Geology 284 - Mineralogy, Fall 2008
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Mineralogy and the Development of Modern Chemistry

A Bit of History

- Mineral processing and isolation of elements dates back to 2900 B.C. (gold, silver, bronze (copper-tin alloy))
- Alchemists developed techniques for purifying elements from minerals and studied mineral properties (~1500 B.C.)
- Greeks (Aristotle, Theophrastus and others) debated the nature of matter and came up with the concept of ATOMS (smallest, indivisible building blocks of matter) 400-300 B.C.

History (continued)

- Then there was a big gap….
- Philosophers & theoreticians were isolated from practitioners (ivory tower?)
- Utility of combining theory and practice was realized at beginning of Industrial Revolution
- Big advances in Chemistry and Mineralogy finally began in the 1800s

Elements

- Simple, uncombined chemical substances of which all compounds are made
- Concept of **atoms** revived. **Atoms** consist of:
- **protons** - massive nuclear particles with + charge
- **neutrons** - massive nuclear particles with no charge
- **electrons** - very low mass wave/particles with negative charge, orbit nucleus in elusive **orbitals** (variously shaped areas in which electrons have a high probability of being found)
- Niels Bohr model of atom, 1905, now modified

Filling Electron Orbitals

- Electrons occupy discrete energy levels, each represented by different quantum numbers
- Orbitals are filled in order of increasing energy from inner to outer shells
- Within each shell
- **s** orbitals are filled first

- **p** orbitals are filled next
- **d** orbitals, next
- finally **f** orbitals are filled

The Periodic Table

- It was recognized in about 1870 that if elements are arranged in order of increasing atomic weight, there is a periodic repetition of chemical properties
- Led to arrangement of elements in rows and columns
- And eventually, to the **modern periodic table**

See Handout - WebElements Periodic Table

Atomic and Molecular Weight

- Atomic weight of an atom (A) = number of protons (Z) + number of neutrons (N)
- Atomic weight of an element = weighted average of atomic weights of all its isotopes
- In compounds (molecules, minerals) elements are combined in proportion to their atomic weights

Bonding

- Noble gases are particularly stable because they have completely filled electron shells
- Other elements try to fill their electron shells by "stealing" or sharing electrons, this results in **bonding**
- When an atom gains one or more electrons it becomes a negative **anion**
- When an atom loses one or more electrons it becomes a positive **cation**

Types of Bonding

- Positively charged **cations** attract negatively charged **anions** to form **ionic bonds**
- When electrons are **shared**, the bonds are called **covalent**
- **Metallic bonds** result when loosely bound valence (outer) electrons move freely through-out the structure (are shared among many atoms, not just two as in covalent)

Covalent Bonds

- Occur among identical atoms or those close together on the periodic table
- Are the strongest type of bonds
- therefore form the hardest minerals
- that have the highest melting temperatures

- Are directional - the angle between bonds is controlled by orientation of the shared orbitals

Ionic Bonds

- Occur among atoms that are far apart on the periodic table
- Are weaker than covalent, but stronger than metallic bonds
- Form minerals that are soluble in H_2O
- Are non-directional - anions and cations can be approximated as charged spheres that pack closely together in mineral structures

Metallic Bonds

- Are common in minerals that contain transition metals like Cu, Fe, Au, Zn...
- Are the weakest of the bond types
- therefore metallic minerals are relatively soft
- Because electrons are free to move throughout the structure, metallic minerals are good conductors of electricity

What is a mole?

- One mole of an element is the amount of that element whose weight in grams is equal to its atomic weight
- A mole of any element always contains the same number of atoms: 6.022×10^{23} atoms, called Avogadro's number (A)
- A mole of quartz, which has the chemical formula SiO_2, has
- 1 mole (6.022×10^{23} atoms) of Si 28.086 grams
- 2 moles ($2 \times 6.022 \times 10^{23}$ atoms) of O $\underline{2 \times 15.999 \text{ grams}}$
- Molecular weight of quartz is 60.084 grams
- One mole of quartz contains 6.022×10^{23} molecules of SiO_2