Study of Alpha decay Half-lives for Tungsten and Osmium Isotopes

T. Tripathi, V. Kumar, and A. Shukla*
Department of Physics, University of Lucknow, Lucknow-226007, India

Introduction

The N = 82 shell closure significantly affects the α decay process, much like the N = 126 neutron shell closure impacts the probability of α decay preformation. This influence is evident in the sudden transition from α decay to β decay as one moves toward lower neutron numbers across the N = 82 shell. Additionally, there is a notable drop in α decay rates from N = 84 to N = 82, attributed to the N = 82 shell gap. The extensive α decay data for W and Os isotopes, extending from the proton to the neutron drip line, including the recent experimental observation of α decay in ^{160}Os, the lightest Os isotope (the most proton-rich N=84 isotone to date) [1], serves as the primary motivation for this study.

Furthermore, exploring the nuclear structure and decay characteristics of W and Os isotopes offers an intriguing opportunity to investigate fundamental nuclear interactions. The complex dynamics of nuclear forces within Os isotopes not only enhance our understanding of heavy nuclei but also allow for the examination of isotopes spanning from N=82 to N=126, covering a complete range of the highest magic numbers. Despite notable progress in nuclear theory and experimental methodologies, substantial gaps remain in our understanding of W and Os isotopes, particularly regarding their structural properties and the decay mechanisms of newly observed decays in W and Os isotopes.

Mathematical Formalism

The relativistic mean field (RMF) model which contains the spin-orbit naturally, has been successfully used to understand and explain many features of nuclei. This relativistic mean-field approach, particularly with the NL3 effective interaction (or with a slightly modified version i.e. NL3* effective interaction), has been widely used in many nuclear structure studies. However, the non-linear RMF model has certain limitations: It systematically overestimates the value of r_n-r_p [2], predicts an equation of state for neutron matter which is very different from the standard microscopic many-body neutron equation of state, and also fails in correctly predicting the masses that match the standards of nuclear astrophysics.

Therefore, the relativistic Hartree-Bogoliubov (RHB) model is employed in the present work which explicitly includes density-dependent meson-nucleon couplings. In this approach, the effective Lagrangian is characterized by a phenomenological density dependence for the σ, ω, and ρ meson-nucleon vertex functions, adjusted to properties of nuclear matter and finite nuclei. The Density-dependent RHB model (DDRHB) i.e. RHB with density-dependent meson-nucleon couplings represents a significant improvement in the relativistic mean-field description of the nuclear many-body problem and, in particular, for exotic nuclei lying far from β-stability. The improved isovector properties of the effective interaction in the ph-channel on one hand, and the unified description of mean-field and pairing correlations in the Hartree-Bogoliubov framework on the other, offer a unique possibility for accurate studies of nuclei with extreme ground-state isospin values as also done in our previous works [3].

Results and Discussion

To have a comparable look and analyze the model dependence of the results, we have per-

*Electronic address: shukla_as@lkouniv.ac.in

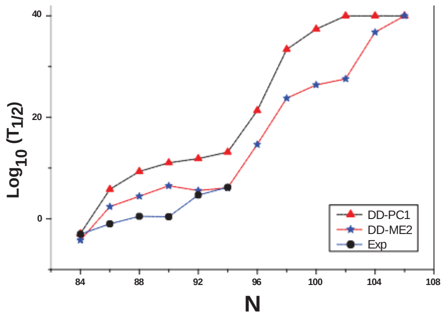

FIG. 1: Comparison of calculated Half-lives (as a function of Neutron Number) along with experimentally observed values for W isotopes (Z=74).

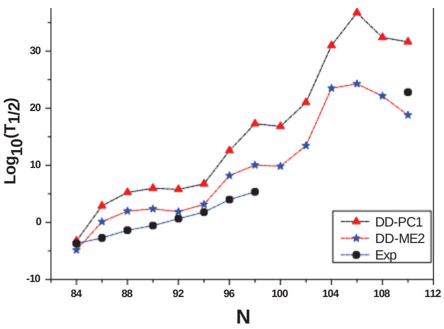

FIG. 2: Same as fig1, but for Os isotopes (Z=74).

formed the calculations using two different parameter sets (the nonlinear self-coupling of meson fields and the DD meson-nucleon couplings) in the present work. The mass excess obtained from RHB calculations has been used further as input to obtain a Q value and determine the alpha decay half-lives in conjunction with the ELDM. Comparisons of our results for the half-live calculations with the available experimental results have been shown in Fig. 1 and Fig. 2. In Fig. 1, and Fig. 2, we have shown the results of half-lives for alpha decay of Os (Z=76) and W (Z=74) iso- topic chains respectively, for two different set of parameters namely DD-PC1 and DD-ME2 calculations performed (to compare with experimental observations, the same are also marked in the figure). One can see that the same isotopic chains, the calculated Q_{α} values vary and can be said to be moderately model-dependent. Also, Since the α -decay half-lives are very sensitive to the Q_{α} values, the variation can give rise to large differences in predicted half-lives. The detailed systematic study of the Os and W isotopes involving ground state properties, (binding energy, RMS charge radii, neutron skin), coherently with alpha decay half-lives will be presented at the conference. Further, the calculated results for half-lives are also compared with the values obtained using the empirical formula Universal Decay Law (UDL), Viola-Seaborg (VS), TM, and the Scaling Law by Horoi *et al.* and will be presented at the conference.

Conclusion

In summary, we have calculated ground state observables in conjunction with DD-PC1 and DD-ME2 parameter sets for all the nuclei considered in the present work and compared our results with available experimental data. Further, we have also calculated Q value, and alpha decay half-lives using ELDM. The comparison with the experimental results is quite good and it would be worthwhile to investigate further the cluster radioactivity for the potential cases among the above-mentioned alpha emitters [4].

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References

[1] H. B. Yang, Z. G. Gan, Y. J. Li et al., Phy. Rev. Lett. **132**, 072502 (2024)
[2] T. Niksic, D. Vretenar, P. Finelli and P. Ring, Phys. Rev. C**66**, 024306 (2002).
[3] Ajeet Singh, A. Shukla and Mitko Gaidarov, Nucl. Phys. A **1023**, 122439 (2022) and references therein.
[4] Tathagat Tripathi, V. Kumar, and A. Shukla, Communicated with Phy. Rev. C.