Unit 6. Standard Particle Model of Quantum Mechanics: Inside an Atom

Standard Particle Model of Quantum Mechanics is a mathematical model which explains the particle-wave nature of sub-atomic particles. This model proposed two major groups of elementary particles of matter, ie. Quarks and Leptons. The model also proposed elementary force carriers known as Gauge Bosons (responsible for the forces in nature) and one Higgs Boson. Standard Particle Model explains the matter-energy conversions, with the help of Quarks, Leptons, Gauge Bosons and Higgs Boson.

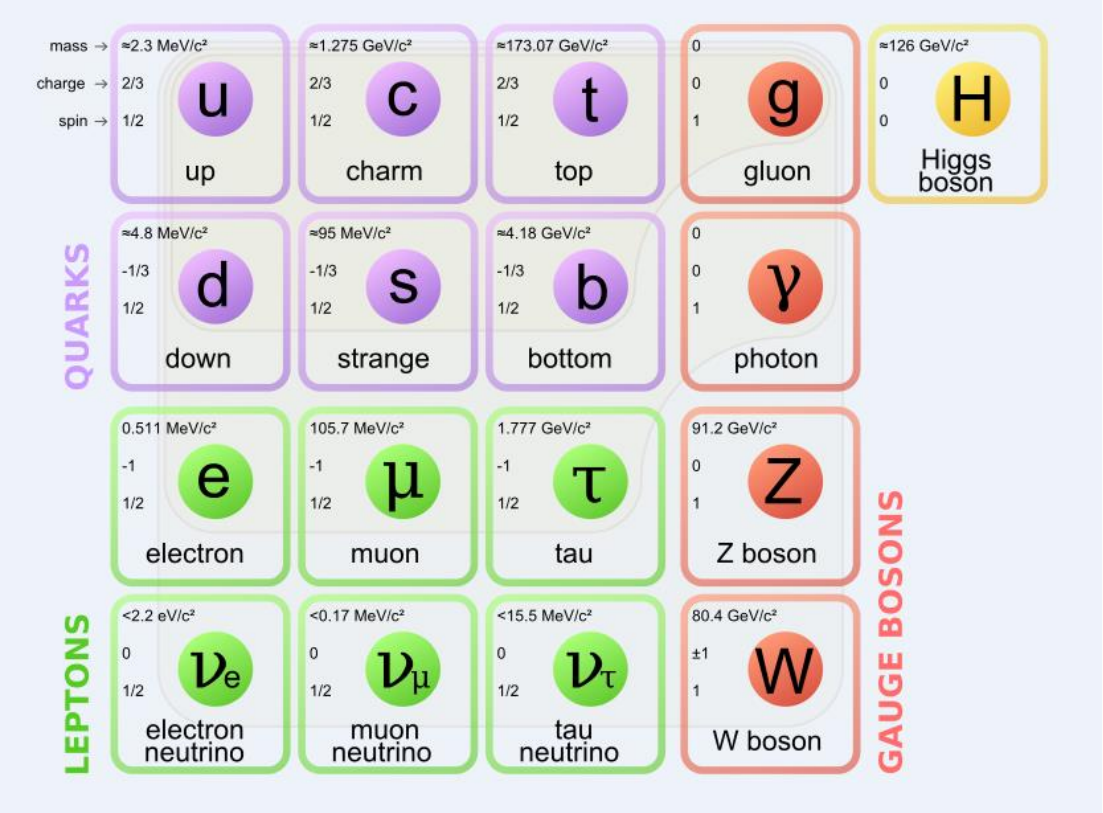
What's inside an atom?

You know about the Protons, Neutrons and Electrons, which make up the atom. Electrons are not further divisible. Electons are one type of elementary particle type under a broad category called Leptons. But what about the particles inside the nucleus, ie.Protons and Neutrons? Are they made up of still smaller particles? Yes, they are composite particles made of elementary particles. These elementary particles are called Quarks.

Elementary (Fundamental) Particles of Matter – Quarks and Leptons

Elementary particles occur in two basic types called quarks and leptons. There are 6 Quark types and 6 Lepton types. Together, Quarks and Leptons are part of a larger class known as Fermions. Fermions have spin like 1/2, 3/2, 5/2 etc. Quarks and Leptons are ***Fermions*** with 1/2 spin.

6 Quarks



Standard Particle Model

1. Up Quark
2. Down Quark
3. Charm Quark
4. Strange Quark
5. Top Quark
6. Bottom Quark

The six quarks are paired in the three generations – the “up quark” and the “down quark” form the first generation, followed by the “charm quark” and “strange quark”, then the “top quark” and “bottom (or beauty) quark”. The lightest and most stable particles make up the first generation, whereas the heavier and less stable particles belong to the second and third generations. All stable matter in the universe is made from particles that belong to the first generation; any heavier particles quickly decay to the next most stable level.

Quarks also come in three different “colours” and only mix in such ways as to form colourless objects.

6 Leptons

1. Electron
2. Electron Neutrino
3. Muon
4. Muon Neutrino
5. Tau
6. Tau Neutrino

The six leptons are similarly arranged in three generations – the "electron" and the "electron neutrino", the "muon" and the "muon neutrino", and the "tau" and the "tau neutrino". The electron, the muon and the tau all have an electric charge and a sizeable mass, whereas the neutrinos are electrically neutral and have very little mass.

Fundamental Forces

1. Gravitational Force – Weakest force; but infinite range. (Not part of standard model)
2. Weak Nuclear Force – Next weakest; but short range.
3. Electromagnetic Force – Stronger, with infinite range.
4. Strong Nuclear Force – Strongest; but short range.

PS : The weak and strong forces are effective only over a very short range and dominate only at the level of subatomic particles. Weak nuclear forces are responsible for radioactivity.

Force Carrier Particles or Bosons

Particles of matter transfer discrete amounts of energy by exchanging bosons with each other. Each fundamental force has its own corresponding boson. Bosons have spin like 0, 1, 2, 3 etc. Bosons can again be divided into Gauge Bosons and Higgs Bosons.

Gauge Bosons (Responsible for energy transfer)

1. Gravitational Force – Graviton (Not part of standard model)
2. Weak Nuclear Force – W and Z bosons (ie W+, W- and Z-0 bosons)
3. Electromagnetic Force – Photon.
4. Strong Nuclear Force – Gluon.

Higgs Boson or God's Particle (Responsible for mass)

The proposed Higgs Boson particle is responsible for the mass of every particle.

How many confirmed elementary particles are there in the standard model?

Name	Types	Generations	Antiparticle	Colors	Total
Quarks	2	3	Pair	3	36
Leptons	2	3	Pair	None	12
Gluons	1	1	Own	8	8

W	1	1	Pair	None	2
Z	1	1	Own	None	1
Photon	1	1	Own	None	1
Higgs	1	1	Own	None	1

Quarks come in 6 flavors and 3 colors, which gives us 18 unique quarks. The leptons come in 6 flavors, but none of which are colored.
Fermions are matter particles. For every particle of matter there is a corresponding antiparticle of antimatter. So there are 18 anti-quarks and 6 anti-leptons.

On to the bosons. Gluons come in 8 color combinations. There are two kinds of W boson, one kind of Z boson, and one kind of photon for a total of 4 electroweak bosons. There is only one kind of higgs boson.

Since bosons aren't matter particles, they have no antiparticle counterparts. There are no "antibosons". I think we're ready to wrap it up. 8 gluons, 4 electroweak, and 1 Higgs gives us 13 bosons in total. So, 48 Fermions + 13 total Bosons = 61 known elementary particles.