Minerals

Mineral: Mineral is naturally occurring, solid crystalline substance, generally inorganic with a specific chemical composition. Minerals are generally homogeneous: they cannot be divided mechanically into smaller components.

Properties of a Mineral:

- **Naturally occurring** … must be found in nature and synthetic versions produced in laboratories are not minerals.
- **Solid crystalline substance** … they are neither liquids nor gases. Crystalline means that its atoms are arranged in an orderly, repeating, three-dimensional array.
- **Generally inorganic** … excluding the organic materials that make up plant and animal bodies (e.g. though natural but not mineral).
- **With specific chemical composition** … i.e. either fixed or varies within defined limits. The mineral quartz has a fixed ratio of two atoms oxygen to one atom of silicon. The chemical elements that make up the mineral olivine – iron, magnesium and silicon – always have a fixed ratio. Although the number of iron and magnesium atoms may vary.

So:

Minerals are the basic components of rocks, and mineralogy defines the properties of the rocks.

The properties of minerals are a function of their chemical composition and crystal structure.

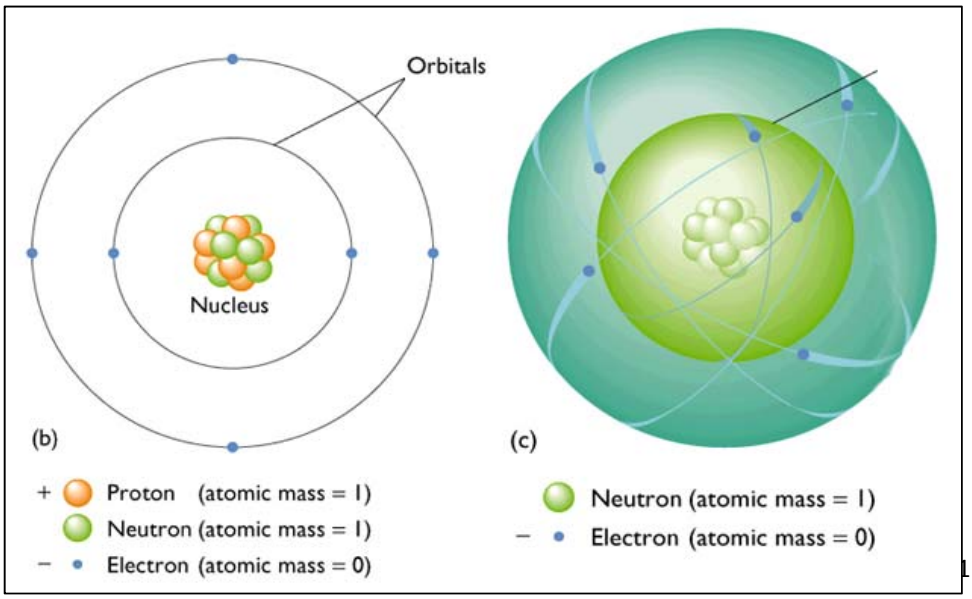
Minerals form at specific temperatures and pressures, and from fluids of specified composition.

Where to start – Elements

6 number

C

12.011 mass



Atomic number = # protons (# protons = # electrons)

(defines the element – properties)

Atomic mass = # protons + # neutrons (electrons negligible mass)

Isotopes = same # protons different # neutrons

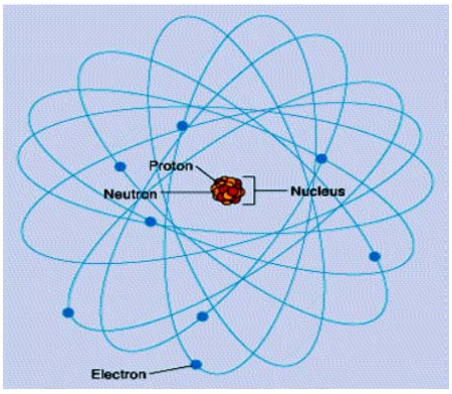
Atoms and Elements:

Since minerals (in fact all matter) are made up of atoms, we must first review atoms. Atoms make up the chemical elements. Each chemical element has nearly identical atoms. An atom is composed of three different particles:

- **Protons** -- positively charged, reside in the center of the atom called the nucleus
- **Electrons** -- negatively charged, orbit in a cloud around nucleus
- **Neutrons** -- no charge, reside in the nucleus.

Each element has the same number of protons and the same number of electrons.

- Number of protons = Number of electrons.
- Number of protons = atomic number.
- Number of protons + Number of neutrons = atomic weight.

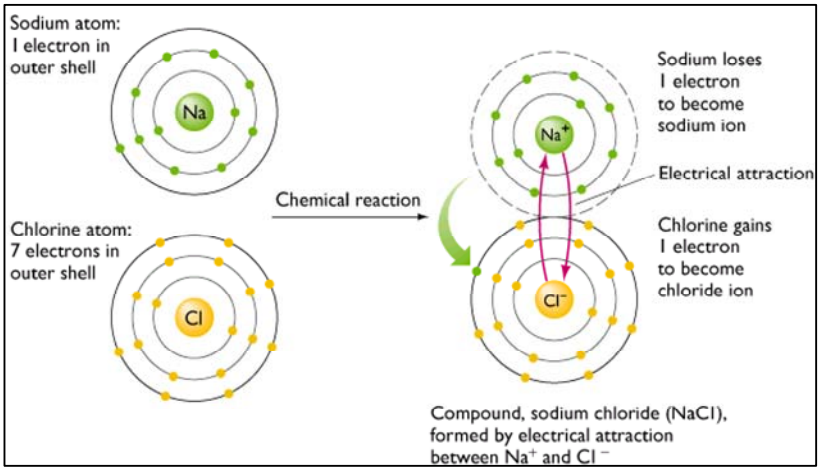


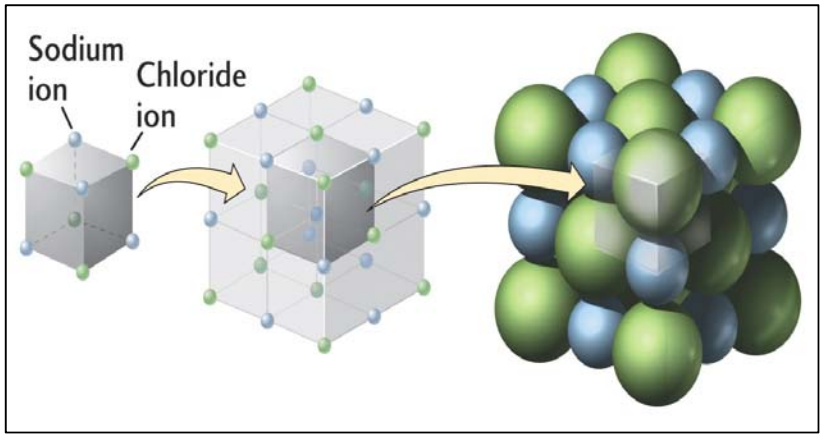
From elements to minerals

- Atoms of elements interact in fixed proportions (CHEMICAL REACTIONS) to form compounds
- Example: 2 H + O → H2O
- Properties of the compound may be entirely different from its constituent elements
- Minerals are compounds
- In compounds, elements are joined by:
  - Electron transfer (Ionic bonding)
  - Electron sharing (Covalent bonding)

- Both mechanisms of joining involve electrical forces of attraction between protons (+) and electrons (-).

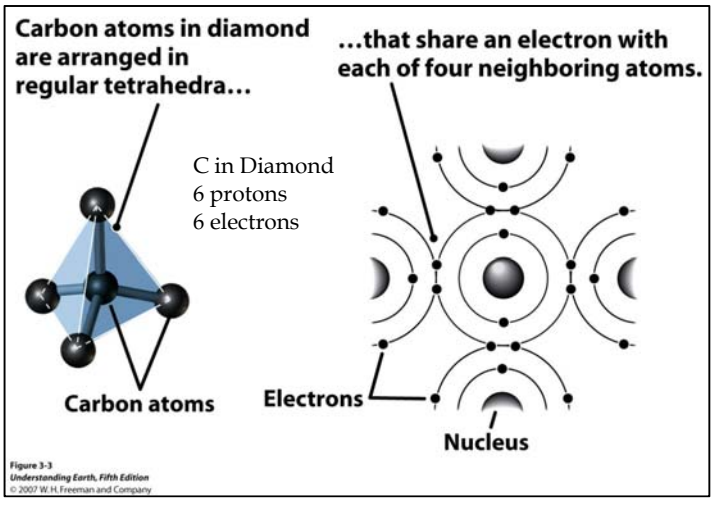
Ionic Bonding – Most Minerals

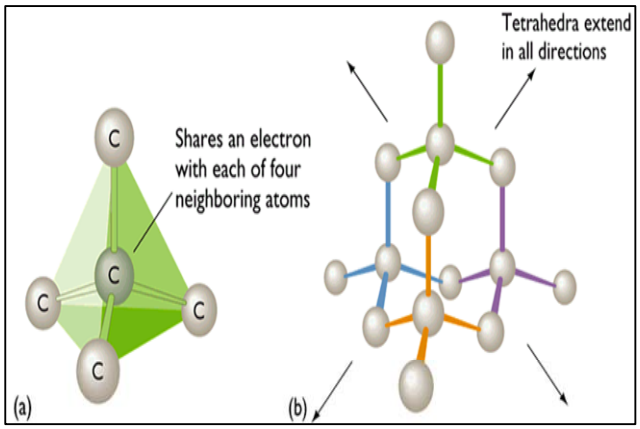




NaCl = Halite (Salt)
Each Na ion is surrounded by 6 Cl ions, and vice versa.

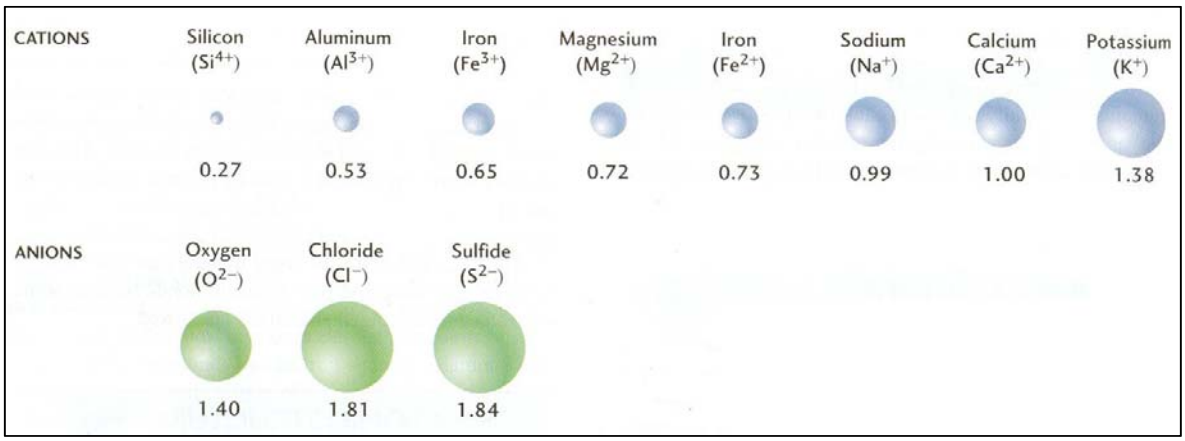
Covalent Bonding – Strongest Bond





Cations and anions

Many of the cations are relatively small; most anions are large.



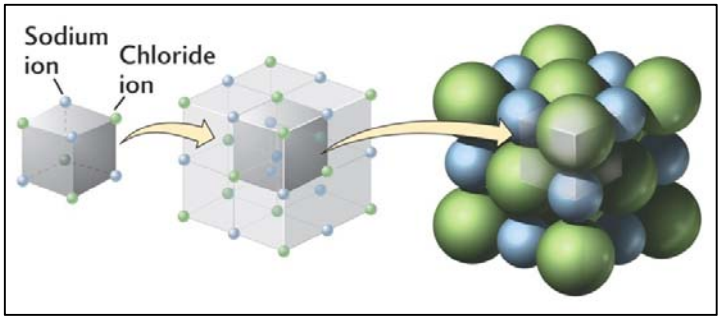
Elements in the Earth's crust:

An atom is the basic unit of an element.

A total of **88** elements occur naturally in the Earth's crust. However, eight elements of them make up more than **98%** of the crust, these are:

Element	wt %
O	46.60
Si	27.72
Al	8.13
Fe	5.00
Ca	3.63
Na	2.83
K	2.59
Mg	2.09
Total	98.59

Crystallization: Atoms continue to join according to bonding relationship.



NaCl = Halite (Salt)

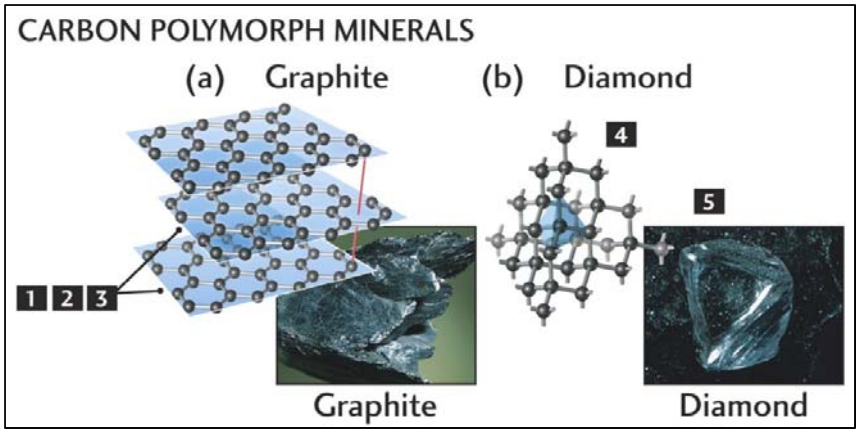
Atomic structure is often reflected in mineral outward appearance – Crystals

How do minerals form?

- Minerals form by the process of **crystallization**, in which the atoms of a gas or liquid come together in the proper chemical proportions and crystalline arrangement.
- Cations of similar sizes and charges tend to substitute for one another and to form compounds having the same crystal structure but differing chemical composition. This is called *cation substitution* (e.g. Mg and Fe in olivine mineral).

What defines the crystal that forms?

Pressure, temperature, elements available and fluids control which minerals will form (or break down).



Polymorphs of carbon (C): same chemical composition, very different form.

Rock-forming mineral groups

The group defined by their anion group:

1. **Silicates - SiO_4^{-4}** (5 structures – quartz, garnet, etc)
2. **Carbonates – CO_3^{-2}** (calcite, dolomite)
3. **Sulfates - SO_4^{-2}** (anhydrite, gypsum)
4. **Halides – Cl^-, F^-, Br^-, I^-** (halite)
5. **Oxides and Hydroxides – O^{-2}, OH^-** (hematite, magnetite)
6. **Native elements** – (gold, copper, sulfur, carbon)
7. **Sulfides – S^{-2}** (pyrite, galena)
8. **Phosphates – PO_4^{-3}** (apatite, monazite)

Physical properties of minerals

They help in identifying minerals:

- Hardness – is a measure of the ease with which the surface of a mineral can be scratched.
  Mohs scale – ability of one mineral to scratch another.
- Cleavage – breaking habit of mineral, along crystal faces.
- Fracture – (e.g., conchoidal as in glass).
- Luster - (e.g., metallic, vitreous, pearly, greasy, …)
- Color – streak test
  - mineral color – usually reflects specific ions like Fe.
- Specific gravity (density) – mineral weight divided by weight of equal volume of water.
- Crystal habit

Hardness

Ease with which the surface of a mineral can be scratched

Mohs Hardness Scale

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

Fingernail (2.5)

Iron nail (4.5)

Glass, Knife blade (5.5)

Streak plate (6.5)

Cleavage

Tendency of the mineral to break along a flat planar surface, mostly along crystal faces.

Weak bonds = good cleavage Characterized by:

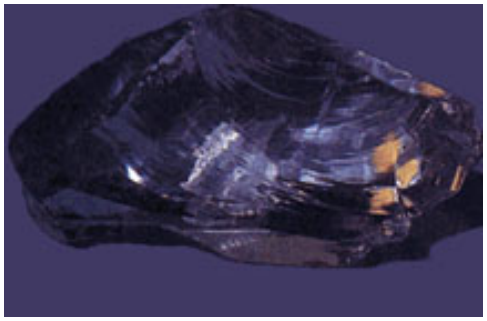
1) number of planes
2) quality of surfaces
3) orientation of planes

Calcite
Rhomboidal Cleavage
3 planes of perfect cleavage

Biotite
1 planes of perfect cleavage

Fracture

The tendency of a crystal to break along irregular surfaces other than cleavage planes (e.g. conchoidal, fibrous, irregular).



Cochoidal Fracture
Quartz

Luster

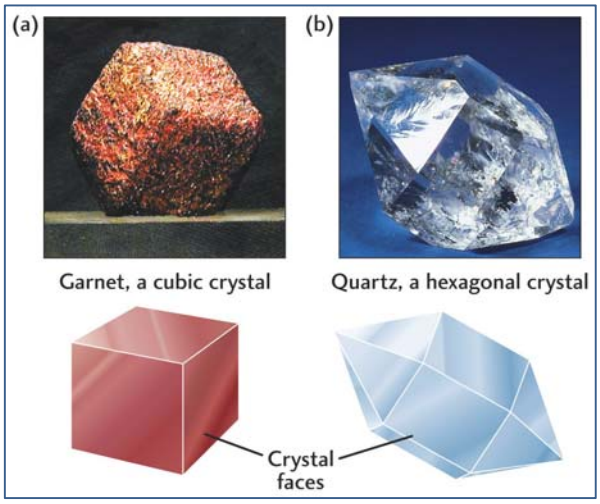
Luster is the way in which the surface of a mineral reflects light to produce the shine of its surface (e.g., metallic, vitreous, pearly, greasy, …).

Streak

Streak is the color of the mineral powder,
or the fine mineral dust left on an abrasive surface.

Crystal Habit

Crystal Habit – is the shape in which a mineral's individual crystals or aggregates of crystals grow.



Specific gravity and density

- Density is mass per unit volume (usually expressed in grams per cubic centimeters).
- Specific gravity is the weight of a mineral divided by weight of equal volume of pure water at 4°C.