A Possibility for Electron Capture in Low-Energy Nuclear Reactions

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Abstract

We explore the possibility of electron capture by protons as a means to trigger low-energy nuclear reactions (LENRs), which could potentially produce neutrons in research settings.

1. Formulation

In this section, we present a calculation of electron capture (EC) based on energy-momentum conservation before and after the EC event. We consider the interaction of EC as follows:

$$p + e \rightarrow n + \nu_e \tag{1}$$

Where a proton p captures an electron e, then a neutron n and a neutrino ν_e is produced. In this calculation, we set a condition before EC that the proton is at rest and the electron moves towards the proton with velocity v. After EC, we set the neutron to be at rest and the neutrino to not be produced. Therefore, we can derive the minimum energy required for EC. The total energy-momentum E before EC is calculated by applying relativistic velocity to the electron and electric potential energy, which is given by:

$$E = m_p c^2 + m_e c^2 \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} + k \frac{e_p e_e}{r} \tag{2}$$

In this equation, m_p represents the mass of a proton, c is the speed of light, m_e is the mass of an electron, k is the Coulomb constant, e_p is the charge of a proton, e_e is the charge of an electron, and r represents the distance of separation between the two particles.

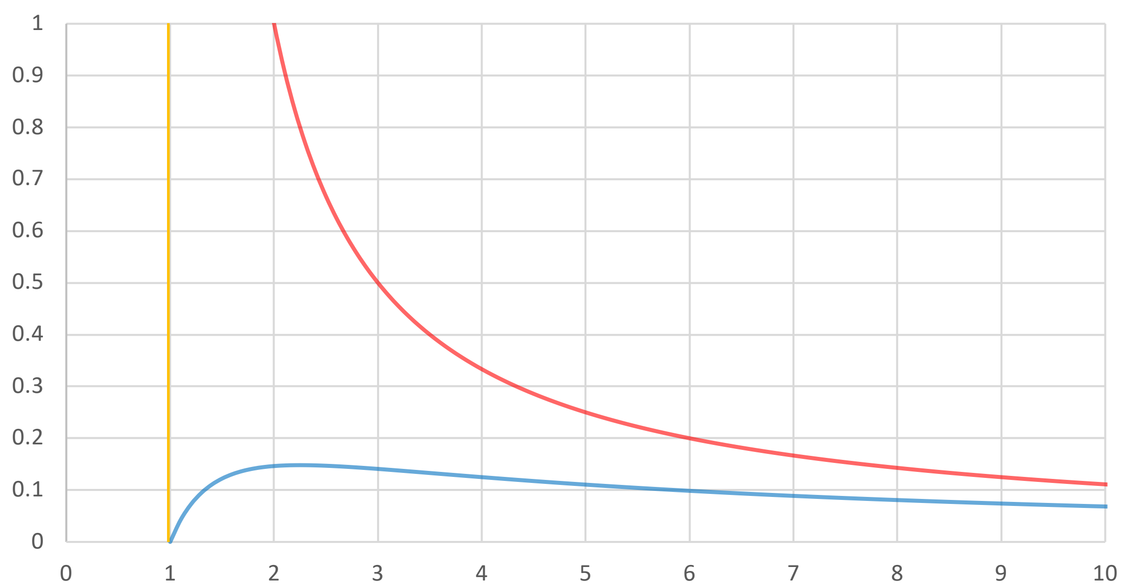
As r approaches zero, the total energy becomes infinite. This infinite problem remains unanswered. To accurately calculate the EC, we cannot ignore this phenomenon. In this paper, we employ a solution for the gravitational potential energy proposed by Fischer [1], which expresses the energy distribution as $\sqrt{1 - r_s/r}$, where r is the distance from the center of the object and r_s is the Schwarzschild radius. We modify equation (2) by replacing the electron radius r_s with the proton radius r_p.

$$E = m_p c^2 + m_e c^2 \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} + k \frac{e_p e_e}{r} \sqrt{1 - \frac{r_p}{r}} \tag{3}$$

2. Energy Distribution Comparison

Before plugging in values to equation (3), we will examine how the energy distribution is affected as shown in Figure 1. We plot the horizontal axis on r, substituting $r_p = 1$, and the vertical axis on the simplified electric potential function $\sqrt{1-1/r}\,/r$ shown in blue, compared with $1/(r-1)$ which is represented in red. As the electron approaches the proton, we observe a significant difference in the potential distribution. The red line exhibits an increasing divergence as it gets closer to the proton's surface, which is depicted by the yellow line. On the other hand, the blue curve shows a decrease in value and approaches zero once it reaches the surface.

Figure 1. Energy Distribution Comparison



3. Calculation

Finally, we input the values into equation (3). Our estimate of the total energy-momentum before EC is equal to the neutron's mass after EC, which we represent as E. To acquire the electron's velocity v that triggers EC, we set neutron mass m_n = 1.6749 * 10^{-27} kg, where $E = m_n c^2$, m_p = 1.6726 * 10^{-27} kg, m_e = 9.1094 * 10^{-31} kg, e_p = 1.60 * 10^{-19} C, e_e = -1.60 * 10^{-19} C, r_p = 1 * 10^{-15} m, k = 9 * 10^{9} N * m^2 / c^2, c = 3 * 10^{8} m / s. We set r = 2.3 * r_p since this value is approximately the maximum potential, as shown in Figure 1.

From this, we obtain $\underline{v = 3.1610 \text{ m / s}}$. It is highly relevant as a Fermi or draft velocity for electrons in cases where LENRs are observed.

References

[1] Ernst Fischer, Does gravitational collapse lead to singularities? https://doi.org/10.48550/arXiv.1303.6528 (2013)