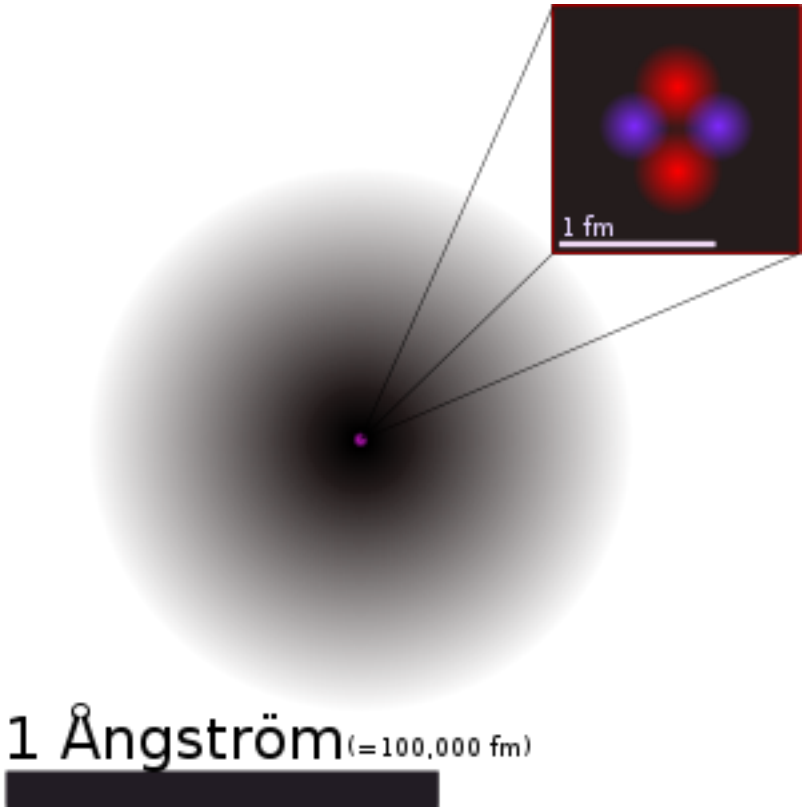
Basic Chemistry of Life

Everything in the universe is composed of two things: matter and energy. We can never detect energy directly. We observe energy through its effects on matter.

Matter is composed of atoms. An **atom** is the smallest particle into which an element can be divided and still have the properties of that element. There are many different types of atoms called **elements**. According to this definition, an atom of gold is different from atoms of any other element. Elements can be combined into **molecules** that are made of two or more atoms. Molecules can be made of the same element or different elements. Oxygen (O_2) in the air is made of two oxygen atoms chemically bonded together. If a molecule is made of atoms from two or more elements, it is called a **compound**. It follows from deductive reasoning that all compounds are molecules but all molecules are NOT compounds.

The helium atom including its electrons is about 1 angstrom in diameter. Its nucleus is about a femtometer (10^{-15} meters)



There are 94 non-synthetic elements (they occur in nature without human intervention. There are more than 25 more elements that are made in research laboratories (mostly in the USA, Germany and Russia... there might be an extraterrestrial intelligence that can also make elements). 99.9% by weight of most living things is made of the six elements: **h**ydrogen, **c**arbon, **n**itrogen, **o**xygen, **p**hosphorus, and **s**ulfur (backwards using just the letter abbreviations this spells SPONCH). Many other elements occur in small (e.g. iron, Fe) or trace (very small) amounts (e.g. copper, Cu).

Atoms are made of protons, neutrons, and electrons. These are sometimes called sub-atomic particles because they are particles that make up atoms. If you have any hope of it stopping there, you will be disappointed. Nature is seldom simple. Protons and neutrons are each made of smaller particles, but that is for another discussion. Happily, electrons are an elementary particle. Elementary particle means (to a physicist) that the particle is made of nothing else…it is what it is.

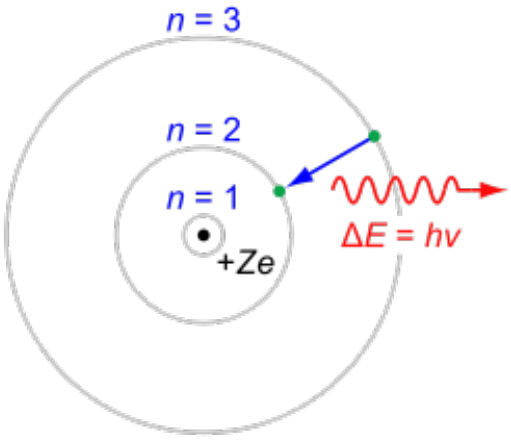
A **Proton** is a positively charged particle with a mass of a little more than one atomic mass unit (the "amu" is explained later).

A **Neutron** has no charge and a mass of a little more than one atomic mass unit (weighs almost the same as a proton).

An **Electron** is a negatively charged particle with an atomic mass of about 1/1800th of a proton…they have such little mass that we usually ignore their masses.

Particles of the same charge will repel each other. Particles with opposite charges…protons and electrons, will attract each other.

Protons and the electrically neutral neutrons make up the center or **nucleus** of an atom and we call them **nucleons** because of where they often are located. The electrons occur in energy levels (sometimes called shells or clouds) moving around the nucleus. Electrons are held in shells by the attraction of oppositely charged protons in the nucleus. Electrons are the creators of light (photons). When electrons are excited to higher levels of energy, they will return to their "ground state" and in doing so give birth to a photon (see figure below). Most of the light we encounter is from this creation.



The **Atomic Number** of an element is the number of protons in the nucleus of an atom of a given element. Since hydrogen has only a single proton in its nucleus, its atomic number is 1. Helium is 2 and Lithium is 3. In a neutral atom, the number of protons is balanced by an identical number of electrons. Therefore, "neutral" atoms have no net charge because the positive protons are balanced by the negative electrons.

The **mass number** (I do not like this term but I have to live with it) of an element is the sum of the protons and neutrons in a nucleus. The total number of nucleons of an atom is the mass number. IT IS NOT THE MASS OF AN ATOM.

The **atomic mass unit,** abbreviated amu, is used for the mass of atoms since they have such small masses that most other units such as grams would be cumbersome. The amu is defined by assigning a mass of 12 to the carbon-12 atom. 1 amu = 1.66054×10^{-24} grams Chemistry. The amu has no units since it is based on $1/12^{th}$ of a carbon-12 isotope.

Isotopes of an element differ in the number of neutrons in the nucleus. For example, hydrogen has 3 naturally occurring isotopes. H-1, H-2 and H-3. H-1 has a mass number of 1 because it has 1 proton. H-2 has a mass number of 2 because it has 1 proton and 1 neutron and H-3 has 1 proton and 2 neutrons. Ice cubes of H-2 will sink in liquid "normal" H-1 water! Would they sink in H-3 water?

Ions are atoms that do not have a balance of charged particles…electrons and protons. The calcium in our bodies is most often found as a divalent cation…very fancy name for an ion with 2 positive charges (written as Ca^{++} or Ca^{2+}. Sodium is often found as a monovalent cation (written as Na^{+}) …1 positive charge. Chlorine exists often as a monovalent anion (written as Cl^{-})

The Periodic Chart has a series of identically sized boxes arranged in rows and columns. Each box has the symbol for that element (first a capital letter and sometimes a lower case letter second). The box will usually include the atomic number of that element and the atomic mass (sometimes called atomic weight). As you read from left to right the atomic numbers increase until the row (called a period) ends. Then you move to the next row and continue on increasing in atomic number. The atomic number is a quick way to find out how many protons an element has because the atomic number is also the number of that element's protons. The simplest element is Hydrogen with one proton. Helium is next with two protons. To find an elements number of neutrons in its most common isotope, subtract its atomic number from it atomic mass rounded to the nearest whole number. For carbon with an atomic number of 6 and an atomic mass of 12.011 round 12,011 to 12 subtract 6 from this number 12. This gives a remainder of 6. Therefore, the most common isotope of Carbon has 6 neutrons.