

On Nature of Hyperons

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Abstract

The purpose of this article is to show that a neutron can have excited states. The well known characteristic feature of the Bohr atom is that its electron shell can exist in a stable ground state or in various excited states. These states differ by integer numbers of de Broglie waves filled in their electronic orbits. Considering neutron to be an analog of the Bohn atom [1] differing in relativistic nature of its electron, a question arises on a possibility for neutron to have similar excited states. The calculations of the properties of these states show that two hyperons Λ^0 and Σ^0 which are usually considered as elementary particles, are excited states of neutron.

Keywords

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1. Introduction

The foundation of modern physics was laid during the Middle Ages. Since then, the most important achievements include the postulate or principle of W. Gilbert [2]. This postulate formed the basis of all modern natural sciences and created the basis for the successful development of modern physics.

According to this postulate, all theoretical constructs that claim to be scientific must be verified and confirmed experimentally.

It can be formulated in another way: in theoretical physics, all objects must correspond to experimental data, and, even more important, there cannot be objects whose physical properties are principally immeasurable experimentally.

For religious people, the existence of angels seems quite normal and natural.

Similar constructions are unacceptable for theoretical physics.

Based on the Gilbert postulate, modern scientific society excludes consideration of the objects whose properties are fundamentally immeasurable.

However, the twentieth century left us a legacy of a number of theoretical

constructions that violate this principle [3].

The fallacy of some provisions of particle physics arose provisions the fact that was based on the model of quarks, and the main method of their description was the construction of tables illustrating the quark structure of particles.

The idea that elementary particles consist of quarks is quite attractive and is confirmed by a number of experiments.

On the other hand, construction of particles by quarks with fractional charge is unsatisfactory. Such particles could not be detected experimentally. The confinement model makes them essentially unobservable, which contradicts the Gilbert principle.

Nevertheless, it is still supposed that in order to understand the world of particles, they need to be collected in tables, sorted by the composition of quarks.

At that new immeasurable quarks are introduced into tables to describe new particles: strange quarks, charmed quarks, beauty quarks, which also differ in colors and aroma.

It is important to emphasize that the ability to classify objects of study by constructing some tables of complex structure (for example, decouplets) proves nothing by itself and can not play the role of experimental proof. At least in such a construction it is necessary first to prove the uniqueness of this classification.

Modern quark theory is based on the fundamental quarks of the lower level u and d . They are needed to explain the important property of neutron: its transformation into proton. However, other properties of neutron cannot be explained by fundamental quarks of the lower level.

All this construction is based on the assumption that neutron is an elementary particle. This hypothesis arose at an early stage of the study of atomic nuclei, when the properties of neutron had not yet been studied.

The question of whether the neutron can be considered a fundamental particle was discussed in the physical community repeatedly in the last century and was solved without relying on measurement data.

One of the first attempts to consider the neutron as a composite particle constructed from proton and electron was made by I. E. Tamm [4]. However, this attempt failed for the reason that became obvious now, it is impossible to construct neutron from proton and a nonrelativistic electron.

In order for theoretical consideration to explain the formation of a composite corpuscle possessing the properties of neutron, it is necessary to consider the unification of a proton with a relativistic electron [5] [6].

This model allows calculating with high accuracy all the main parameters characterizing neutron: its magnetic moment, mass and spin. The mechanism of neutron decay does not require a complicated explanation, but the model allows calculating the energy of this decay.

In addition, this approach makes it possible to explain the nature of nuclear forces on the basis of standard quantum mechanics, whereas gluons, mesons and the strong interaction are excluded from consideration (at least for light nuclei) [1] [6].

Additionally, this model predicts the existence of excited states of neutron.

The existence of excited states of the electron shell is a characteristic feature of the Bohr atom model. In describing the excited states of the electron shell of atom, it is assumed that the degree of excitation is determined by how many de Broglie waves of electron fit on the circumference of the electron orbit.

Using the same principle of formation of excited states, it is possible to determine them for neutron. It turns out that among particles currently classified as elementary, there are those that are not, since their parameters correspond to the excited states of neutron.

Let us consider this question in more detail.

2. The Energy of Interaction of Relativistic Electron with Proton

Consider a composite particle in which an electron having a rest mass m_e and a charge $-e$ is moving around a proton in a circle of radius R_e with a speed $v_e \rightarrow c$ (Figure 1).

Since we initially assume that the motion of the electron is likely to be relativistic, it is necessary to take into account the relativistic effect of the growth of its mass:

$$m_e^* = \gamma m_e, \quad (1)$$

where the relativistic factor

$$\gamma = \frac{1}{\sqrt{1 - \beta_e^2}} \quad (2)$$

and $\beta_e = \frac{v_e}{c}$.

The rotation of the heavy electron m_e^* does not allow considering the proton as at rest. The proton will also move, revolving around the center of mass common with the heavy electron.

Let's introduce a parameter characterizing the ratio of the mass of a relativistic electron to the mass of proton:

$$g = \frac{\gamma m_e}{M_p / \sqrt{1 - \beta_p^2}}. \quad (3)$$

Since the ratio of orbit radii is inverse to the ratio of particle masses we get

$$\frac{R_p}{R_e} = g \quad (4)$$

and radii of orbits of the electron and proton can be written as:

$$R_e = \frac{R_{ep}}{1 + g}, \quad R_p = \frac{R_{ep} g}{1 + g}. \quad (5)$$

where $R_{ep} = R_e + R_p$.

The relativistic factor characterizing the electron in this case is equal to

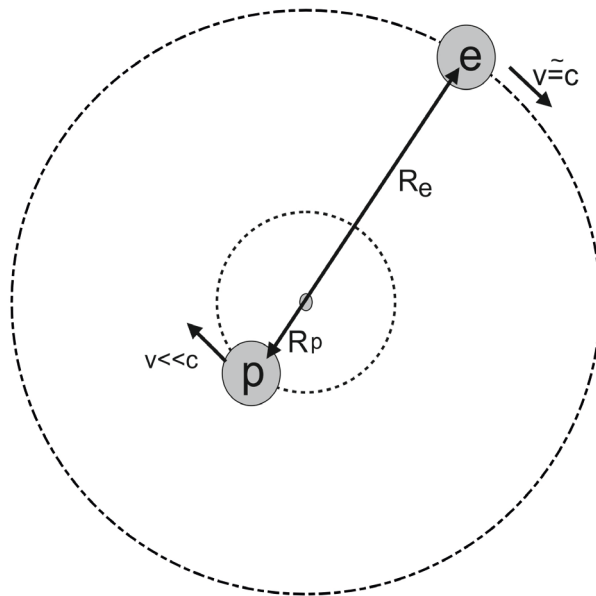


Figure 1. A system consisting of a proton and a heavy (relativistic) electron, revolving around a common center of mass.

$$\gamma = \frac{g}{\sqrt{1-g^2}} \frac{M_p}{m_e}. \tag{6}$$

In accordance with Larmor theorem [7], a rotating proton is affected by magnetic field. The magnitude of this field is determined by proton gyromagnetic ratio. The influence of this field will cause the magnetic moment of proton to be oriented perpendicular to the plane of rotation. In other words, due to the interaction with this field, the electron must rotate in the plane of the “equator” of the proton.

2.1. Quantization of Equilibrium Orbit

It can be assumed that, as in the formation of a stable orbit in a hydrogen atom, the orbit of a relativistic electron will be stable if an integer number of de Broglie wavelengths λ_{dB} fits on the circumference of the electron ring $2\pi R_e$, that is:

$$2\pi R_e = n\lambda_{dB}. \tag{7}$$

where n is integer number and

$$\lambda_{dB} = \frac{2\pi\hbar}{\gamma m_e c}. \tag{8}$$

That is, in accordance with this assumption, the stability condition of the electronic orbit takes the form:

$$\frac{r_c}{R_e} = \frac{g}{n\sqrt{1-g^2}} \frac{M_p}{m_e} = \frac{\gamma}{n} \tag{9}$$

where $r_c = \frac{\hbar}{m_e c}$ is Compton radius.

2.2. The Kinetic Energy of the System of Relativistic Electron + Proton

The kinetic energy of a relativistic electron is expressed by the equality:

$$\mathcal{E}_{kin}^e = (\gamma - 1) \cdot m_e c^2 \quad (10)$$

Due to the assumption of the electron to be ultrarelativistic

$$\mathcal{E}_{kin}^e \approx \gamma \cdot m_e c^2 \quad (11)$$

In this case, the centrifugal force acts on the electron:

$$\mathcal{F}_1 = \gamma m_e [\omega [\omega, R_e]] = \frac{\gamma m_e c^2}{R_e} \quad (12)$$

The kinetic energy of the proton is equal to:

$$\mathcal{E}_{kin}^p = \left(\frac{1}{\sqrt{1 - \vartheta^2}} - 1 \right) \cdot M_p c^2 \quad (13)$$

2.3. The Coulomb Interaction in the System of Relativistic Electron + Proton

The energy of Coulomb attraction between a proton and a relativistic electron is proportional to the relativistic factor γ [7], §24:

$$\mathcal{E}_C = -\gamma \frac{e^2}{R_{ep}} = -\gamma \frac{\alpha r_c}{R_e (1 + \vartheta)} m_e c^2. \quad (14)$$

where $\alpha = \frac{e^2}{\hbar c}$ is the fine structure constant.

Therefore, the Coulomb attraction force acting between these particles is equal to

$$\mathcal{F}_2 = -\gamma \frac{e^2}{R_{ep}^2} = -\gamma \frac{\alpha}{(1 + \vartheta)^2} \frac{r_c}{R_e} \frac{m_e c^2}{R_e}. \quad (15)$$

2.4. The Magnetic Interaction of a Rotating Relativistic Electron

2.4.1. Magnetic Energy of the Electron Current Ring

An additional contribution to the kinetic energy of the system is made by the magnetic energy of a rotating electron.

The energy of the magnetic field created by the rotation of electron tends to break the ring of electron current. This energy depends on the magnitude of the magnetic flux in the ring Φ and the current J which creates it:

$$\mathcal{E}_\Phi = \frac{\Phi J}{2}. \quad (16)$$

Due to the fact that the electron orbit is quantized, the magnetic flux penetrating the ring of radius R_e should be equal to the magnetic flux quantum

Φ_0

$$\Phi = \Phi_0 = \frac{2\pi\hbar c}{e}. \tag{17}$$

By definition the magnetic flux in the ring is determined by the current J_0 and the area of the ring S_0 :

$$\mu_0 = J_0 \cdot S_0 \tag{18}$$

i.e.

$$\mathcal{E}_{\Phi_e} = \frac{e^2}{R_e} \frac{1}{2\alpha} \frac{r}{R_e} = \frac{1}{2n} \frac{g}{\sqrt{1-g^2}} \cdot M_p c^2. \tag{19}$$

The force arising at the same time, tending to break the current ring, turns out to be equal

$$\mathcal{F}_3 = \frac{\gamma}{2n} \frac{m_e c^2}{R_e}. \tag{20}$$

The magnetic energy created by the rotation of a proton is much less:

$$\mathcal{E}_{\Phi_p} = \frac{\sqrt{2} \cdot g^2}{\sqrt{1-g^2}} \cdot M_p c^2. \tag{21}$$

The force corresponding to this energy is applied to proton and does not directly affect the electron equilibrium orbit.

2.4.2. Interaction of Electron with Magnetic Field of Proton

In the present case a proton possesses two magnetic moments. This is its own internal magnetic moment:

$$\mu_p = \frac{\xi e \hbar}{2M_p c} \tag{22}$$

and the orbital magnetic moment which occurs due to the fact that proton rotates in an orbit of radius R_p :

$$\mu_{0p} = \frac{e g R_p}{2} \tag{23}$$

Therefore, the energy of interaction of rotating electron with the proton magnetic field consists from two components:

$$\mathcal{E}_\mu = \pm \frac{\gamma e}{2R_e^2} (\mu_{0p} - \mu_p). \tag{24}$$

In order for the system energy to be less, the magnetic moments μ_p and μ_{0p} must be oppositely directed. But the total contribution of the energy of this interaction can be either positive or negative. It depends on the direction of electron rotation relative to the orientation of the proton magnetic moment. Therefore, in the future, when solving these equations, it will be necessary to take into account both options with different signs.

The force that acts on the rotating electron can be written as:

$$\begin{aligned}\mathcal{F}_4 &= \pm \gamma e \beta \left(\frac{\mu_{0p}}{R_e^3} - \frac{\mu_p}{R_{ep}^3} \right) = \pm \gamma e \left(\frac{\mu_{0p}}{R_e^3} - \frac{\mu_p}{R_e^3 (1+g)^3} \right) \\ &= \pm \gamma \frac{m_e c^2}{R_e} \left(\frac{g^2}{2} - \frac{\xi}{(1+g)^3} \frac{g}{2n\sqrt{1-g^2}} \right) \frac{g}{2n\sqrt{1-g^2}} \alpha \frac{M_p}{m_e}.\end{aligned}\quad (25)$$

where $\xi \approx 2.79$ is the proton magnetic moment expressed in Bohr magnetons.

The magnetic moment of electron is not considered because, as will be shown below, the generalized momentum (spin) of the electron orbit is equal to zero and there is no direction for the selected orientation of the electron magnetic moment in the system.

3. Equilibrium Electron Orbit

The equilibrium condition for the electron orbit is:

$$\sum_{i=1}^4 \mathcal{F}_i = 0. \quad (26)$$

At summing of Equation (12), Equation (15), Equation (20) and Equation (25) after simplifying transformations taking into account Equation (9) we get:

$$1 + \frac{1}{2n} - \left(\frac{g}{n\sqrt{1-g^2}} \frac{\alpha M_p}{m_e} \right) \left[\frac{1}{(1+g)^2} \pm \left(\frac{g^2}{2} - \frac{\xi}{2n(1+g)^3} \frac{g}{\sqrt{1-g^2}} \right) \right] = 0. \quad (27)$$

The double sign \pm before the last term on the left side of this equality is explained by the fact that the direction of this force depends on the direction of rotation of relative to the magnetic field created by the magnetic moment of proton.

To find the electron orbit with minimum energy, the solution of this equation with respect to g must be carried out for each directions of the electron rotation.

3.1. The State with $n = 1$

Under this condition, one needs to find a solution to the equation:

$$\begin{aligned}1 + \frac{1}{2} - \left(\frac{g}{\sqrt{1-g^2}} \frac{\alpha M_p}{m_e} \right) \left[\frac{1}{(1+g)^2} \right] \\ - \left(\frac{g}{\sqrt{1-g^2}} \frac{\alpha M_p}{m_e} \right) \left[\frac{g^2}{2} - \frac{\xi}{2(1+g)^3} \frac{g}{\sqrt{1-g^2}} \right] = 0.\end{aligned}\quad (28)$$

As a result, the solution of this equation is

$$g = 0.1991. \quad (29)$$

3.2. The State with $n = 2$

Under this condition the equation is

$$1 + \frac{1}{2 \cdot 2} - \left(\frac{g}{2\sqrt{1-g^2}} \frac{\alpha M_p}{m_e} \right) \left[\frac{1}{(1+g)^2} \right] + \left(\frac{g}{2\sqrt{1-g^2}} \frac{\alpha M_p}{m_e} \right) \left[\frac{g^2}{2} - \frac{\xi}{2 \cdot 2(1+g)^3} \frac{g}{\sqrt{1-g^2}} \right] = 0. \tag{30}$$

The solution to this equation is

$$g = 0.263. \tag{31}$$

3.3. The State with $n = 3$

At that the equation is

$$1 + \frac{1}{2 \cdot 3} - \left(\frac{g}{3\sqrt{1-g^2}} \frac{\alpha M_p}{m_e} \right) \left[\frac{1}{(1+g)^2} \right] - \left(\frac{g}{3\sqrt{1-g^2}} \frac{\alpha M_p}{m_e} \right) \left[\frac{g^2}{2} - \frac{\xi}{2 \cdot 3(1+g)^3} \frac{g}{\sqrt{1-g^2}} \right] = 0 \tag{32}$$

and its solution is

$$g = 0.479. \tag{33}$$

4. The Particle Magnetic Moment

The particle magnetic moment is the sum of the proton magnetic moment and magnetic moments of orbital currents of electron and proton.

The total magnetic moment generated by of both circular currents

$$\mu_0 = -\frac{e\beta_e R_e}{2} + \frac{e\beta_p R_p}{2} = \frac{eR_{ep}}{2} \frac{(1-g^2)}{(1+g)} = \frac{eR_{ep}}{2} (1-g). \tag{34}$$

If to express this moment in the magnetons of Bohr μ_B , we get

$$\xi_0 = \frac{\mu_0}{\mu_B} = -\frac{(1-g^2)\sqrt{1-g^2}}{g^2}. \tag{35}$$

Thus, the magnetic moment of the electron orbit:

$$\mu_0 = \left[-\frac{(1-g^2)\sqrt{1-g^2}}{g} \right]. \tag{36}$$

Summing it with the proton magnetic moment, we get

$$\mu_{total} = \left[-\frac{(1-g^2)\sqrt{1-g^2}}{g} + 2.79 \right]. \tag{37}$$

These values at different g are shown in **Table 1**.

It should be noted that the magnetic moment of Σ^0 -hyperon in [8] is designated as the transition moment of $\mu_{\Sigma\Lambda}^0$.

5. Mass of Particles

The mass of a composite particle is determined by the sum of the rest masses of

Table 1. Comparison of calculated values of magnetic moments with measurement data.

n	\mathcal{G}	μ_0	μ_{total}	experimental	Ref.
		Equation (36)	Equation (37)	data	
$n = 1$	0.1991	-4.727	-1.9367	$\mu_{\Lambda_0} = -1.9130427 \pm 0.0000005$	[8]
$n = 2$	0.263	-3.4147	-0.6247	$\mu_{\Lambda_0} = -0.613 \pm 0.004$	[8]
$n = 3$	0.479	-1.4121	1.3779	$\mu_{\Sigma\Lambda} = 1.61 \pm 0.08$	[8]

the particles, their relativistic kinetic energy and the mass defect arising from the potential energy of their internal interaction. Calculate these contributions.

5.1. Kinetic Energy of Electron and Proton

Summing Equations (11), (13), (19) and (21) we obtain

$$\mathcal{E}(kin) = \frac{\mathcal{G}}{\sqrt{1-\mathcal{G}^2}} \left[1 + \left(\frac{1}{\sqrt{1-\mathcal{G}^2}} - 1 \right) \frac{\sqrt{1-\mathcal{G}^2}}{\mathcal{G}} + \left(\frac{1}{2n} + \sqrt{2}\mathcal{G} \right) \right] \cdot M_p c^2 \quad (38)$$

5.2. Potential Energy of Electron and Proton

Summing Equations (14) and (24) we obtain

$$\mathcal{E}(pot) = \frac{\alpha M_p}{nm_e} \left[\frac{1}{1+\mathcal{G}} - \frac{\mathcal{G}^2}{2} \left(1 - \frac{1}{(1+\mathcal{G})^3} \cdot \frac{\xi}{n \cdot \mathcal{G} \sqrt{1-\mathcal{G}^2}} \right) \right] \left(\frac{\mathcal{G}}{\sqrt{1-\mathcal{G}^2}} \right)^2 \cdot M_p c^2. \quad (39)$$

5.3. Neutron and Hyperon Masses

The total mass of proton and electron at taking in to account their energies:

$$\begin{aligned} M_{total} &= m_e + M_p + \frac{\mathcal{E}(kin)}{c^2} - \frac{\mathcal{E}(pot)}{c^2} \\ &= m_e + M_p + \frac{\mathcal{G}}{\sqrt{1-\mathcal{G}^2}} \left[1 + \left(\frac{1}{\sqrt{1-\mathcal{G}^2}} - 1 \right) \frac{\sqrt{1-\mathcal{G}^2}}{\mathcal{G}} + \left(\frac{1}{2n} + \sqrt{2}\mathcal{G} \right) \right] \cdot M_p \\ &\quad - \frac{\alpha M_p}{nm_e} \left[\frac{1}{1+\mathcal{G}} - \frac{\mathcal{G}^2}{2} \left(1 - \frac{1}{(1+\mathcal{G})^3} \cdot \frac{\xi}{n \cdot \mathcal{G} \sqrt{1-\mathcal{G}^2}} \right) \right] \left(\frac{\mathcal{G}}{\sqrt{1-\mathcal{G}^2}} \right)^2 \cdot M_p \end{aligned} \quad (40)$$

This formula allows us to calculate masses of particles in question as a function of the parameter n . The results of calculations are summarized in **Table 2**.

The sum of kinetic and potential energy thus obtained must correspond to the energy released during the decay of the particle. For the neutron, this estimate is in qualitative agreement with the measured data.

6. Spin Particles

Since in the relativistic case the vector-potential takes the form [7], §24:

$$A = \gamma(A' + \beta\varphi'), \quad (41)$$

Table 2. The comparison of calculated particle mass values with measurement data.

n	$\frac{\mathcal{E}_{kin}}{c^2}$	$\frac{\mathcal{E}_{pot}}{c^2}$	M_{total}	experimental	$\Delta = \frac{M_{exp} - M_{calc}}{M_{exp}}$
				Equation (40)	
$n = 1$	$702m_e$	$700m_e$	$1839m_e$	$M_{n_0} = 1837m_e$	0.001
$n = 2$	$879m_e$	$778m_e$	$1938m_e$	$M_{\Lambda^0} = 2183m_e$	0.11
$n = 3$	$2103m_e$	$1740m_e$	$2200m_e$	$M_{\Sigma^0} = 2335m_e$	0.06

the force that acts on the charge of a relativistically rapidly rotating particle can be represented as:

$$F_e = \gamma e \cdot rotA, \tag{42}$$

and as a result, taking into account the Equation (37) to obtain a condition for the generalized momentum of the particle

$$P_0 = \gamma mc + \gamma \frac{e}{c} A = 0. \tag{43}$$

Thus, in the case under consideration, the moment of the generalized momentum of rotating particles

$$S_0 = [R_e, P_0] = 0. \tag{44}$$

For this reason, the total spin of the particles in question is 1/2 because it is created by the spin of the proton.

A detailed computation of neutron spin is considered in [1] [6].

7. Conclusions

It should be emphasized that the above estimates of the basic parameters of the corpuscles under consideration are obtained in a simple and usual way. They do not contain any hidden fitting parameters. The agreement that the calculated parameters show when compared with the corresponding measured values leads to important conclusions.

As a consequence, neutron, Λ^0 - and Σ^0 -hyperons (as well as π -mesons and μ -mesons [9]), cannot be considered elementary particles, as it is commonly thought at present.

There is no need to introduce strange quarks to describe Λ^0 - and Σ^0 -hyperons (just as there is no need to introduce basic u and d quarks to describe neutron decay [1] [6]).

The exclusion of hyperons, as well as mesons and neutrons, from the table of elementary particles deconstructs these tables, built on the hypothesis of the existence of quarks with a fractional charge, thus destroys the hypothesis of the existence of the baryon decuplet because it included Σ^0 -hyperons.

It can be assumed that many other particles like Σ^+ and Σ^- are also not elementary particles, but are short-living excited states of other constituent corpuscles.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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