16.2: Nuclei and Atoms

Quarks bind together to make protons and neutrons. A proton is composed of two up quarks and a down quark, and a neutron is composed of two down quarks and an up quark. Together, protons and neutrons are called nucleons. Nucleons can themselves bind together to make nuclei. These nuclei are always positively charged, with the total charge depending on the total number of protons. Nuclei are so called because they sit at the nucleus of atoms; an atom is a nucleus that has gathered negative electrons into the various electron states (i.e. orbitals) allowed by the electric potential created by its positive charge. The smallest nucleus is the Hydrogen nucleus, composed of but a single proton; it is about 10^{-15} m across. The largest stable nuclei have a more than 200 nucleons in them. Nuclei with more nucleons than that tend to be unstable, and spontaneously fission into smaller nuclei.

The binding energy— that is, the potential energy that results from combining nucleons together to make nuclei— is an appreciable fraction (1% or so) of the mass energy of the nucleons. The nucleus with the greatest binding energy per nucleon is Iron-56, which makes it (in a sense) the most stable nucleus. You can get energy out by fusing lighter elements together until you get to Iron-56; after that, it costs energy to build up heavier elements.

Of course, in nature, most materials are mostly electrically neutral, at least on Earth. It turns out that most of the baryonic material in space is in the form of plasma (mostly ionized Hydrogen, i.e. free protons and free electrons) filling the void between galaxies inside galaxy clusters. On Earth, though, for the most part if there's a free electron, it will be captured by the first nucleus that comes by with an extra positive charge. Hence, in our everyday experience, all things are composed of atoms. We organize our understanding of the various different types of atoms via the Periodic Table, as was discussed at length in Chapter 15.