Alpha decay chains of newly synthesized ^{298,299}120 SHN

B. Priyanka and K. P. Santhosh*
School of Pure and Applied Physics, Kannur University, Swami Anandatheertha Campus, Payyanur - 670327, Kerala, INDIA
* *email: drkpsanthosh@gmail.com*

Introduction

The significant progresses made in the experimental and theoretical investigations in the region of superheavy nuclei have always aimed at expanding the periodic table and thereby prove the theoretical prediction on the existence of a "magic island" or the "Island of Stability". The heaviest element known so far is Z = 118 and an attempt has been made to produce Z = 120.

As our recent theoretical studies on the isotopes of Z = 115, Z = 117, Z = 118 and Z = 119, could successfully prove the applicability of CPPMDN in predicting the decay half lives and mode of decay of superheavy nuclei, we have extended our study on the isotopes of Z = 120.

The Coulomb and Proximity Potential Model for Deformed Nuclei

The potential energy barrier in CPPMDN [1] is taken as the sum of deformed Coulomb potential, deformed two-term proximity potential and the centrifugal potential, for the touching configuration and for the separated fragments. For the pre-scission region, a simple power law interpolation was used.

The Coulomb interaction between the two deformed and oriented nuclei is given as,

$$V_C = \frac{Z_1 Z_2 e^2}{r} + 3 Z_1 Z_2 e^2 \sum_{\lambda, i=1,2} \frac{1}{2\lambda+1} \frac{R_{0i}^{\lambda}}{r^{\lambda+1}} Y_{\lambda}^{(0)}(\alpha_i) \left[\beta_{\lambda i} + \frac{4}{7} \beta_{\lambda i}^2 Y_{\lambda}^{(0)}(\alpha_i) \delta_{\lambda,2} \right] \tag{1}$$

with

$$R_i(\alpha_i) = R_{0i} \left[1 + \sum_{\lambda} \beta_{\lambda i} Y_{\lambda}^{0}(\alpha_i) \right] \tag{2}$$

Here $R_{0i} = 1.28 A_i^{1/3} - 0.76 + 0.8 A_i^{-1/3}$ where α_i is the angle between the radius vector and symmetry axis of the ith nuclei. The two-term proximity potential for interaction between a deformed and spherical nucleus is given by Baltz et. al., as

$$V_{P2}(R,\theta) = 2\pi \left[\frac{R_1(\alpha) R_C}{R_1(\alpha) + R_C + S} \right]^{1/2} \left[\frac{R_2(\alpha) R_C}{R_2(\alpha) + R_C + S} \right]^{1/2} \times$$

$$\left[\left[\varepsilon_0(S) + \frac{R_1(\alpha) + R_C}{2 R_1(\alpha) R_C} \varepsilon_1(S) \right] \left[\varepsilon_0(S) + \frac{R_2(\alpha) + R_C}{2 R_2(\alpha) R_C} \varepsilon_1(S) \right] \right]^{1/2} \tag{3}$$

Here $R_1(\alpha)$ and $R_2(\alpha)$ are the principal radii of curvature of the daughter nuclei at the point where polar angle is α, S is the distance between the surfaces along the straight line connecting the fragments, R_C is the radius of the spherical cluster, $\varepsilon_0(S)$ and $\varepsilon_1(S)$ are the one dimensional slab-on-slab function. Using one dimensional WKB approximation, the barrier penetrability P is given as

$$P = \exp\left\{ -\frac{2}{\hbar} \int_a^b \sqrt{2\mu(V-Q)}\, dz \right\} \tag{4}$$

The turning points "*a*" and "*b*" are determined from the equation, V(a)=V(b)=Q. The half life time is given by

$$T_{1/2} = \left(\frac{\ln 2}{\lambda} \right) = \left(\frac{\ln 2}{\nu P} \right) \tag{5}$$

where, $\nu = (\omega/2\pi) = (2E_v/h)$, represents the number of assaults on the barrier per second and λ the decay constant. E_v, is the empirical vibration energy.

Results and Discussions

Within CPPMDN, an extensive study on the feasibility of alpha decay from the isotopes of Z = 120 in the range 272 ≤ A ≤ 319 have been done. 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

$$Q_{gs \to gs} = \Delta M_p - (\Delta M_\alpha + \Delta M_d) + k(Z_p^{\varepsilon} - Z_d^{\varepsilon}) \tag{6}$$

where ΔM_p, ΔM_d, ΔM_α are the mass excess of the parent, daughter and alpha particle respectively. The Q values are evaluated using the mass excess values taken from Wang et al., and Koura-Tachibana-Uno-Yamada (KTUY). The term kZ^{ε} represents the screening effect of atomic electrons.

The alpha half life calculations have also been done using the CPPM formalism, the Viola-Seborg semi-empirical relationship (VSS), the Universal curve (UNIV) of Poenaru et al., and the analytical formulae of Royer.

So as to identify the mode of decay of the isotopes under study, the spontaneous fission (SF) half lives have also been evaluated using the semi empirical relation of Xu *et al.*, given as

$$T_{1/2} = \exp\left\{2\pi\left[C_0 + C_1A + C_2Z^2 + C_3Z^4 + C_4(N-Z)^2 - (0.13323\frac{Z^2}{A^{1/3}} - 11.64)\right]\right\}$$

Those isotopes with small alpha decay half lives than the spontaneous fission half lives survive fission and hence can be detected through alpha decay in the laboratory. Thus by comparing the alpha decay half lives with the spontaneous fission half lives, we could identify the nuclei (both parent and decay products) that will survive fission.

It is to be noted that, even though no exact experimental evidence exists regarding the production of new elements with Z > 118, recently, an attempt to produce the element 120 in the ^{244}Pu+^{58}Fe reaction was made by Oganessian et al., [2].

The α decay half lives of 48 isotopes within the range 272 ≤ A ≤ 319, have been done focusing on the isotopes ^{298,299}120, were the experimental data are available. The figures 1 and 2 represent the plots of ^{298}120 and ^{299}120 respectively. All the calculations done within various theoretical models have been depicted in these figures along with the experimental decay half lives represented as scatted points. It can be seen that the experimental half lives matches well with CPPMDN values and thus, we have predicted 4α chains from ^{298}120 and 3α chains from ^{299}120.

Our study on the rest of the isotopes of Z = 120 leads to the prediction of 1α chain from $^{277\text{-}279,\ 305\text{-}308}$120, 2α chains from ^{280,281,303,304}120, 3α chains from $^{282,283,299\text{-}302}$120, 4α chains from ^{284,285,298}120, 5α chains from ^{286,296,297}120, 6α chains from $^{287\text{-}289,\ 291\text{-}295}$120 and 7α chains from ^{290}120. Thus our study reveals that those isotopes with A ≤ 276 and with A ≥ 309, do not survive fission and thus the alpha decay is restricted within the range 277 ≤ A ≤ 308.

It is to be noted that the experimental attempt on Z = 120 clearly predicts 8α chains from the isotope ^{299}120 and also predicts 90% spontaneous fission of ^{279}110, thereby resulting in a inconsistency in the mode of decay of the same. So we look forward for further experimental works on the isotopes of Z = 120 and we also hope that our predictions on the isotopes within the range 282 ≤ A ≤ 302, giving consistently long decay chains, to provide a new guide for future experiments.

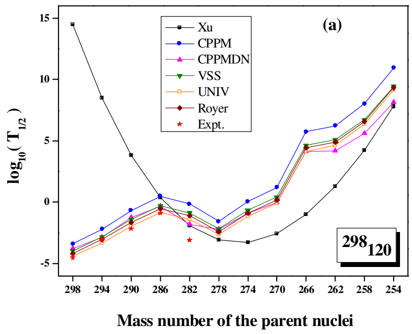

Fig.1. The comparison of the calculated alpha decay half lives with the spontaneous fission half lives for the isotopes ^{298}120 and its decay products.

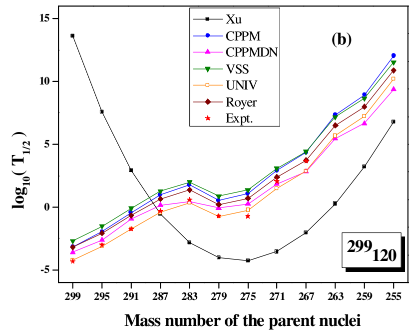

Fig.2. The comparison of the calculated alpha decay half lives with the spontaneous fission half lives for the isotopes ^{299}120 and its decay products.

References

[1] K. P. Santhosh, S. Sabina and G. J. Jayesh, Nucl. Phys. **A 850**, 34 (2011).

[2] Yu. Ts. Oganessian et al., Phys. Rev. C 79, 024603 (2009).