



On the beta decay of of ^{11}C and ^{15}O nuclei

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Abstract The ground state of ^{11}C (^{11}B) can be interpreted as a $1p_{3/2}$ neutron (proton) hole coupling with the ground state and first excited state of ^{12}C . The same interpretation can be used for the ground states of ^{15}O and ^{15}N with a hole coupling with the ground state of ^{16}O . In this study, we report the analysis of the β^+ -decay of the ^{11}C and ^{15}O nuclei using the one-hole nucleus model. Additionally, we provide an empirical approach for quenching the axial-vector coupling constant for the beta decay of nuclei.

1 Introduction

Beta decay is one of the types of radioactive decay of unstable nuclei and plays an important role in nuclear astrophysics. The mechanism of this process is described in the literature (see [1, 2] and references therein). The studies of nuclear beta decay offer information essential for nuclear spectroscopy. It is well known that the capture of an atomic electron is a competing decay branch of any nucleus that decays by positron emission. The fundamental conservation laws are upheld during beta decay, and we also observe the lepton number conservation principle in this process. In light of this, one can observe the emission of an electron (positron) and an antineutrino (neutrino) in addition to the daughter nucleus. In Fermi theory [3], it is demonstrated that the energy is allocated among the daughter nucleus, the electron (positron), and the neutrino (antineutrino). One can neglect the kinetic energy of the daughter nucleus, assuming that the energy is shared between the electron (positron) and antineutrino (neutrino) [1].

Currently, the *ab initio* method is used to describe the states of light atomic nuclei and provides excellent results for systems consisting of three or four nucleons. However, for more complex systems, additional modifications are needed. The structure and behavior of light nuclei have been successfully described by *ab initio* approaches in nuclear physics. Recently, studies have started to appear that use the *ab initio* method to calculate the beta decay of light nuclei, such as ^6He [4], as well as neutron-rich heavy nuclei [5] for analysis of *r*-process nucleosynthesis. Additionally, the no-core *ab initio* shell model is employed when discussing various nuclear properties [6]. The *ab initio* method requires powerful computational resources, which makes it less accessible compared to shell models. Therefore, employing simpler methods that yield acceptable results and offer a clear physical understanding of the processes being studied is quite justified. One such method involves using hole states in nuclei, a technique that has been well-established in nuclear physics for a long time [2, 7, 8].

The radius of the weak interaction is much smaller than the size of a nucleon or the diameter of an atomic nucleus. As a result, when describing beta decay in nuclei, the weak interaction potential can be treated as a zero-range potential. This approach simplifies calculating the beta decay of the nucleus. There are challenges during the analysis of the transition matrix element, since the nuclear wave functions of the parent and daughter nuclei are computed using different nuclear models. As a result, distinct $\log ft$ and half-life values are calculated for each nucleus. The ^{11}C lacks one neutron to fill the $3/2^-$ subshell, as does the ^{15}O for the $1/2^-$ subshell. As a result, these nuclei are commonly referred to as nuclei with a single-hole relative to the closed subshell. For all such nuclei, the spin and parity are determined by the moment and parity of the “missing” nucleon, i.e., the moment and parity of the hole, which is confirmed by experimental results. In such scenarios, considering a hole in the nucleus rather than a many-nucleon system simplifies the problem because computing the wave function for the many-nucleon system is more complex than calculating the hole wave function. Furthermore, the computed magnetic moments in the single-particle approximation closely match the measured data. During the beta decay of ^{11}C and ^{15}O , the daughter nuclei, ^{11}B and ^{15}N , are formed, exhibiting holes too. Here, beta decay can be interpreted as the transformation of a “neutron hole” in the parent nuclei into a “proton hole” in the daughter nuclei, accompanied by the emission of a positron and neutrino. It should be emphasized that with this interpretation, we do not utilize the isotopic formalism. Several investigations have been conducted on the beta decay of ^{11}C [9–16] and ^{15}O [17–23] nuclei. Behrens et al. [12] considered ^{11}C and ^{11}B consisting of a core formed by ^4He nucleus and a cloud of seven $1p_{3/2}$ nucleons

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