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Systematic analysis of α-decay of the superheavy elements using different semi-empirical mass formulae

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Introduction

Alpha decay is one of the prominent decay modes observed in the ground state and the isomeric heavy and super heavy regions of the atomic nuclei. It plays a crucial role in describing the structural as well as decay properties of a given nucleus. The probability of emission of α-particle can be well explained by quantum mechanical tunnelling and directly related to the Q-values. The α-decay energies (Q_α) and the accompanying half-lives are employed in studying neutron-rich heavy and superheavy nuclei (SHN). The relevance of a parent nucleus's half-life is that a daughter nucleus with a shell stabilized structure will arise from α-decay, but a parent nucleus with a longer half-life has a shell stabilized parent nucleus that resists α-decay. In the present work, we have calculated the Q-values from the binding energies of the nuclei using NL3* force parameters within the relativistic mean field model (RMF) [1]. And corresponding α-decay half-lives of SHN from Z = 100 to 120 have been calculated using different semi-empirical formulae, namely, modified Viola-Seaborg formula (MVS), Modified scaling law Brown formula (MSLB), Yibin *et al.* formula (YQZR), and Modified Yibin *et al.* formula (MYQZR) [2] and compared with the theoretical and experimental results.

Theoretical Formalism

The relativistic mean-field (RMF) formalism has been generally used to explain the properties of finite nuclei and infinite nuclear matter along with the drip-line region. In RMF, the nucleus is considered as a combined system of nucleons interacting through the interchange of photons and mesons. A detailed study of the RMF can be found in Ref. [1] and references therein. The total binding energy and other observable are also attained by using the standard relations given in Ref.[3] and references therein.

Result and Discussions

The alpha decay properties of SHN from Z = 100 to 120 and neutron numbers in the range $156 \leq N \leq 184$ have been studied with the help of relativistic mean-field formalism for the NL3* parameter set, which is the modified version of the NL3 parameter set. The calculated Q-values for Z = 108 using the non-linear NL3* parameter set are compared to the experimental data displayed in Fig.1. It is evident from Fig.1 that RMF formalism is observed to slightly overestimate the FRDM [4], WS4 [5], (FRDM and WS4 are theoretical models), and experimental Q-values [6]. Similar results are obtained for the other even Z nuclei between Z=100-120 as well.

We have calculated the half-lives for considered nuclei using our calculated Q-values for NL3* force parameters and the available experimental Q-values. The alpha decay half-lives for these isotopes have been systematically analyzed by using different semi-empirical formulae, namely, modified Viola-Seaborg formula (MVS), Modified scaling law Brown formula (MSLB), Yibin et al. formula (YQZR), and Modified Yibin et al. formula (MYQZR) and compared with the theoretical and experimental data [7]. The estimated α-decay half-life ($T^{\alpha}_{1/2}$) for Z = 108, 110, 112,

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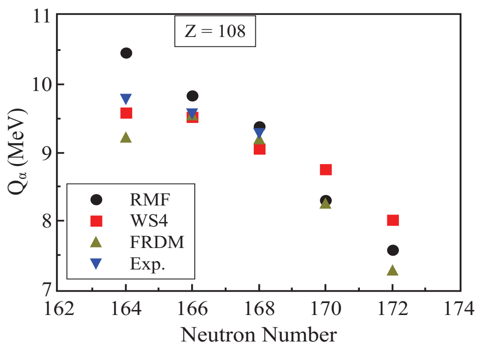

FIG. 1: The α-decay (Q_α energy) for Z = 108 nuclei using RMF (NL3*) are given along with the FRDM [4], WS4 [5], and available experimental data [6].

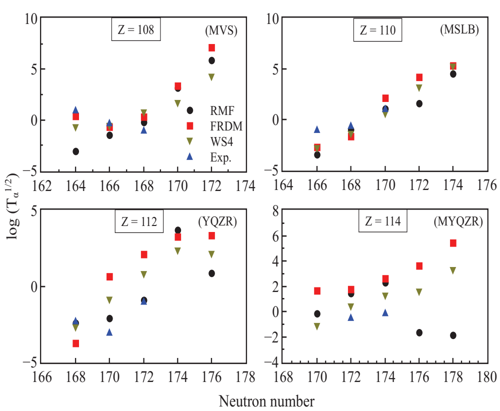

FIG. 2: The estimated α-decay half-life ($T^{\alpha}_{1/2}$) for Z = 108, 110, 112, and, 114 nuclei using MVS, MSLB, YQZR, and MYQZR formulae respectively is given along with the FRDM, WS4 predictions, and available experimental data [7].

and, 114 nuclei using MVS, MSLB, YQZR, and MYQZR formulae respectively is given along with the FRDM, WS4 predictions, and available experimental data [7] as shown in Fig.2. It can be predicted from the results that the MSLB formula shows good agreement with the experimental results. On the other hand, the modified Viola-Seaborg formula (MVS), Yibin et al. formula (YQZR), and Modified Yibin et al. formula (MYQZR) show slightly lower values in comparison to the Modified scaling law Brown formula (MSLB), with isotopic effect. We have obtained similar results for the other chosen nuclei (not shown here).

Conclusion

The Modified scaling law of Brown (MSLB) is more consistent than the other semi-empirical formulae for the predictions of half-lives of the SHN. These theoretical predictions may be helpful for the upcoming experiments.

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