Lecture Notes - Mineralogy - Atoms, Bonding

- It's time to face the fact that minerals are made of atoms. We must consider some of the quantum mechanical aspects of atoms and how they may be bonded to one another to form crystals. Atoms may be thought of as an assemblage of subatomic particles that seems to occupy a very large volume relative to the sizes of the particles themselves. The massive particles (**neutrons** and positively charged **protons**) reside in the tiny center (**nucleus**) of the atom and are surrounded by a large (10^4-10^5 larger in diameter than the nucleus) "cloud" of much smaller particles (negatively charged **electrons**). Protons and neutrons have a mass 1837 times that of electrons. Atoms are identified by the number of protons in the nucleus. Two atoms with the same number of protons, but a different number of neutrons are termed **isotopes**. Atoms in crystals or liquids that do not have the same number of electrons and protons are electrically charged and are called **ions**.

- Electrons moving in the electron cloud are restricted (in terms of probable location) to certain regions of space surrounding the nucleus (**orbitals**) and to certain energy levels. The possibilities are listed in the book and grouped according to principal quantum numbers. The **Periodic Table of the Elements** is constructed from the similarities of the electron configurations of the atoms. All the elements in each row of the Periodic Table have the same principal quantum number. All the elements in the same column of the Periodic Table have a similar type of electron configuration. Atoms tend to form ions that give them the complete electron configuration of one of the inert gases of Group VIII of the Periodic Table. Due to their charge imbalance, ions are either much larger (negative ions) or much smaller (positive ions) than neutral atoms. Compare the **ionic radii** and **atomic radii** of atoms listed on the Periodic Table. The apparent sizes of atoms and ions play an important role in the design of crystal structures.

- Atoms may be held together by electrical forces called **bonds**. Bonds are infinitely variable in character, but may be described in terms of a **resonance** between several end-member types. An **ionic bond** forms when one or more of the electrons from one atom are transferred to outer orbitals of an adjacent atom. The opposite charges of the resulting ions hold the atoms together. The strength of the bond increases with the charges on the ions and decreases with the separation of the two atoms. A **covalent bond** forms when one or more electrons are shared between two adjacent atoms. The bond is purely covalent if there is an equal probability of the electron being found around either atom. If the probability is not equal, then the bond is partially covalent, partially ionic. The percent ionic character of a bond may be estimated from Pauling's **electronegativity** scale. A **metallic bond** forms when a collection of atoms share outer orbal electrons collectively and weakly. A **van der Waals bond** is the weak electrical attraction between two adjacent (neutral) atoms that are slightly **polarized**. Many of the physical properties of minerals depend on the type of bonding in their structure (see Klein & Hurlbut, Table 4.10).

- The minerals that geologists observe in crustal rocks do not begin to encompass the possibilities for inorganic crystals. Our task in using mineralogy to solve geologic problems is much simplified by the fact that only a few types of atoms are common in the crust (see data below taken from *Principles of Geochemistry*, Mason and Moore, 1982). The fact that over 83% of the atoms in the crust are Si and O is responsible for the importance of silicate minerals in geology. The fact that over 93% of the volume of the crust is occupied by oxygen ions will be used to help us understand common crystal structures and many of the chemical variations of minerals.

Element	Weight %	Atom %	Ionic Radius	Volume%
O	46.60	62.55	1.40	93.8
Si	27.72	21.22	0.42	0.9
Al	8.13	6.47	0.51	0.5
Fe	5.00	1.92	0.74	0.4
Ca	3.63	1.94	0.99	1.0
Na	2.83	2.64	0.97	1.3
K	2.59	1.42	1.33	1.8
Mg	2.09	1.84	0.66	0.3
Totals	98.59	100.00		100.0

Readings

Klein and Hurlbut: p. 150-177
Bloss (*Crystallography and Crystal Chemistry*): p.221-258