

HONORS CHEMISTRY – Atomic and Nuclear Structure

I'm sure you're all very familiar with the concepts of electron, proton and neutron. Many students still believe that these three particles alone compose the atom! Others of you may have heard or read about quarks, but don't really have a clear idea how they fit into our understanding of atomic structure. Continued research has shown that the proton and neutron are not truly "elementary" particles. That is, they appear to be composed of yet simpler particles. All evidence about the electron, however, indicates that it is truly elementary.

The uranium nuclide with mass number 238 contains 92 protons and 146 neutrons. These particles are bound tightly in the nucleus. Electrostatic attraction alone would not be enough to prevent the uncharged neutrons from floating away (Why?). Furthermore, because all protons have the same positive charge, electrostatic forces should cause them to fly apart (Why?). Gravitational force, which keeps us at the surface of Earth, is not strong enough to hold the nucleus together. The force that holds the protons and neutrons together in the nucleus is called the **nuclear force**. It is effective for very short distances only (about 10^{-3} picometer, which is equivalent to about one ten-trillionth of a centimeter). This distance is about the same as the diameter of the nucleus, as it turns out. Ideas explaining nuclear structure differ, but scientists do agree on certain facts:

- *Nucleons (protons and neutrons) have a property that corresponds to spinning on an axis*
- *Electrons do not exist in the nucleus, yet they can be emitted from the nucleus*

The particles composing atoms are called **subatomic particles**. Nuclear scientists divide subatomic particles into two broad classes, leptons and hadrons. Current theory holds that **leptons** ("light" particles) are truly elementary particles. The electron is the best known lepton. **Hadrons**, on the other hand, appear to be made of even smaller particles. Neutrons and protons are the best known hadrons.

For every particle, a mirror-image particle called an **antiparticle** exists, or is believed to exist. Thus, there is an antielectron, called a positron, which is like an electron in every way except that it has a positive charge. Positrons are not common. They exist only until they collide with an electron. Such a collision is very likely in our world. When the collision occurs, both particles are destroyed and energy is produced. It is interesting to note that there is at least one particle that is its own antiparticle. This particle is the neutral **pion**.

There are several other leptons. In order to account for a certain kind of nuclear decay, a neutral particle called a **neutrino** was postulated. The neutrino has been identified and found to be essentially massless. The **muon** and the **tau**, both much more massive than the electron, make up the rest of the lepton family. A neutrino has been discovered for the muon and for the tau. There are antiparticles for all of these particles.

The hadrons are subdivided into two groups, the mesons and the baryons. Protons and neutrons are baryons, as are a number of short-lived particles. There are several kinds of mesons.

Mesons and baryons are made of smaller particles called **quarks**. There are six kinds of quarks: "up," "down," "charm," "strange," "top," and "bottom." The names convey nothing about the properties of these quarks. They are just identification labels. Each quark comes in three "colors", red, blue and