ATOMS, MOLECULES, MINERALS, CRYSTALS, PERIODIC TABLE

1 Atoms and the Periodic Table

Atoms: Much of the universe is composed of **atoms** and **molecules** which are combinations of atoms. Until recently, atoms were thought of as the smallest particles and that everything else was made up from atoms.

Then sub-atomic particles, smaller than an atom, were discovered over 100 years ago, and it became clear that all atoms were composed of **protons**, **neutrons** and **electrons**. The mass of Protons is m = 1.67 x 10^{-24}g. Neutrons have a similar mass. The Electron mass = m/2000.These were then thought to be the smallest basic particles which made up everything else. But now, it is known that protons and neutrons are made up from even smaller particles. Two of these are known as **quarks** (up quarks and down quarks) which, with electrons, are the basic particles making up all matter.

The simplest atom comprises one proton, which has a +ve electrical charge, and one electron, which has an equal, but -ve electrical charge. So, the simplest atom is electrically neutral and with one proton and one electron with an **atomic number** (AN) of – the number of protons and electrons. This atom is **hydrogen** (H).

The next simplest atom has two protons and two electrons (with electrical neutrality), and one or two neutrons. This is **helium** (He) with AN 2. After that comes atoms with three protons and electrons (**lithium** (AN 3)), then four (**beryllium** (AN 4)), then five (**boron** (AN 5)), six (**carbon** (AN 6)), seven (**nitrogen** (AN 7)) and so on up to 92 protons and electrons (**uranium** (AN 92)). Each different atom is an **element** with a name and number. It is electrically neutral and occurs naturally. Atoms with AN greater than 92 exist, but are man-made (in nuclear reactors). The 3 heaviest metals in order are Osmium, Iridium & Platinum.

Each atom (except H) also contains neutrons in about the same number as the protons and electrons. Specific atoms containing different numbers of neutrons are called **isotopes**. For example, hydrogen normally has no neutrons, but with one it is called **deuterium** and with two it is called **tritium** which are isotopes of hydrogen. Hydrogen comprises about 90% of the universe with Helium 2^{nd}. Caesium & Xenon have 36 isotopes. Caesium is the biggest atom. Atom size is approx. nucleus size x 10,000. [There is a lot of space between the nucleus & the electron shells.]

The structure of atoms comprises the protons and neutrons together as a small mass called the **nucleus** around which the electrons circulate in several **shells**. Each shell can accommodate a particular number of electrons: 2 in shell 1called K, 8 in shell 2/L, 18 in shell 3/M, 32 in shell 4/N, 50 in shell 5/O, 72 in shell 6/P. It is the electrons in the outermost shell of an atom that determine many properties of that atom – including the Valence.

Mole: Oxygen is the standard for atomic weight = 16 A.M.U. The atomic weight in grams is a **mole**. A mole of every element contains the same number of atoms. Called Avagadro's number/constant = 6.02214076 x 10^{23} atoms.

Periodic Table: Different atoms were found to have similar properties and progressively, scientists found it useful to group these together in a way that made use of the similarities. Eventually, a grouping was formed which is known as the **Periodic Table**. This table lists the atoms by atomic number, in rows & columns of atoms with similar properties.

- -**Period** (the horizontal row:) each element has the same number of electron shells.
- -**Group** (the vertical column;) each element has the same number of outer shell electrons.

2 Molecules and Minerals

Valency:
Atoms with full electron shells are stable. Atoms with incomplete electron shells will readily lose electrons or take them from another atom. Such transfer creates + & - ions. So, valency is an atom's capacity to combine with other atoms, due to incomplete (unstable) shells easily losing/gaining an electron between atoms. Also, larger shells do not fill up completely with electrons before starting to fill the next larger shell.

The atoms in the first column of the periodic table (such as sodium Na), have stable electron configurations except for one electron in the outer shell. The atoms in the second last column (such as chlorine Cl), also have stable electron configurations except for a deficiency of one electron in the outer shell. If a Na atom and a Cl atom are close, the outer electron of the Na can move to the outer shell of the Cl. The Na, now missing an electron becomes a positively charged **ion**. The Cl having gained an electron becomes a negatively charged ion. These two ions will be electromagnetically attracted to each other and form a **molecule** by an **ionic bond**. The molecule is sodium chloride **NaC**l, the composition of the mineral **halite**.

Large numbers of other molecules are formed by ionic bonding when electrons transfer between atoms to form stable electron configurations. This is particularly true of atoms in the first and second columns and atoms on the top right of the Table.

Another type of bond occurs when atoms share electrons. For example, carbon has 4 electrons in the L shell, but needs 8 for a stable configuration. One C atom can achieve that stability by sharing each of its' outer 4 electrons with an outer electron of 4 other C atoms. Those other four atoms achieve stability in the same way. This electron sharing, forms very strong **covalent bonds** and is the structure of **diamond,** explaining why this mineral is so hard. The structure of compounds such as SiC, SiO_2 – quartz, the hydrogen molecule H_2, and H_2O are covalently bonded.

A third type of bonding occurs in metals. In the **metallic bond**, the outer electrons cease to be attached to specific atoms but form a "cloud" that circulates through all the atoms. Each atom, having lost the outer electrons, is a positive ion and so is attracted to the cloud of negatively charged electrons by the metallic bond. This explains why metals are good conductors of heat and electricity.

There are several other types of bonding, but most **compounds** and most **minerals** are formed by ionic, covalent or metallic bonds or combinations of those three.

3 Crystals

Minerals can form in only four ways: solidification of a liquid, condensation of a gas, deposition from a solution and transformation of one solid into another. When a mineral forms by one of these processes, the product atoms will mostly be in an orderly, 3-dimensional array and this is called a **crystal** or **crystalline state**. That 3-dimensional array can be one of only seven kinds called the **crystal systems**. We will look at these in a later Topic.

It is far less energetically favourable for a mineral to form with an irregular array of atoms and so there are very few **non-crystalline** minerals.