β^--decay half-life study for $f_{5/2}pg_{9/2}$ shell nuclei

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Introduction

The study of beta decay is essential for modeling astrophysical events such as stellar core collapse because residual nucleon interactions significantly influence electron capture rates. Even mass copper[1–5] isotope beta decay and their corresponding zinc daughter nuclei studies are vital to the researcher when evaluating the validity of shell model predictions and change of structure of nuclei around the nuclei ^{73}Zn and ^{75}Zn[6, 7] in this region of the nuclear chart. The interest in beta decays of the neutron-rich zinc isotopes ^{72}Zn [8], ^{73}Zn[9], ^{75}Zn[10], ^{76}Zn[11], ^{78}Zn[12], and ^{80}Zn[13] is related to their ability to provide insight into their nuclear structure and properties of their daughter nuclei. These studies extend to questions about the general context of nuclear physics, especially those concerning the rapid neutron capture process, or r-process, one of the main processes responsible for synthesizing heavy elements in the universe.

In the present study, we use the JUN45 [14] Hamiltonian of the $f_{5/2}pg_{9/2}$ model space for the investigation of β^--decay half-life. In the JUN45 interaction, the single-particle energies of the $f_{5/2}$, $p_{3/2}$, $p_{1/2}$, and $g_{9/2}$ orbits are taken as -9.8280, -8.7087, -7.8388, and -6.2617 MeV, respectively. No truncation in the model space has been invoked for protons and neutrons. The Gamow-Teller matrix elements for relevant transitions are computed in the present study to estimate half-life for various isotopes in β^--decay. This gives an insight into the interaction strength in these decay modes, and the calculated result shows good agreement with experimental data. These results are crucial for understanding the weak interaction responsible for β^- processes; their comparison with experimental observables will support theoretical models.

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β^--decay formalism

The ft [15]value is given by

$$ft = \frac{6289}{[(g_A)^2 B(GT) + B(F)]} \tag{1}$$

g_A (1.270) is the axial-vector coupling constant for weak interactions, and f is a phase-space integral containing the lepton kinematics. $B(GT)$ and $B(F)$ are matrix elements for the Gamow-Teller and Fermi transitions. The total half-life is expressed as

$$t_{1/2} = \left(\sum_i \frac{1}{t_i}\right)^{-1} \tag{2}$$

where t_i represents the partial half-life for the decay of some daughter state. The partial half-life for allowed β decay is

$$t_i = 10^{\log ft - \log f_A} \tag{3}$$

where f_A is the Gamow-Teller phase space factor and $\log ft$ is used to express large ft values. The partial half-life is related to the total half-life by

$$t_i = \frac{t_{1/2}}{b_r} \tag{4}$$

where b_r is the branching ratio. $B(GT)$ is given by

$$B(GT) = \left(\frac{g_A}{g_V}\right)^2 \langle\sigma\tau\rangle^2 \tag{5}$$

summed for all nucleons, where $\langle\sigma\tau\rangle$ is the matrix element of nuclear processes and g_A is the coupling constant.

Results and discussion

The theoretical half-life of Cu and Zn isotopes half-life has been shown in Fig 1. In the case of Cu isotopes, the theory predicts half-lives to be close to the experimental values. Deviations may

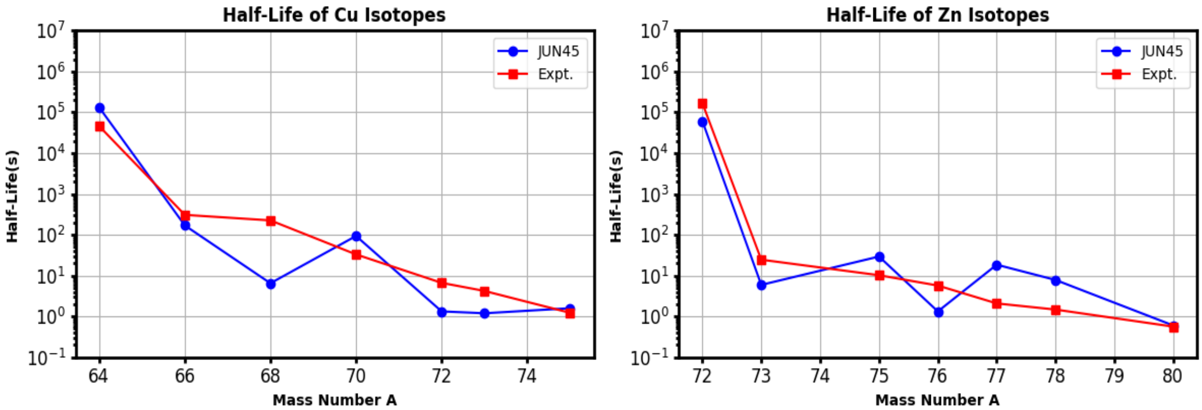

FIG. 1: The theoretical and experimental β^-- decay half-life values versus mass number A of the concerned nuclei for $jj44$ space.

appear for A = 68 and 70, where the theoretical model overestimates the half-life. For A = 70, the theoretical half-life is 93 sec, whereas the experimental half-life is 33 seconds. In the case of Zn isotopes, the theoretical prediction shows a good agreement with the experimental half-life and expects some discrepancies in the case of A = 76 and 77. The half-life of the theoretical and experimental values is also well matched for the case of A = 80, reflecting that the theoretical model works better in this region. Summing up, JUN45 gives reasonable estimates. The obtained agreement is quite good for the experimental half-lives, mainly considering the heavy mass region for Cu and Zn. However, some deviations were seen in the middle range of these isotopes because not all the possible intruder configurations are well accommodated by the given model space, and the shape of the given nuclei is strongly deformed in the middle mass region. Further, the theoretical value of matrix elements is more significant than experimental values; hence, the quenching factor is needed to negate this effect, which is the motivation of the present study and will be presented in the upcoming meeting.

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