
Oxygen	O	46.6	93.8	60.5
Silicon	Si	27.7	0.9	20.5
Aluminum	Al	8.1	0.8	6.2
Iron	Fe	5.0	0.5	1.9
Calcium	Ca	3.6	1.0	1.9
Sodium	Na	2.8	1.2	2.5
Potassium	K	2.6	1.5	1.8
Magnesium	Mg	2.1	0.3	1.4
All other elements		1.5	—	3.3

III. Chemical Composition of Earth's Crust

B. Silicon:

1. The second most abundant element in the crust.
2. Silica
   a. The is the name for the substance formed when oxygen combines with silicon.
   b. Most minerals contain silica.

BOX 2.2 ■ TABLE 1

Crustal Abundance of Elements

Element	Symbol	Percentage by Weight	Percentage by Volume	Percentage of Atoms
Oxygen	O	46.6	93.8	60.5
Silicon	Si	27.7	0.9	20.5
Aluminum	Al	8.1	0.8	6.2
Iron	Fe	5.0	0.5	1.9
Calcium	Ca	3.6	1.0	1.9
Sodium	Na	2.8	1.2	2.5
Potassium	K	2.6	1.5	1.8
Magnesium	Mg	2.1	0.3	1.4
All other elements		1.5	—	3.3

III. Chemical Composition of Earth's Crust

C. ___Aluminum___:

1. More common in rocks than iron.
2. The third most abundant element in the crust.

BOX 2.2 ■ TABLE 1

Crustal Abundance of Elements

Element	Symbol	Percentage by Weight	Percentage by Volume	Percentage of Atoms
Oxygen	O	46.6	93.8	60.5
Silicon	Si	27.7	0.9	20.5
Aluminum	Al	8.1	0.8	6.2
Iron	Fe	5.0	0.5	1.9
Calcium	Ca	3.6	1.0	1.9
Sodium	Na	2.8	1.2	2.5
Potassium	K	2.6	1.5	1.8
Magnesium	Mg	2.1	0.3	1.4
All other elements		1.5	—	3.3

III. Chemical Composition of Earth's Crust

D. Only ___**eight**___ elements account for more than 98% of the crust's weight.

- All other elements total only about 1.5%.

BOX 2.2 ■ TABLE 1

Crustal Abundance of Elements

Element	Symbol	Percentage by Weight	Percentage by Volume	Percentage of Atoms
Oxygen	O	46.6	93.8	60.5
Silicon	Si	27.7	0.9	20.5
Aluminum	Al	8.1	0.8	6.2
Iron	Fe	5.0	0.5	1.9
Calcium	Ca	3.6	1.0	1.9
Sodium	Na	2.8	1.2	2.5
Potassium	K	2.6	1.5	1.8
Magnesium	Mg	2.1	0.3	1.4
All other elements		1.5	—	3.3

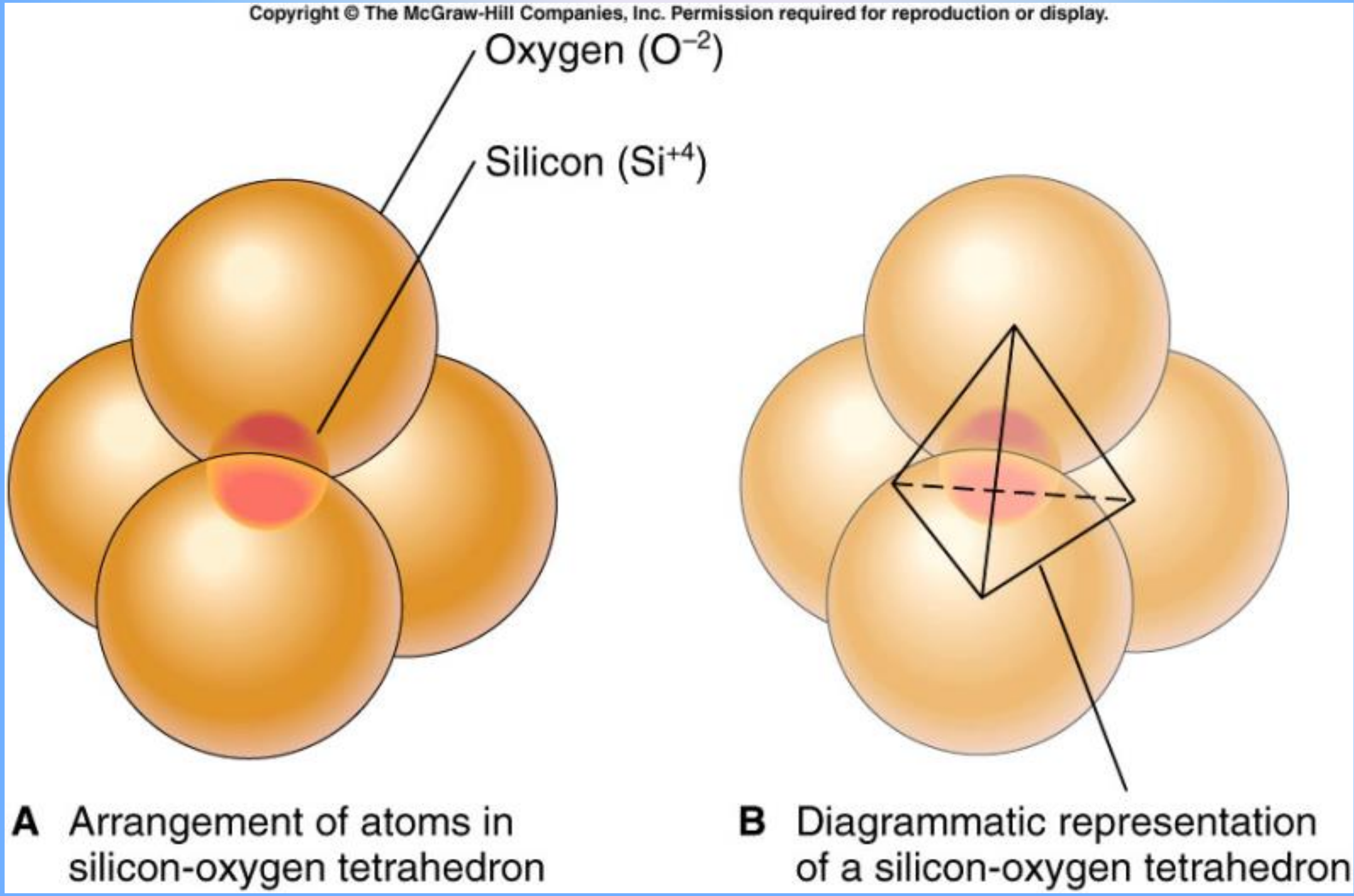
8 elements

IV. Silicates

A. The Silicon-Oxygen Tetrahedron

1. About 60% of all minerals are Silicon (Si) and Oxygen (O) combined with abundant metals such Al, Fe, Ca, Na, K, and Mg.
   - This group of minerals is called the silicates.
2. The "building block" of this group of minerals is a four-sided pyramidal geometric shape called a tetrahedron.

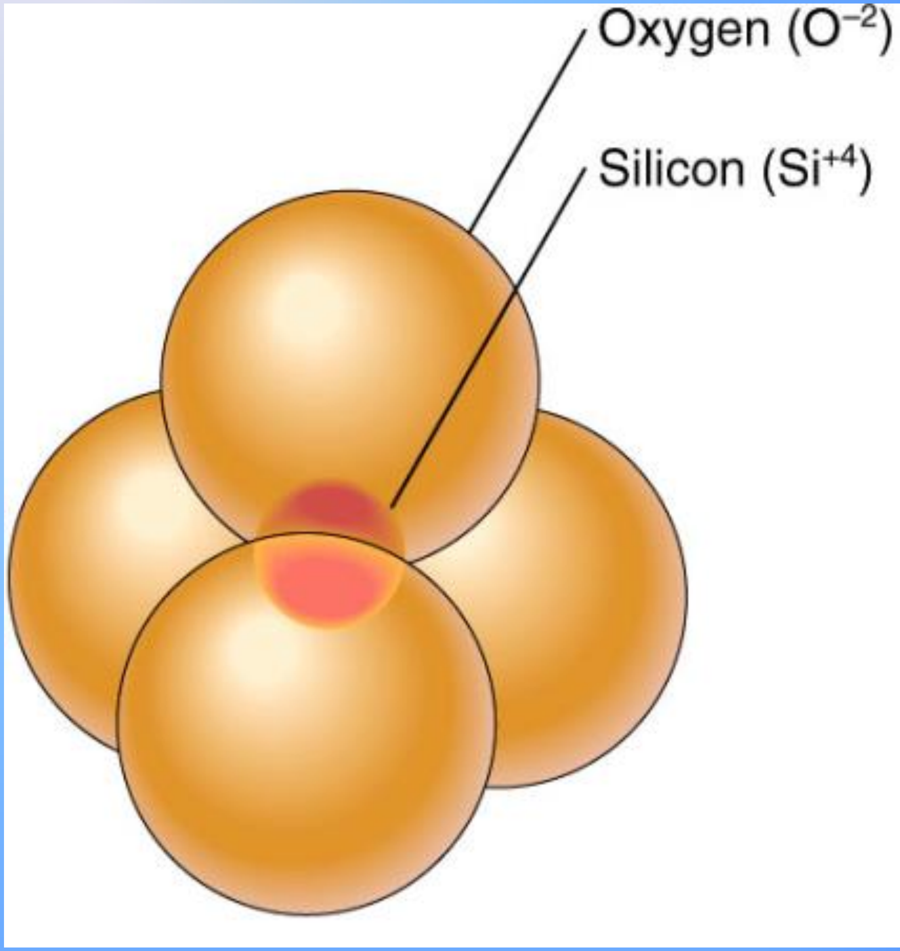
The Silicon-Oxygen Tetrahedron

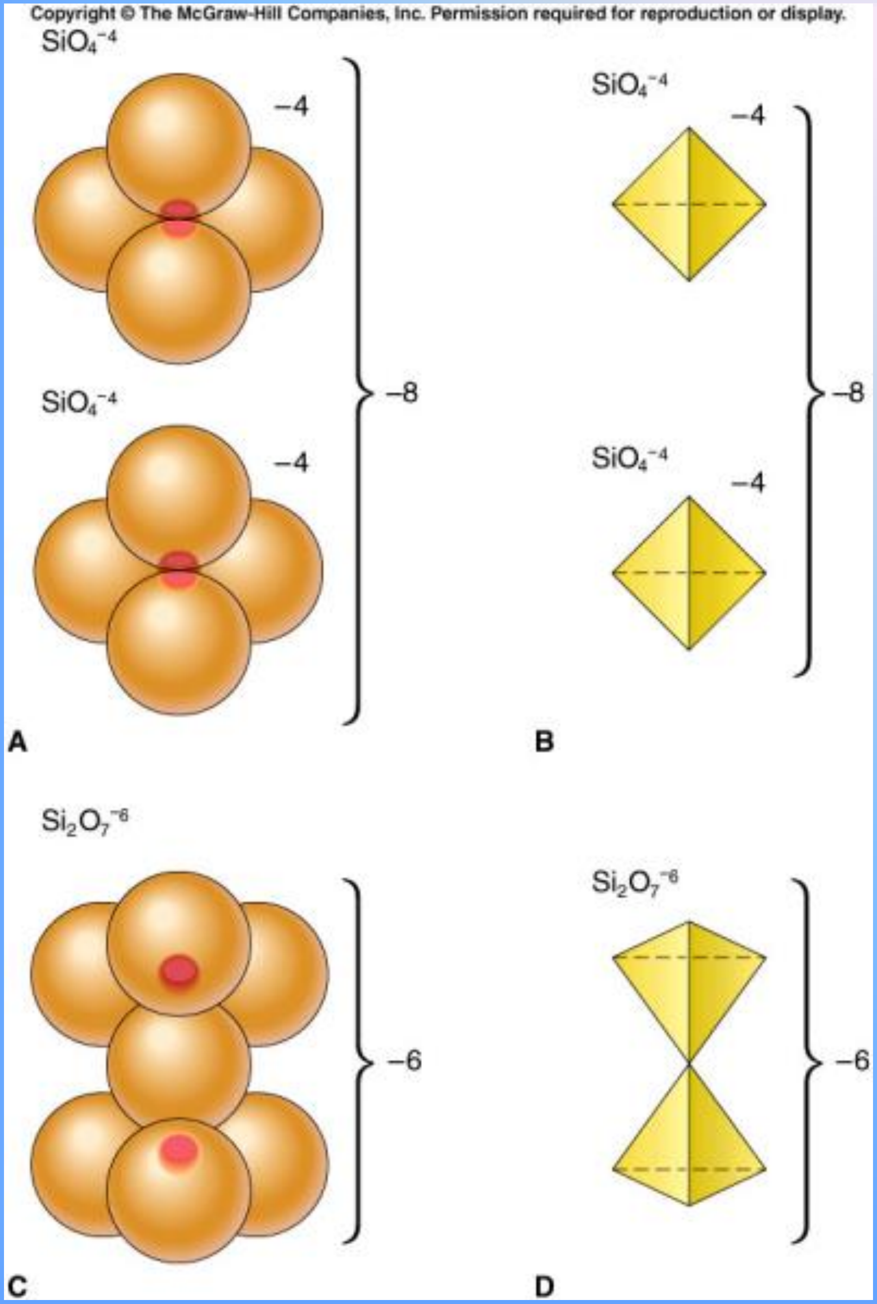


- A *four sided* arrangement with
  - Four oxygen atoms surrounding a single silicon atom.

The Silicon-Oxygen Tetrahedron

- **SiO_4 $^{-4}$** (+4 due to Si and -8 due to oxygen (-2 x 4)
- Bonds with positive ions (e.g., Fe or Al)
- Or, bonds with adjacent tetrahedra reducing need for extra + ions



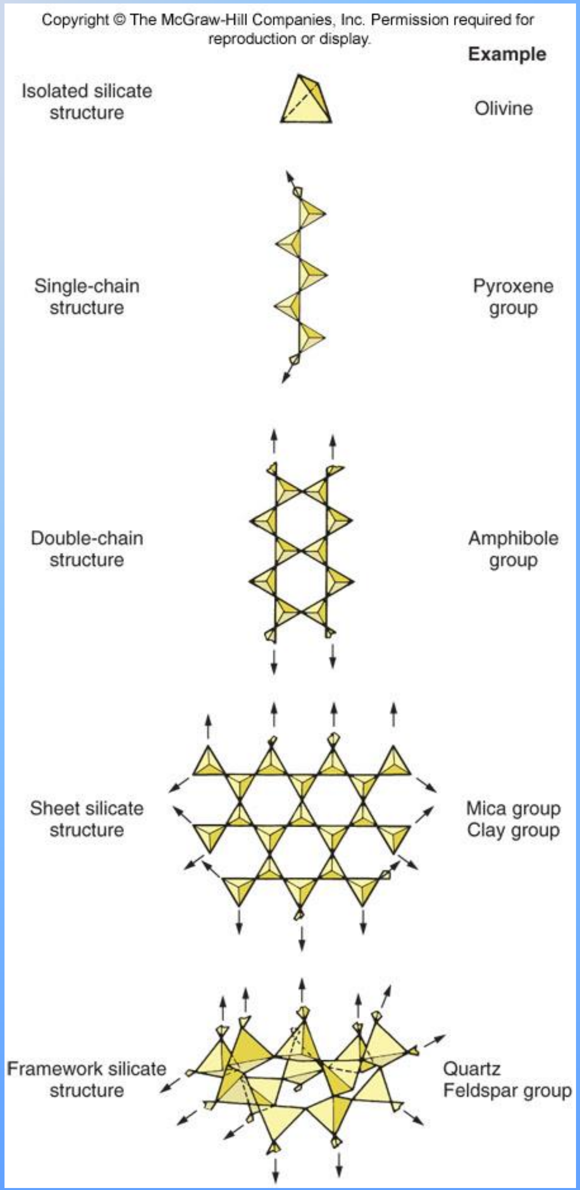


- Shared tetrahedra need fewer positive ions to be stable in a crystal structure than two single tetrahedra.
- Oxygen atoms are shared.

B. Silicate Structure Groups

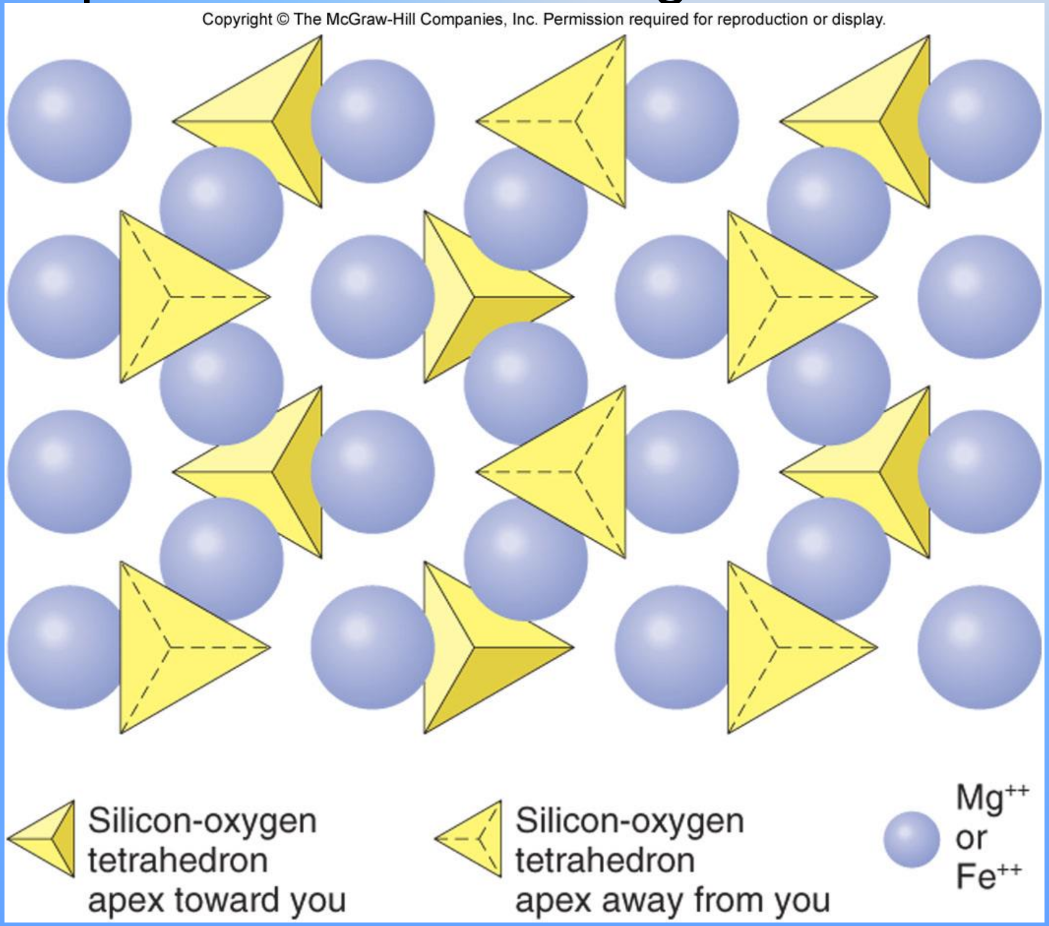
- The different silicate types arise from
  - the various ways in which the silicon-oxygen tetrahedra are related to one another.

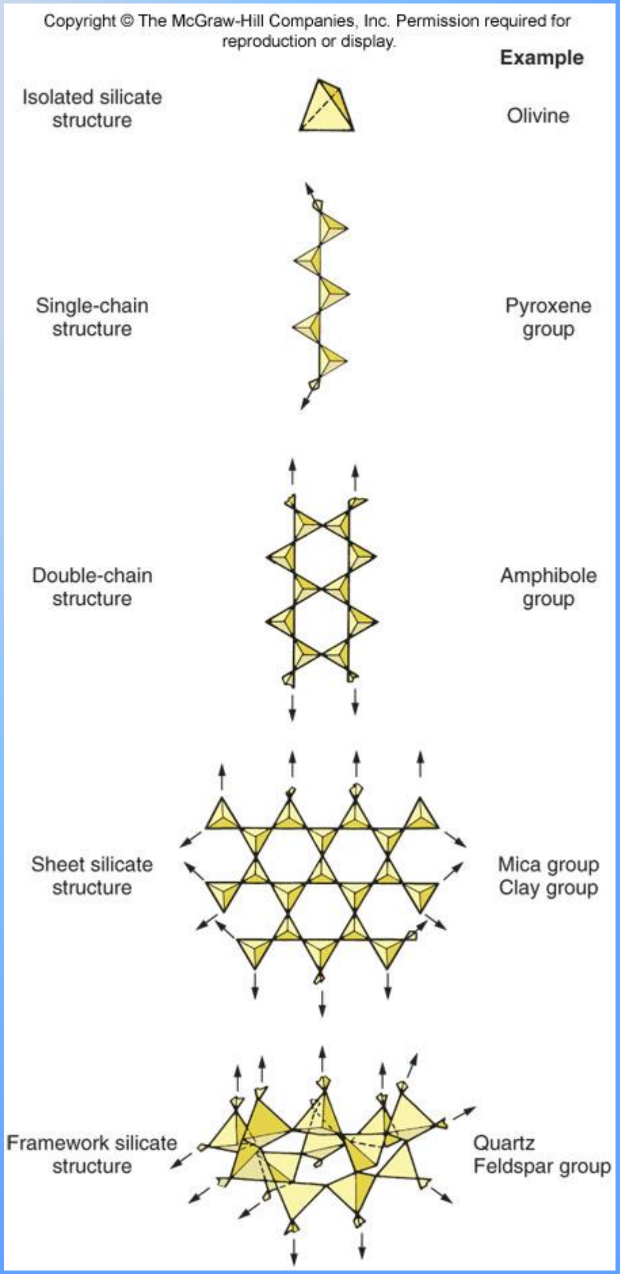
- They may exist as separate and distinct units, or
  - they may be linked by sharing corners.
- Silicate classification is based on the types of linkages.



1. Isolated Tetrahedra (Nesosilicates)

- Individual tetrahedra linked by positive iron and magnesium ions.



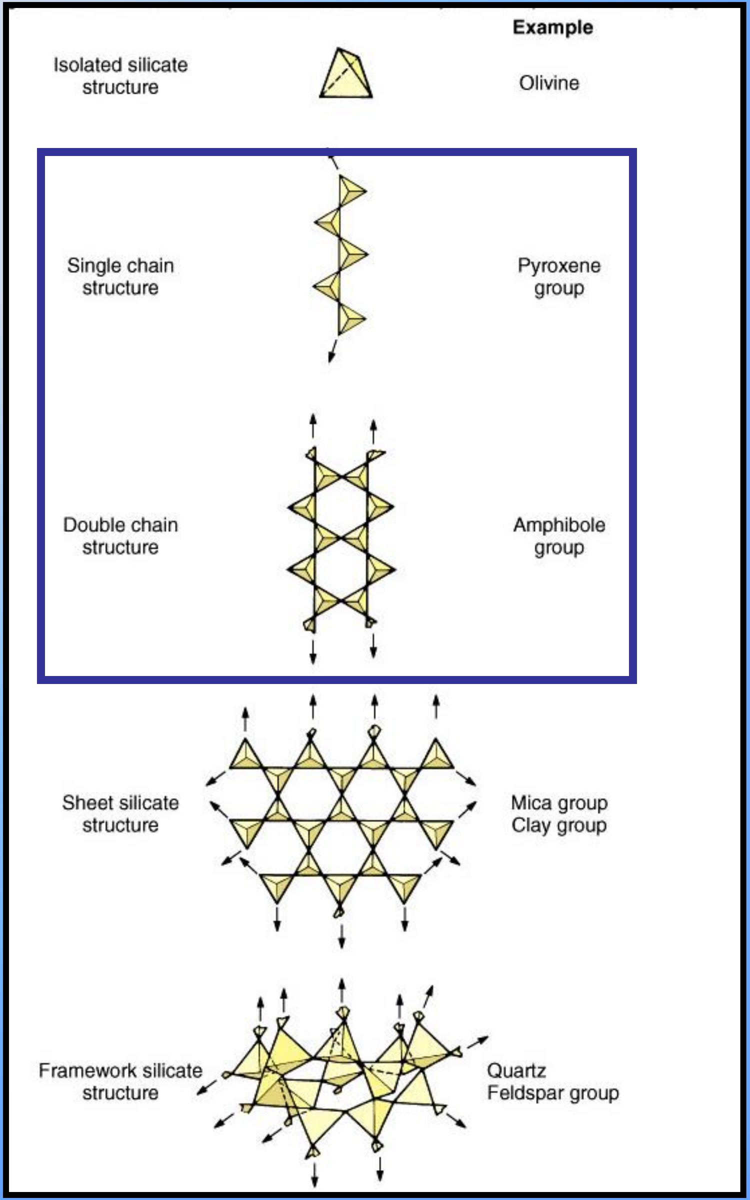


Isolated Tetrahedra (Nesosilicates)

- Example: ***olivine***

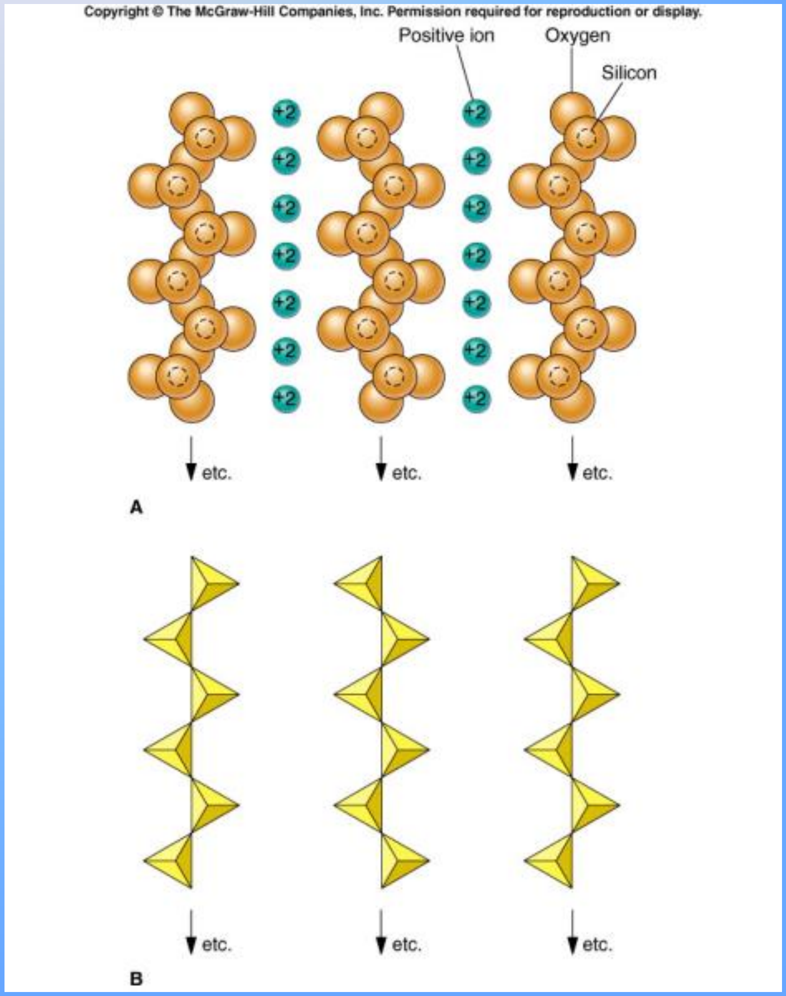
2. Chain Silicate Structure (**Inosilicates**)

- Two of a tetrahedron's oxygen atoms are shared with adjacent tetrahedrons



Single-Chain Silicate Structure (Pyroxene Group)

- Each chain has an excess of negative charges.
- Ratio of silicone to oxygen is 1:3 (has SiO_3^{-2} in formula)
- Is electrically balanced by positive ions that hold the parallel chains together.
- Minerals tend to be shaped like columns, needles, or even fibers.

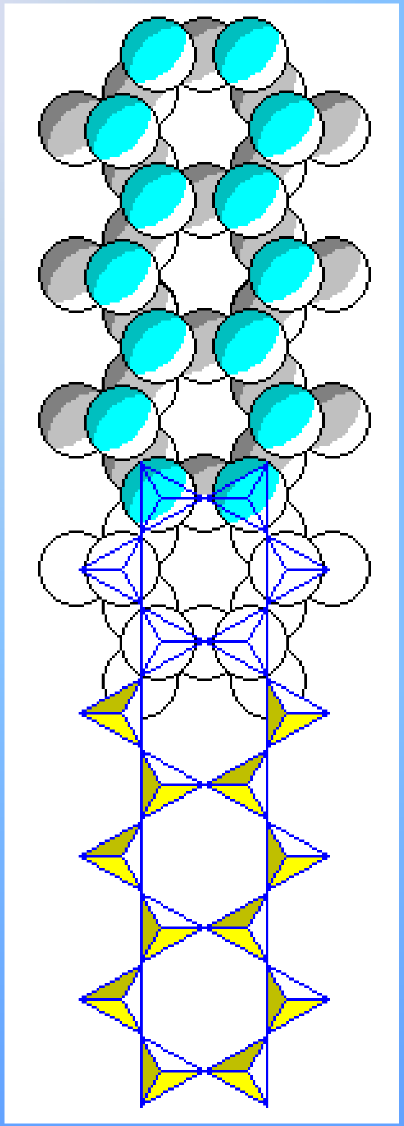


Single Chains – Pyroxene Group

Spodumene

Double Chain Structure - Amphiboles

- Two parallel chains
- Every other tetrahedron along a chain
  - Shares an oxygen atom with the adjacent chain
  - Double chains are bonded by positively charged ions.



Double Chains – Amphibole Group

Actinolite

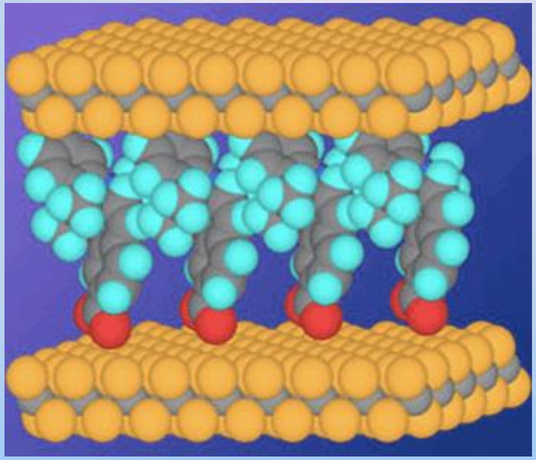
Tremolite Fibers

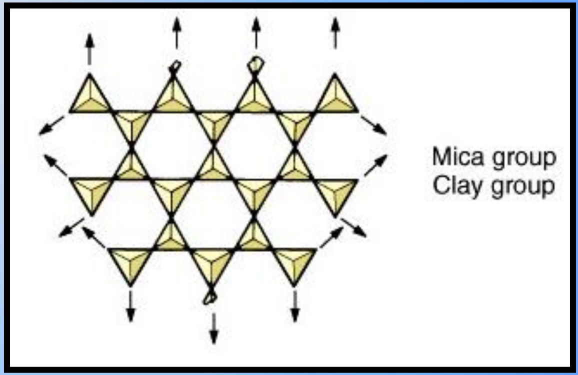
Tremolite
(Radiating Fibers)

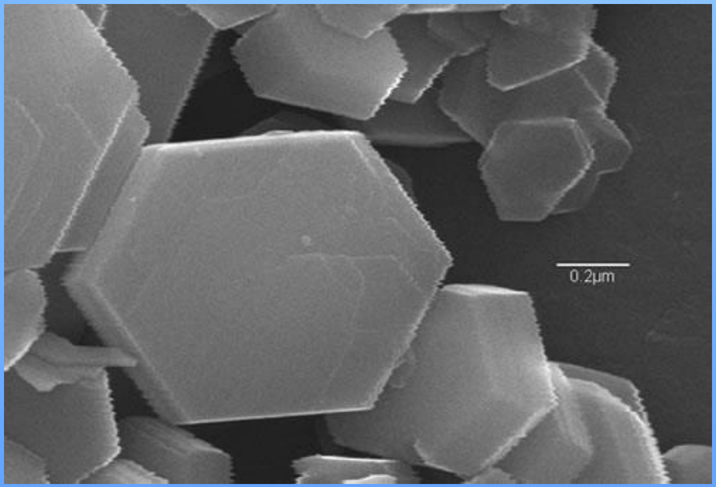
Hornblende

3. Sheet Structures: Also called **Phyllosilicates**

- Three oxygen atoms of each tetrahedra are shared with adjacent tetrahedra.
- Form extended sheets.
- Positive ions are "sandwiched" between the silicate sheets.
- *Kaolinite*







Phyllosilicates – The Micas

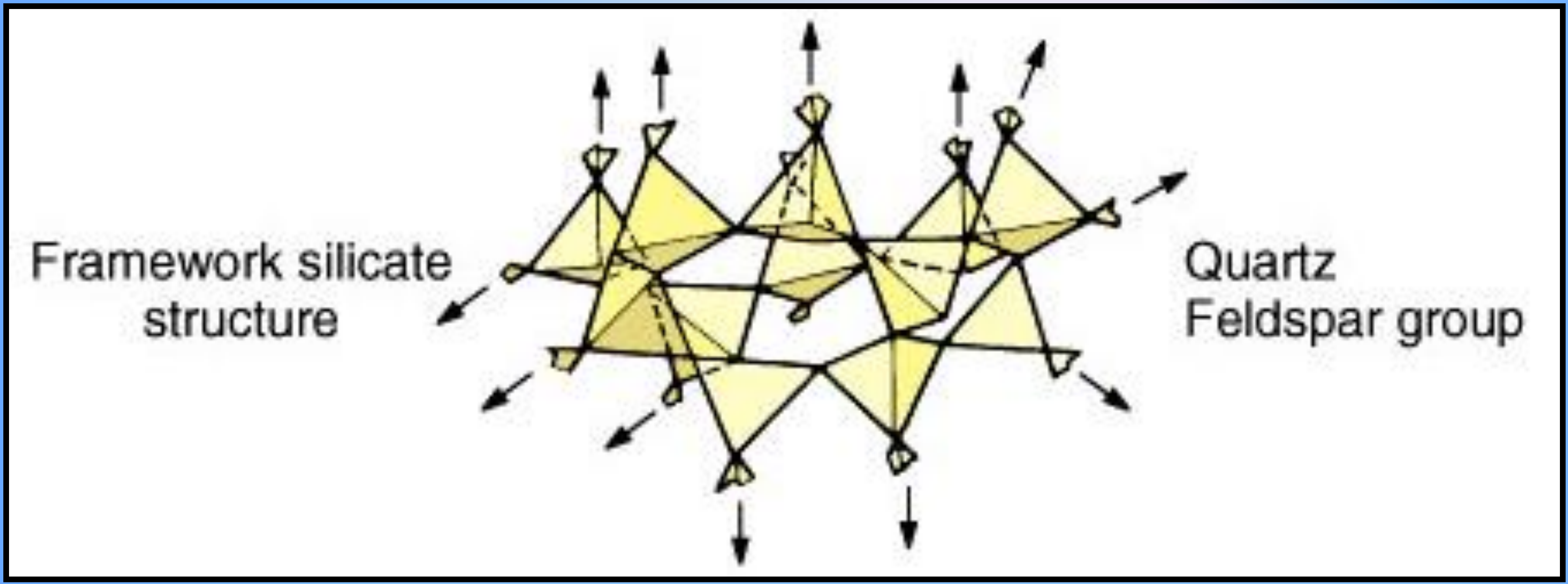
Lepidolite

Biotite

Muscovite

Phologopite

4. Framework Structure: (Tektosilicates)



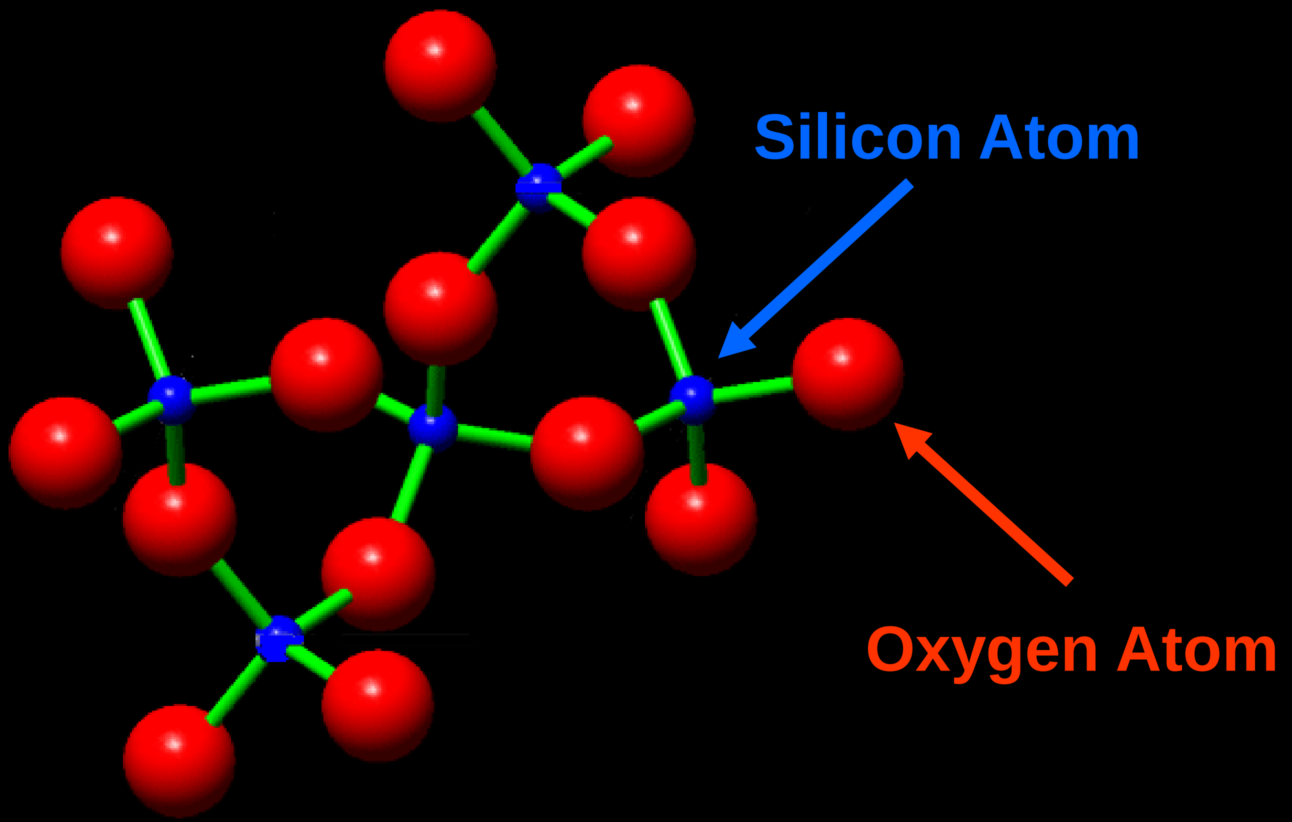
- Each tetrahedron shares four oxygen atoms with others to form a continuous three-dimensional framework

Tektosilicates – Silica Group






If quartz has a formula of SiO_2 how is it still made of the silicon-oxygen tetrahedra with a formula of SiO_4?



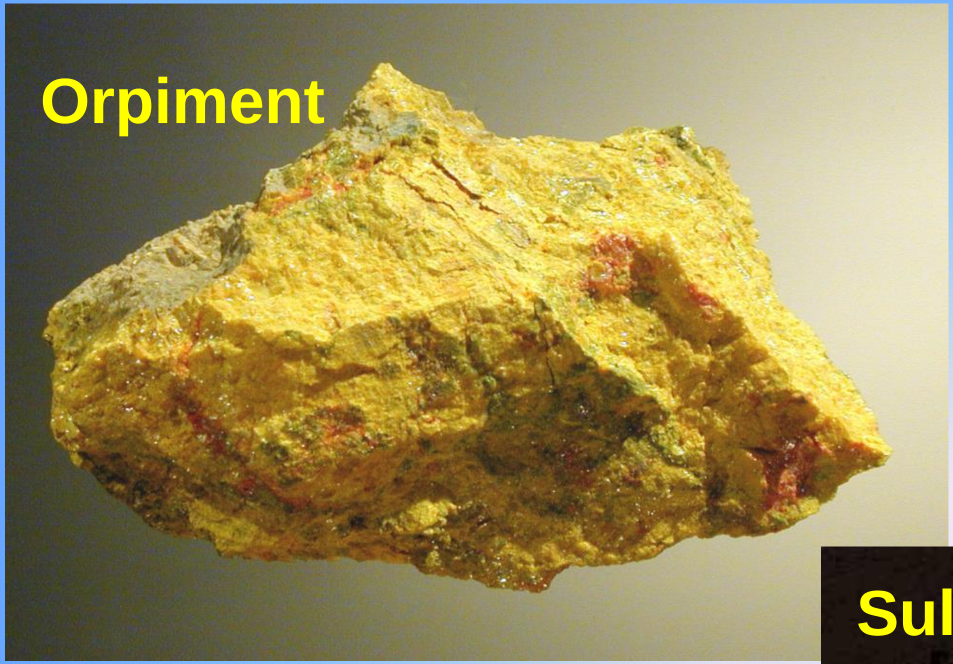
- **Two oxygen atoms are shared by adjacent tetrahedra. Si to O is in the ratio of 1:2 but the tetrehedron unit with Si to O of 1:4 is still present.**

V. Mineral Identification

A. Physical Properties

1.____________ Color

a. Usually the most noticeable property, but may be one of the least-accurate diagnostic properties
b. Observed color in white light.
c. Minerals may have many varieties due to slight impurities.



d. Many minerals have ___similar___ color

2. **Streak**

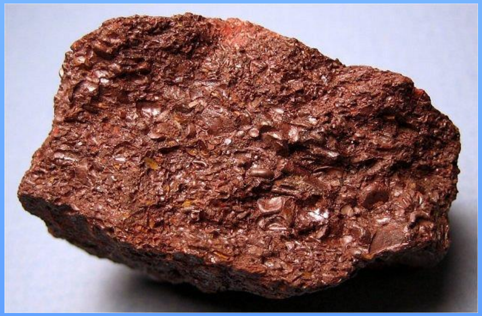
a. The color of the mineral after it has been ground to a fine power.

b. Scraping the edge of a mineral sample across the edge of an unglazed porcelain plate

Streak

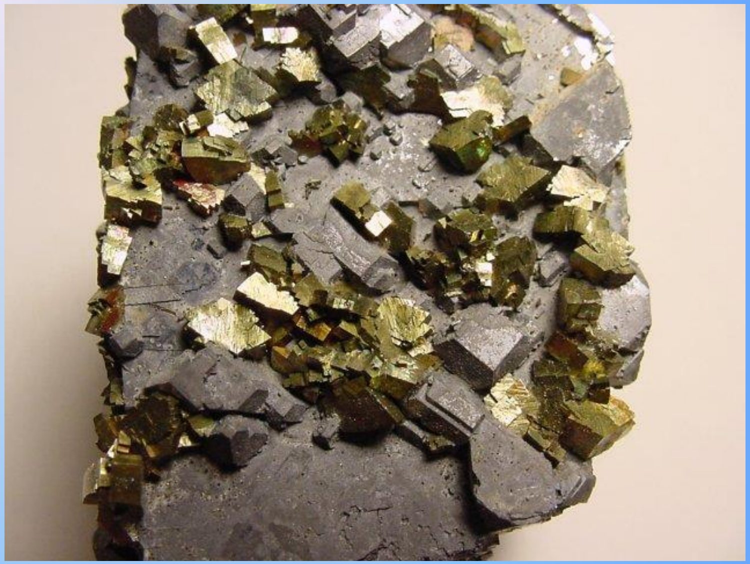
c. Streak color is representative of the mineral’s true color.

- It is often different from the apparent color of an unground sample.
- *The streak color of a mineral will always be the same, even it its external color varies.*



d. Most metallic minerals have a **dark** streak

Magnetite



Chalcopyrite and Galena

Galena

Graphite

- while most nonmetals have a light to white streak

calcite

Amethyst

Peridot (polished)

Citrine

3. __Luster__

a. The quality and intensity of *light* that is reflected from the surface.

b. Luster is either __metallic__ or __nonmetallic__.

Metallic Luster

- Metal-like shine
- Dark Streak





Nonmetallic Luster

- More common
- Most important type is *glassy* (vitreous)
- Can be greasy, waxy, pearly, and silky
- Light streak color

4. Hardness

a. Measure of resistance to scratching.

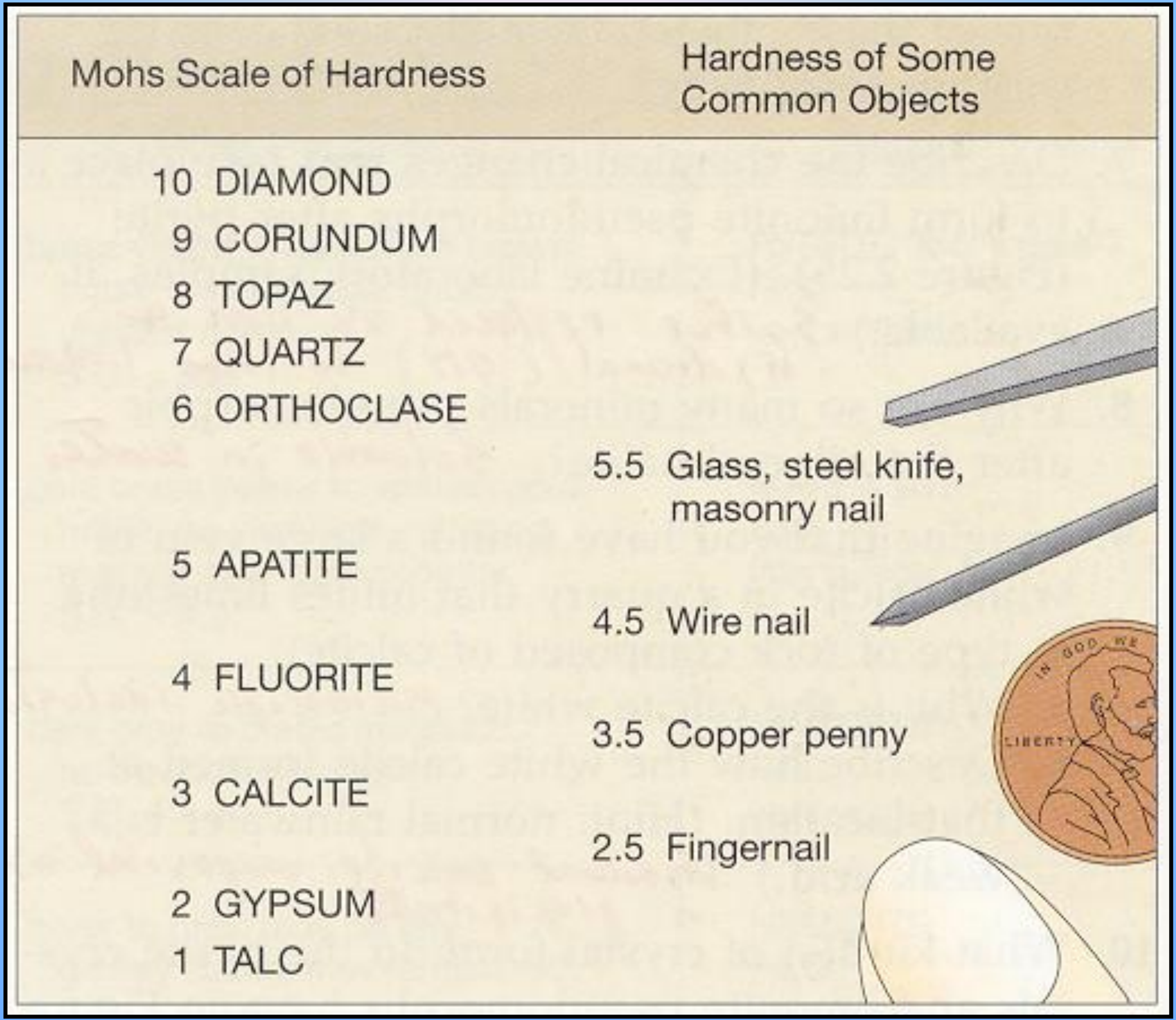
b. A harder substance will scratch a softer substance.

c. German mineralogist, Friedrich Mohs (1773-1839) developed a quantitative scale on which the softest mineral (talc) has a hardness of 1 and the hardest mineral (diamond) has a hardness of 10.

d. Mohs Harness is now widely accepted by geologists and engineers.

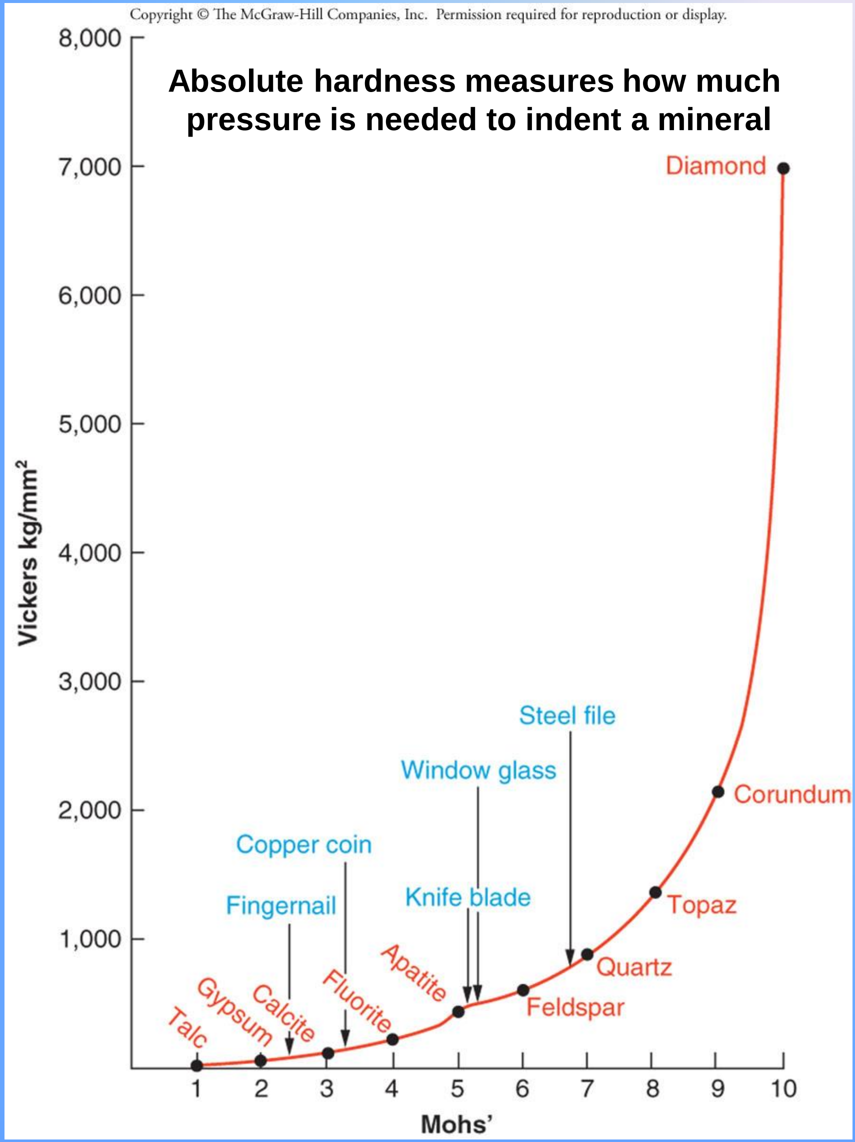
1		Talc
2		Gypsum
3		Calcite
4		Fluorite
5		Apatite
6		Orthoclase Feldspar
7		Quartz
8		Topaz
9		Corundium
10		Diamond

Hardness Determination



e. Rather than carry samples of the ten standard minerals, a geologist doing field work usually relies on common objects to test for hardness (fingernail, copper penny, steel nail or knife blade, glass plate).

Hardness


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
Absolute hardness measures how much pressure is needed to indent a mineral
Vickers kg/mm²
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
Diamond
Corundum
Topaz
Quartz
Feldspar
Apatite
Fluorite
Calcite
Gypsum
Talc
Steel file
Window glass
Knife blade
Copper coin
Fingernail
1
2
3
4
5
6
7
8
9
10
Mohs'


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
Photo © Parvinder Sethi

5. How Minerals Break

a. **Cleavage**

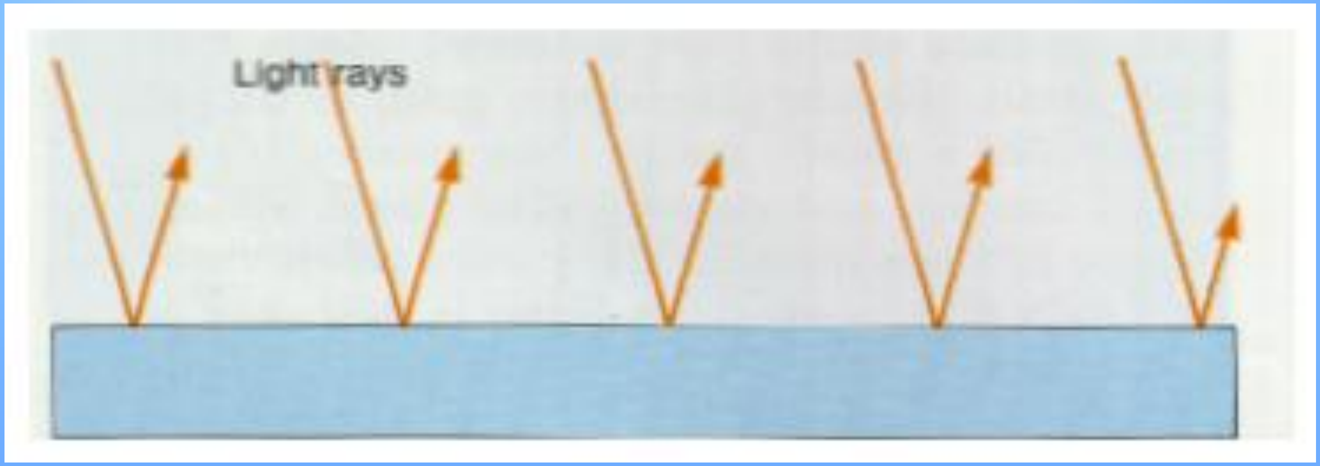
   i. The ability of a mineral to break ("split') along preferred directions.

   ii. Results because of weakness in their crystalline structure due to

   ■ weak chemical bonding between repeating , parallel layers of atoms.

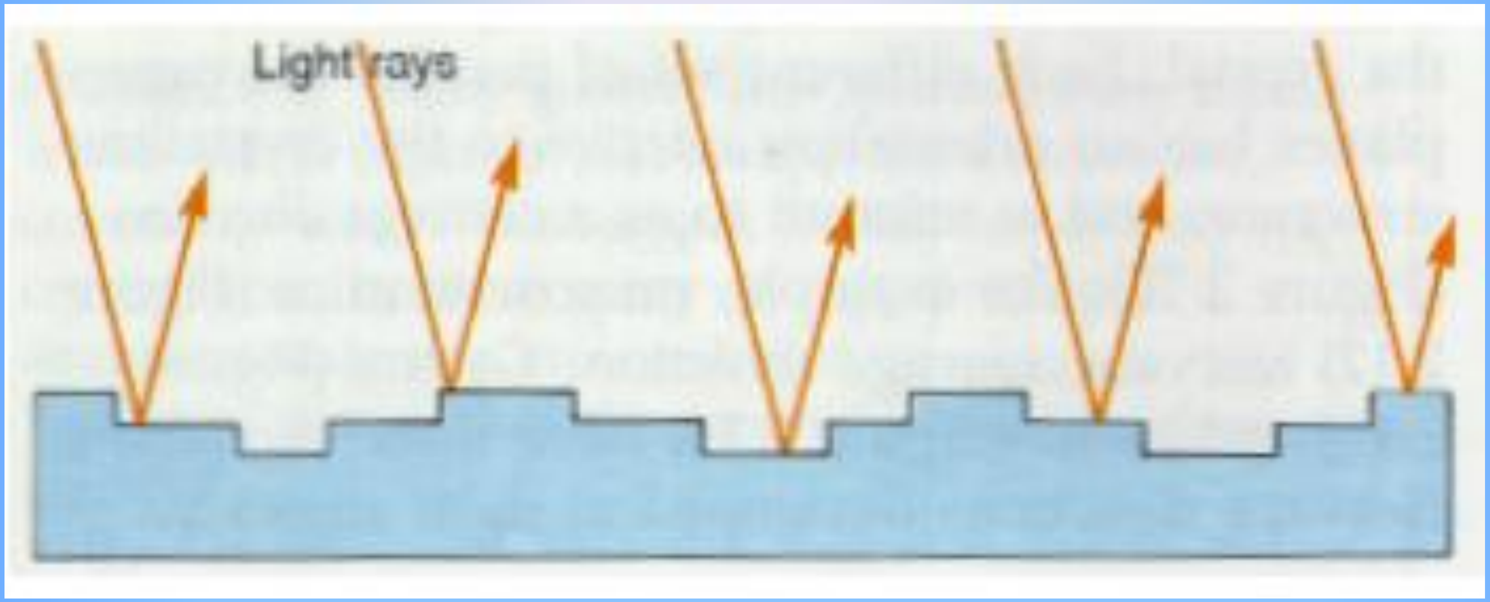
iii. Cleavage Faces

- The term used for each set of parallel cleavage planes.
- These surfaces usually reflect light providing an appearance similar to a polished table top.



Good Cleavage
Mineral reflects light from obvious parallel flat surfaces

Recognizing Cleavage Surfaces



Poor Cleavage:

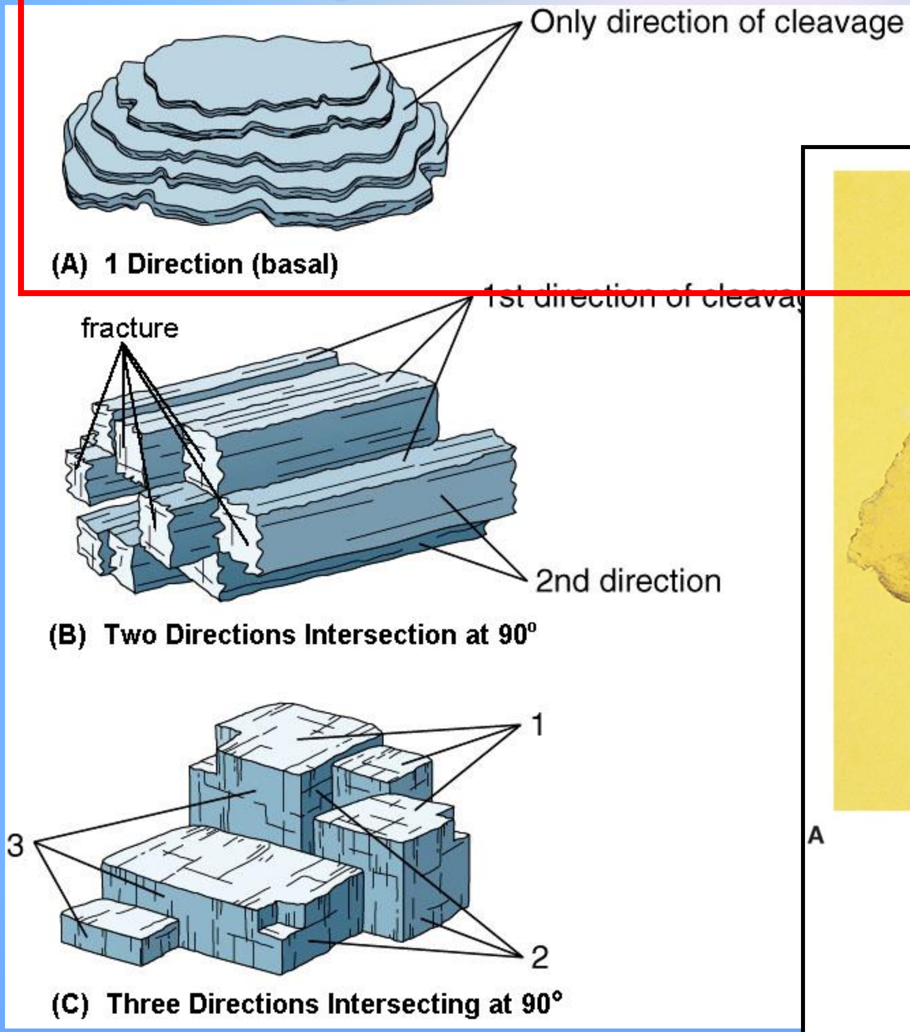
Mineral reflects light from many flat parallel surface.
They’re not obvious because they are so small.

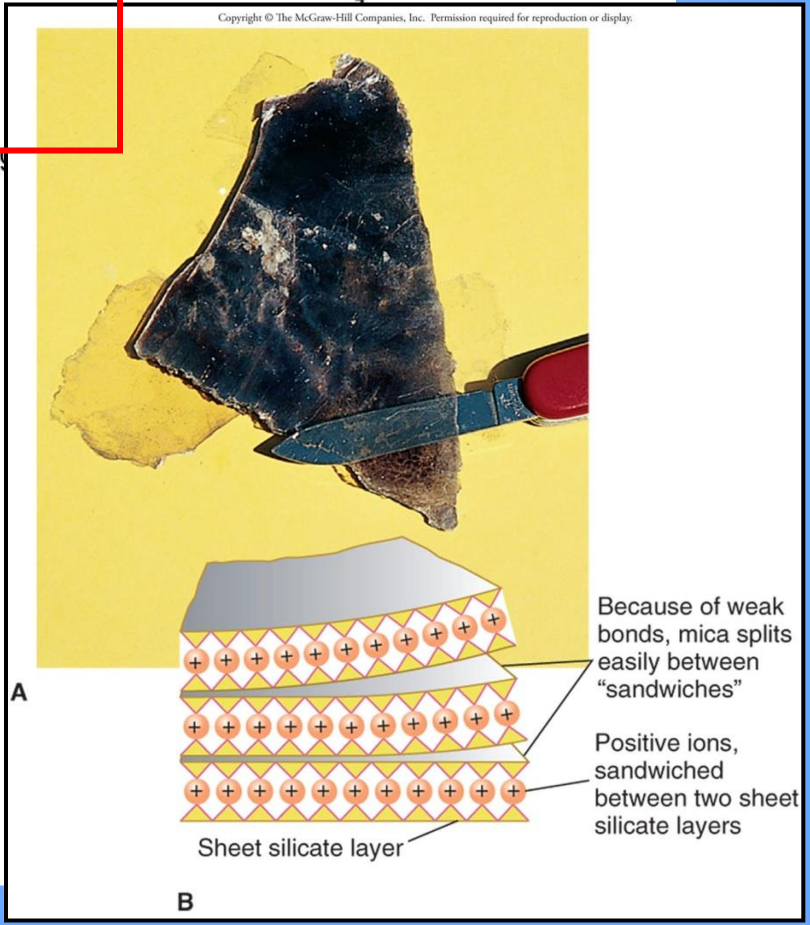
iv. Striations

- Straight "hairline" grooves on the cleavage faces of some minerals. Typical of *plagioclase feldspars*.

Photo by C. C. Plummer

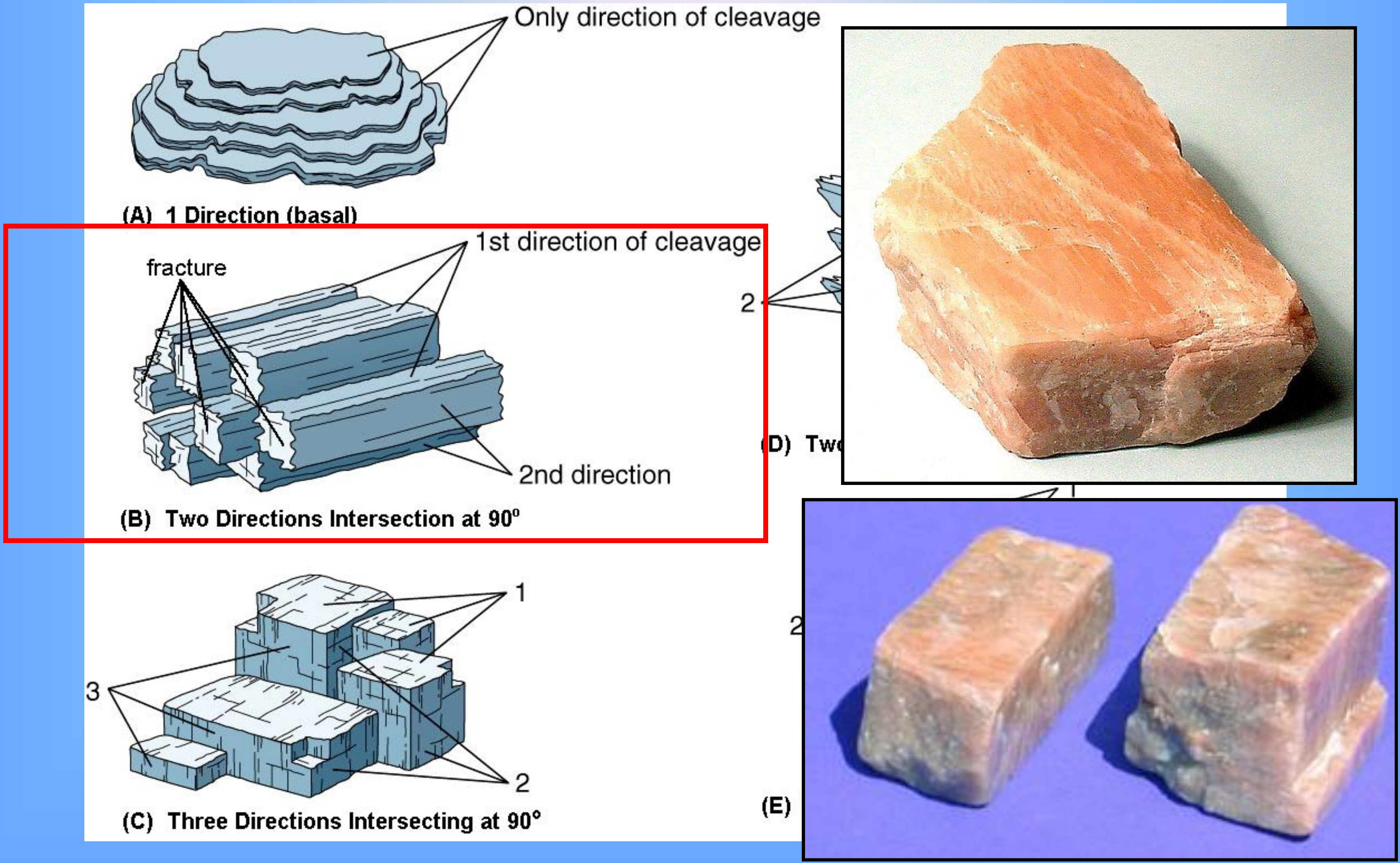
Types of Cleavage



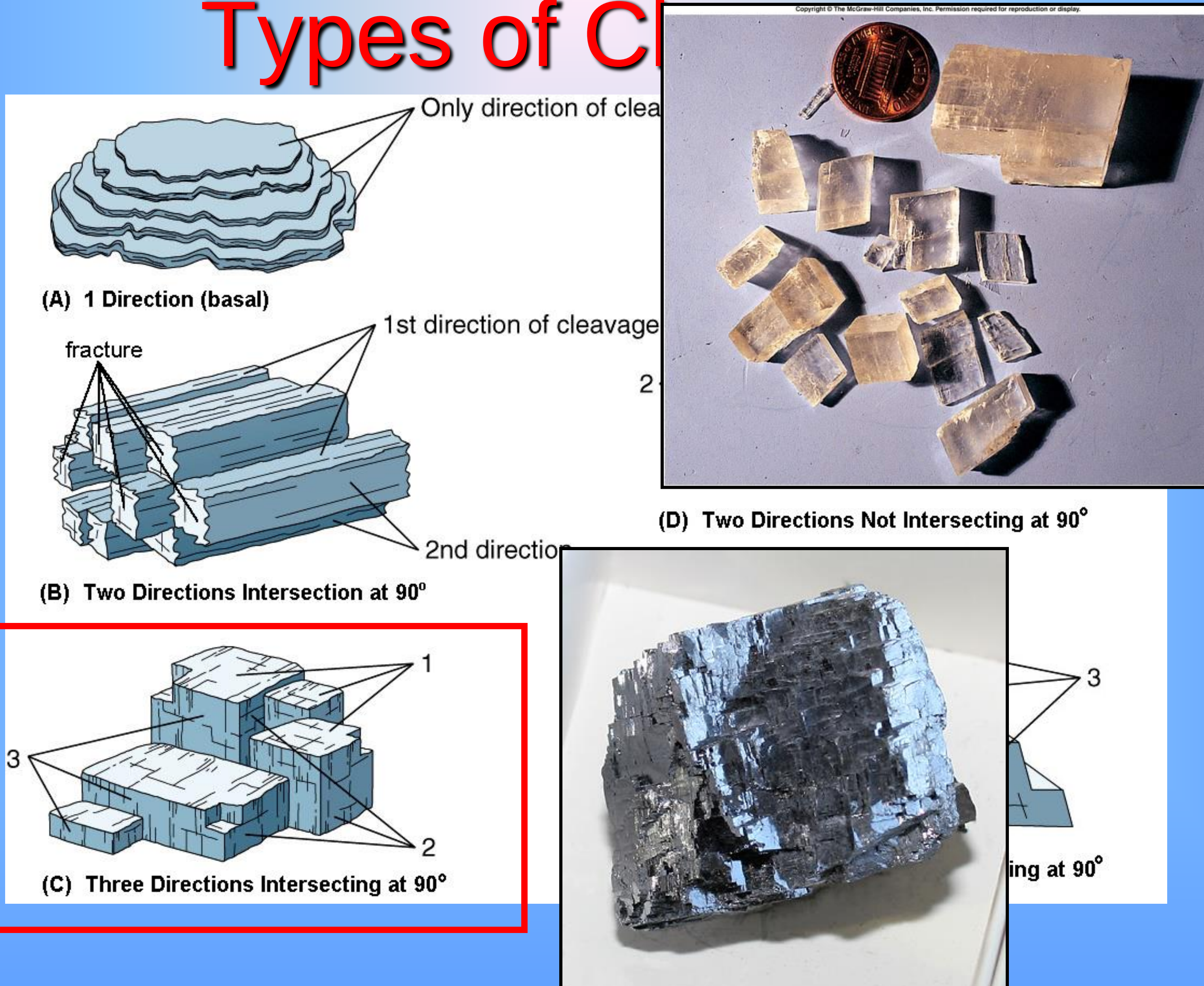


Cleavage in One Direction

Types of Cleavage



Types of Cl



(A) 1 Direction (basal)

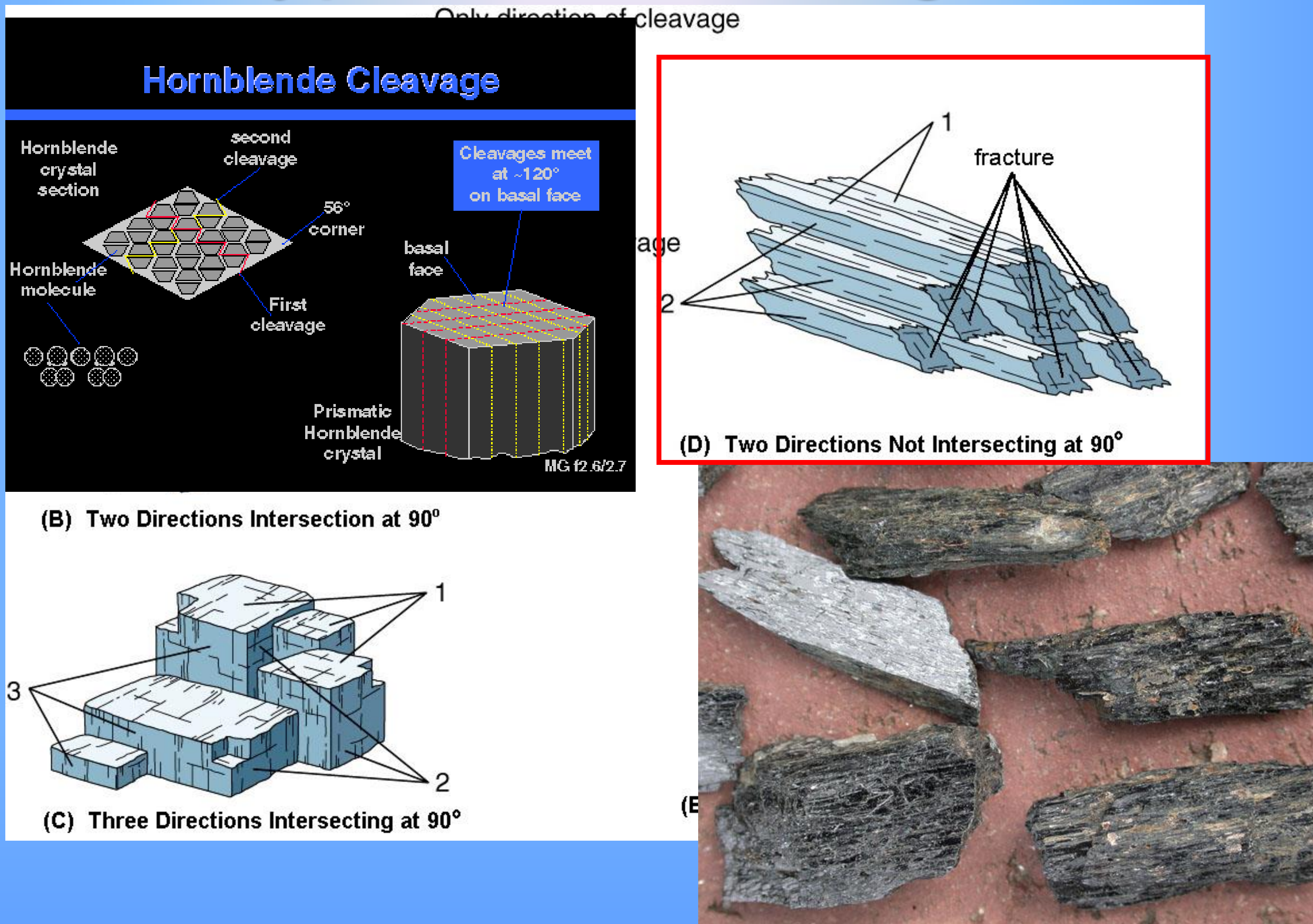
(B) Two Directions Intersection at 90°

(C) Three Directions Intersecting at 90°

(D) Two Directions Not Intersecting at 90°

ing at 90°

Types of Cleavage

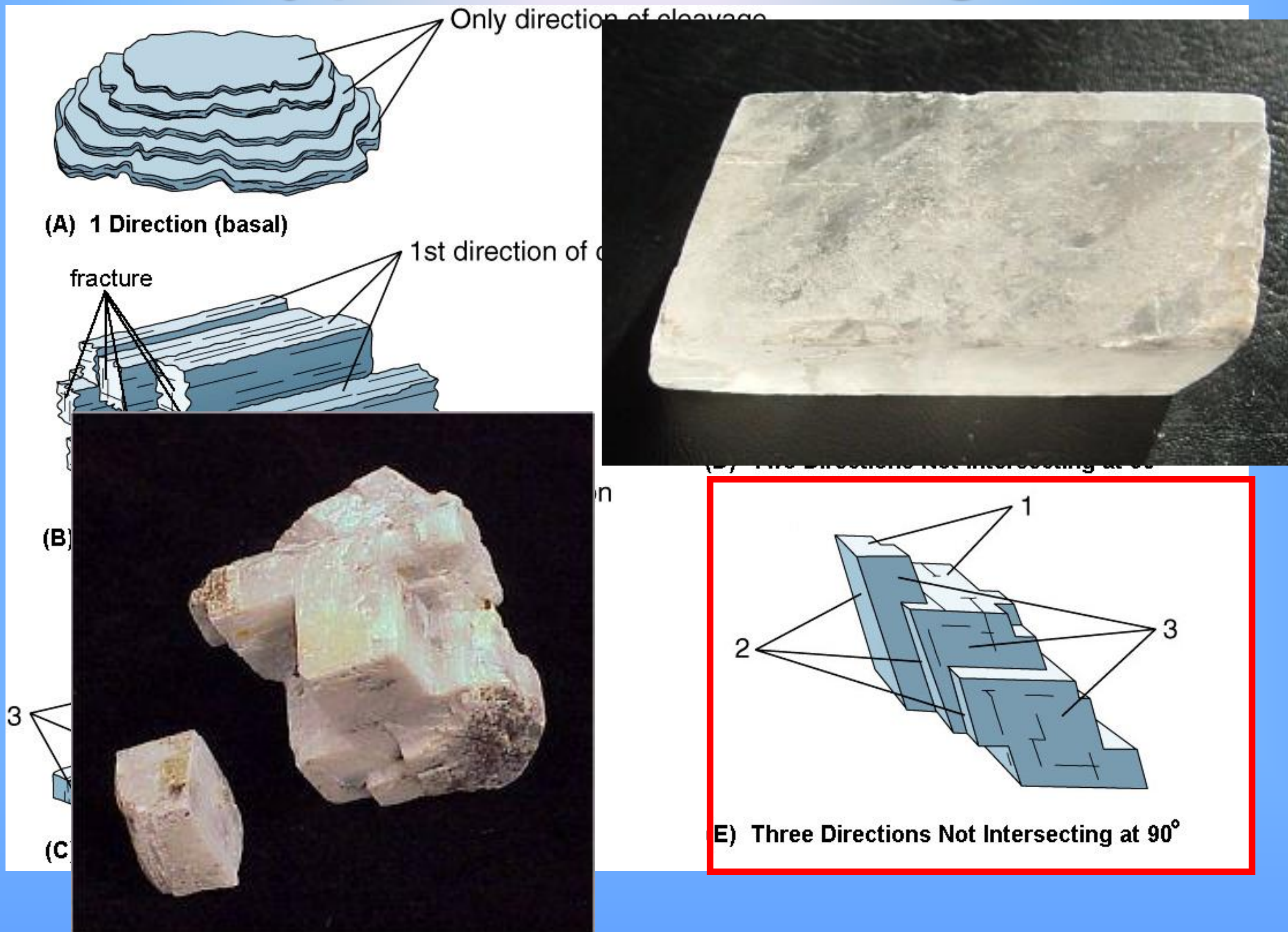


(B) Two Directions Intersection at 90°

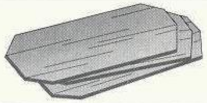
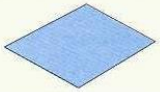
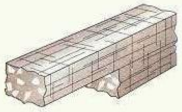
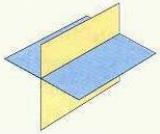
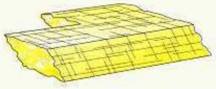
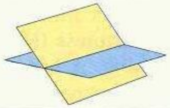
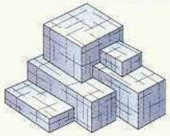
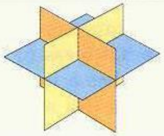
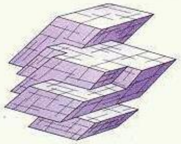
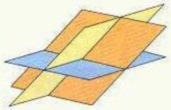
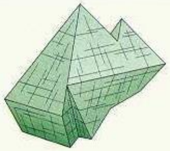
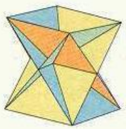
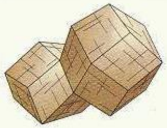
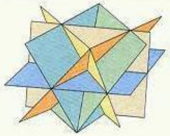
(C) Three Directions Intersecting at 90°

(D) Two Directions Not Intersecting at 90°

Types of Cleavage



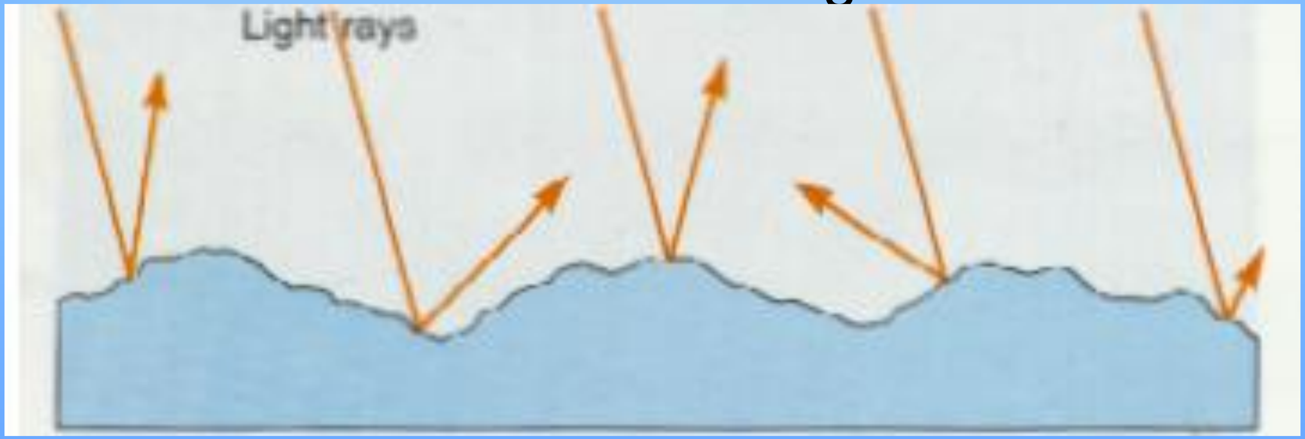
Common Cleavage Patterns

Number of Cleavage Directions	Shapes that Crystal Breaks Into	Sketch	Ilustration of Cleavage Directions
0 No cleavage, only fracture	Irregular masses with no flat surfaces		None
1	"Books" that split apart along flat sheets		
2 at 90°	Elongated form with rectangular cross sections (prisms) and parts of such forms		
2 not at 90°	Elongated form with parallelogram cross sections (prisms) and parts of such forms		
3 at 90°	Shapes made of cubes and parts of cubes		
3 not at 90°	Shapes made of rhombohedrons and parts of rhombohedrons		
4	Shapes made of octahedrons and parts of octahedrons		
6	Shapes made of dodecahedrons and parts of dodecahedrons		

b. __**Fracture**____: The way a substance breaks when not controlled by cleavage

i. Fracture surfaces are nonplanar and nonparallel surfaces along which minerals may break.

- These surfaces may be in addition to cleavage
- A mineral may only have fracture surfaces in the absence of cleavage



Light is reflected in many directions

ii. "__Irregular__" Fracture (like concrete)

- Also referred to as "uneven."
- The most common type of fracture

iii. Conchoidal Fracture

- Resembles the inside of clam shell with smoothly curved surfaces.

Fibrous Fracture – Crysotile Asbetsos

Splintery Fracture - Actinolite

Remember, a mineral may cleave in some directions and fracture in others.

Generally, we say a mineral exhibits cleavage if it has cleavage in at least one direction *even if it also shows fracture.*

6. Specific Gravity :

The ratio of the mass of a substance to the mass of an equal volume of water.

a) This is how the density of a mineral is usually given. It is a comparison to the weight of an equal volume of water.

b) Liquid water has a specific gravity of 1. Therefore, a mineral with a specific gravity of 2.65 weighs 2.65 as much as an equal volume of water.

c) Special scales are used to precisely determine specific gravity, but a person can easily distinguish heavy minerals from much lighter minerals

B. Other Properties

1. **Chemical Test** "Acid Test"

a) Many carbonate minerals such as ***calcite*** "fizz" (effervesce) when a drop of dilute hydrochloric acid (HCl) is applied to a freshly exposed surface.

b) The bubbles produced are the result of CO_2 gas forming as the acid reacts with the mineral.

c) ***Chemical Reaction:*** $\mathbf{CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2 \uparrow}$

2. Double Refraction

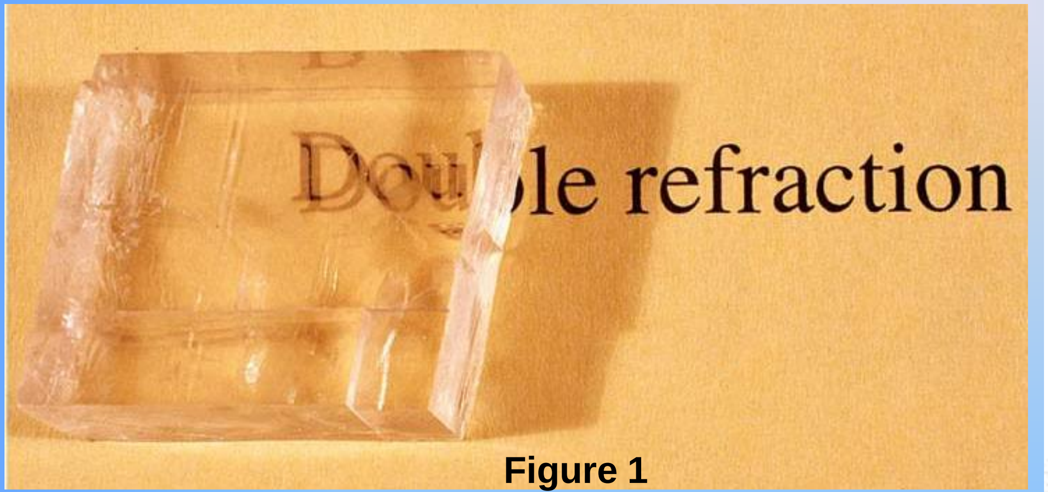


Figure 1

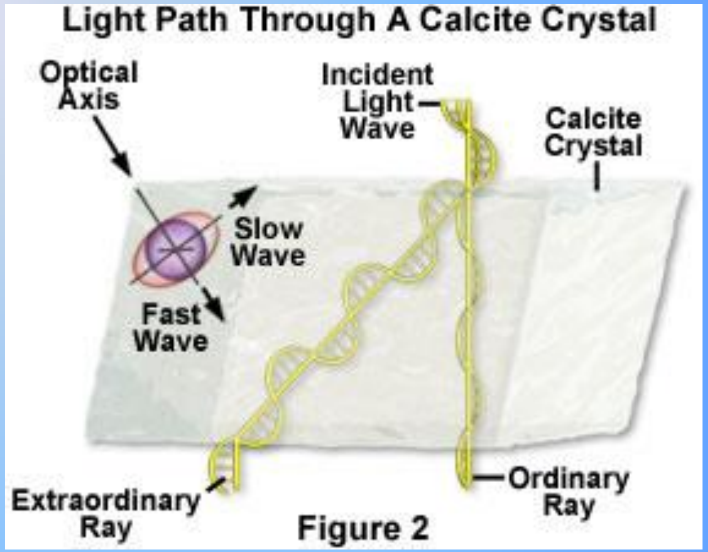
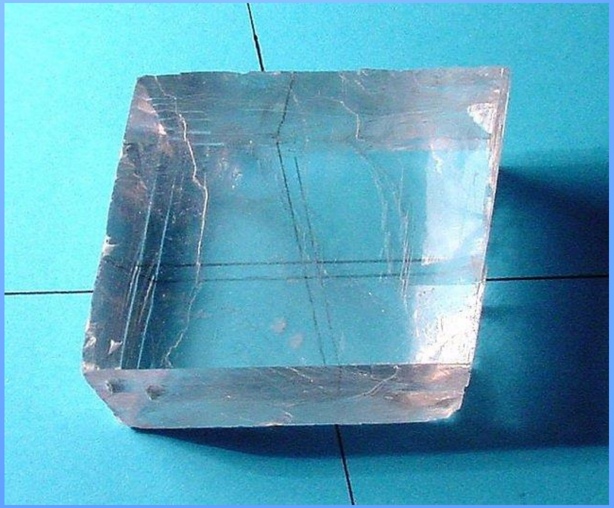


Figure 2

a) Light is *refracted* into two rays producing a double image.

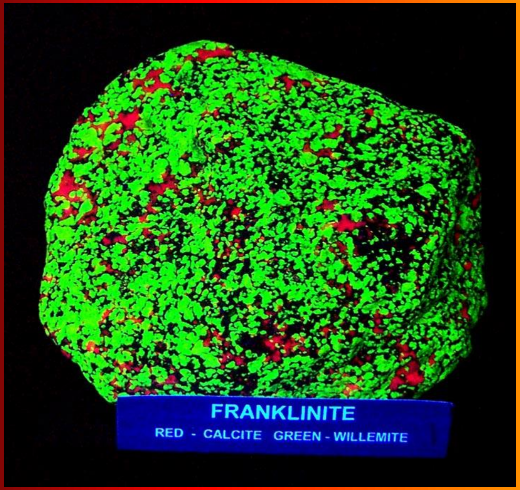
b) Clear calcite (the variety known as *Iceland Spar*) displays excellent double refraction.

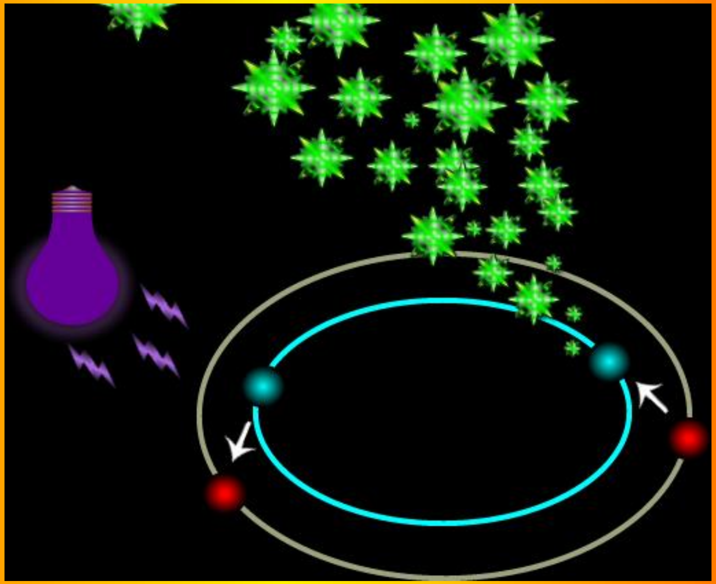


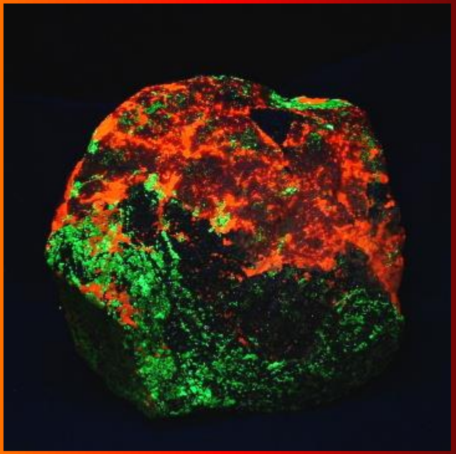
3. __Magnetism__ is exhibited by some minerals such as magnetite.

a. The test is simple. Magnetite is attracted to a magnet.
b. Lodestone is a variety of magnetite that is itself a natural magnet.

4. Luminescence







The emission of light

- **This property is related to defects in the crystal structure or the presence of foreign ions that function as activators.**
- **Is usually produced by irradiation, general with *ultraviolet light.***

Types of Luminescence

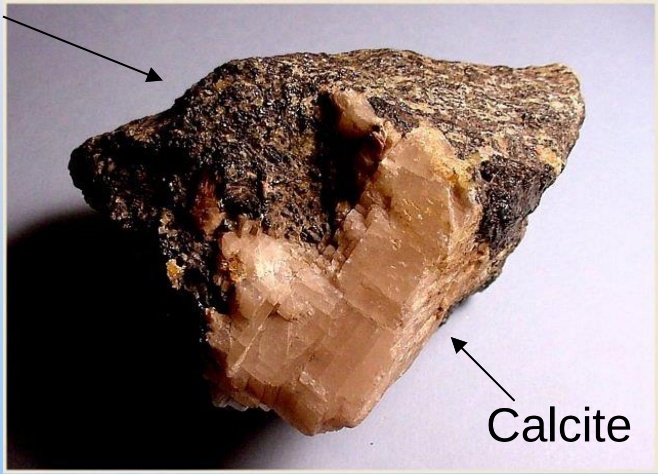
a. ___Fluorescence___ is the emission of light at the same time as the irradiation.

- Named after a variety of fluorite that exhibited this property.

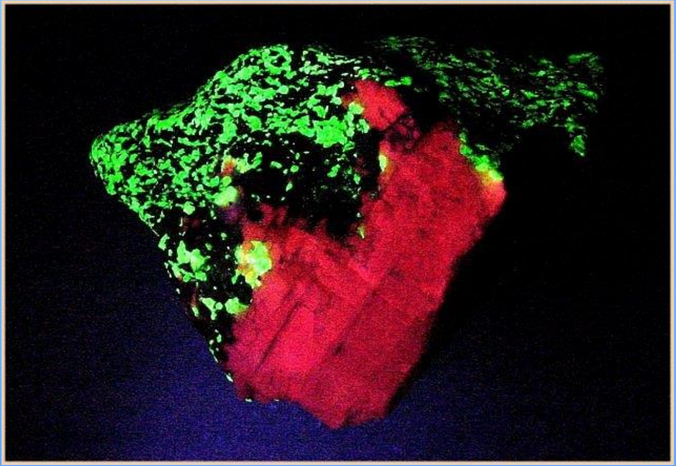
b. ___Phosphorescence___ is the continued emission of light after the irradiation is turned off.

c. ___Triboluminescence___ is the unusual property of emission of light induced when the mineral is broken, crushed scratched, or rubbed.

- Some diamonds, Wint-O-Green Life Savers



Normal Light



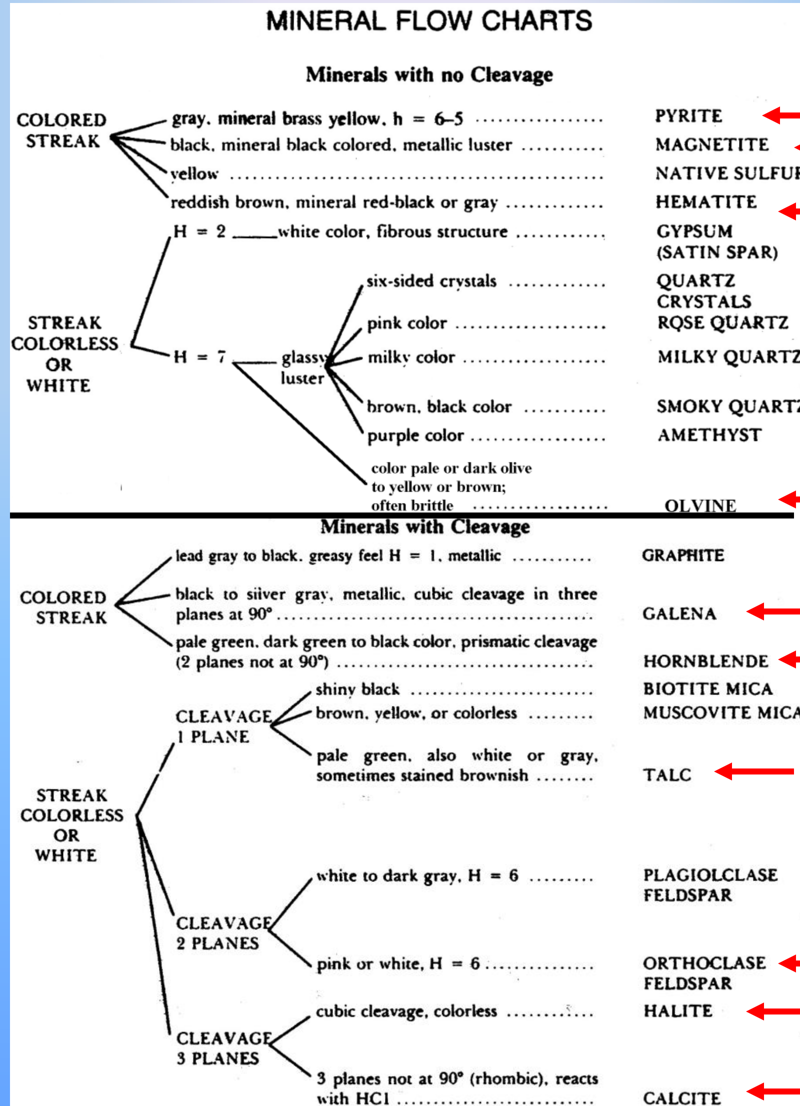
In Ultraviolet Light

Identifying Minerals

- Observe the various physical properties.
- Refer to identification flow charts to determine the mineral name of the sample.
  - If you determine that a sample is calcite, perform the acid test on that sample *only*.
  - Not every mineral will exhibit “special properties.” These could include:
    - Attraction to a magnet
    - Double Refraction
    - Brittle breakage
    - A greasy feel – Usually means cleavage in one direction
    - Dissolves in water (salty taste, but don’t taste the minerals!)
    - Reacts to HCl (hydrochloric acid)

Mineral Identification Flowchart

Explorations in Earth Science Lab Manual



A variety of the ***amphibole*** Silicate group

Earth Science Reference Tables – Page 16

Properties of Common Minerals

LUSTER	HARD-NESS	CLEAVAGE	FRACTURE	COMMON COLORS	DISTINGUISHING CHARACTERISTICS	USE(S)	COMPOSITION*	MINERAL NAME
Metallic luster	1–2	✔		silver to gray	black streak, greasy feel	pencil lead, lubricants	C	**Graphite**
Metallic luster	2.5	✔		metallic silver	gray-black streak, cubic cleavage, density = 7.6 g/cm^3	ore of lead, batteries	PbS	**Galena**
Metallic luster	5.5–6.5		✔	black to silver	black streak, magnetic	ore of iron, steel	Fe_3O_4	**Magnetite**
Metallic luster	6.5		✔	brassy yellow	green-black streak, (fool's gold)	ore of sulfur	FeS_2	**Pyrite**
Either	5.5 – 6.5 or 1		✔	metallic silver or earthy red	red-brown streak	ore of iron, jewelry	Fe_2O_3	**Hematite**
Nonmetallic luster	1	✔		white to green	greasy feel	ceramics, paper	$Mg_3Si_4O_{10}(OH)_2$	**Talc**
Nonmetallic luster	2		✔	yellow to amber	white-yellow streak	sulfuric acid	S	**Sulfur**
Nonmetallic luster	2	✔		white to pink or gray	easily scratched by fingernail	plaster of paris, drywall	$CaSO_4 \cdot 2H_2O$	**Selenite gypsum**
Nonmetallic luster	2–2.5	✔		colorless to yellow	flexible in thin sheets	paint, roofing	$KAl_3Si_3O_{10}(OH)_2$	**Muscovite mica**
Nonmetallic luster	2.5	✔		colorless to white	cubic cleavage, salty taste	food additive, melts ice	NaCl	**Halite**
Nonmetallic luster	2.5–3	✔		black to dark brown	flexible in thin sheets	construction materials	$K(Mg,Fe)_3$ $AlSi_3O_{10}(OH)_2$	**Biotite mica**
Nonmetallic luster	3	✔		colorless or variable	bubbles with acid, rhombohedral cleavage	cement, lime	$CaCO_3$	**Calcite**
Nonmetallic luster	3.5	✔		colorless or variable	bubbles with acid when powdered	building stones	$CaMg(CO_3)_2$	**Dolomite**
Nonmetallic luster	4	✔		colorless or variable	cleaves in 4 directions	hydrofluoric acid	CaF_2	**Fluorite**
Nonmetallic luster	5–6	✔		black to dark green	cleaves in 2 directions at 90°	mineral collections, jewelry	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$	**Pyroxene** (commonly augite)
Nonmetallic luster	5.5	✔		black to dark green	cleaves at 56° and 124°	mineral collections, jewelry	$CaNa(Mg,Fe)_4(Al,Fe,Ti)_3Si_6O_{22}(O,OH)_2$	**Amphibole** (commonly hornblende)
Nonmetallic luster	6	✔		white to pink	cleaves in 2 directions at 90°	ceramics, glass	$KAlSi_3O_8$	**Potassium feldspar** (commonly orthoclase)
Nonmetallic luster	6	✔		white to gray	cleaves in 2 directions, striations visible	ceramics, glass	$(Na,Ca)AlSi_3O_8$	**Plagioclase feldspar**
Nonmetallic luster	6.5		✔	green to gray or brown	commonly light green and granular	furnace bricks, jewelry	$(Fe,Mg)_2SiO_4$	**Olivine**
Nonmetallic luster	7		✔	colorless or variable	glassy luster, may form hexagonal crystals	glass, jewelry, electronics	SiO_2	**Quartz**
Nonmetallic luster	6.5–7.5		✔	dark red to green	often seen as red glassy grains in NYS metamorphic rocks	jewelry (NYS gem), abrasives	$Fe_3Al_2Si_3O_{12}$	**Garnet**

*Chemical symbols:

Al = aluminum	Cl = chlorine	H = hydrogen	Na = sodium	S = sulfur
C = carbon	F = fluorine	K = potassium	O = oxygen	Si = silicon
Ca = calcium	Fe = iron	Mg = magnesium	Pb = lead	Ti = titanium

- **Go back to Lab 2-2 ☺**

VI. Important Rock Forming Minerals

A. _Silicates_______

1. _Feldspar_______

    a. Most abundant constituents of the crust.

    b. About 60% of crust's total weight

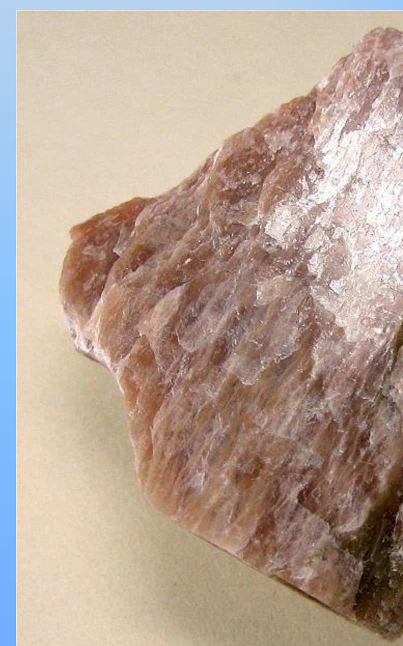
    c. Two major families of feldspars

Feldspar Families

i. ___**Potassium**___ Feldspar

- Contain potassium (K) and aluminum (Al)
- Common varieties are orthoclase and microcline.

Orthoclase (high temps.)
$KAlSi_3O_8$



Amazonite

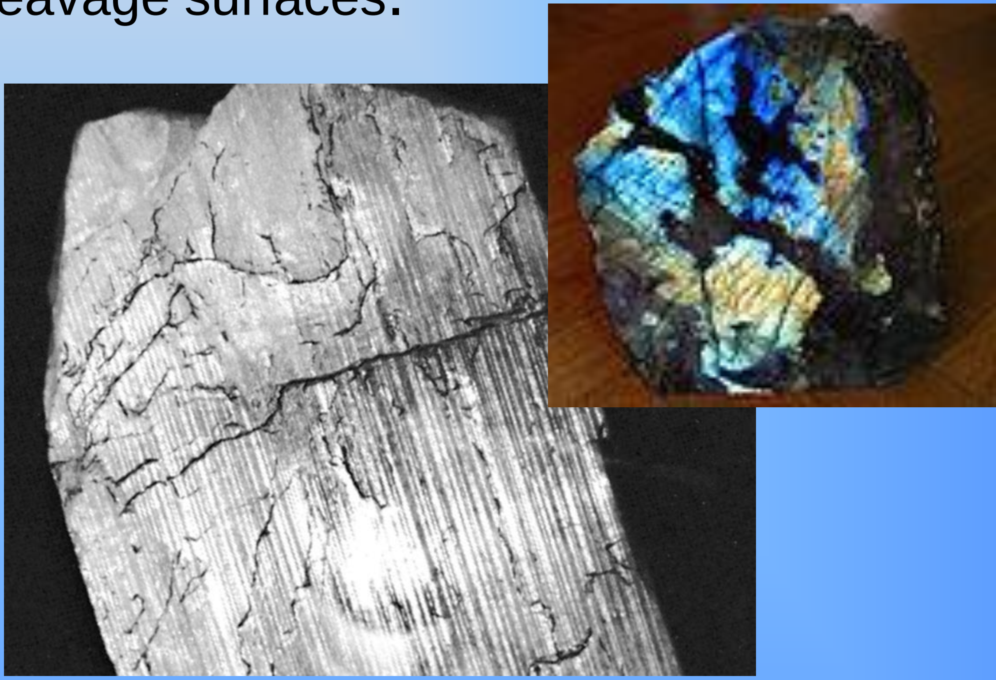
Microcline (lower termps.)
$KAlSi_3O_8$

Feldspar Families

ii. **Plagioclase** Feldspar

- Aluminosilicates of sodium (Na) and calcium (Ca)
- Have a wide range of composition.
- Striations are seen on cleavage surfaces.

Albite
(NaCa)AlSi$_3$O$_8$



Labradorite

2. Ferromagnesium Minerals

- This is the group of silicates that have in their composition
  - Iron
  - Magnesium
- Their colors are generally blackish or greenish

2. Ferromagnesium Minerals

a. **Amphiboles**
   i. Silicates of Al, Ca, Mg, and Fe
   ii. Double chains
   iii. Hornblende is most common

2. Ferromagnesium Minerals

b. Pyroxenes

i. Resemble amphiboles

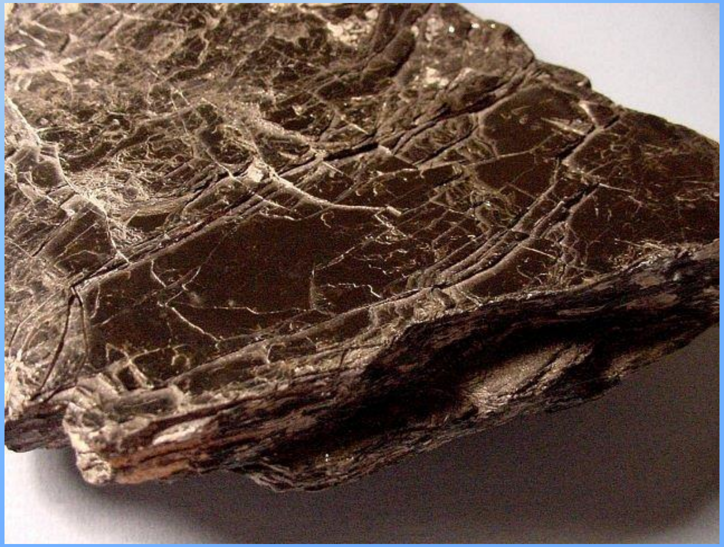
ii. Single chain silicates

iii. Representative pyroxene is augite

2. Ferromagnesium Minerals

b. Mica

- Chief varieties are muscovite and biotite



2. Ferromagnesium Minerals

d. Olivine

i. Oxygen atoms in tetrahedra are not shared and are strongly bonded by iron or magnesium ions.

ii. Typically designated by the formula $(MgFe)_2SiO_4$.

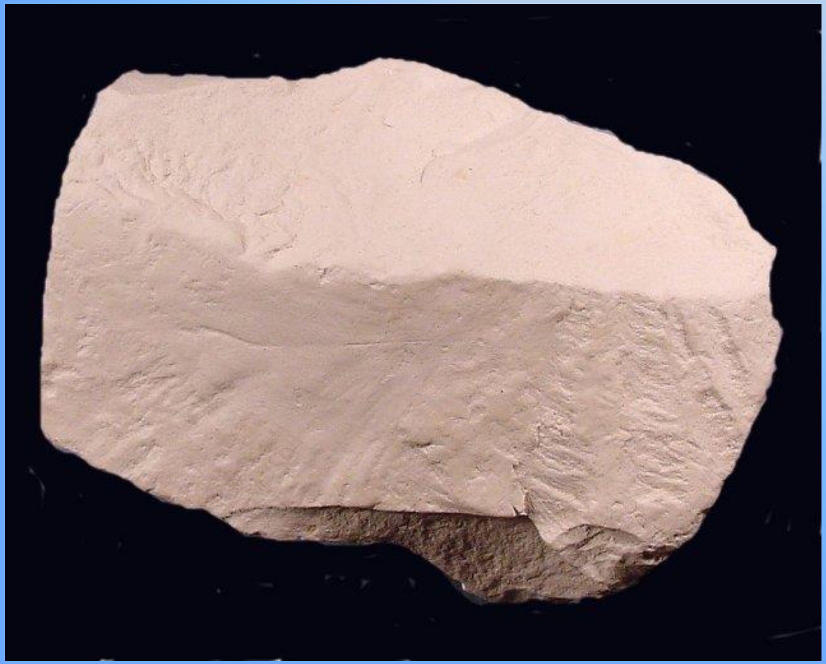
Granular Olivine

Faceted Olivine (Peridot)

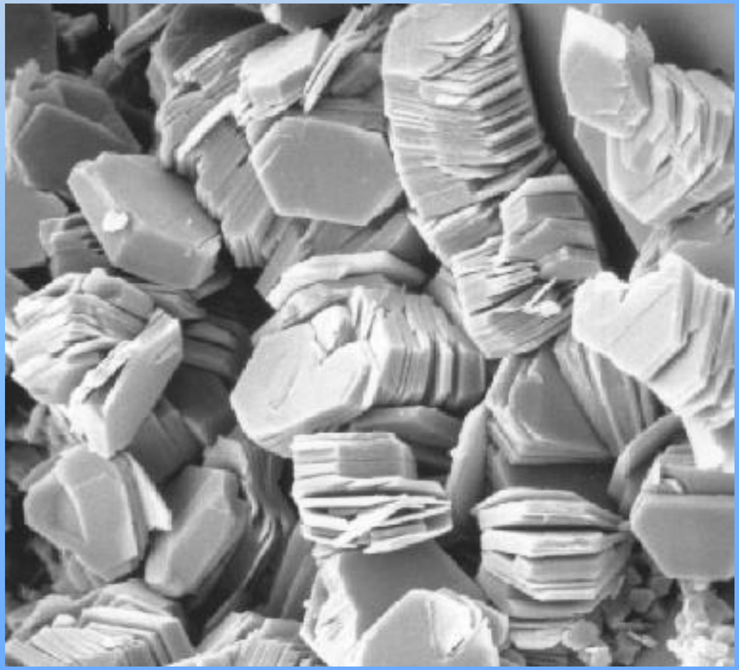
Silicates

3. Clay Minerals

i. Sheet structure (seen microscopically)
ii. Form as a result of the weathering of feldspars
iii. Are soft, low density, and exhibit plasticity when wet.



Hand Sample



Microscopic View

Clay Minerals

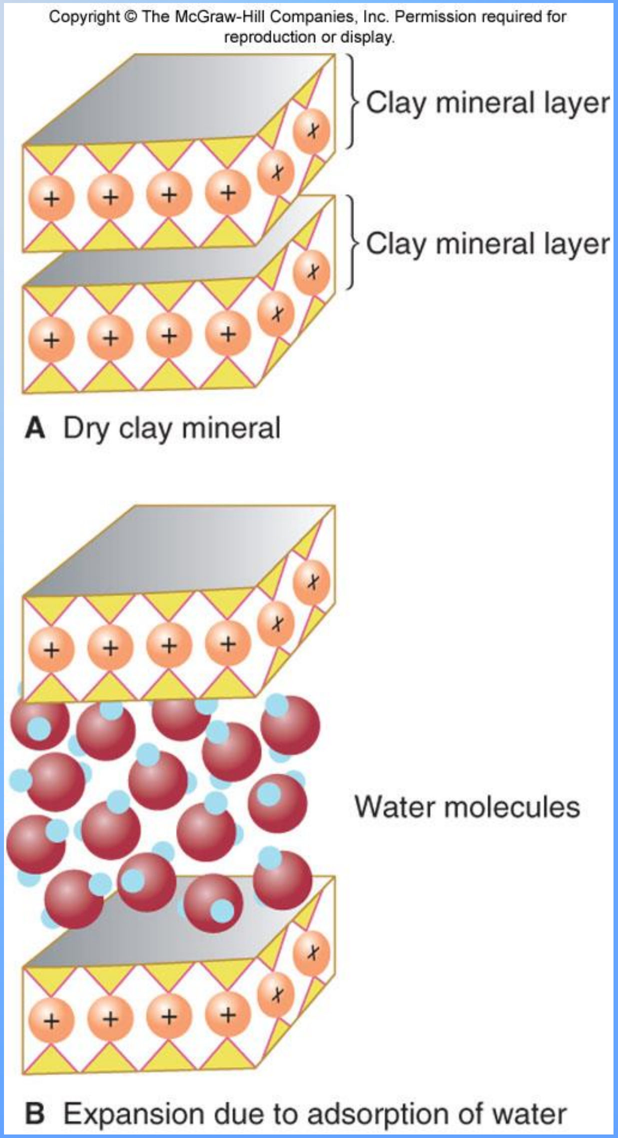
- Clay minerals are very common at Earth's surface
  - They are a major component of soil
- Ceramic products and bricks are made of clay minerals

Clay Minerals

- Kaolinite is used for
  - Kaopectate
    - Medicinal use for treating upset stomachs
  - A thickener for shakes by fast food restaurants

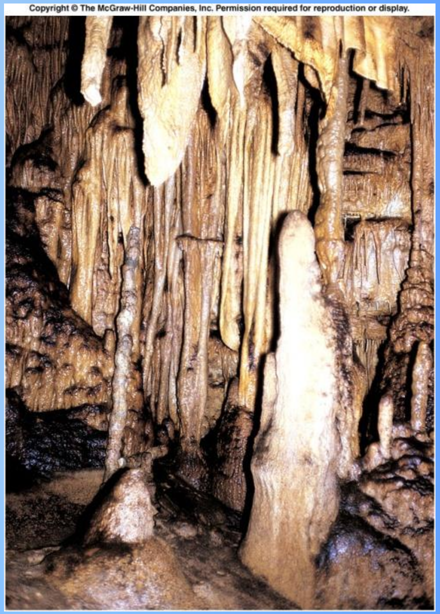
Clay Minerals

- Montmorillonite
  - Known as
    - Swelling clay
    - Expansive clay
  - Water is absorbed into spaces between sheets
  - Results in a large increase in volume
  - Buildings constructed on clay can be damaged by pressure as high as 50,000 kg/m^2
  - A mixture of clay and water can be injected into cracks in rock or concrete, sealing the crack as it expands.
  - Can be used as a desiccant (drying material)



B. Nonsilicate Minerals

1. **Carbonates:** All have the fundamental unit $(CO_3)^{-2}$
   a. Calcite
      i. Calcium carbonate ($CaCO_3$) and reacts with HCL
      ii. Main constituent of limestone and marble.
      iii. Secreted as skeletal material by certain invertebrate animals
      iv. Precipitated from sea water and forms dripstone in caves



Carbonates

b. Dolomite

i. Occurs in dolostone

ii. Will not effervesce in HCl unless powdered

iii. Magnesium replaces calcium - $CaMg(CO_2)_3$

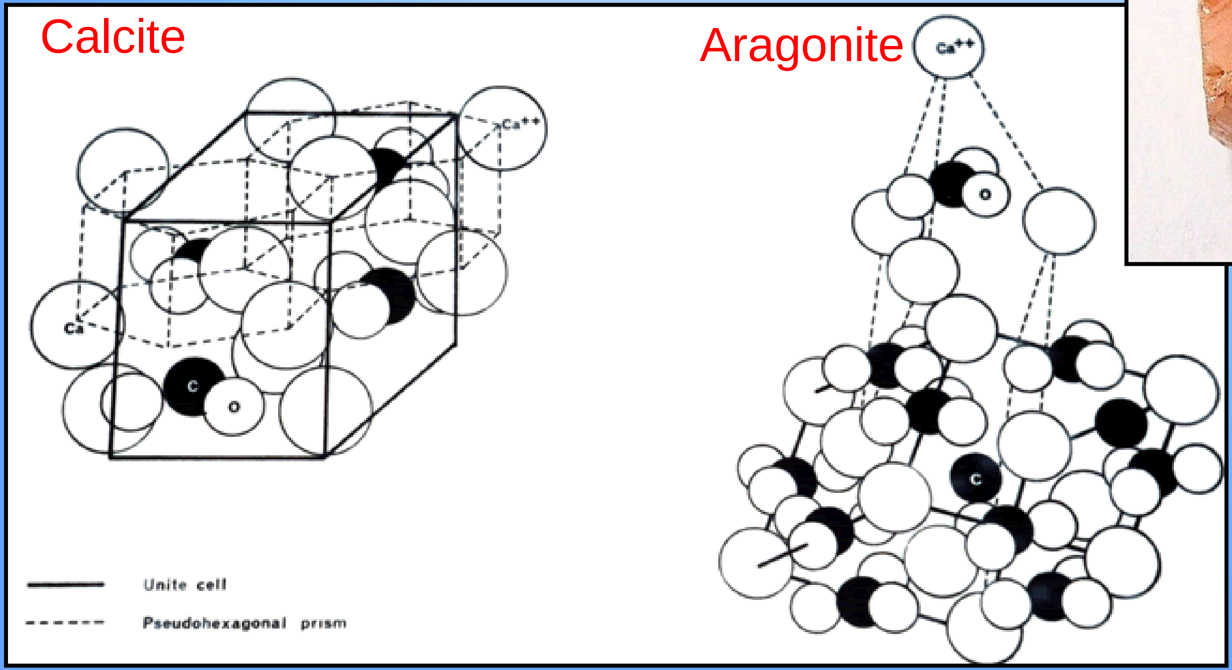
Carbonates

c. Aragonite

i. The same composition as calcite

ii. Different crystal form and cleavage

iii. Not as common as calcite or dolomite



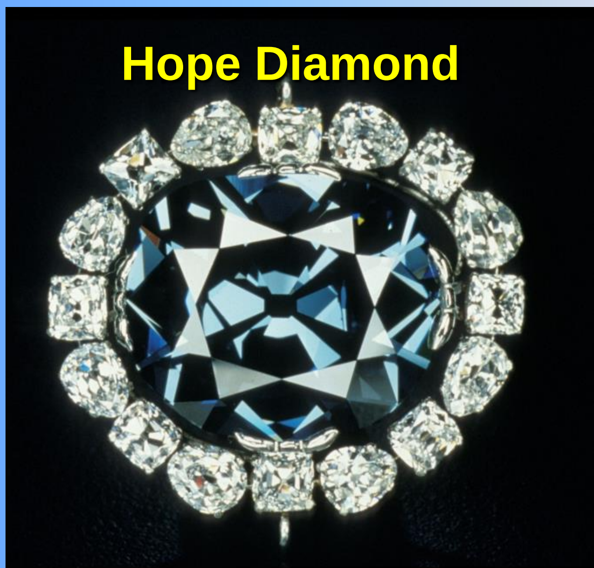
2. Evaporites

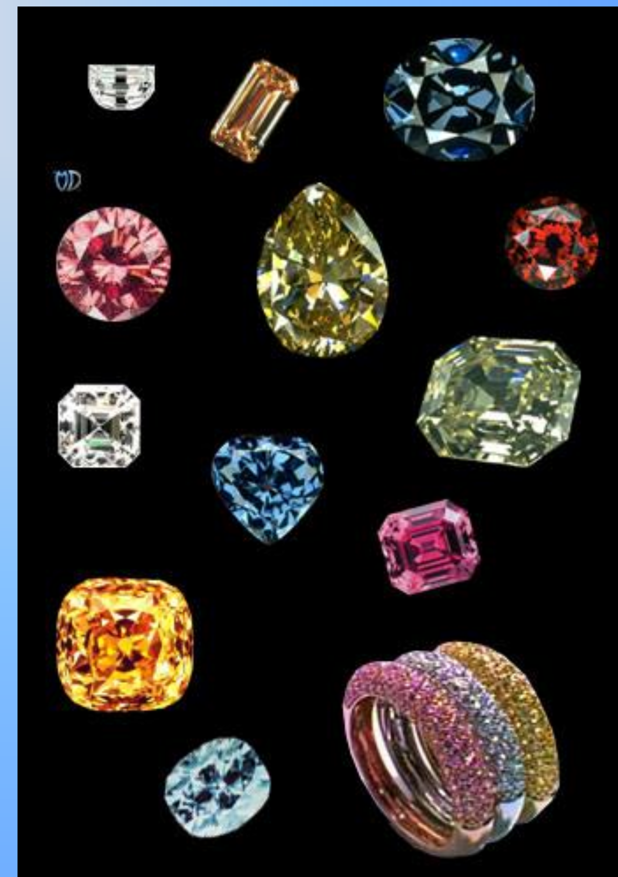
- Minerals that have precipitated from bodies of water
  - Subjected to intense evaporation
- These include: halite, gypsum, calcite

VII. Gemstones

- A **gemstone** or **gem**, also called a **precious** or **semi-precious stone**
  - It is a piece of attractive mineral, which — when cut and polished — is used to make jewelry or other adornments
  - Most gemstones are hard, but some soft minerals are used in jewelry because of their luster or other physical properties that have aesthetic value.
  - Rarity is another characteristic that lends value to a gemstone.
  - Certain rocks, (such as lapis-lazuli) and organic materials (such as amber) are not minerals,
    - but are still used for jewelry, and are therefore often considered to be gemstones as well.

Diamond – “King of Gems”





At 45.54 carats, it’s the largest blue diamond in the world
[1 caret = 200mg]
9,108 mg (9.108 g) = 0.02 lbs.

- Pure carbon
- Hardness of 10 but can be broken

What is a Carat?

- It's the unit used to measure the weight of gemstones.
- But, it's not based on the weight of this vegetable!

A Carat Weighs 200 mg

- 1 Ct = 200 mg (0.01 oz)
- The word carat is French and is derived from Greek keration which means “from the fruit of the carob.”
  - Carob seeds were used as weights on precision scales because of their reputation for having uniform weight.

Emerald

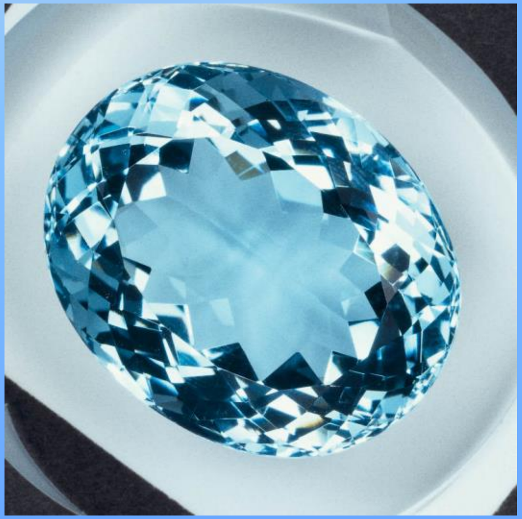
- The mineral beryl ($Be_3Al_2Si_6O_{18}$)
- Colors result from traces of other elements in the composition.

Rubies and Saphires are Varieties of Corundum

- Ruby is from the Latin *ruber* meaning red.
  - From traces of chromium
- Saphire is also from a Latin word meaning blue.
  - Can be blue, yellow, gold
  - From traces of iron, chromium, titanium, and other metals.

Aquamarine

- Blue-Green variety of beryl

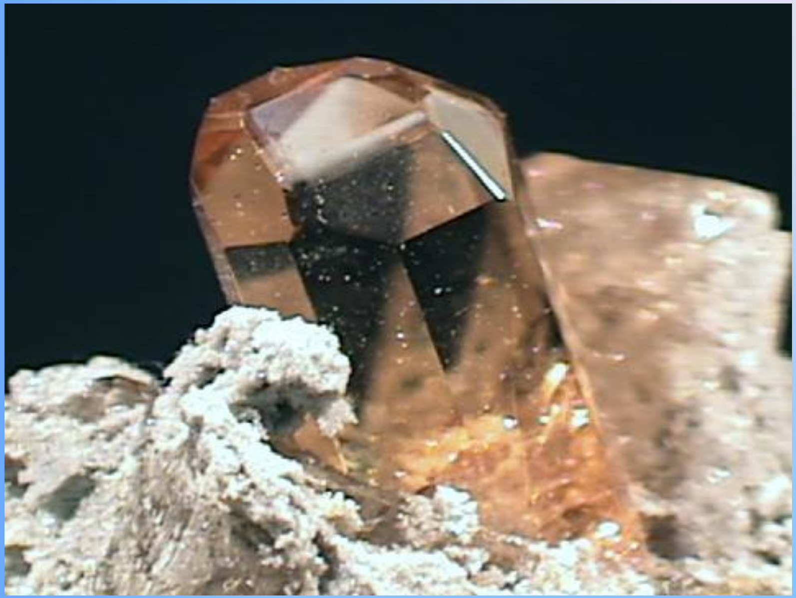


Jade

Nephrite

- Used for two gems
  - Jadite (a variety of pyroxene)
  - Nephrite (a variety of amphibole

Topaz

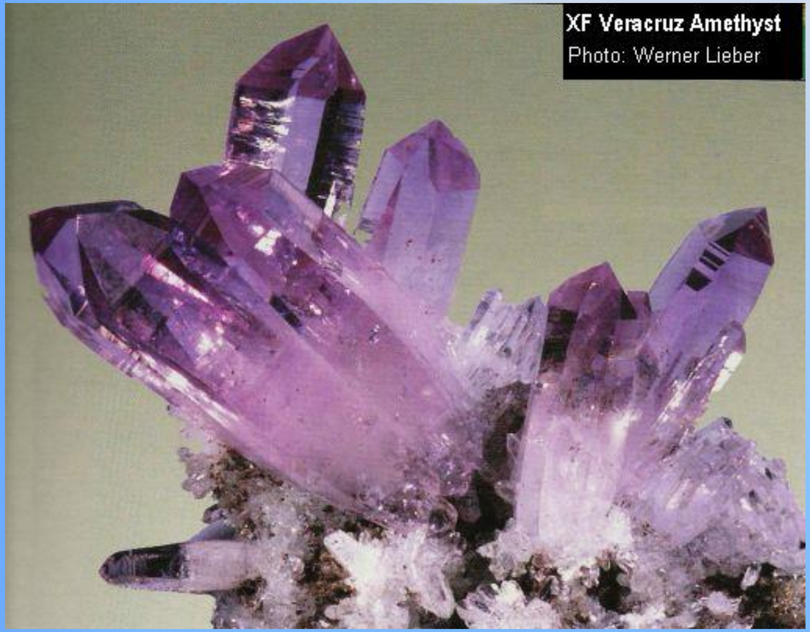


- Aluminum silicate containing fluorine
- Commonly colorless
- Hardness of 8

Peridote

- A variety of olivine

Amethyst

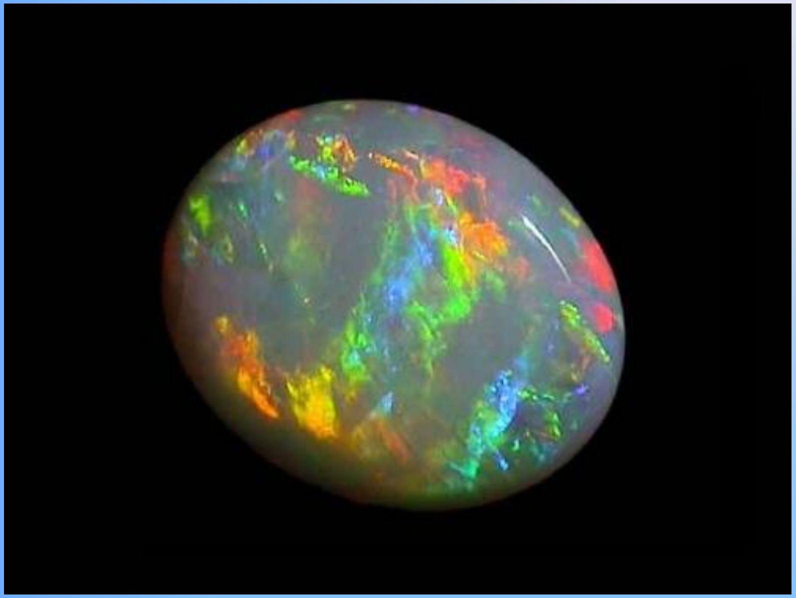


- Purple quartz
- Color is likely due to iron impurities
- If it wasn't so common, it would be very expensive.

Citrine

- Yellow quartz from the presence of iron

Opal



- A mineraloid with water in its composition but is primarily SiO_2 (silica).
- Random chains of oxygen and silicon are packed into tiny spheres.
- Forms in a sedimentary environment.

The end ☺

Results of a study in 2006 . . .

- Carot seeds don't have uniform weight as previously thought.
  - They have as much variation in weight as other seeds (about 25%)
- Because it's easier to recognize size variations in these seeds than others,
  - they were used because they can easily be standardized.

Determining the Weight of a Diamond in Carats