20.1: Hadrons and Leptons

The standard model of hadrons and leptons is a united set of quantum mechanical theories encompassing electromagnetism; the weak force, which is responsible for beta decay; and the strong force, which holds atomic nuclei together. Before investigating the standard model, we need to describe the state of affairs previous to its development. The creation of high energy particle accelerators led to the discovery of a plethora of particles in addition to those already known. These particles fall into the following categories:

- Leptons are spin 1/2 particles that do not interact via the strong force. The electron, muon, and the electron and muon neutrinos are examples.
- Hadrons are particles that interact via the strong force. They are divided into two sub-categories depending on their spin:
  - Baryons are hadrons with half-integral spin, mainly 1/2 and 3/2. The proton and neutron are well known examples. The neutral lambda particle is another.
  - Mesons are hadrons with integral spin, mainly 0 and 1. Examples are the pions and kaons.
- Strange particles are baryons and mesons that are unstable, but have much longer half-lives than other particles of similar mass and spin. This is interpreted to mean that such particles possess a property called strangeness that is conserved by strong processes, thus making strange particles stable against strong decay into non-strange particles. However, strangeness is not conserved by weak processes, allowing strange particles to decay via the weak interaction, which indeed is much weaker than the strong interaction at low energies. This explains their anomalously long half-lives. Strange particles are always created in pairs by strong processes in such a way that the total strangeness remains zero. For instance, if one particle has strangeness +1 then the other must have strangeness -1. An example of strange particle production is when a negative pion collides with proton, giving rise to a neutral lambda particle and a neutral kaon.
- Intermediary particles are those that transfer energy, momentum, charge, and other properties from one particle to another in association with one of the four fundamental forces.
  - Photons transmit the electromagnetic force and have zero mass and spin 1.
  - Gravitons are thought to transmit the gravitational force, though they have not been directly observed. The graviton is postulated to have zero mass and spin 2.

  We will discover additional intermediary particles in our discussion of the standard model.
- Antiparticles exist for all particles. These have the same mass and spin but opposite values of the electric charge and various other quantum numbers such as lepton number or baryon number. The lepton number is the number of leptons minus the number of antileptons, with a similar definition for baryon number. Thus, a lepton has lepton number 1 and a baryon has baryon number 1. Their antiparticles have lepton number -1 and baryon number -1. As far as we know, baryon number and lepton number are absolutely conserved, which means that baryons and leptons can only be created or destroyed in particle-antiparticle pairs.[1] Antiparticles are represented by the symbol of the particle with an overbar.