Is the Proton Unstable?

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February 2015 (v1) – April 2015 (v5)

Abstract

The problem I shall address in this paper is concerned with the mean lifetimes of the delta minus particle, the neutron and the proton. This research suggests that the proton is unstable with a mean lifetime between 5×10^{34} *and* 7×10^{34} *years, approximately.*

Keywords: *mean lifetime, fine-structure constant, electromagnetic coupling constant, atomic structure constant, baryon, delta minus particle, neutron, proton, electron, u quark, d quark, gluon, Planck's constant, reduced Planck's constant, Planck time, GUT.*

1. Introduction

Before the advent of the Grand Unified Theories (GUTs) (an attempt to unite all the fundamental forces of nature except the gravitational force) physicists used to believe the proton was a stable particle. These theories, which predict the proton decay, have generated considerable doubt about this belief. This investigation also suggests that the proton is an unstable particle. Therefore, should the proton proved to indeed be unstable, the whole universe, as we know it, would have a dramatic and unavoidable end. According to the Hyperphysics web page [1]: *"The lifetime of a decay is proportional to the inverse square of the coupling constant between the initial and final products"*. This can be expressed mathematically as follows

$$lifetime \propto \frac{1}{\alpha^2} \tag{1}$$

It doesn't matter the exact details of this assertion since I shall generalize this law by postulating that the lifetimes of baryons are proportional to the inverse of the *n* power of the electromagnetic coupling constant, α ; where *n* is a positive integer. Mathematically this postulate establishes that

$$mean\ baryon\ lifetime \propto \frac{1}{\alpha^n} \tag{2}$$

2. Nomenclature

I shall use the following nomenclature for the constants and variables used in this paper

α = fine-structure constant, electromagnetic coupling constant, or atomic structure

constant.
c = speed of light in vacuum
e = absolute value of the electric charge of the electron (or the proton).
h = Planck's constant
$\hbar$ = reduced Planck's constant $(\hbar = h/2\pi)$
m_{Δ^-} = delta minus particle rest mass
m_n = neutron rest mass
m_p = proton rest mass
m_e = electron rest mass
τ_{Δ^-} = delta minus particle mean lifetime
τ_n = neutron mean lifetime
τ_p = proton mean lifetime
$F_{JeV} = 1.602\,176\,564 \times 10^{-19}\ J/eV$ = conversion factor from Joules to electron-volts
$F_{S\text{-}year} = 365.25 \times 24 \times 60 \times 60 = 31{,}557{,}600\ S/year$ = conversion factor from seconds to years

3. The Mean Lifetime Formulas

I shall introduced the formulas for the mean lifetimes of the following three baryons:

a) **The delta minus particle** (*ddd*). This particle consists of three *down* quarks *.
b) **The neutron** (*udd*). This particle consists of one *up* quark, two *d* quarks *.
c) **The proton** (*uud*). This particle consists of two *u* quarks, one *d* quark *.

* and a cloud of glouns.
The following table shows the measured mean lifetimes for these baryons.

Particle	Quark content	Electric Charge (e)	Mean lifetime (measured) (S)	Minimum mean lifetime (measured) (S)	Maximum mean lifetime (measured) (S)	Mass (MeV/c^2)
Δ^- (delta minus)	ddd	-1	$5.58 \pm 0.09 \times 10^{-24}$ [2]	5.49×10^{-24}	5.67×10^{-24}	1232 (Heaviest)
n (neutron)	udd	0	885.7 ± 0.8 [3][4]	884.7	886.5	939.565346 (Medium weight)
p (proton)	uud	+1	Stable? (No decays observed)	Infinite?	Infinite?	938.272013 (Lightest)

Table 1: Measured mean lifetime for the delta minus particle and the neutron. As far as the proton is concerned no decays have been observed so far.

The reason I have chosen the above three baryons is because, as we descend in the above table, the quark content differs in only one quark. Because the *d* quark is heavier than the *u* quark, the heaviest baryon in the list is the delta minus particle $(1232\,MeV/c^2)$ and the lightest is the proton $(938.27\,MeV/c^2)$. The formula for the heaviest baryon is the simplest of the three formulas. In this research there are no known rules that allow us to build these formulas from the heaviest particle up, as opposed to the case of the lifetimes of leptons [5]. Despite this lack of rules I made an attempt to describe the lifetimes of the chosen baryons in a similar way. Perhaps the difference is due to the fact that in this paper I have used the mass of each particle instead of the mass of the lightest baryon in the list.

3.1 The Delta Minus Particle Mean Lifetime Formula

The formula for the mean lifetime of the delta minus particle is

$$\tau_{\Delta^-} \approx \frac{1}{12} \frac{\hbar}{m_{\Delta^-} c^2} \frac{1}{\alpha} \tag{3.1-1}$$

3.2 The Neutron Mean Lifetime Formula

Because different authors have published different values for the mean lifetime of the neutron, I have included two different formulas. The first formula for the mean lifetime of the neutron is

$$\tau_n \approx 12 \left(\frac{m_n - m_p}{m_e} \right) \frac{\hbar}{m_n c^2} \frac{1}{\alpha^{12}} \tag{3.2-1}$$

The second formula for the mean lifetime of the neutron is

$$\tau_n \approx 11.391 \left(\frac{m_n - m_p}{m_e} \right) \frac{\hbar}{m_n c^2} \frac{1}{\alpha^{12}} \tag{3.2-2}$$

3.3 The Proton Mean Lifetime Formula

The formula for the mean lifetime of the proton is

$$\tau_p \approx 12 \left(\frac{m_n - m_p}{m_e} \right) \frac{\hbar}{m_p c^2} \frac{1}{\alpha^{12\left(\frac{m_n - m_p}{m_e} \right)}} \tag{3.3-1}$$

Appendix 1 introduces another approximate formula based on the Planck time.

Because the ratio: $\left(\frac{m_n - m_p}{m_e}\right)$ is an extremely important dimensionless quantity it will be denoted by $\rho'_{\text{bar}-lep}$. Then its definition is

$$\rho'_{\text{bar}-lep} \equiv \frac{m_n - m_p}{m_e} \tag{3.3-2}$$

and its inverse, $\rho'_{lep-\text{bar}}$, is defined as

$$\rho'_{lep-\text{bar}} \equiv \frac{m_e}{m_n - m_p} \tag{3.3-3}$$

If we consider the mass of the electrino, the formula for the mean lifetime for the proton turns out to be

$$\tau_p \approx 12\left(\frac{m_n - m_p}{m_e - m_l}\right)\frac{\hbar}{m_p c^2}\frac{1}{\alpha^{12\left(\frac{m_n - m_p}{m_e - m_l}\right)}} \tag{3.3-4}$$

Let us define the lepto-baryonic ratio, $\rho_{lep\text{-}bar}$, as

$$\rho_{lep\text{-}bar} \equiv \frac{m_e - m_l}{m_n - m_p} \tag{3.3-5}$$

The value of this ratio is

$$\rho_{lep\text{-}bar} \approx 0.394\,356\,174$$

Since the lepto-baryonic ratio is part of formula for the lifetime of the proton and also part of the exponent of the lepto-baryonic formula (or exponential formula) for the fine-structure constant [6]:

$$\alpha = 2^{-18\left(\frac{m_e - m_l}{m_n - m_p}\right)} = 2^{-18\rho_{lep\text{-}bar}} \tag{3.3-6}$$

this ratio must be a very important dimensionless quantity in physics and it is worthy to keep it in mind. Now form equations (3.3-4) and (3.3-7) we can write

$$\tau_p \approx 12\left(\frac{m_n - m_p}{m_e - m_l}\right)\frac{\hbar}{m_p c^2}\frac{1}{2^{-18\left(\frac{m_e - m_l}{m_n - m_p}\right)12\left(\frac{m_n - m_p}{m_e - m_l}\right)}} \tag{3.3-7}$$

$$\tau_p \approx 12 \times 2^{12\text{x}18}\left(\frac{m_n - m_p}{m_e - m_l}\right)\frac{\hbar}{m_p c^2} \tag{3.3-8}$$

Formula (3.3-8) is the formula for the lifetime of the proton in terms of the numbers 2, 12 and 18. Finally this formula can be expressed compactly as follows

$$\tau_p \approx \frac{12 \times 2^{216}}{\rho_{lep\_bar}} \frac{\hbar}{m_p c^2} \tag{3.3-9}$$

4. Predicted Mean Lifetimes

The following table shows the mean lifetime formulas for the three chosen baryons and the corresponding predicted values.

Because different authors have published different values for the mean lifetime of the neutron, I have included two different formulas for the this particle. It is worthy to observe that the two formulas for the neutron are very similar and do not have any fundamental differences, except for a minor difference in their numeric factors (12 versus 11.391). I have also included two formulas for the proton. The first one does not include the electrino mass while the second one does (see next page).

Particle	Rest mass (Kg)	Mean lifetime formula	Predicted value of the mean lifetime
Δ^- (Delta minus)	$2.196\,239\times10^{-27}$ $(1232\ MeV/c^2)$	eq. (3.1-1) $$\tau_{\Delta^-} \approx \frac{1}{12}\frac{\hbar}{m_{\Delta^-}c^2}\frac{1}{\alpha}$$	$6.101\times10^{-24}\,S$
n (neutron)	$1.674\,927\,351\,239\times10^{-27}$	Formula 1 eq. (3.2-1) $$\tau_n \approx 12\left(\frac{m_n-m_p}{m_e}\right)\frac{\hbar}{m_n c^2}\frac{1}{\alpha^{12}}$$ Formula 2 eq. (3.2-2) $$\tau_n \approx 11.391\left(\frac{m_n-m_p}{m_e}\right)\frac{\hbar}{m_n c^2}\frac{1}{\alpha^{12}}$$	Formula 1 $933.0956\ S \approx$ $15.55\,min$ Formula 2 $885.741\ S \approx$ $14.762\,min$
p (proton)	$1.672\,621\,777\times10^{-27}$	Formula 1 eq. (3.3-1) $$\tau_p \approx 12\left(\frac{m_n-m_p}{m_e}\right)\frac{\hbar}{m_p c^2}\frac{1}{\alpha^{12\left(\frac{m_n-m_p}{m_e}\right)}}$$ Formula 2 eq. (3.3-4) $$\tau_p \approx 12\left(\frac{m_n-m_p}{m_e-m_l}\right)\frac{\hbar}{m_p c^2}\frac{1}{\alpha^{12\left(\frac{m_n-m_p}{m_e-m_l}\right)}}$$ or equivalently $$\tau_p \approx 12\times2^{216}\left(\frac{m_n-m_p}{m_e-m_l}\right)\frac{\hbar}{m_p c^2}$$	$1.691\times10^{42}\,S \approx$ $5.3585\times10^{34}\,years$ $2.2481\times10^{42}\,S \approx$ $7.1236\times10^{34}\,years$

Table 2: Mean lifetime formulas for the $\Delta(1232)$ particle, the neutron and the proton.

5. Conclusions

This investigation allow us to draw the following conclusions

(1) The predicted lifetimes for both the delta minus particle, $\Delta(1232)$, and the neutron are in agreement with the observed values.

(2) The delta minus particle turned out to be the baryon with the simplest lifetime formula.

(3) The predicted lifetime for the proton, which, according to this formulation is between 5.3585×10^{34} and 7.1236×10^{34} years, is in excellent agreement with the experiments which have been unable to observe the proton decay so far. The failure to observe this decay means that the lifetime of the proton is either infinite or longer than 10^{33} years. The physicist R. Oerter [7] quotes *"...today physicists agree on the fact that no real proton decays have been observed over almost 20 years of experiments. This means that the mean lifetime of the proton is about 7×10^{33} years. This rules out the SU(5) GUT, but not the SO(10) model that is still possible"*. The article entitled *Proton Decay* [8] quotes: *"No events have been observed and a limit on the lifetime has been set to be over 10^(33) years. From this, the most basic GUT has been ruled out."*

(4) The the lepto-baryonic ratios: $\left(\frac{m_e}{m_n - m_p}\right)$ and $\left(\frac{m_e - m_l}{m_n - m_p}\right)$, (or their inverses – the baryo-leptonic ratios) are very important ratios in physics.

(5) Should the proton proved to indeed be unstable, the Universe (that started as a Meta-transformation known as the Big Bang [9]), as we know it, would have a dramatic and unavoidable end.

Thus the GUT's theories, the present formulation and the theory on the electron decay (which I developed in 2012) proposed by the author in another paper [5], support the author's claim that all matter in the Universe is unstable.

Appendix 1
Formula for the Mean Lifetime of the Proton Based on the Planck Time

The formula is

$$\tau_p \approx \frac{T_P}{\alpha^{40}} \tag{A.1}$$

where T_P is the Planck time which is defined as

$$T_P \equiv \sqrt{\frac{hG}{2\pi c^5}} \tag{A.2}$$

The value formula (A.1) yields is

$$\tau_p \approx 5.08 \times 10^{34} \quad \text{years}$$

which is quite close to the value obtained through equation (3.3-1)

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