Chapter 3
Atoms and Minerals

Earth Materials

Atoms and Elements: Isotopes and Ions
A Review of Chemistry

Atoms
• Atoms are composed of Protons, Neutrons and Electrons
  – A proton has an electric charge of +1 and a rest mass of \(1.67 \times 10^{-24}\) gm.
  – A neutron has a charge of 0 and a rest mass of \(1.67 \times 10^{-24}\) gm. (about the same as a proton).
  – An electron has a charge of -1 and a rest mass of \(9.11 \times 10^{-28}\) gm. (much, much less than a proton).
• The electron mass is negligible relative to protons and neutrons.

Atoms and Elements
• The chemical properties of an element depend on the number of protons (i.e. the net electric charge) of the nucleus.
• The number of protons in the nucleus is known as the atomic number of the element.
• Atomic numbers for natural element range from 1 (hydrogen) to 92 for uranium.

Chemistry
• The chemical reactions an element is capable of is determined by the electron configuration
• Atoms with complete outer shells don't enter chemical reactions (Inert).
• The number of lost electrons (net electric charge) is the valence.

Ions and Valence
• Atoms with 1, 2, 3, or 4 outer electrons may lose them and form positive ions (cations).
• Atoms with 6 or 7 outer electrons may gain electrons to form negative ions (anions).
• The number of lost electrons is the valence.
• The elements are arranged by chemistry into the Periodic Table.
**Ions and Valence**  
*Charge Denoted by Superscript*

- **Cations**
  - $H^+$
  - $Na^+$
  - $Mg^{2+}$
  - $Al^{3+}$
  - $Si^{4+}$

- **Anions**
  - $F^-$
  - $O^{2-}$
  - $S^{2-}$

**Chemical Compounds**

- **Elements occur in integer ratios to maintain charge balance**
  - $H_2$
  - $H_2O$
  - $SiO_2$
  - $CaCO_3$

**Isotopes**

- **The number of protons plus neutrons in the nucleus is known as the mass number of the atom.**
- **Atoms of a given element (atomic number) may have differing numbers of neutrons.**
- **Atoms of the same element with different mass numbers are known as isotopes.**

**Isotopes: Mass number is denoted by a preceding superscript**

- Hydrogen has isotopes $^1H$, $^2H$, $^3H$
- Helium is $^3He$, $^4He$
- K has atomic number 19
- How many neutrons are in the nucleus of $^{40}K$?
- $^{40}K$, $^{87}Rb$, $^{235}U$, $^{238}U$, $^{232}Th$ are naturally occurring radioactive isotopes

**Element Symbols: subscripts and superscripts**

- $H_2$ is a molecule with 2 $H$ atoms
- $H^+$ is an ion of a $H$ nucleus without its electron.
- $^2H$ is an atom of deuterium (an isotope of Hydrogen).
Minerals

- A mineral is a naturally occurring, homogeneous solid of definite chemical composition and ordered atomic arrangement that is usually formed by inorganic processes.
- A Natural Crystalline Phase

Minerals

- A mineral must occur naturally.
- It must be chemically homogeneous down to the atomic level
- It must have a chemical formula (e.g., SiO$_2$, FeS$_2$)
- It must have a defined crystal structure.
- It must be inorganic (not the result of biological processes alone).

Some Familiar Minerals

- Quartz (SiO$_2$)
- Pyrite (FeS$_2$)
- Calcite (CaCO$_3$)
- Gold (Au)
- Silver (Ag)
- Copper (Cu)
- Diamond (C)
- Graphite (C)
- K-feldspar (KAlSi$_3$O$_8$)
- Na-feldspar (NaAlSi$_3$O$_8$)
- Olivine (Mg$_2$SiO$_4$)
- Garnet (Mg$_3$Al$_2$Si$_3$O$_12$)
- Gypsum (CaSO$_4$.2H$_2$O)
- Apatite (Ca$_5$(PO$_4$)$_3$OH)
- Ice (H$_2$O)
- Halite (NaCl) (Salt)

Hydrothermal Gold

Occurrence: Evaporites, Salt Domes
Uses: Table salt, De-icing, Nuclear waste host rock?

Halite NaCl (Salt)

Calcite CaCO$_3$
Ice $H_2O$

Quartz $SiO_2$

Some Non-Mineral Solids
- Obsidian (Glass)
- Opal (Amorphous)
- Coal (Amorphous)
- Wood (Organic)
- Amber (Organic)

Quartz $SiO_2$
- We often display the crystal structure of minerals as polyhedra where the corners of the polyhedra represent oxygen and center is a cation like $Si^{4+}$.

Mineral Properties
- Hardness (Mohs Scale)
- Luster
- Color
- Shape
- Density

Polymorphs
- Same composition - different structure
  - Graphite - Diamond (C)
  - Quartz - Tridymite - Cristobalite - Coesite
  - Calcite - Aragonite ($CaCO_3$)
  - Pyrite - Marcasite ($FeS_2$)
Isomorphs

- Same Structure - Different Composition
  - Olivine (Mg$_2$SiO$_4$) (Fe$_2$SiO$_4$)
  - Calcite - Rhodochrosite (CaCO$_3$) (MnCO$_3$)
  - Apatite (Ca$_5$(PO$_4$)$_3$OH) - (Ca$_5$(PO$_4$)$_3$F)

Rocks are Composed of Minerals

A Rock is an Aggregate of Minerals

- Igneous -
  - Crystallized from melts
  - Surface - Volcanic; Subsurface - Intrusive
- Sedimentary -
  - Deposited from air and water on the surface
- Metamorphic
  - Recrystallized from pre-existing igneous or sedimentary rocks.
### Atoms & Elements Terms
- Proton
- Neutron
- Electron
- Atomic weight
- Atomic number
- Mass Number
- Cation
- Anion
- Valence
- Isotope
- Fusion
- Fission
- Chondrule
- Siderophile
- Atmosphere
- Chalcophile
- Lithophile

### Mineral & Rock Terms
- Mineral
- Crystal
- Hardness
- Luster
- Habit
- Density
- Isomorph
- Polymorph
- Isotope
- Fusion
- Fission
- Chondrule
- Siderophile
- Atmosphere
- Chalcophile
- Lithophile