

REMINDERS

Computer Resources

- **Class website** -- provides syllabus and power points
 - (<http://www.uh.edu/~geos2j/physical.htm>)
 - Username: geology
 - Password: geology
- **Blackboard** – provides streaming video of some lectures, sample quizzes, Geode guided learning exercises.. To access Blackboard, log into AccesUH using your Cougarnet ID and password!!!

UH Email

- I am required to use the UH email if I want to send a message to you about the class. Please log into AccessUH and forward your @uh.edu email to an email address you read daily.
- My class emails are often rejected as spam since they are sent to over 100 students, please add my email to your list of contacts.

Chapter 3

Matter and Minerals

Quartz crystals



What is a **mineral**?

By definition a mineral _____.

1. is naturally occurring

- does not include synthetic gems, cast iron, or cement

2. is solid

- does not include oil or liquid water

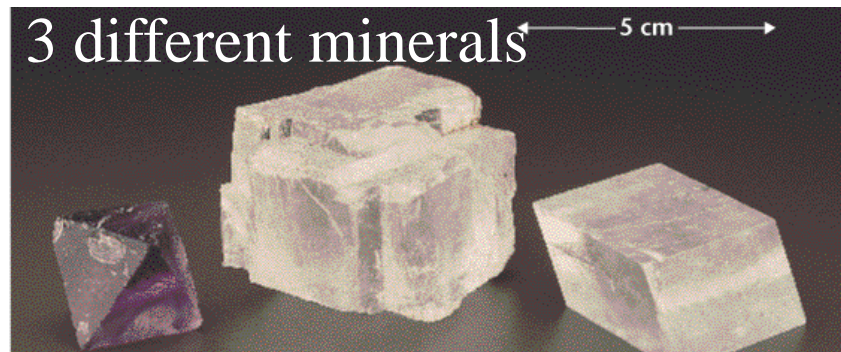
3. is generally inorganic

- includes the mineral calcite that composes shells and reefs secretions by marine life
- does not include coal which is composed of plant debris

4. has an orderly (crystalline) internal structure

- does not include amorphous phases so opal and glass not minerals

5. has a definite chemical composition



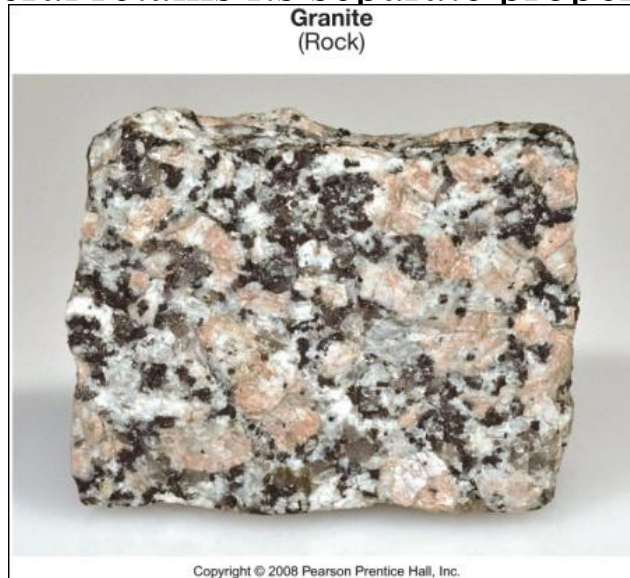
Minerals in a vitamin pill or cereal are different from geologic minerals



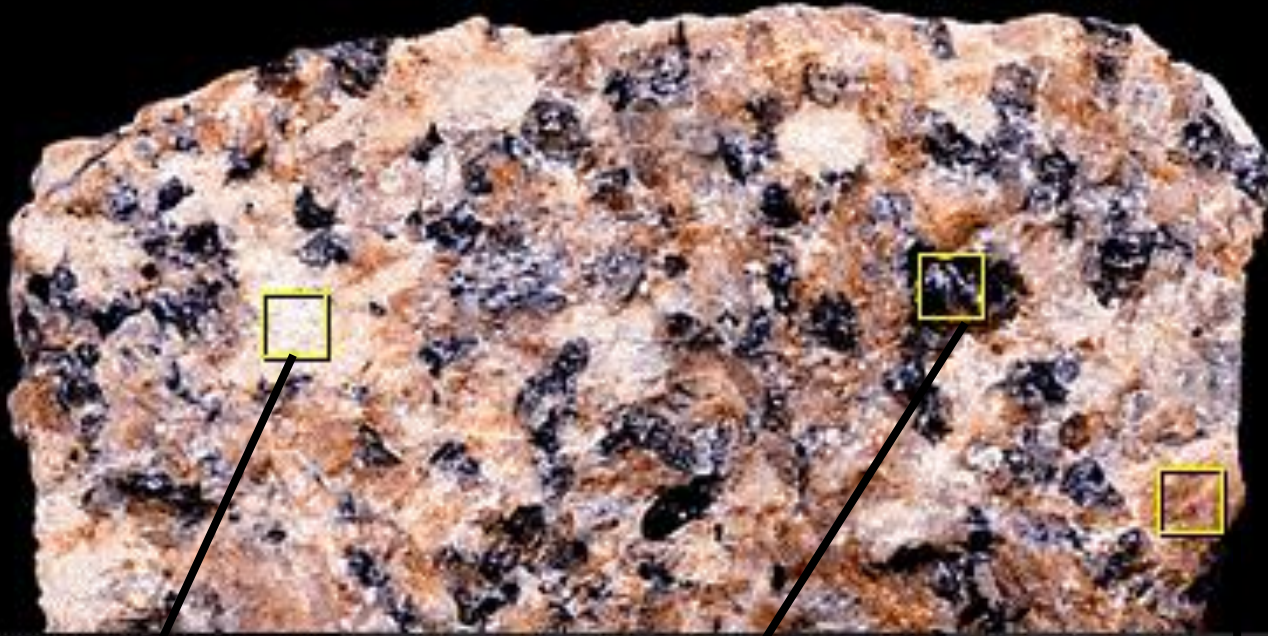
- Often in pills they are single elements (not minerals)
 - For example calcium (Ca), zinc (Zn), iron (Fe)
- Often elements in pills are chemically extracted from mineral and then added to the vitamin or cereal.
- Often the mineral calcite (CaCO_3) is added to cereal for calcium.

What is a **rock**?

- A rock is a naturally occurring solid of mineral or mineral like matter
 - Not mine sledge or cement
 - Coal is a rock even though it is not a mineral
 - (composed of compacted plant material = mineral like matter)
- a rock can be composed of one mineral or an aggregate of mineral
 - (each mineral retains its separate properties)



Granite (rock)



Quartz (mineral)



Hornblende (mineral)



Feldspar (mineral)

Minerals are composed of elements

- **Elements**

- Basic building blocks of minerals
- > 100 are known (92 naturally occurring)

Tendency to lose outermost electrons to uncover full outer shell

2
He
4.003
Helium

Atomic number
Symbol of element
Atomic weight
Name of element

Metals
Transition metals
Nonmetals
Noble gases
Lanthanide series
Actinide series

Tendency to fill outer shell by sharing electrons

Tendency to gain electrons to make full outer shell

Noble gases (inert)

VIII A

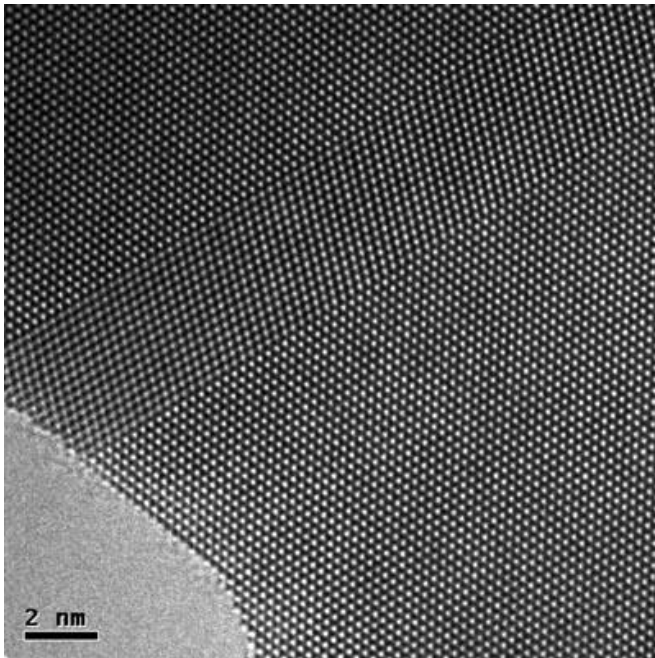
Tendency to lose electrons

1 H 1.0080 Hydrogen																	2 He 4.003 Helium	
I A																	VIII A	
3 Li 6.939 Lithium	4 Be 9.012 Beryllium																	10 Ne 20.183 Neon
11 Na 22.990 Sodium	12 Mg 24.31 Magnesium																	18 Ar 39.948 Argon
19 K 39.102 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.90 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.71 Nickel	29 Cu 63.54 Copper	30 Zn 65.37 Zinc	31 Ga 69.72 Gallium	32 Ge 72.59 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.909 Bromine	36 Kr 83.80 Krypton	
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc (99) Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.90 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.87 Silver	48 Cd 112.40 Cadmium	49 In 114.82 Indium	50 Sn 118.69 Tin	51 Sb 121.75 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.30 Xenon	
55 Cs 132.91 Cesium	56 Ba 137.34 Barium	57 TO 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.09 Platinum	79 Au 197.0 Gold	80 Hg 200.59 Mercury	81 Tl 204.37 Thallium	82 Pb 207.19 Lead	83 Bi 208.98 Bismuth	84 Po (210) Polonium	85 At (210) Astatine	86 Rn (222) Radon	
87 Fr (223) Francium	88 Ra 226.05 Radium	89 TO 103	90 Ac (227) Actinium	91 Th 232.04 Thorium	92 Pa (231) Protactinium	93 U 238.03 Uranium	94 Np (237) Neptunium	95 Pu (242) Plutonium	96 Am (243) Americium	97 Cm (247) Curium	98 Bk (249) Berkelium	99 Cf (251) Californium	100 Es (254) Einsteinium	101 Fm (253) Fermium	102 Md (258) Mendelevium	103 Lw (261) Lawrencium		
		57 La 138.91 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium	61 Pm (147) Promethium	62 Sm 150.35 Samarium	63 Eu 151.96 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.92 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.97 Lutetium		

Elements are composed of atoms

Atoms

- Smallest particles of matter that retains all the characteristics of an element



Atoms of gold
(Electron microscope image)

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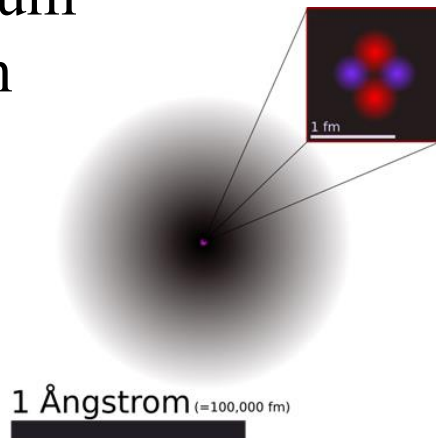
From <http://www.nanotech-now.com/products/nanonewsnow/issues/034/034.htm>

Atoms are composed of a

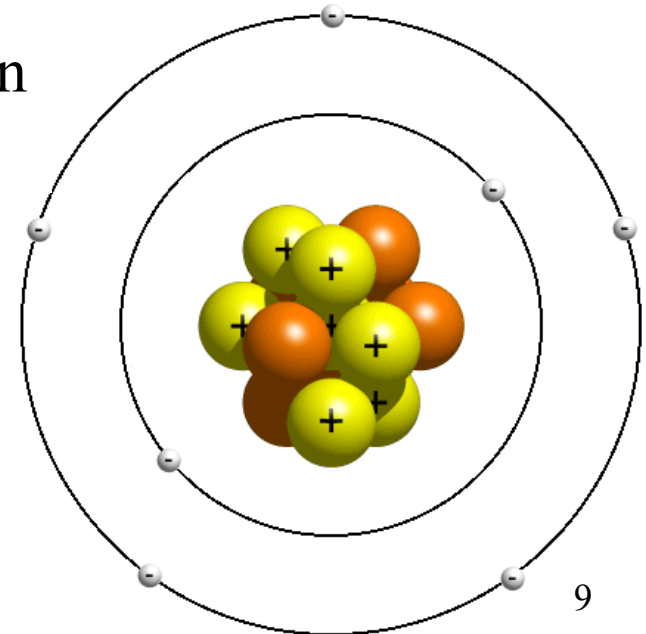
Central region called the **nucleus** consisting of **protons** (+ charge) and **neutrons** (no charge)

Electrons are negatively (-) charged particles that surround the nucleus and are located in discrete energy levels called shells

Helium
atom

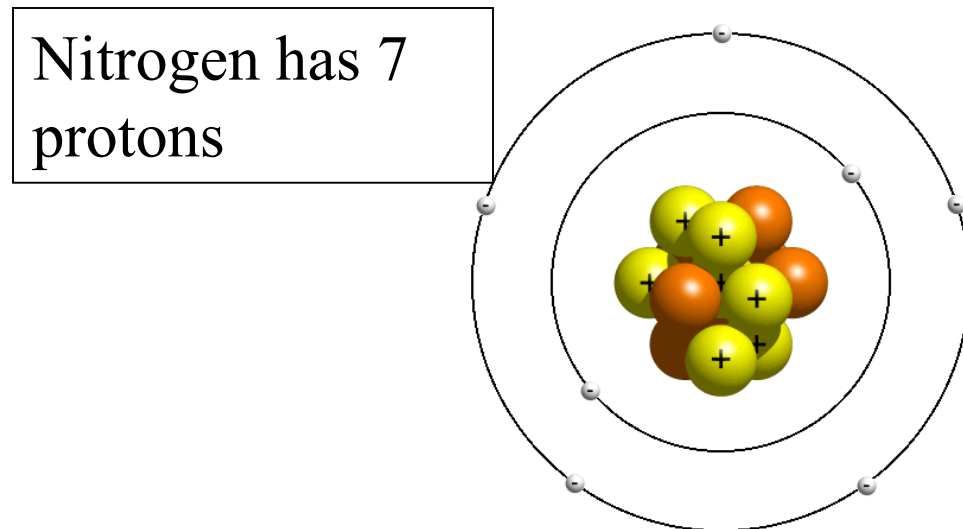


Nitrogen
atom



What differentiates atoms of different elements?

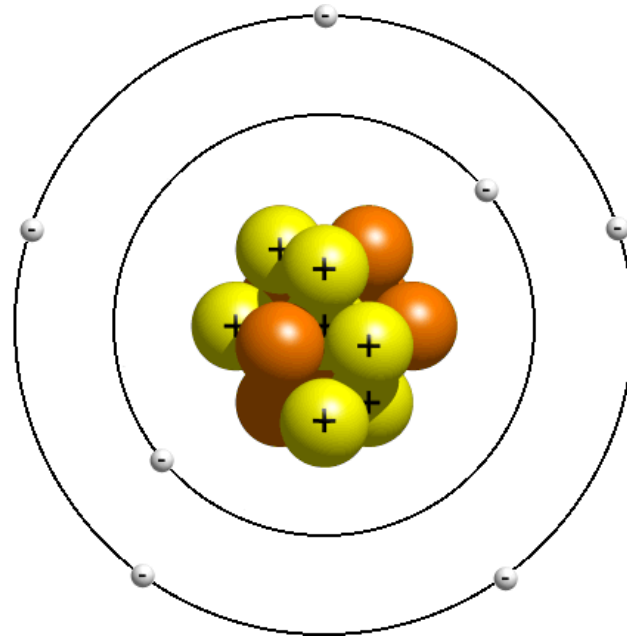
- The number of protons is used to define an element.
 - The number of neutrons and electrons may change but the atom remain the same element if the number of protons does not change.



Neutral atom

- An atom is neutral (has no charge) when it contains an equal number of electrons and protons.

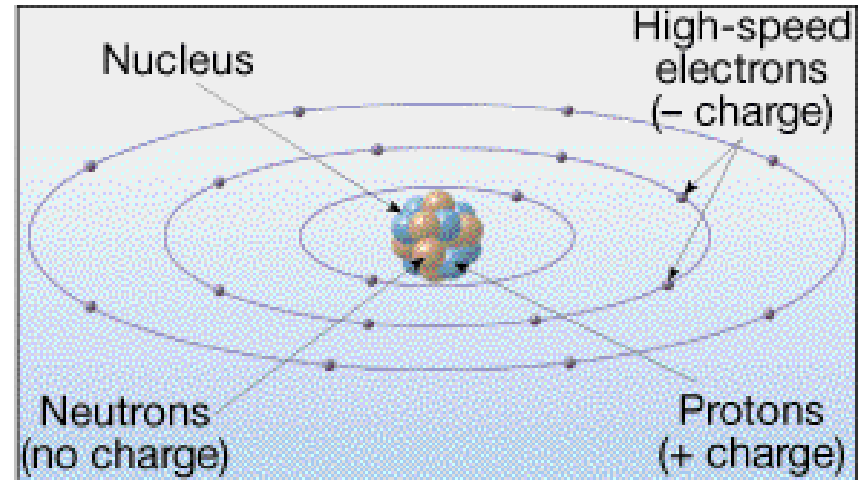
This neutral atom of nitrogen has 7 protons and 7 electrons



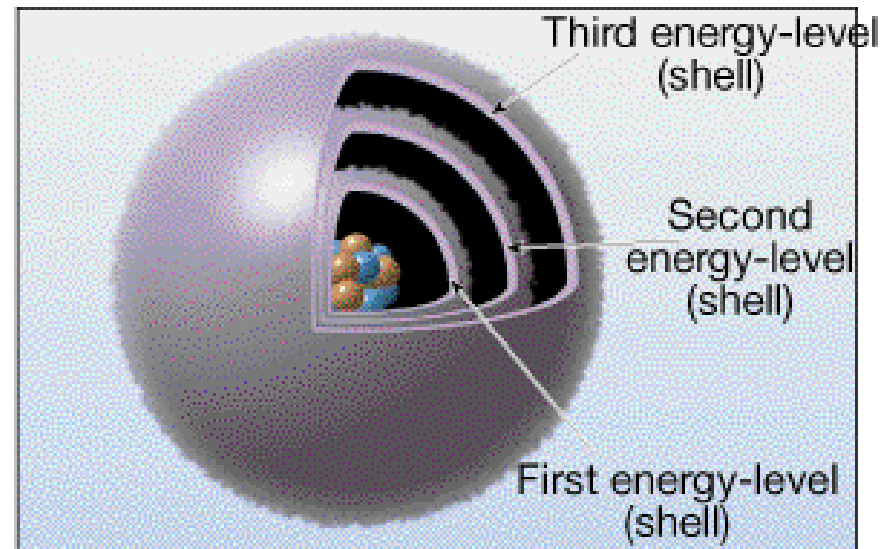
Each electron shell can hold up to 8 electrons, except for the inner most shell which holds 2 electrons.

Atoms tend to be most stable when their outer most shell contains 8 electrons (is full).

This is the **octet rule**.



A.



B.

Why do atoms chemically bond?

- They form compounds by sharing or transferring electrons to attain stable outer shells with 8 electrons

Electron Dot Diagrams for Some Representative Elements

I	II	III	IV	V	VI	VII	VIII
H •							He ••
Li •	• Be •	• B •	• C •	• N •	• O •	• F •	• Ne •
Na •	• Mg •	• Al •	• Si •	• P •	• S •	• Cl •	• Ar •
K •	• Ca •	• Ga •	• Ge •	• As •	• Se •	• Br •	• Kr •

The red dots are the number of electrons in the outer shell.

Atoms tend to combine so they each have 8 electrons in their outer shell

- An atom with 8 electrons in the outer shell is stable and will not gain or lose electrons.
 - Thus it is not involved in any chemical reactions and remains a neutral ion with no charge.

Electron Dot Diagrams for Some Representative Elements							
I	II	III	IV	V	VI	VII	VIII
H •							He ••
Li •	•Be•	•B•	•C•	•N•	•O•	•F•	•Ne•
Na •	•Mg•	•Al•	•Si•	•P•	•S•	•Cl•	•Ar•
K •	•Ca•	•Ga•	•Ge•	•As•	•Se•	•Br•	•Kr•

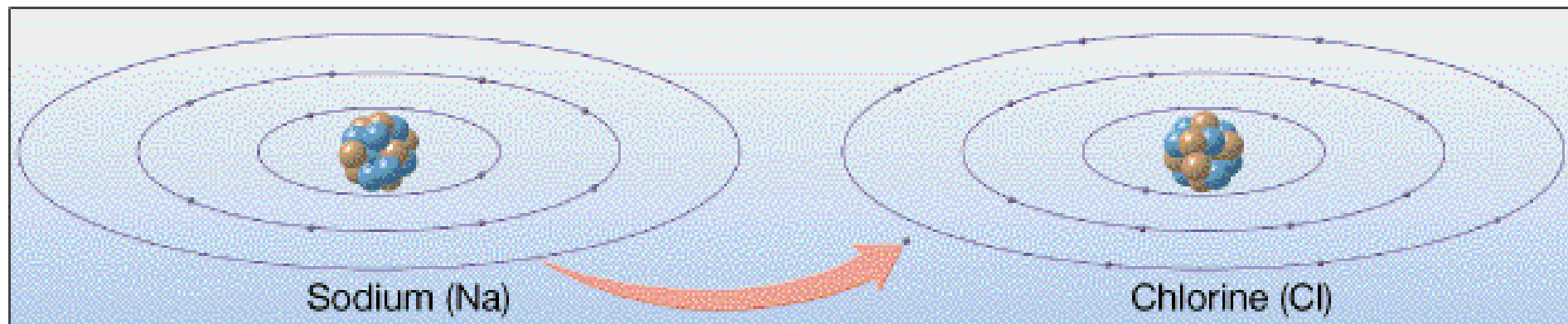
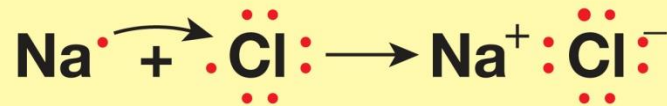
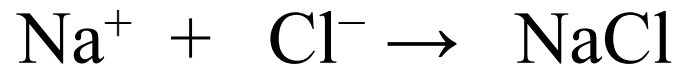
- An atom with an outer shell that contains 5 to 7 electrons will tend to gain electrons to fill to 8.
 - It becomes a negatively charged ion called an **anion**
- An atom with an outer shell that contains 4 or less electrons will tend to lose these electrons
 - It becomes a positively charged ion called a **cation**

Electron Dot Diagrams for Some Representative Elements							
I	II	III	IV	V	VI	VII	VIII
H •							He ••
Li •	• Be •	• B •	• C •	• N •	• O •	• F •	• Ne •
Na •	• Mg •	• Al •	• Si •	• P •	• S •	• Cl •	• Ar •
K •	• Ca •	• Ga •	• Ge •	• As •	• Se •	• Br •	• Kr •

Two main types of bonds.

- **Ionic bonding**

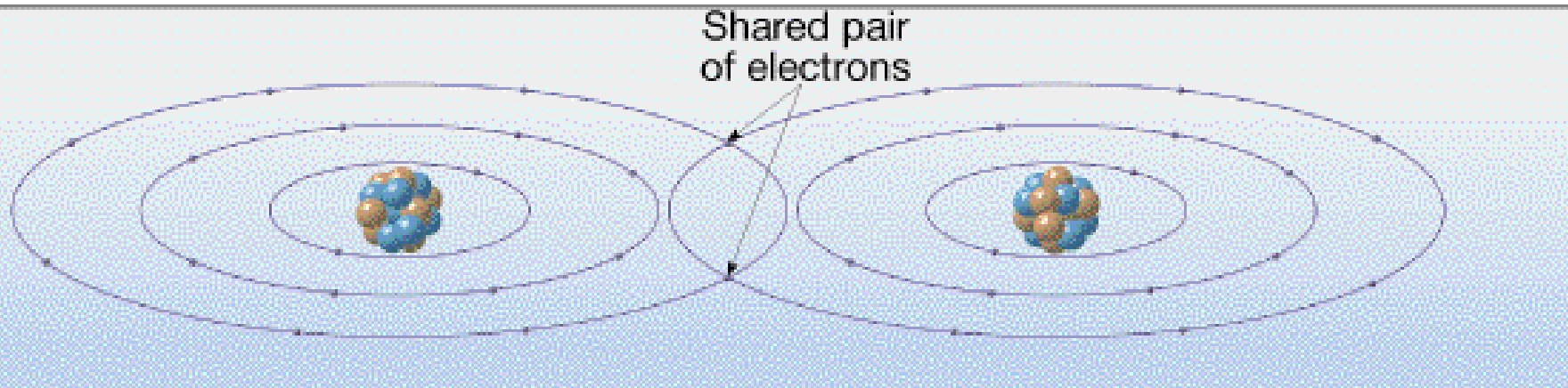
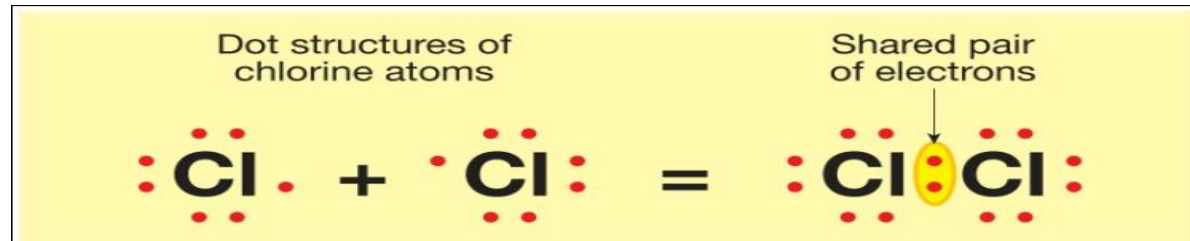
- Atoms gain or lose an electron to form a stable outer shell.
- These oppositely charged ions then bond together
- This is a weak bond that dissolves more readily in water
- Many **non-silicate minerals** are formed by ionic bonds



Two main types of bonds.

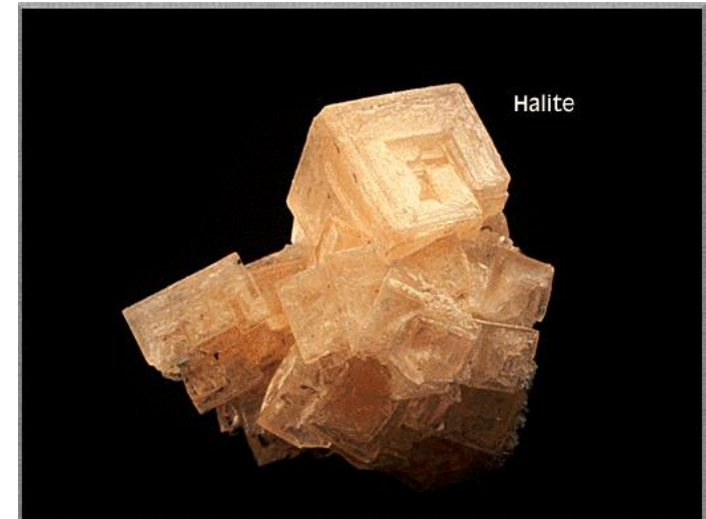
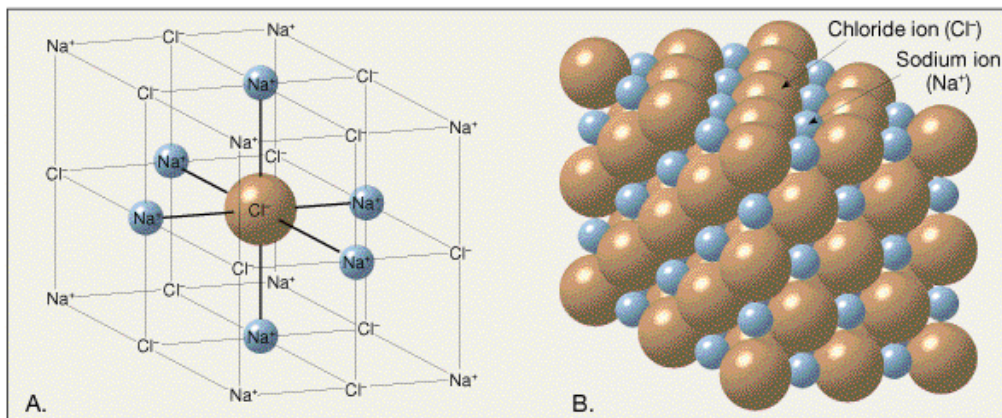
- **Covalent bonding**

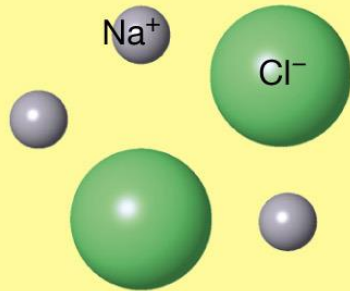
- Atoms combine by sharing electrons to achieve a stable outer shell
- Covalent bonds are generally stronger than ionic bonds and dissolves less readily in water
- Most **silicate** minerals are formed by covalent bonds



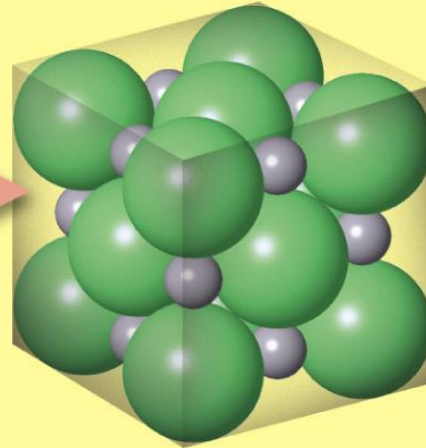
Structure of Minerals

- Minerals have an orderly internal structure
 - ordered array of atoms bonded together
 - Gives the mineral its crystal shape and cleavage.
- Example - Halite NaCl (table salt)
 - Na and Cl packed together into a cubic shape
 - halite grows into cube shaped crystals
 - halite breaks into cube shape





A. Sodium and chloride ions.



B. Basic building block of the mineral halite.

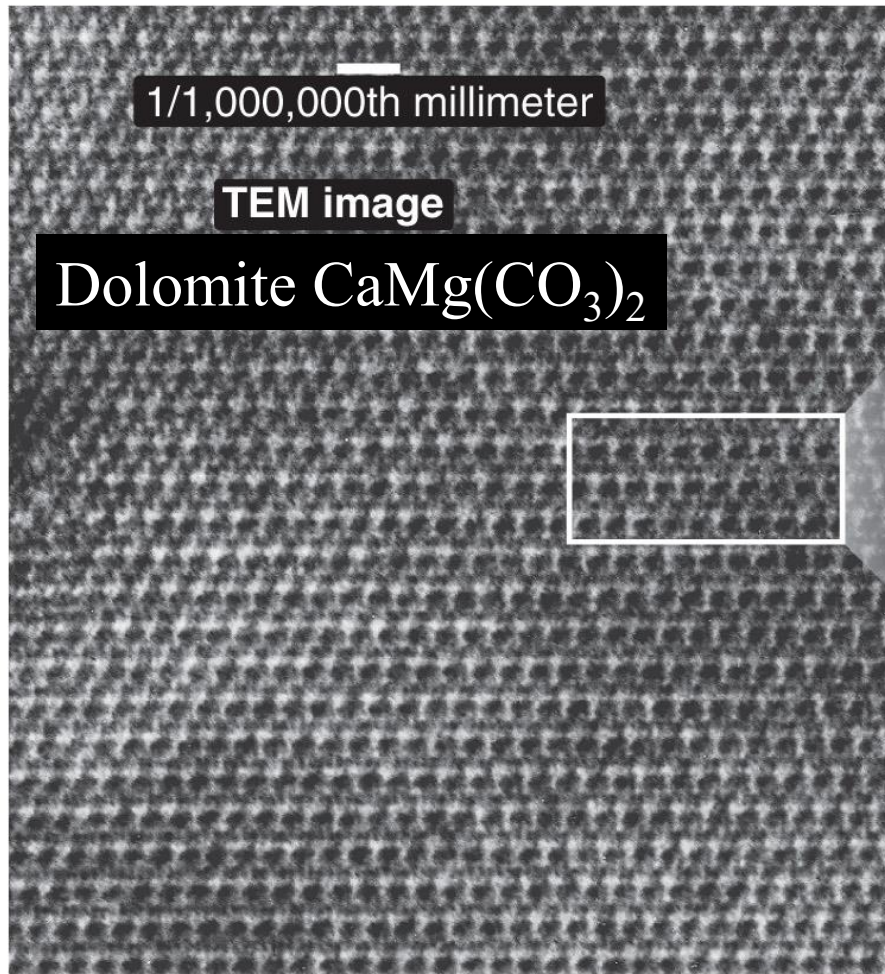


D. Intergrown crystals of the mineral halite.



C. Collection of basic building blocks (crystal).

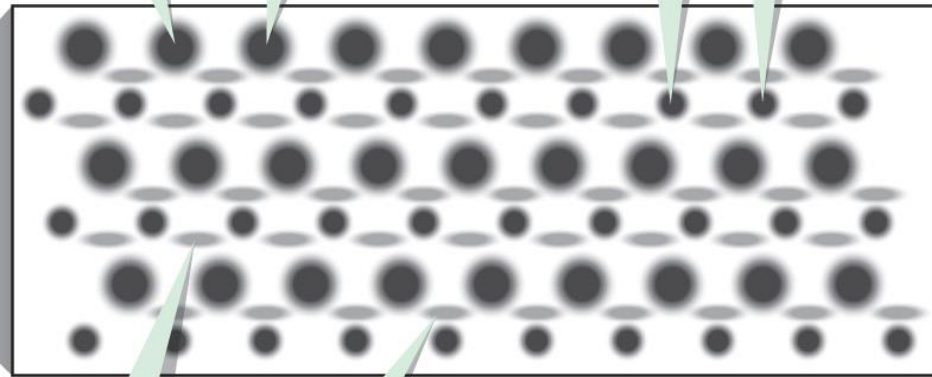
Visualizing atoms inside a mineral



Interpretation of TEM image

Calcium atoms

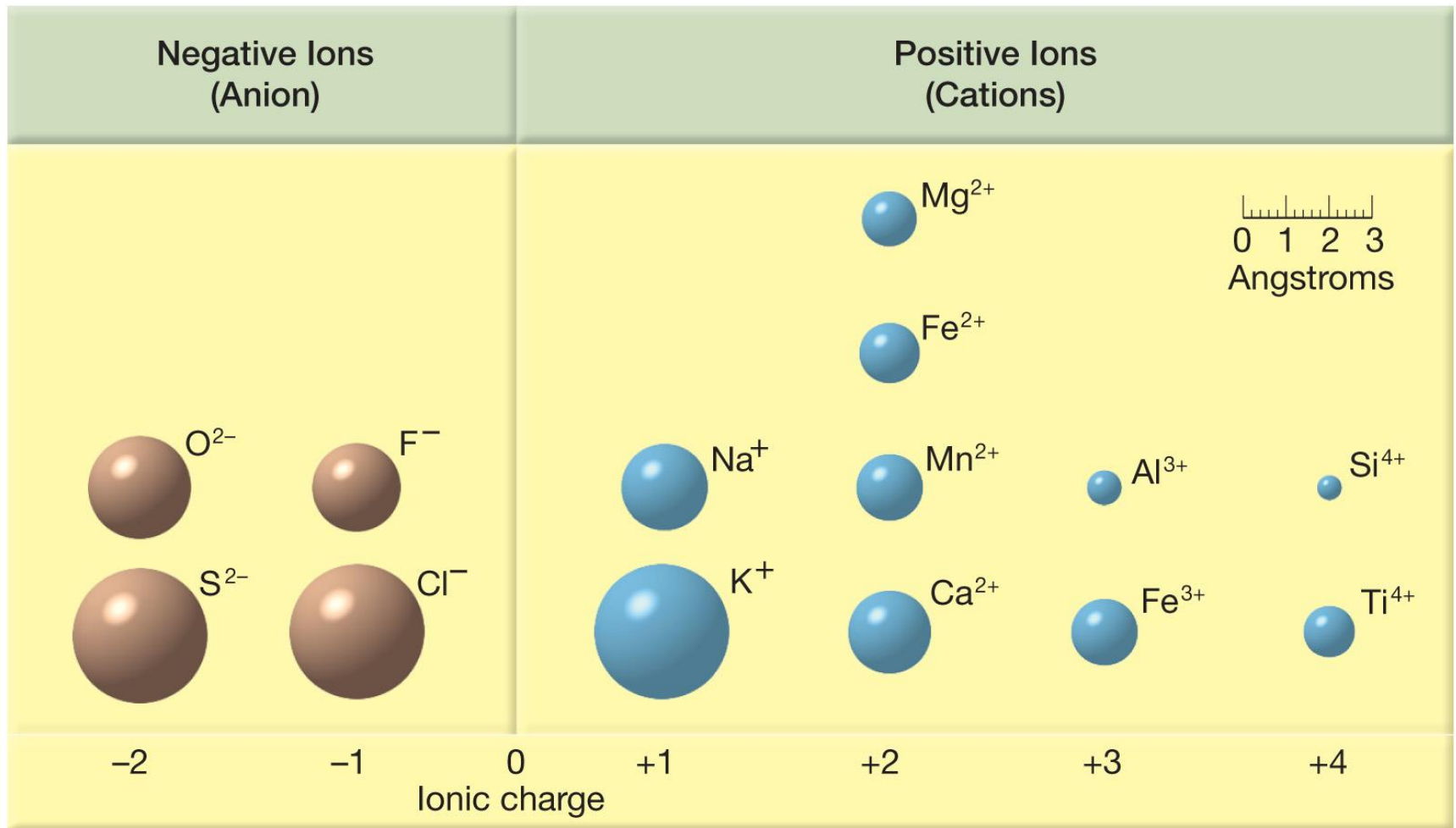
Magnesium atoms



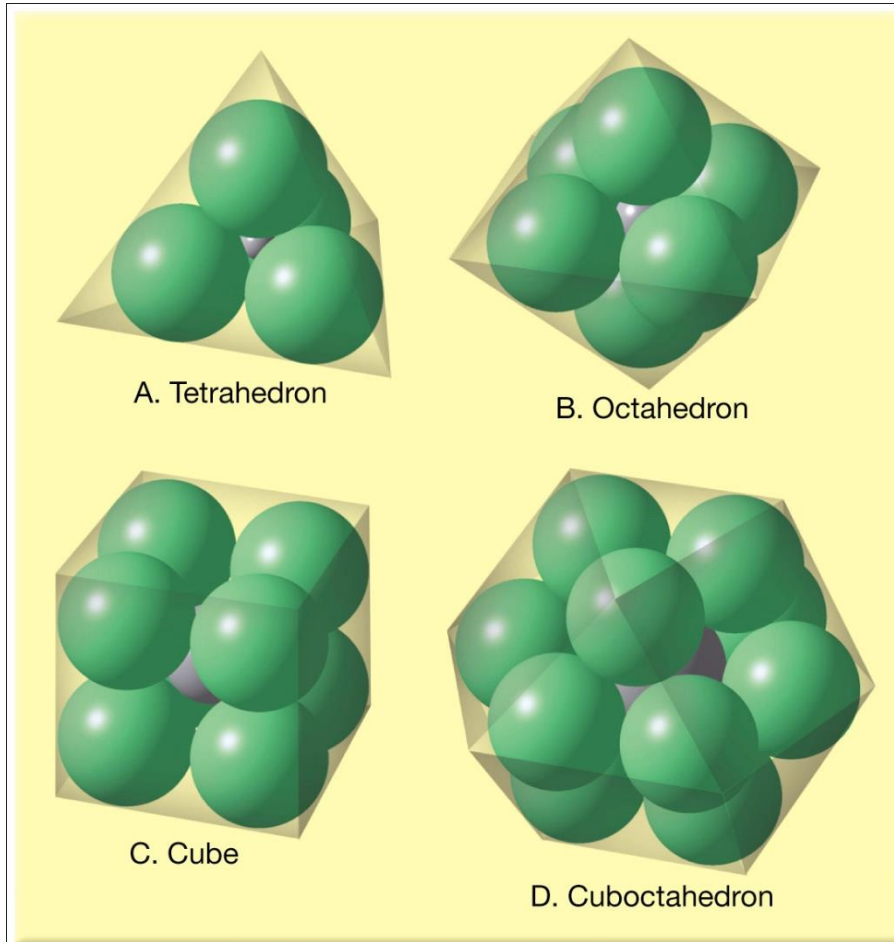
Groups of carbon and oxygen atoms form rows between calcium and magnesium ions but are not visible in image because electrons are widely spaced.

Why do different mineral compositions result in different shaped crystals?

- It is because ions are different sizes.
 - The different sizes result in different packing arrangements.



Different packing arrangements result in different shaped crystals?



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Galena Cubes



Pyrite Pyritohedrons



Hexagonal Beryl



Calcite Scalenohedrons



Tabular Wulfenite



Prismatic Stibnite

You will not be tested on the names of the different shapes

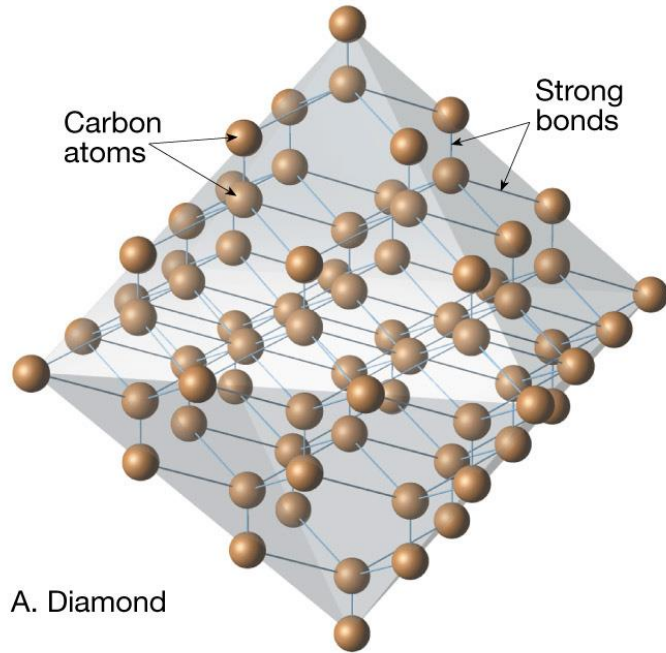
Many possible crystal shapes



Crystal Polymorphs

- Two minerals with exact the same chemical composition but with different crystal structures (arrangement of the atoms)
 - Polymorphs can have drastically different properties
- Example:
 - Graphite is carbon bonded into sheets
 - It is opaque, soft and slippery
 - Diamond is carbon bonded with strong covalent bonds
 - It is glassy in appearance and the hardest mineral

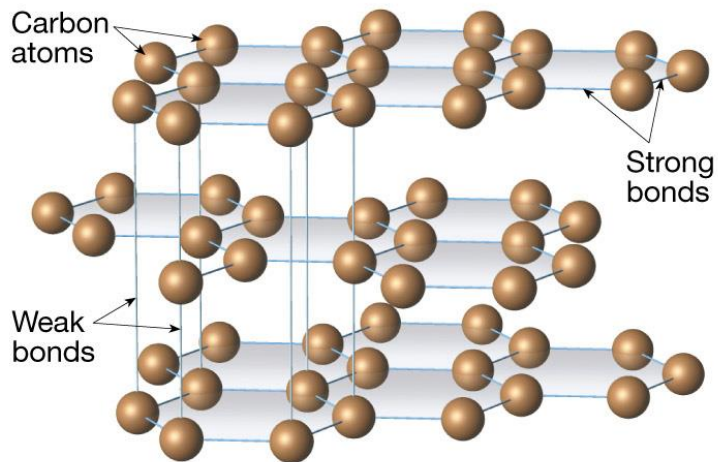
Crystal Polymorphs



A. Diamond



Diamond



B. Graphite



Graphite

Is pencil lead really made of lead?

- No, it is the mineral graphite (C)
- Graphite was originally identified as lead because it was soft and black like lead.
- Pencil lead is now a mixture of clay and graphite. The more clay the harder the lead in the pencil.



Mineral Identification using Physical Properties

- Crystal form
- Cleavage
- Fracture
- Luster
- Color
- Streak
- Hardness
- Density (Specific gravity)

Crystal Faces, Cleavage and Fracture

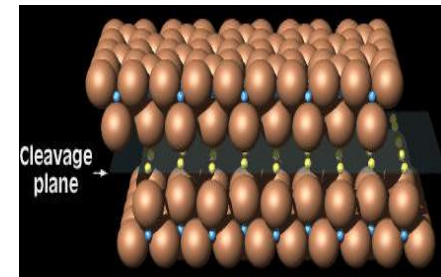
Don't confuse these 3 properties

crystal faces – are the natural growth surface as a crystal forms from a liquid

Halite movie (NaCl)



cleavage – regular breakage along a molecular plane



fracture – irregular breakage of a mineral in the absence of cleavage (for example conchoidal fracture in quartz)



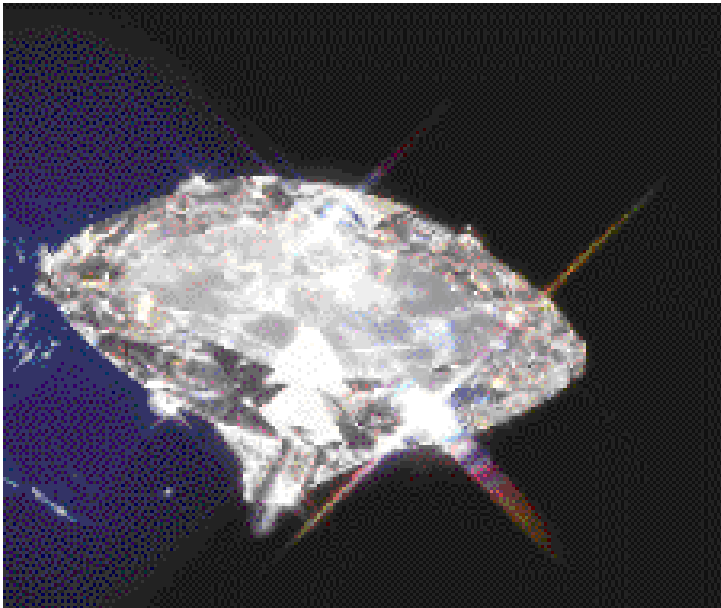
A. Irregular fracture
(Quartz)



B. Conchoidal fracture
(Quartz)

Crystal Face versus Cleavage Surface

Diamond gem stones in jewelry, are broken along cleavage surfaces

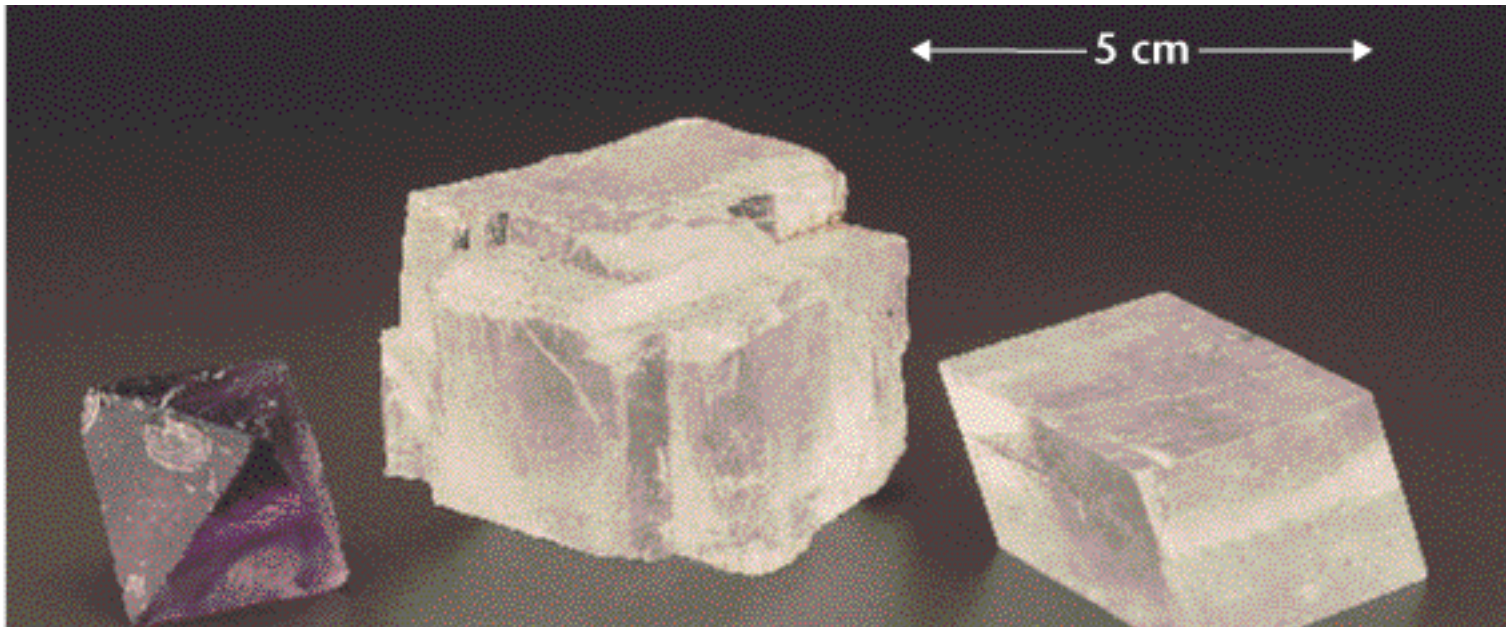


Diamond crystals in its original form is grown from a melt, and is not as attractive



Crystal Face versus Cleavage Surface

Smooth **CLEAVAGE** surfaces (breakage surfaces) shown below look like crystal faces, but they are not!




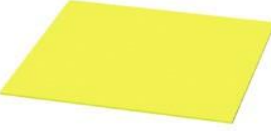

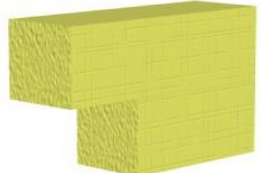
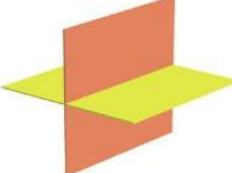




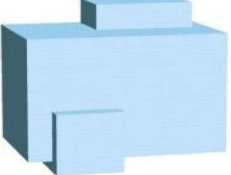








fluorite
(CaF_2)

halite
(NaCl)

calcite
(CaCO_3)

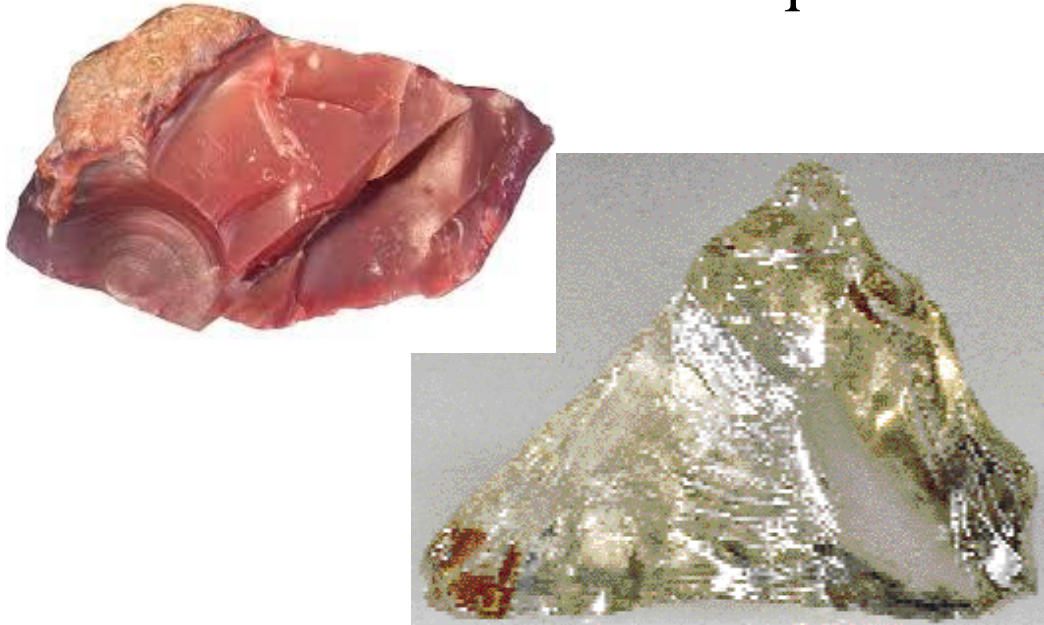
Common Cleavage Directions

(you will not be tested on these)

Number of Cleavage Directions	Sketch	Illustration of cleavage directions	Example
1			
2 at 90°			
2 not at 90°			
3 at 90°			
3 not at 90°			
4			

Fracture Surface versus Crystal Face

Conchoidal fracture of quartz



Crystals of quartz



Quartz does not produce cleavage faces when it breaks, it fractures instead into conchoidal shaped fractures

Luster/Color/Streak

- luster- how light reflection on the surface
 - nonmetallic vs. metallic luster

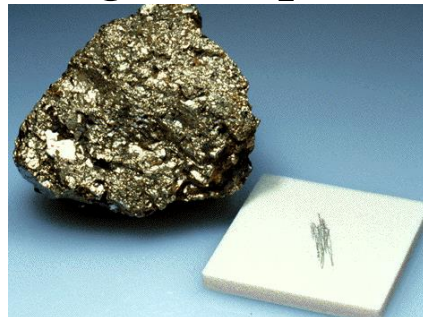


- color – chemical impurities
 - Most unreliable method of identifying a mineral

The many colors of the mineral fluorite



- streak - powdered color on unglazed porcelain (streak plate)
 - streak color is reliable



Example: Mineral color is from chemical impurities

Three colors of quartz from chemical impurities



Colorless quartz

99.998%
 SiO_2



Rose quartz

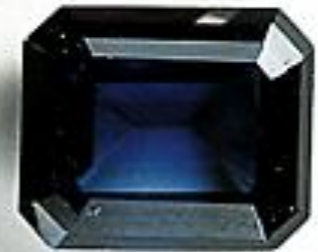
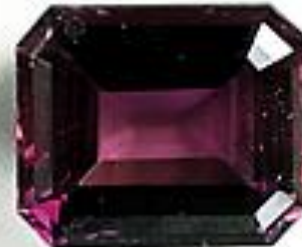
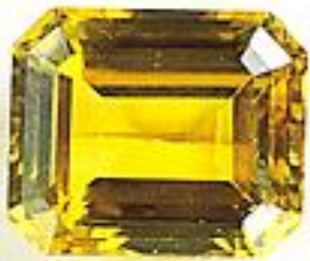
0.003%
Titanium
99.996%
 SiO_2



Amethyst

0.020%
Iron
99.978%
 SiO_2

The Many Colors of Corundum

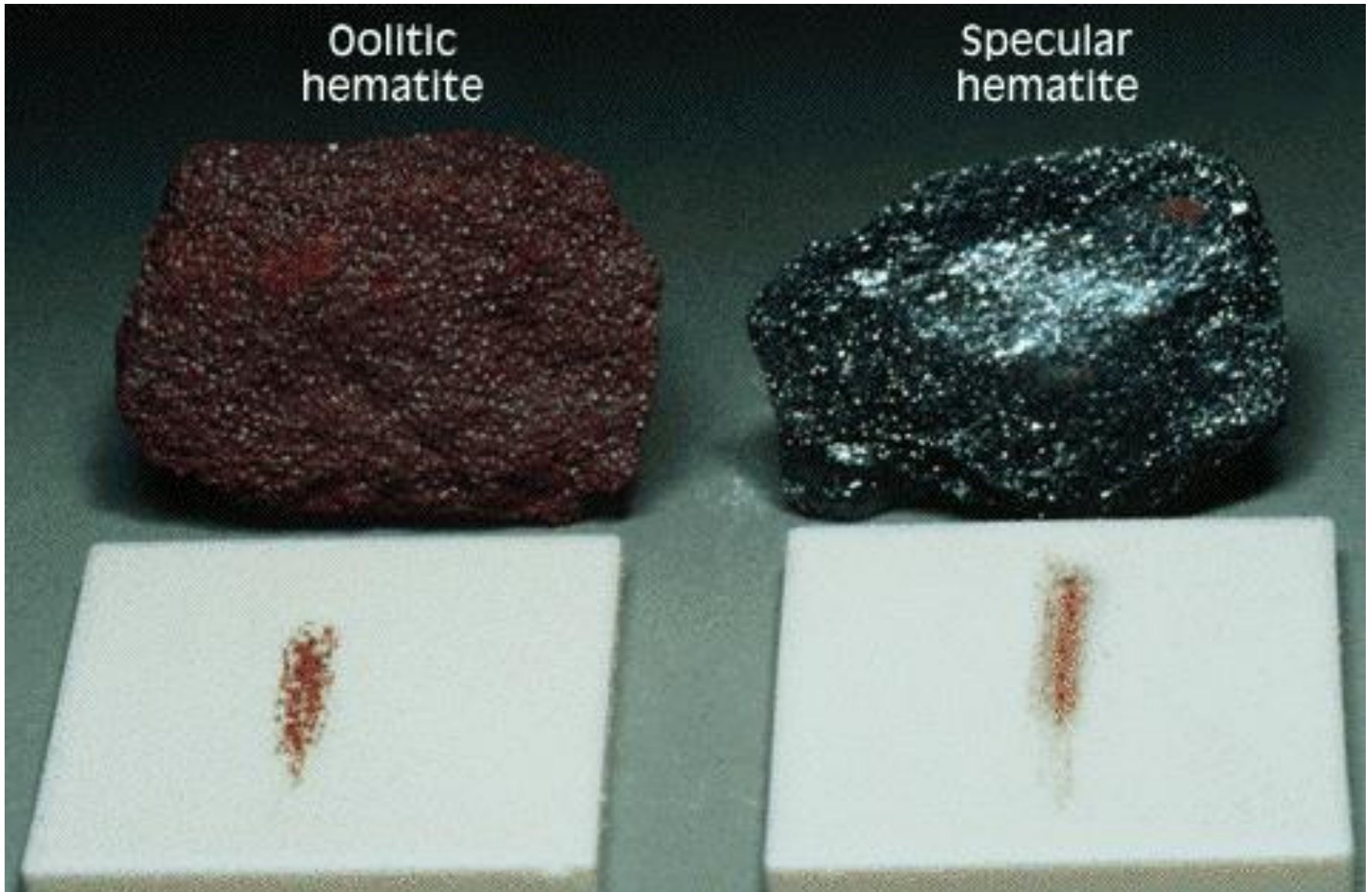


Ruby(Cr^{3+})

**Sapphire
(Fe^{3+} & Ti^{4+})**

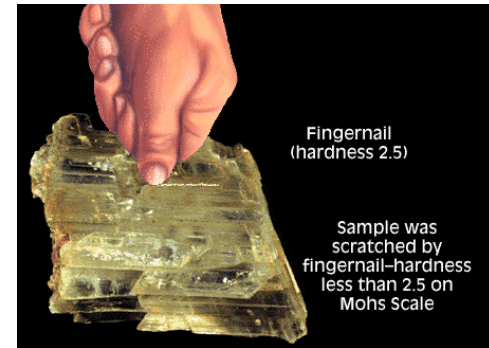


Example of streak not matching mineral color

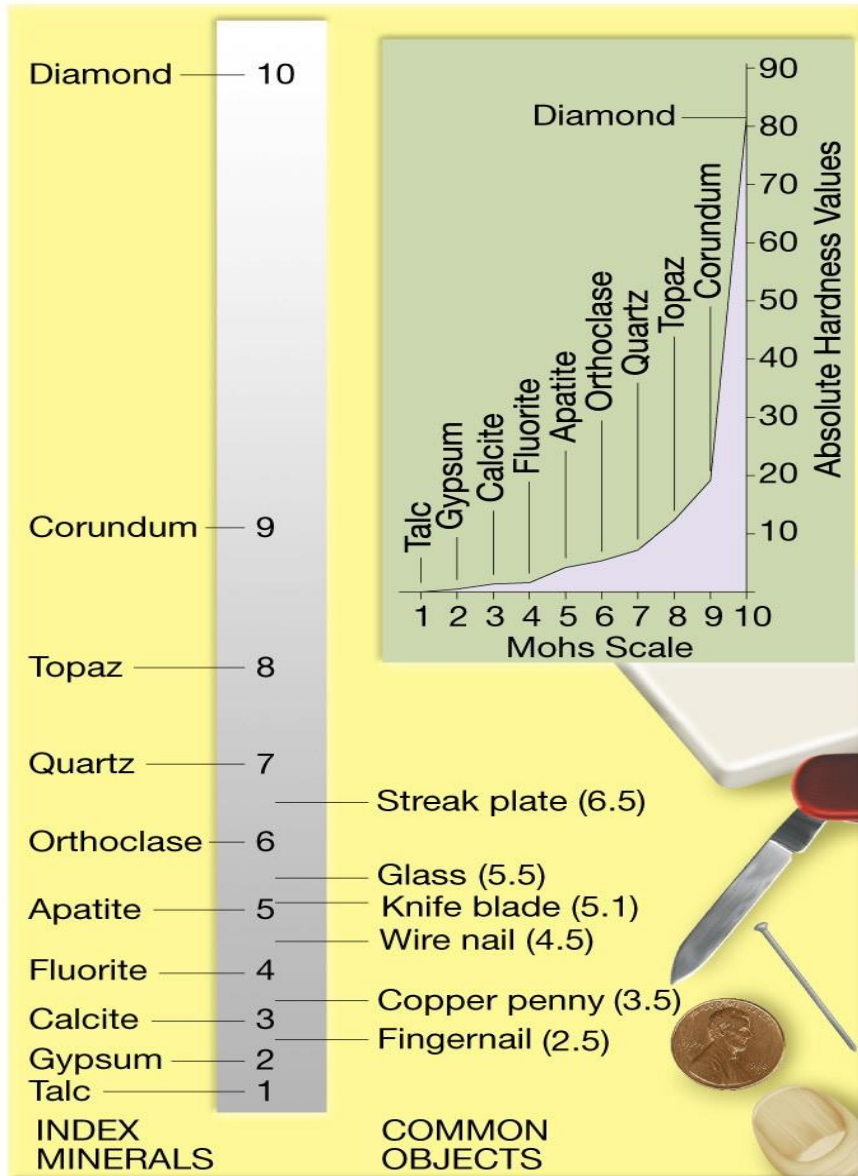


Hardness

- Hardness is a mineral's resistance to scratching
 - It is the most reliable property for identifying a mineral
- How to determine hardness:
 - rub a mineral or material of known hardness against unknown mineral
 - Mohs Hardness Scale (a relative hardness scale)



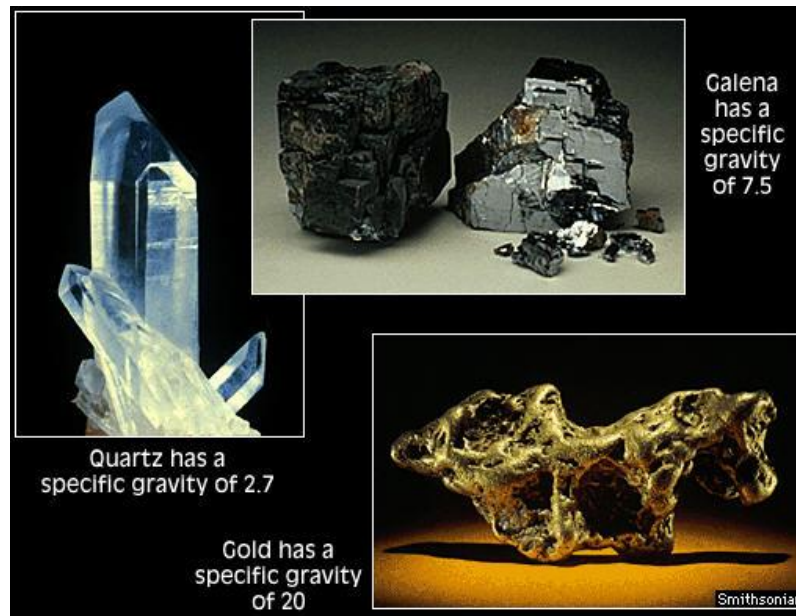
Mohs Hardness Scale



- You do not need to memorize this scale
- Make sure you know
 - Hardness is not measured with a hardness meter, it is a relative scale based on hardness relative to known items
 - that the silicate minerals you are required to memorize (see end of lecture for list) are generally harder than all the nonsilicate minerals
 - the main exception to this is diamond which is composed of only carbon and is the hardest of all minerals.

Density

- Density = mass per unit volume
- When a rock that is more dense than another rock, it means the same weight of rock takes up less volume.



Other Physical Properties of Minerals

(you will not be tested on these properties)

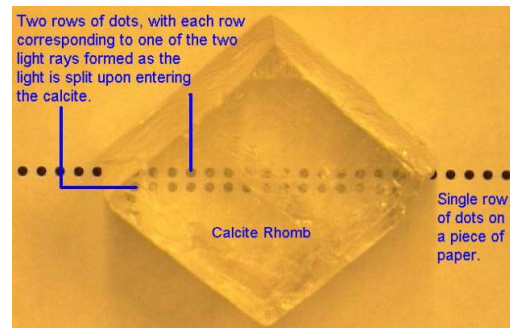
- **Magnetic – magnetite (Fe_3O_4)**



- **Reacts to hydrochloric acid**
 - calcite (CaCO_3) fizzes



- **Double refraction - calcite**



- **Malleability - graphite**
- **Taste – halite (table salt) tastes salty**
- **Smell – (sulfur smells like rotten egg smell)**

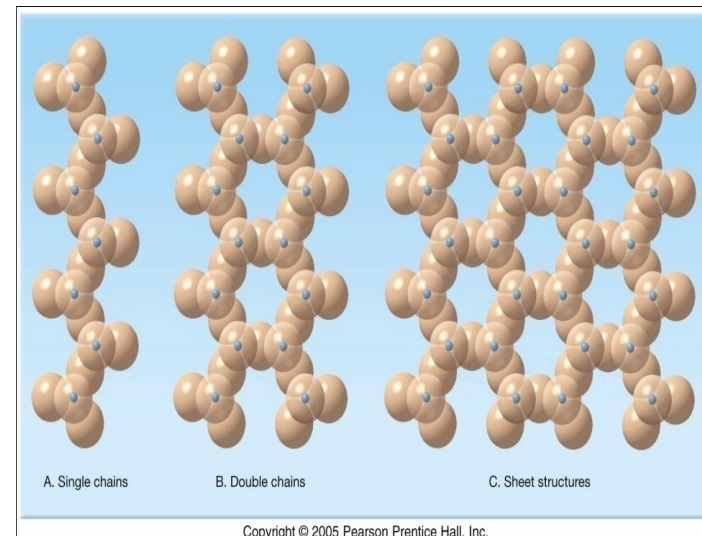
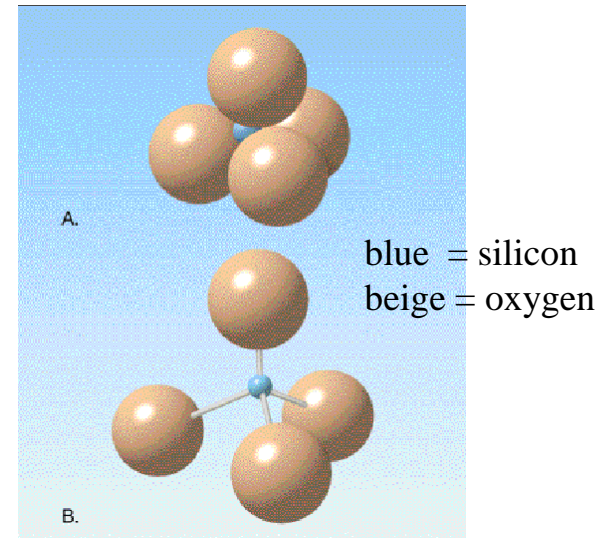
Common minerals you must know....

- **Silicate minerals** – are composed of Si and O
 - Si and O comprise 74% of crust so silicate minerals are the most common minerals on Earth
 - The form from crystallization of magma
 - (magma is a silicate melt)
 - Silicate minerals are divided into two groups
 - **Ferromagnesian silicate minerals**
 - **Nonferromagnesian silicate minerals**
- **Clay minerals:** are separate group of silicate minerals formed from the near-surface weathering of silicate minerals (clay minerals are not crystallized from a melt)
- **Nonsilicate minerals** – contain no silica (Si)

Silicate Minerals

- The basic building block of silicate minerals is the Si-O tetrahedron
- The Si-O tetrahedron are bonded to each other by cations
 - Predominantly Fe and Mg for ferromagnesian silicate minerals
 - Predominantly Al, Ca, Na and K for nonferromagnesian silicate minerals
- Silicate minerals are grouped based on how the silicate tetrahedrons are bonded together
 - single silica tetrahedra
 - single chain
 - double chain
 - sheets

Si-O tetrahedron



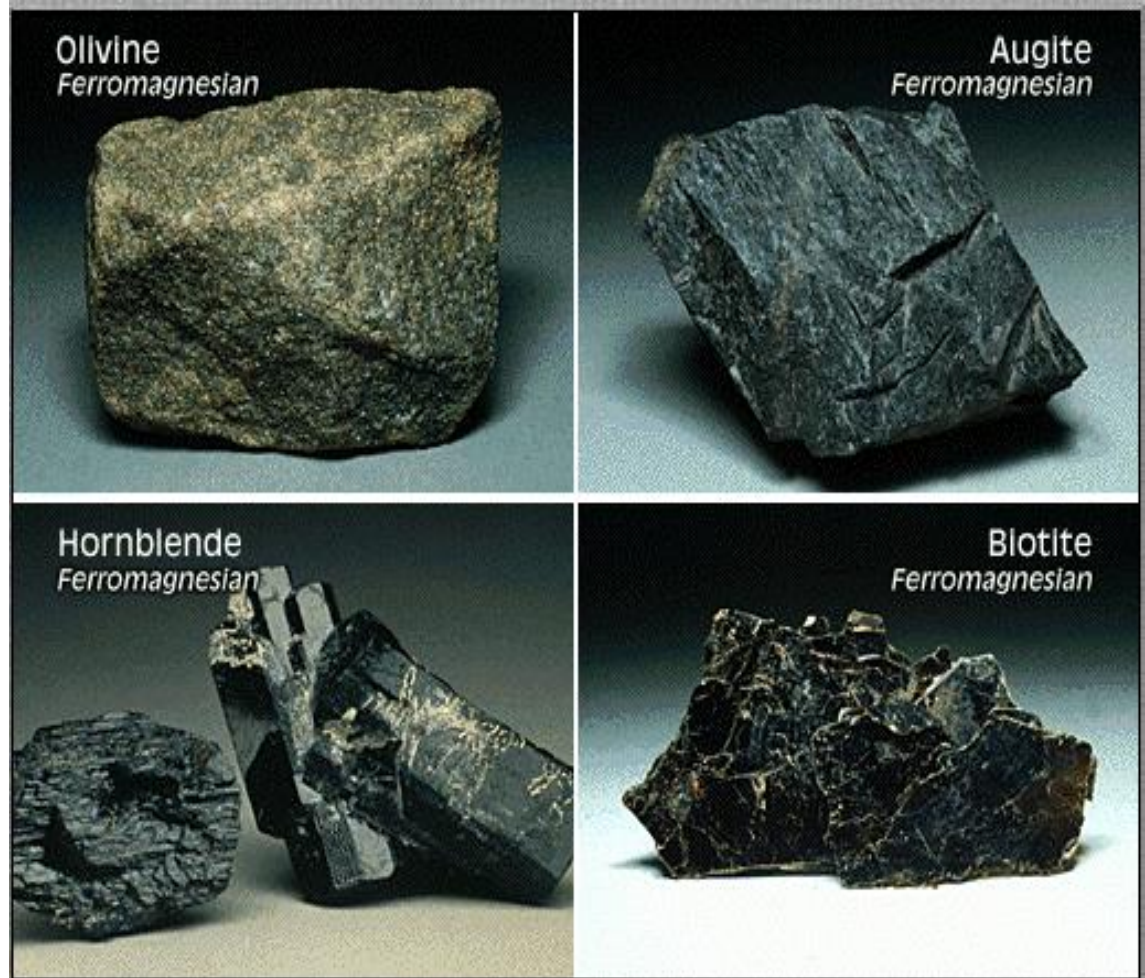
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Ferromagnesian Silicate Minerals

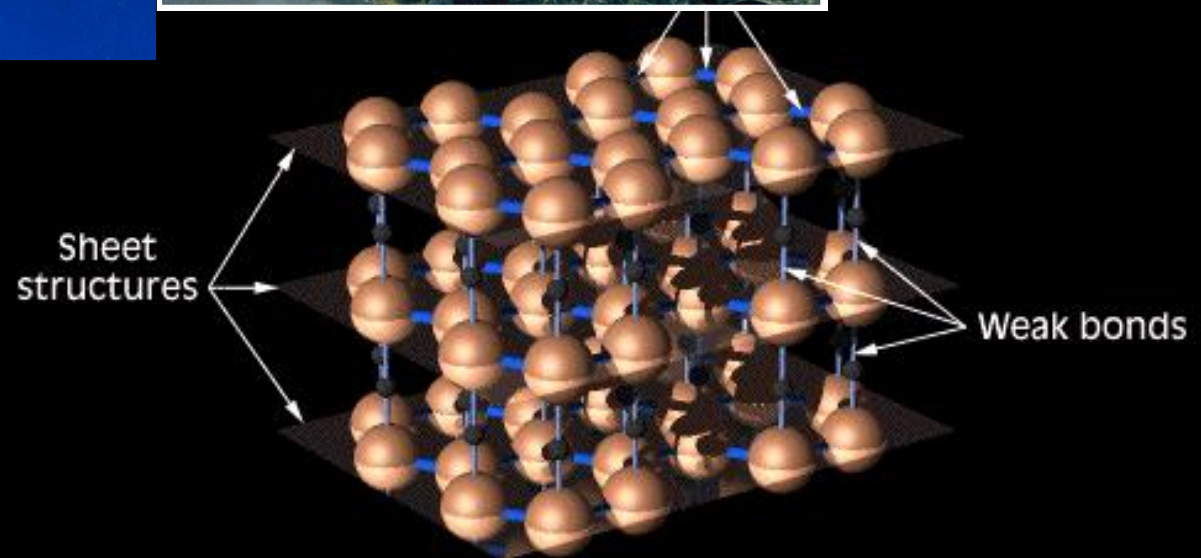
Fe-Mg rich, mafic, dark colored

You must know that the following minerals are ferromagnesian silicate minerals

- olivine
- pyroxenes
- amphibole group (hornblende)
- biotite mica



Biotite mica: has an interesting sheet structure

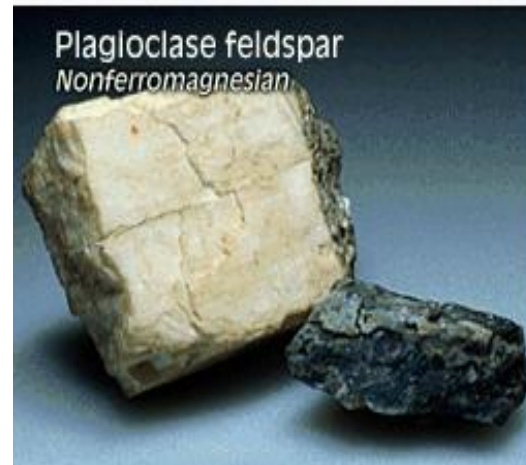
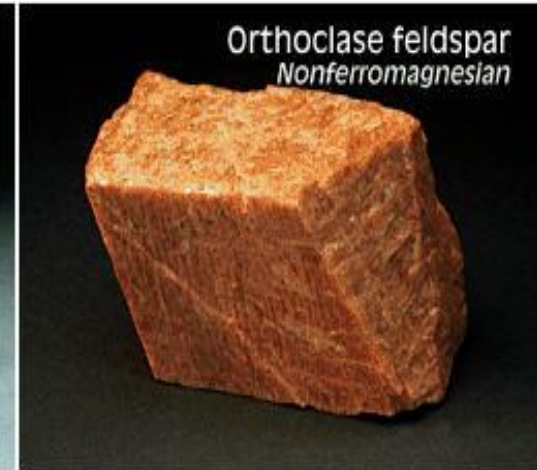
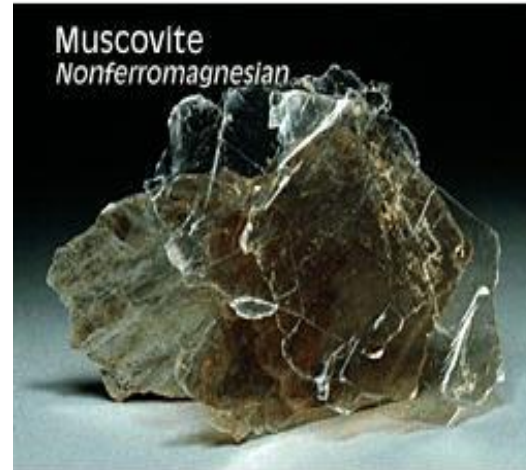


Nonferromagnesian Silicate Minerals

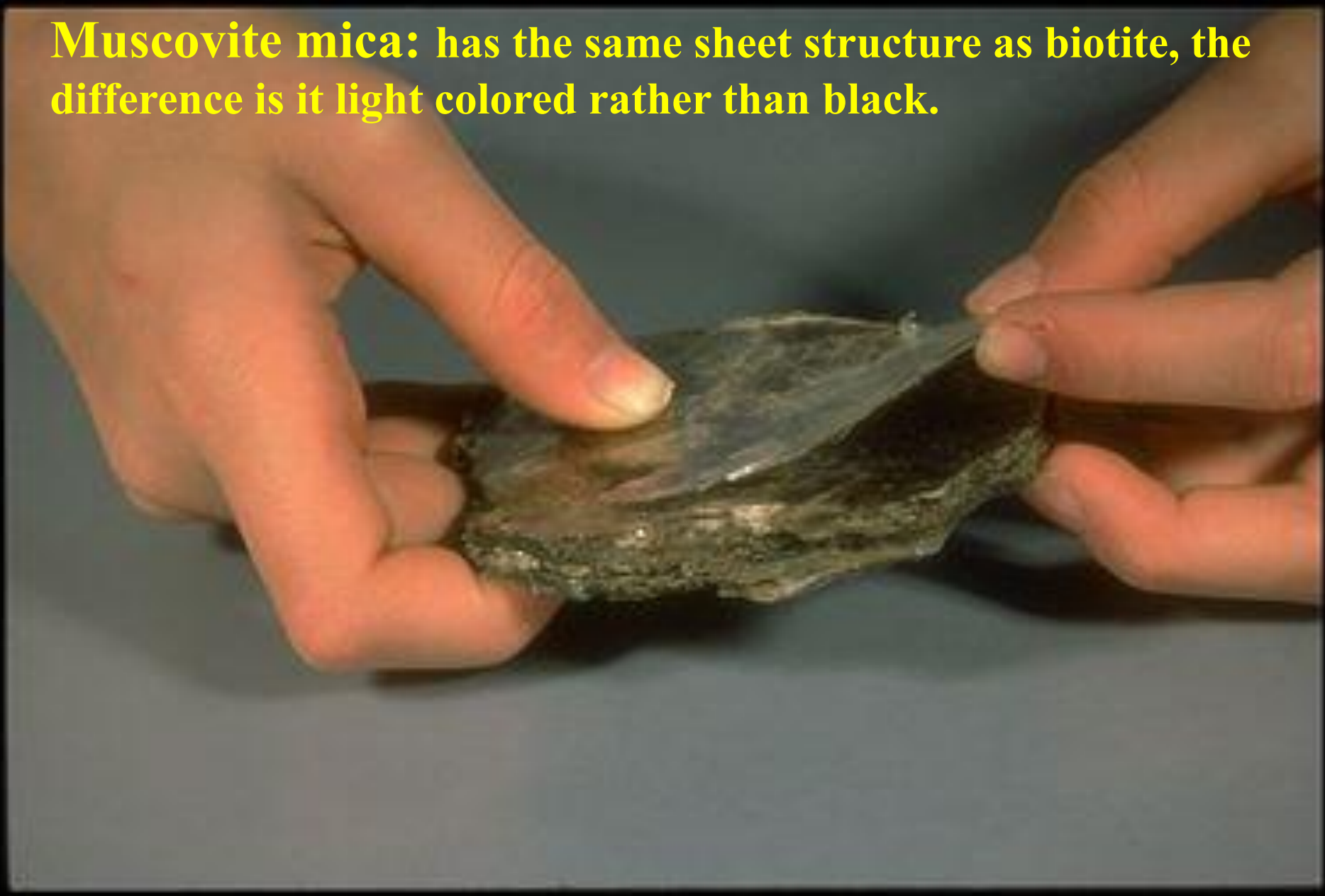
Ca – Na –K rich, felsic, light colored

You must know that the following minerals are nonferromagnesian silicate minerals

- muscovite mica
- Quartz (SiO_2)
- K-feldspar (orthoclase)
- Ca-Na plagioclase
- clay minerals

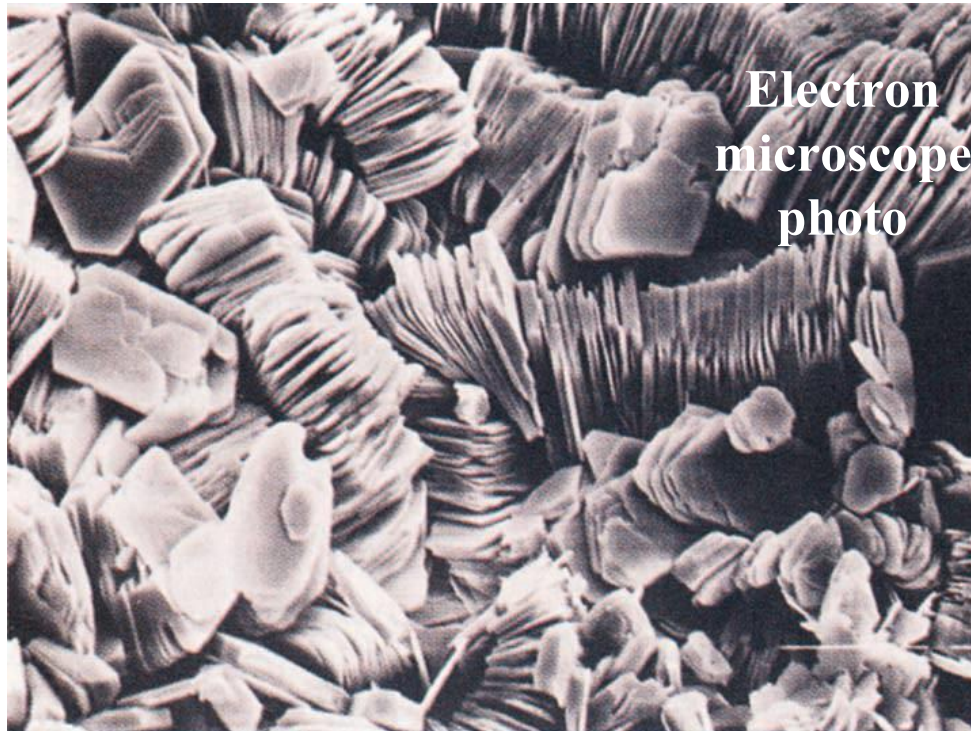


Muscovite mica: has the same sheet structure as biotite, the difference is it light colored rather than black.



Clay Minerals

- Clay sized minerals composed of Si-O and a wide range of elements, that are produced by the near surface weathering of silicate minerals.
- Clay-mineral crystals are flat sheets of microscopic size.
- (You do not need to know the name of any of the clay minerals, just the group as a whole.)

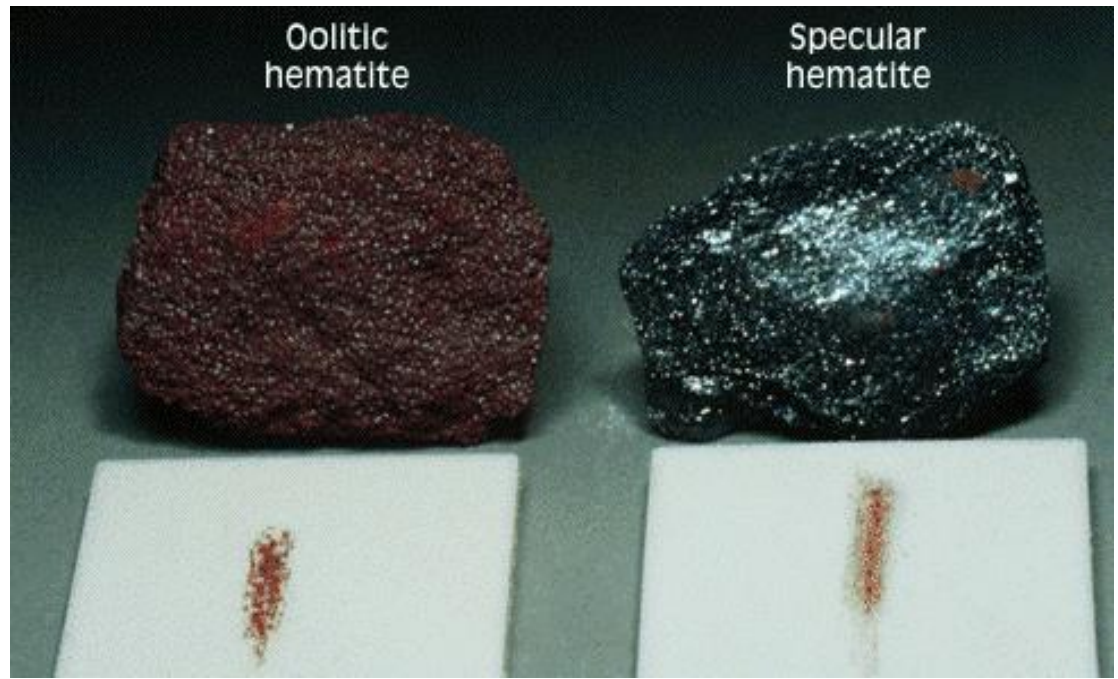


Nonsilicate Minerals

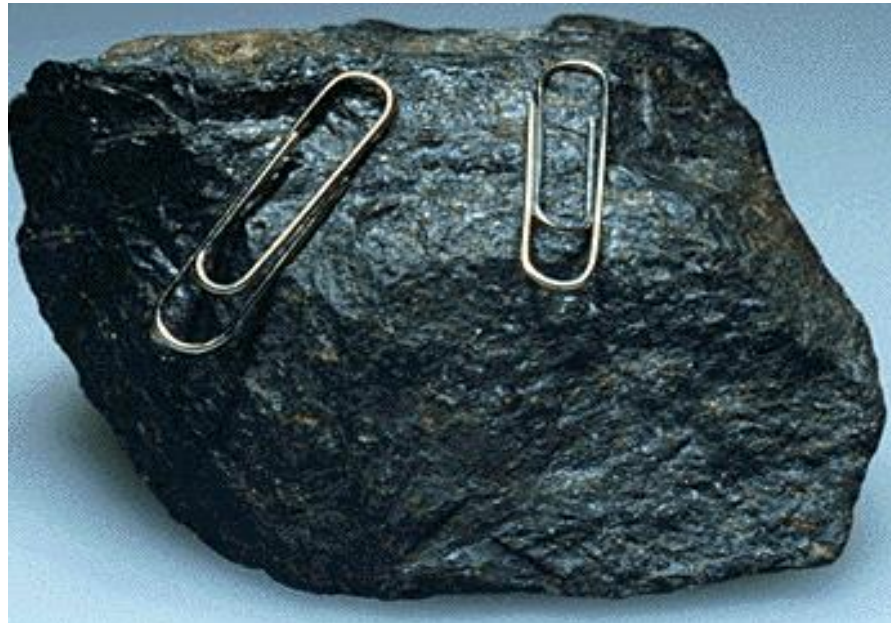
This group does not contain silica (Si)

- Nonsilicate minerals generally crystallize from water at near surface conditions.
- Nonsilicate minerals you must know
(Be able to match these formula with the mineral name)
 - hematite Fe_2O_3
 - magnetite Fe_3O_4
 - gypsum CaSO_4
 - halite NaCl (memorize this mineral and formula)
 - calcite CaCO_3 (memorize this mineral and formula)
 - dolomite $\text{CaMg}(\text{CO}_3)_2$

Hematite (Fe_2O_3)



Magnetite (Fe_3O_4)





Gypsum
(Sulfate)
 $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

Halite
 NaCl



Calcite
CaCO₃



Dolomite
(Ca,Mg)CO₃



Houston Gem and Mineral Society

<http://www.hgms.org/>

- For amateur collectors
- Teach mineral faceting, polishing etc.
- Hosts mineral collecting trips
- Hosts annual Gem and Mineral Show



End

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