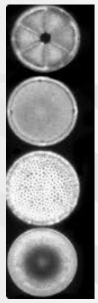
Minerals



What is a Mineral ?

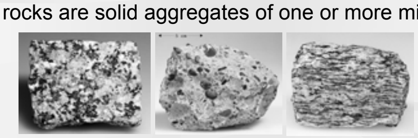
Defining characteristics of minerals:

- Naturally occurring
- Inorganic (or at least never alive)
- Solid
- Ordered internal structure (crystalline)
- Definite chemical composition (allowing for small variation within set limits)

Can ice be considered a mineral ?

Minerals are building blocks of rocks.

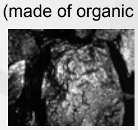
Most rocks are solid aggregates of one or more minerals



igneous sedimentary metamorphic

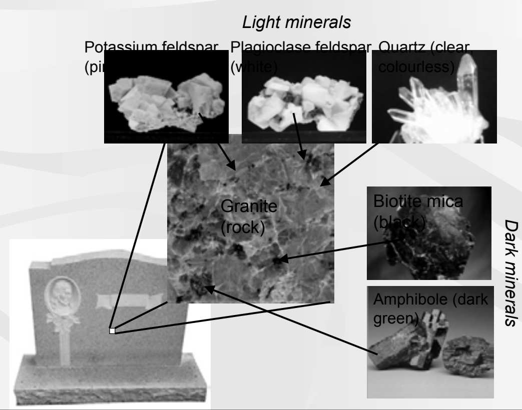
Exceptions:

Coal (made of organic matter)



Volcanic glass (non-crystalline)

This sample of granite contains at least five minerals !



Components of Minerals

Minerals are made of elements

An element is a substance that cannot be broken down to other substances by normal chemical means.

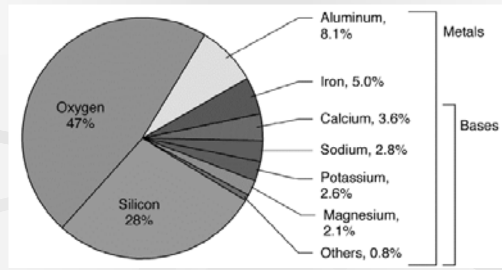
Elements familiar to most people include hydrogen, helium, oxygen, carbon and calcium.

Note that calcium is NOT a mineral- it is an element !

There are 92 of naturally occurring elements on Earth.

Over 2000 distinct minerals are known.

Elemental Abundance



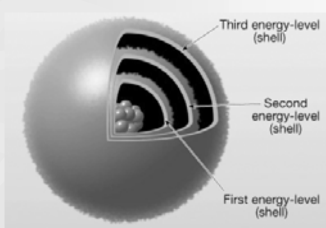
Only about 8 elements make up the bulk of the Earth's crust (oxygen, silicon and various metals)

Atomic Structure

An atom is the smallest particle of matter that retains the characteristics of an element.

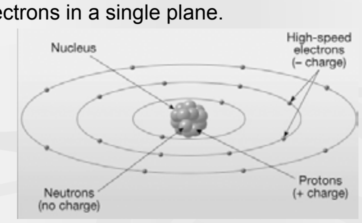
An individual atom has a nucleus made of protons and neutrons.

Orbiting around the nucleus are fast-moving electrons, that form cloud-like shells (each defining an energy level)



Atomic Structure

A more simplified view of an atom showing the nucleus and electrons in a single plane.



Characteristics of subatomic particles

- Each proton: charge of +1, mass of 1
- Each neutron: charge of 0, mass of 1
- Each electron: charge of –1, mass near 0

Note that nearly all of an atom's mass is in its nucleus.

Bonding

Due to interactions of electrons between atoms (or either the same element or of different elements), atom can become bonded to one another.

Main types of bonding:

1. Ionic
2. Covalent
3. Metallic
4. Intermolecular

Principles of Bonding

The innermost shell of an atom can hold up to 2 electrons. Shells beyond this can hold up to 8 electrons.

If the outermost electron shell of an atom contains fewer than the maximum number of electrons it can hold, electrons in the unfilled shell are called valence electrons.

Valence electrons are those electrons that actively participate in chemical reactions.

Ionic Bonding

One atom (in this case, an atom of sodium) can give up electrons in its outermost shell (so its remaining shells are full). Loss of electrons results in a net positive charge for the atom, forming a *positive ion* or *cation*

Another atom (in this case, an atom of chlorine) can accept electrons to full its outermost shell. The gain of electrons results in a net negative charge for the atom, forming a *negative ion* or *anion*

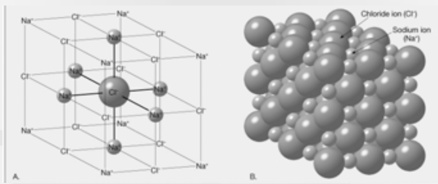
Opposites attract !

When opposite ions love each other very very much, they can form minerals.

In this case, ions of sodium and chlorine form the compound sodium chloride. The mineral made of sodium chloride is called HALITE.

This mineral is what we use as table salt.

The consequences of bonding arrangements



Note that the regular bonding arrangement of sodium and chloride is responsible for the cube-like crystal structure of halite.

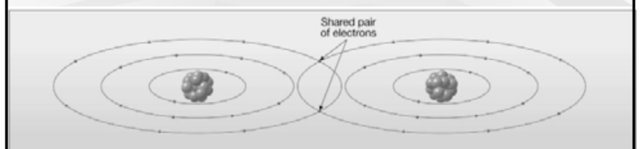
Ionic bonds are fairly strong

Covalent Bonding

Another way that atoms can combine to form minerals is through covalent bonding.

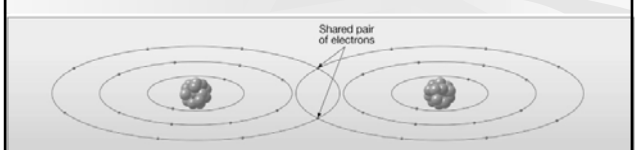
This type of bond occurs due to sharing of electrons

Atoms that share electrons both believe that they "own" the electrons that they are sharing



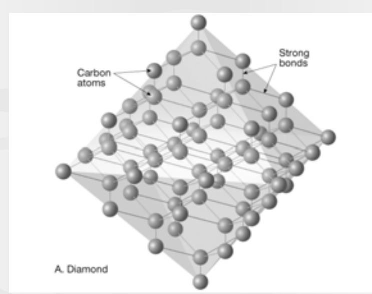
When Atoms Share

The electrons are considered to be part of both atoms and the attractive force of each nucleus for the pair of electrons between the atoms holds the atoms together.



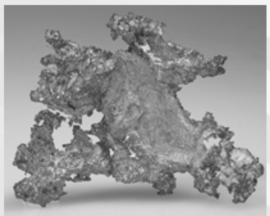
Covalent bonds tend to be *very* strong

Diamond, composed entirely of carbon, is held together by strong covalent bonds between carbon atoms. The carbon atoms share electrons with neighbouring atoms.



Metallic bonding

A special type of bonding occurs in pure metals (native metals).



Highly mobile electrons constantly migrate among the positive ions of the substance.

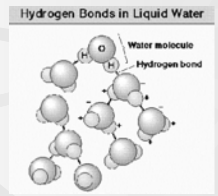
This free migration of electrons allows metals to conduct electricity and to be deformed easily.

Metallic bonds tend to be *weak*

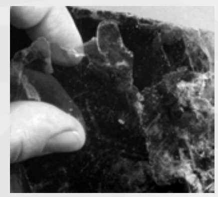
Intermolecular bonding

Bonds can also form due to slight charge imbalances among atoms or molecules.

Bonds formed this way are *very weak*



It is this type of bonding that occurs in liquid water



It is also this type of bond that allows minerals such as micas and clays to flake apart so easily.

Mineral Families

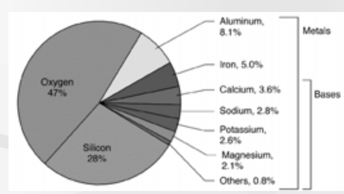
Before we get to looking at the properties of minerals, we should consider how minerals are classified.

Mineral groups are basically classified on the basis of their chemical composition, and more specifically the type of anion contained in the mineral.

The major groups of significance to us are:

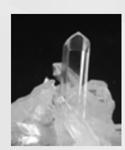
Silicates
Carbonates
Sulphates
Phosphates
Sulphides
Halides
Oxides/Hydroxides

The Silicates



In view of the overwhelming abundance of oxygen and silicon in Earth's crust, it is not surprising that silicates are the most abundant minerals.

Also not surprising is the fact that quartz (pure SiO_2) is the most abundant mineral on Earth

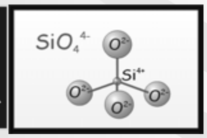


Silica: Building Block of Silicates

The basic unit of all silicates is the complex ion called silica.

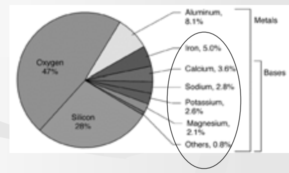
Silica consists of a central atom of silicon bonded to, and surrounded by oxygen atoms.

The resulting shape is that of a tetrahedron.



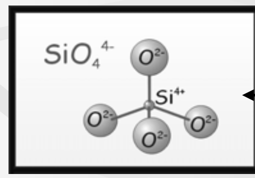
Note: each unit of silica has a net charge of -4

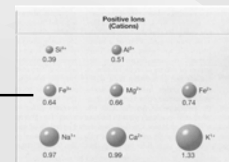
So how do we balance the charge ?



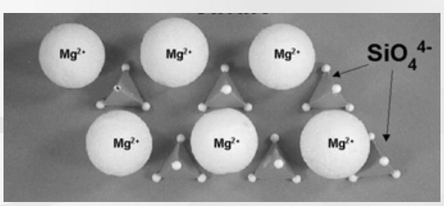
There are plenty of positively charged metal ions.

These metal ions can bond ionically to the negatively charged silica ions.





Simple Silicate: Olivine



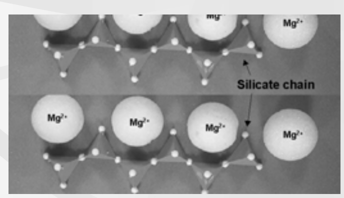
Mineral: olivine

With the addition of magnesium (or iron) cations, the charge is now balanced.

Chain Silicate: Pyroxene

Another type of mineral can be made by linking silica tetrahedra together like a chain (each tetrahedra sharing 2 oxygens with its neighbors)

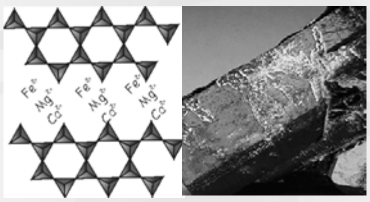
Single chains ionically bonded together by metal cations (the ionic bonds take care of any excess charge).



Mineral: pyroxene

Double Chain Silicate: Amphibole

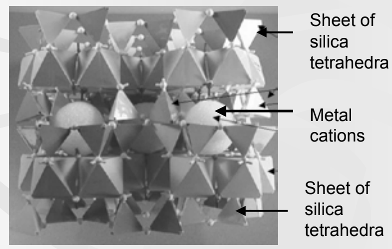
We can also make double chains of linked silica tetrahedra and balance the charge by ionically bonding the double chains with metal cations.



Mineral: amphibole

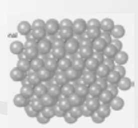
Sheet Silicate: Mica (e.g., Muscovite)

We can make an even more complex mineral by making sheets out of linked silica units (and adding some aluminum and oxygen)

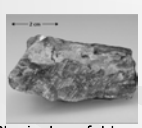


Muscovite mica (side view)

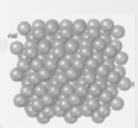
Finally, we can make a three-dimensional structure by linking silica units together, then add cations to balance the charge



plus Al $^{3+}$, Na^{+}, Ca^{2+} =



Plagioclase feldspar
$(Ca,Na)AlSi_3O_8$



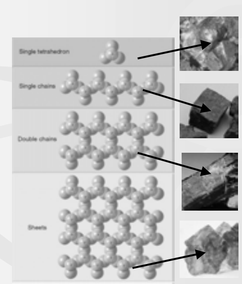
plus Al^{3+}, K^{+} =

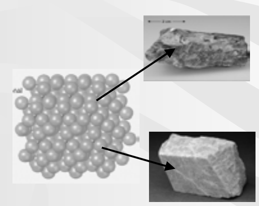
3-dimensional framework of silica tetrahedra

Potassium feldspar

Diversity of Silicate Minerals

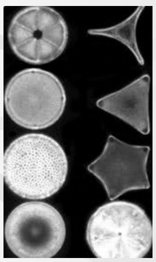
It is because of the many combinations of silica linkages and ionic bonds with metal cations that silicates are so diverse.



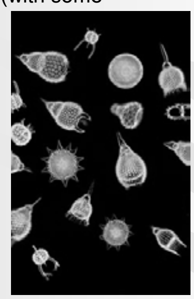


Silicates in Living Things

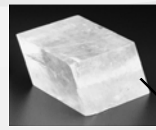
A number of organisms make their skeletons out of opal - a form of finely crystalline silica (with some water). Opal: $SiO_2.H_2O$

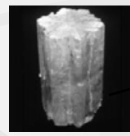

Diatoms


Sponges

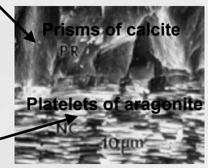

Radiolaria

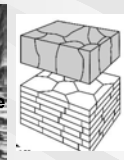
Carbonates (examples)


Calcite ($CaCO_3$)
(calcium carbonate)

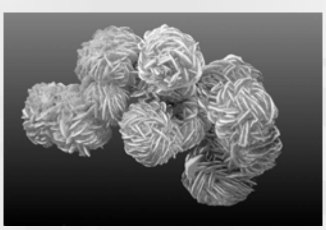

Aragonite ($CaCO_3$)
(calcium carbonate)

Abalone Shell





Sulphates (example)


Gypsum ($CaSO_4$)

Common mineral in marine-deposited rocks
(also the main ingredient in drywall)

…To be continued next lecture

END OF LECTURE