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

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The study of beta decay in the region A = 80 is important as it is relevant for astrophysical processes such as the *rp* process [1], which is directly responsible for synthesizing heavier elements in a stellar environment. In this work, we have studied the β -decay half-lives of Sr and Y isotopes using the nuclear shell model into the mass region A = 78 − 88 [2–6] for Sr and A = 83 − 88 for Y. Their decay proceeds through β^+ and electron capture (EC), filling several excited states of their daughter states of yttrium and strontium. Detailed nuclear level schemes can be obtained by investigating gamma rays, conversion electrons, and decay half-lives. These studies give information on vibrational and rotational collective behaviors because, for instance, Zr decays show that excited 0^+ states in Sr are populated, supporting a possible 6^+ spin assignment in Y. The studies of Y isotopes in the neighborhood of mass 80 − 88 [9–12] show shifts between spherical and deformed nuclear shapes; examples of such properties can be found in the neighboring isotopes ^{80}Y [13] and ^{81}Y [14].

We utilize the JUN45 [15] Hamiltonian in the $f_{5/2}pg_{9/2}$ model space with no truncation to investigate the properties of beta decay, such as excitation energy of daughter nuclei, logft-values, branching ratios, and half-life, which are studied in various experimental facilities. The single-particle energies (SPE) for the $f_{5/2}$, $p_{3/2}$, $p_{1/2}$, and $g_{9/2}$ orbits employed in JUN45 interaction are -9.8280, -8.7087, -7.8388, and -6.2617 MeV, respectively. For β^+ - decay, the study calculates Gamow-Teller matrix elements for the relevant transitions to find the half-life for various isotopes.

The ft value is given by [16, 17]

$$f_0 t_{1/2} = \left[f_0^{(+)} + f_0^{(EC)}\right] t_{1/2} = \frac{\kappa}{[g_A^2 * B(GT) + B(F)]} \tag{1}$$

$g_A(1.270)$ is the axial-vector coupling constant for weak interactions, and f is a phase-space integral containing the lepton kinematics.

$$\kappa \equiv \frac{2\pi^3\hbar^7 ln2}{m_e^5 c^4 (G_F cos\theta_C)^2} = 6289s \tag{2}$$

where, the θ_C is the Cabibbo angle. $B(GT)$ and $B(F)$ are matrix elements for the Gamow-Teller and Fermi transitions. The total half-life is expressed as

$$t_{1/2} = \left(\sum_i \frac{1}{t_i}\right)^{-1} \tag{3}$$

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

$$t_i = 10^{\log ft - \log f_A} \tag{4}$$

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

$$t_i = \frac{t_{1/2}}{b_r} \tag{5}$$

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

$$B(GT) = \left(\frac{g_A}{g_V}\right)^2 \langle\sigma\tau\rangle^2 \tag{6}$$

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

The Fermi reduced transition probability $B(F)$ is given by

$$B(F) \equiv \frac{g_V^2}{2J_i + 1}|M_F|^2 \tag{7}$$

where, g_V (= 1.0) represents the vector coupling constant of the weak interaction and M_F is the Fermi matrix element.

The plots of the half-lives of Zr and Y isotopes as a function of mass number are shown in Fig 1. The theoretical half-life values for Zr isotopes mostly agree with experimental values, showing only a slight deviation in the case of ^{86}Zr. For Y isotopes, the

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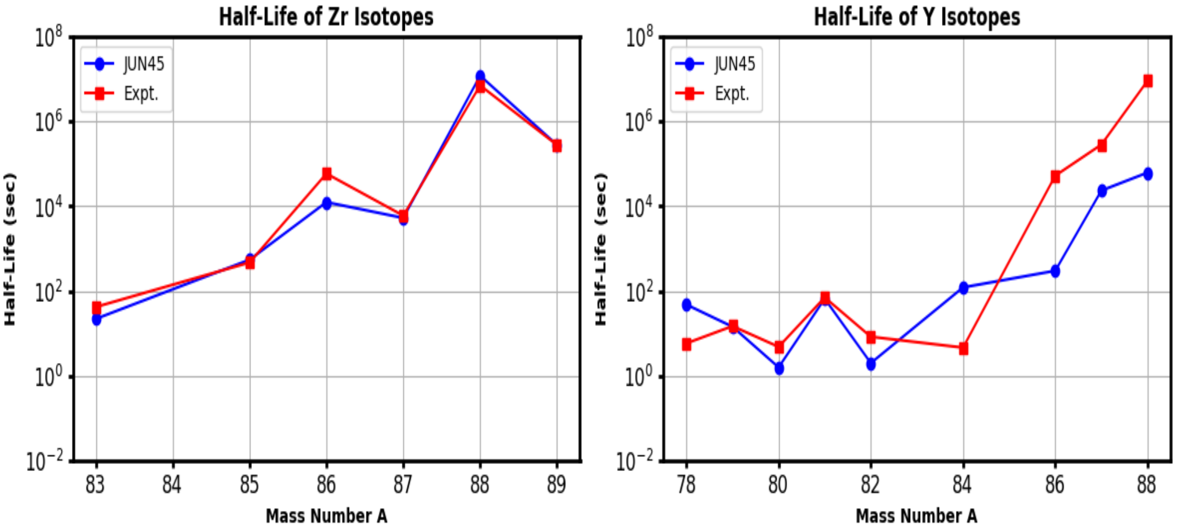

FIG. 1: The theoretical and experimental β^+- decay half-life values versus mass number A of the concerned nuclei for $f_{5/2}pg_{9/2}$ space.

theoretical half-life of low mass region matches and agrees well with experimental values. As masses increase after A = 84, a deviation is seen in the half-life values. In some instances, however, underestimating half-life values points out that a further theoretical model refinement may be needed, particularly by including nuclear structure effects or other factors influencing the decay process. Also, the available model space doesn't fully incorporate all the possible configurations for a given state, which in turn results in higher matrix element values as compared to theoretical values; hence, a quenching factor is required, which is currently the motive of our further study in this model space. During the meeting, we will present the results of the remaining $f_{5/2}pg_{9/2}$ shell nuclei.

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