Is the Proton Unstable?

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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 of about 1.7645×10^{33} *years.*

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

1. Introduction

Until the development of the Grand Unified Theories (GUTs) (an attempt to unite all the fundamental forces of nature except the gravitational force), scientists believed the proton was stable. This analysis indicates that the prediction of the GUT theories about the proton decay could be correct. Therefore, should the proton proved to indeed be unstable, the whole universe, as we know it, would have a drastic unavoidable end.

Let us consider the decays caused by weak and strong forces. The Hyperphysics web page entitled *Decays Caused by Weak and Strong Forces* [1] quotes:

"The lifetime of a decay is proportional to the inverse square of the coupling constant between the initial and final products"

$$lifetime \propto \frac{1}{\alpha^2} \qquad (1)$$

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; where *n* is a positive integer. Mathematically the postulate establishes that

$$mean\ baryon\ lifetime \propto \frac{1}{\alpha^n} \qquad (2)$$

Based on this postulate I shall build the lifetime formulas for the delta particle, the neutron and the proton.

2. Nomenclature

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

α = fine-structure constant (atomic structure constant)
c = speed of light in vacuum
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} = conversion factor from Joules to electron-volts

$$F_{JeV} = 1.602\,176\,564 \times 10^{-19} \frac{J}{eV}$$

$F_{S\text{-}year}$ = conversion factor from seconds to years

$$F_{S\text{-}year} = 365.25 \times 24 \times 60 \times 60 = 31{,}557{,}600 \frac{S}{year}$$

3. The Mean Lifetime Formulas

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

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

The following table shows the measured mean lifetimes for these baryons.

Particle	Quark content	Electric Charge (e)	Mean lifetime (measured) (S) -------------- Reference	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)	-	-	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 (one *d* quark decays into a *u* 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 research I have used the mass of each particle instead of the mass of the lightest baryon in the list. An interesting point to observe is that the factor $12\left(\frac{m_n - m_p}{m_e}\right)$ in the formula for the neutron is the exponent to the fine-structure constant in the formula for the proton.

3.1 The Delta Minus Particle Mean Lifetime Formula

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

$$\tau_{\Delta^-} \approx \frac{1}{12} \frac{\hbar}{m_{\Delta^-} c^2} \frac{1}{\alpha} \qquad (3.1\text{-}1)$$

3.2 The Neutron Mean Lifetime Formula

The formula for the mean lifetime of the neutron is

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

Because different authors have published different values for the mean lifetime of the neutron, I have included two different formulas for this particle in Table 2.

3.3 The Proton Mean Lifetime Formula

The formula for the mean lifetime of the proton is

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

4. Predicted Mean Lifetimes

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

Particle	Mass (Kg)	Mean lifetime formula	Predicted value of the mean lifetime
Δ^- (Delta minus)	$2.196\ 239 \times 10^{-27}$ $\left(1232\ MeV/c^2\right)$	**eq. (3.1-1)** $\tau_{\Delta^-} \approx \frac{1}{12} \frac{\hbar}{m_{\Delta^-} c^2} \frac{1}{\alpha}$	$6.101 \times 10^{-24} S$
n (neutron)	$1.674\ 927\ 351\ 239 \times 10^{-27}$	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 $\tau_n \approx 11.4 \left(\frac{m_n - m_p}{m_e}\right) \frac{\hbar}{m_n c^2} \frac{1}{\alpha^{12}}$	Formula 1 $933.0956\ S \approx 15.55\, min$ Formula 2 $886.44\ S \approx 14.77\, min$
p (proton)	$1.672\ 621\ 777 \times 10^{-27}$	**eq. (3.3-1)** $\tau_p \approx \frac{\hbar}{m_p c^2} \frac{1}{\alpha^{12\left(\frac{m_n - m_p}{m_e}\right)}}$	$5.5677 \times 10^{40} S \approx 1.7645 \times 10^{33}\ years$

Table 2: Mean lifetime formulas for the $\Delta(1232)$ particle, the neutron and the proton. Because different authors have published different values for the mean lifetime of the neutron, I have included two different formulas for 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 vs. 11.4).

5. Conclusions

In summary, we can 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 of the proton of: 1.7645×10^{33} years is in excellent agreement with the GUT theories which predicts a value between 2.9×10^{32} and

7×10^{33} years [6]. (The value depends not only on the specific GUT theory but also on the proton decay mode).

4) Sadly, the Universe (that started as a Meta-transformation known as the Big Bang), as we know it, would have an unavoidable end.

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