Theoretical studies on the decay of odd-even nuclei $^{285-303}119$

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Introduction

The α-decay energies (Q_α) and α-decay half-lives of the odd-even superheavy nuclei (SHN) with Z = 119 within the range 285 ≤ A ≤ 303 have been systematically calculated, and the studies are performed by using 5 mass models and 3 empirical formulas, respectively. The heaviest element known so far is Z = 118 and any further progress in the synthesis of new elements with Z > 118 is not quite evident, even though attempts to synthesize the isotopes $^{298,299}120$ was performed by Oganessian *et al.* in 2009. As the question on the border of the elements' existence remain unanswered, the synthesis and identification of new elements remains a hot topic in nuclear physics.

The alpha decay properties and the mode of decay of both several SHN [1] have already been studied and analyzed extensively by our group using several theoretical and empirical models. Hence, we were confident to carry out the alpha decay studies on the SHN Z = 119, with a different approach of using different mass models. Thus, the present theoretical study on Z = 119, the most hopeful new element with Z > 118 to be synthesized in the near future, along with our earlier works, ensures the validity of our models, and these findings will provide a new guide for future experiments.

Decay Energy Calculation & Empirical Approach for Decay Half-Lives

The energy released in the alpha transitions between the ground state energy levels of the parent nuclei and the ground state energy levels of the daughter nuclei is given as

$$Q_{gs\to gs} = \Delta M_p - (\Delta M_\alpha + \Delta M_d) + k(Z_p^\varepsilon - Z_d^\varepsilon) \qquad (1)$$

where ΔM_p, ΔM_d, ΔM_α are the mass excess of the parent, daughter and alpha particle respectively. The correct estimation of decay half-lives strongly depends on the calculation of *Q* value, as the half-lives are particularly sensitive to decay energies. Hence, the calculation of the *Q* values has been done using different mass tables available in literature [2]. From the previous studies [2, 3] as it was evident that the discrepancy between the experimental and the calculated *Q* value is minimum while using the Hartree-Fock-BCS (HFBCS) mass model, it has been considered to be the best choice for the present study, and the Q values calculated using the HFBCS mass model has been used for the evaluation of alpha decay half-lives. The electron screening effect on the energy of α particle is included by adding the term $k(Z_p^\varepsilon - Z_d^\varepsilon)$ in Eq. (1). The term kZ^ε is the total binding energy of *Z* electrons in the atom. Here, k = 8.7 eV and ε = 2.517 for nuclei with *Z* _ 60 and k = 13.6 eV and ε = 2.408 for nuclei with $Z < 60$. The *Q* value must be positive for α decay to occur.

The mass excess values have been obtained using the macroscopic-microscopic models, namely, the finite range droplet model (FRDM), the Weizsäcker-Skyrme formulas with radial basis function (WS4+RBF), the nuclear Thomas and Fermi model (TFM), and the pure microscopic model, HFBCS. In addition, we have also used the mass table of Koura *et al.* which presents a nuclidic mass formula composed of a gross term, an even-odd term, and a shell term.

The next step is to calculate the alpha decay half-lives, and for the same, we have used 3 analytic formulas, such as the Royer formula, Viola-Seaborg-Sobiczewski (VSS) formula and the Santhosh formula. The Viola-Seborg semi-empirical relationship is given as,

$$\log_{10}(T_{1/2}) = (aZ+b)Q^{-1/2} + cZ + d + h_{\log} \qquad (2)$$

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The half-life is in seconds, Q value is in MeV and Z is the atomic number of the parent nucleus. The constants a = 1.66175, b = -8.5166, c = -0.20228, d = -33.9069 and the value of h_{log} is taken as h_{log} = 0.772 for Z = odd, N = even. The analytical formula of Royer developed by applying a fitting procedure on the α emitters is as follows,

$$\log_{10}(T_{1/2}) = a + bA^{1/6}Z^{1/2} + cZQ^{-1/2} \quad (3)$$

where A and Z represent the mass and charge numbers of the parent nuclei. The constants a, b, and c are given as, $a = -25.68$, $b = -1.1423$, c = 1.5920, for Z = odd N = even. The half-life is in seconds and Q value is in MeV

The semi-empirical formula of Santhosh et al., is given as,

$$\log_{10}(T_{1/2}) = aQ^{-1/2} + b\eta_A + c \quad (4)$$

where a = 131.776, b = 559.188 and c = −585.659, η_A is the mass asymmetry, the half-life is in seconds, Q value is in MeV.

Results & Discussion

The details of the results obtained for the two selected isotopes ^{285}119 and ^{295}119 are given in Figs. 1 and 2. The Fig. 1 gives the comparison of calculated Q values using five different mass models for the isotopes in the decay chain of $^{285, 295}$120. From the figure the difference in the Q value using different mass tables is evident, and the sensitivity of Q value to the mass model has been given by different theoretical studies. An analysis of these values shows that the discrepancies in the Q value increases while going in to the very heavy region. Also, the Q values predicted using the macroscopic-microscopic models FRDM, WS4+RBF, and TFM follow the same trend.

The logarithmic half-lives using the empirical formulas versus mass number of the isotopes has also been plotted and is given in Fig. 2. The difference in predictions of half-lives for an isotopes using Q values calculated with different models can be clearly seen from the figure.

We would like to imply the fact that the present work is just a small part of our extensive study being done on all the possible isotopes of Z = 119, available in the mass tables mentioned above.

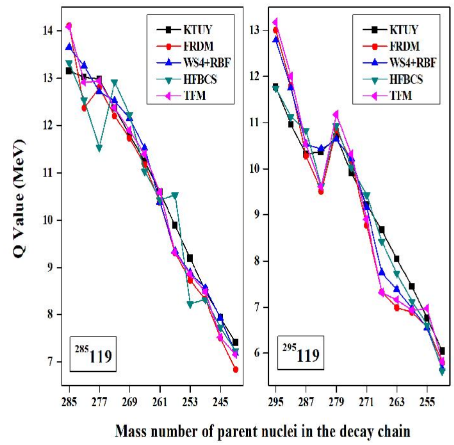

Fig. 1 Comparison of calculated Q values using five different mass models for the isotopes in the decay chain of $^{285, 295}$119.

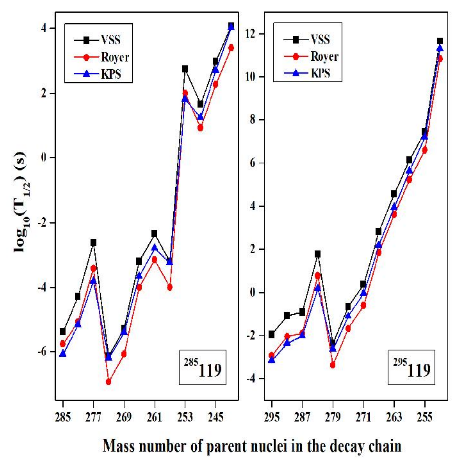

Fig. 2 Comparison of α decay half-lives evaluated with the Q values using five different mass models for the isotopes in the decay chain of $^{285, 295}$119.

References

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