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Atomic corrections for the β decay of neutrino mass measurement candidates

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We reexamine one of the most promising candidates for determining the neutrino mass scale: the unique first forbidden β transition from $^{187}\mathrm{Re}(5/2^{+})$ to $^{187}\mathrm{Os}(1/2^{-})$. With the lowest-known ground-state to ground-state Q-value for a β transition at 2.4709 keV, rhenium's β decay can offer insights into the neutrino mass scale puzzle. However, understanding its electron spectrum is a complex task. Besides involving a mixture of $s_{1/2}$-state and $p_{3/2}$-state electrons, various atomic corrections could strongly influence the rhenium β spectrum. We have incorporated finite nuclear size, diffuse nuclear surface, screening, and exchange corrections into the rhenium β decay model. The last two are accounted for within the Dirac-Hartree-Fock-Slater self-consistent method. We have discovered that both screening and exchange effects significantly alter the partial decay rates for the $s_{1/2}$- and $p_{3/2}$-state emission channels while still maintaining the experimentally confirmed dominance of the $p_{3/2}$-state emission. The ratio between the respective decay rates has been found to be approximately 10^4. Compared to the other corrections, the exchange effect stands out due to the modification it induces in the spectrum shape. We demonstrate that calculations with and without the exchange effect lead to entirely different shape factors for the decay spectrum. Finally, we illustrate that to preserve the linearity of the Kurie plot, it is essential to include the exchange correction in its definition. We conclude that atomic effects, especially the exchange effect, should be considered in current and future investigations of the neutrino mass scale from β decays.

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