The Elementary Particle Masses

Particle	Mass	Status
Higgs Boson	>110 GeV	Predicted
Top Quark	170 GeV	Found
Z Boson	91 GeV	Found
W Boson	80 GeV	Found
Bottom Quark	4.2 GeV	Found
Tauon	1.8 GeV	Found
Charm Quark	1.2 GeV	Found
Strange Quark	120 MeV	Found
Muon	105 MeV	Found
Down Quark	4.0 MeV	Found
Up Quark	2.0 MeV	Found
Tau Neutrino	< 16 MeV	Found
Electron	0.5 MeV	Found
Muon Neutrino	< 0.2 MeV	Found
Electron Neutrino	< 2 eV	Found
Axion	< 1 eV	Predicted
Graviton	0	Predicted
Gluon	0	Found
Photon	0	Found

Most people are familiar with the Periodic Table of the Elements, which summarizes the properties of the 110 known elements starting from Hydrogen. These elements are composed of elementary particles called electrons, protons and neutrons, which combine in various numbers to build up all of the elements.

Since the 1950's, physicists have discovered an even more fundamental collection of particles that seem to be truly elementary, and which combine to produce not only all of the elements, but the very forces that hold them together. The table to the left shows the names of these particles and their mass. Some particles, such as the Higgs Boson are being proposed to exist because some theories require them in order to complete our understanding of how forces and particles interact.

A basic property of a particle is its mass. Because the masses of the fundamental particles are vastly smaller than a gram or a kilogram, physicists use another unit called the electron Volt. This is actually a unit of energy, but because Albert Einstein demonstrated that energy, E, and mass, m, are basically the same things ($E = mc^2$), physicists conveniently state mass as $M = E/c^2$, and then drop the speed-of-light factor c^2 because it is understood to be part of the definition of mass when energy units are used as in the table above. For example, 1 billion electron Volts (1 GeV) are equal to 1.8×10^{-27} kilograms, which is about equal to the mass of a single proton, which is 1.7×10^{-27} kilograms (938 MeV). (Note also that 1 MeV = 1 million electron Volts.)

Problem 1 - What is the mass, in kilograms, of A) An electron? B) A Strange Quark? C) A Top Quark? and D) A Muon?

Problem 2 - A proton consists of two Up Quarks and one Down Quark held tightly together by the strong nuclear force. What is the total quark mass of a proton in A) MeV? B) In kilograms?

Problem 3 - From your answer to Problem 2, what is the mass difference between 1 proton and the combination of the two Up Quarks and one Down Quark in units of A) MeV? B) kilograms?

Problem 4 - An oxygen atom contains a total of 16 protons and neutrons and has a mass of 2.7×10^{-26} kilograms. What is the mass of a Top Quark in terms of the number of oxygen atoms?

Problem 1 - What is the mass, in kilograms, of A) An electron? B) A Strange Quark? C) A Top Quark? and D) A Muon?
Answer:
A) 0.5 MeV x (1 GeV/1,000 MeV) x (1.8 x 10^{-27} kilograms / 1 GeV) = **9.0 x 10^{-31} kilograms.**
B) 120 MeV x (1 GeV/1,000 MeV) x (1.8 x 10^{-27} kilograms / 1 GeV) = **2.1 x 10^{-28} kilograms.**
C) 170 GeV x (1.8 x 10^{-27} kilograms / 1 GeV) = **3.1 x 10^{-25} kilograms.**
D) 105 MeV x (1 GeV/1,000 MeV) x (1.8 x 10^{-27} kilograms / 1 GeV) = **1.9 x 10^{-28} kilograms.**

Problem 2 - A proton consists of two Up Quarks and one Down Quark held tightly together by the strong nuclear force. What is the total quark mass of a proton in A) MeV? B) In kilograms?

Answer: A) 2 Up + 1 Down = 2 x (2 MeV) + 1 x (4 MeV) = **8 MeV**. B) Mass = 8 MeV x (1 GeV/1,000 MeV) x (1.8 x 10^{-27} kilograms / 1 GeV) = **1.4 x 10^{-29} kilograms.**

Problem 3 - From your answer to Problem 2, what is the mass difference between 1 proton and the combination of the two Up Quarks and one Down Quark in units of A) MeV? B) kilograms?

Answer:
A) 938 MeV - 8 MeV = **930 MeV.**
B) Mass = 930 MeV x (1 GeV/1,000 MeV) x (1.8 x 10^{-27} kilograms / 1 GeV) = **1.7 x 10^{-27} kilograms.**

Problem 4 - An oxygen atom contains a total of 16 protons and neutrons and has a mass of 2.7x10^{-26} kilograms. What is the mass of a Top Quark in terms of the number of oxygen atoms?

Answer: From Problem 1C, the Top Quark mass is 3.1 x 10^{-25} kilograms, and so the number of oxygen atoms needed to equal the mass of one Top Quark is 2.7x10^{-26} kilograms / 3.1 x 10^{-25} kilograms is 8.7 or about **9 oxygen atoms**.