Ternary fission of $^{348, 350}$120 isotopes with alpha particle as the light charge particle

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Introduction

Ternary fission is a phenomenon in which a nucleus disintegrates in to three fragments. Former prediction of this process based on liquid drop was given by R. D present in 1941[1]. Later Alvarez [2] and Tsien San-Tsiang et al. [3] in 1943 reported the experimental evidence of light charge accompanied ternary fission process. In light charge accompanied ternary fission process, the third particle will be light compared to other two fragments. Two possible emissions of light charge particles during the process results in equatorial and collinear configuration. In equatorial configuration, light charge particle is emitted perpendicular to axis of main fission fragments, whereas in collinear configuration, it is emitted in the direction of main fission fragments. Exploring multiple fission in super heavy region is significant as the studies on nuclear shape effect suggest that the probability of two or more necks formation is higher in this region [4]. In addition, Swiatecki et. al [5] suggested that the nuclei with fission parameter $30.5 < Z^2/A < 43.3$ may undergo multi fragment emission. Hence in this work, possibility of ternary fission in isotopes ^{348,350}120 is evaluated based on its corresponding cold valley and relative yield plots.

Unified Ternary Fission Model

Spontaneous cold ternary fission accompanied by light charge particle is energetically possible for the reactions that have Q value positive.

$$Q = M - \sum_{i=1}^{3} m_i > 0 \qquad (1)$$

Where M is the mass excess of the parent and m_i is the mass excess of the fragments.

The interacting potential barrier for a parent nucleus exhibiting cold ternary fission consists Coulomb potential Vc_{ij} and nuclear proximity potential Vp_{ij} of Blocki et al. [6], given as;

$$V = \sum_{i}^{3} \sum_{j>i}^{3} (V_{cij} + V_{pij}) \qquad (2)$$

Using one dimensional WKB approximation, barrier penetrability P, probability for which the ternary fragments to cross the three-body potential barrier is computed as;

$$P = \exp\left\{ -\frac{2}{\hbar} \int_{a}^{b} \sqrt{2\mu(V-Q)}\, dz \right\} \qquad (3)$$

Where turning points a= 0 represents touching configuration and b is determined from the equation V (b) = Q, where Q is the decay energy and μ is the reduced mass given by the equation;

$$\mu = \frac{m\mu_{12}A_3}{\mu_{12} + A_3} \qquad \mu_{12} = \frac{A_1A_2}{A_1 + A_2} \qquad (4)$$

Where m is the nucleon mass and A_1, A_2 and A_3 are the mass numbers of the three fragments. The relative yield can be calculated as the ratio between the penetration probability of a given fragmentation over the sum of penetration probabilities of all possible fragmentation as follows,

$$Y(A_i, Z_i) = \frac{P(A_i, Z_i)}{\sum P(A_i, Z_i)} \qquad (5)$$

Result and Discussion

Spontaneous ternary fission in ^{348,350}120 isotopes accompanied by the emission of alpha particle in equatorial configuration is studied using unified ternary fission model. The favorable fission channel is determined from their corresponding cold valley and relative yield plots. First, the driving potential is calculated for all possible ternary fission of parent nucleus at

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*Electronic address: *bijurkn@gmail.com* touching configuration for fixing light charge particle A_3, while considering respective mass and charge asymmetries $n = \frac{A_1 - A_2}{A_1 + A_2}$ and $n_Z = \frac{Z_1 - Z_2}{Z_1 + Z_2}$. Further, the set of charges, which results minima in driving potential corresponding to each fixed pair of masses (A_1, A_2) is singled out. Driving potential is calculated as the difference in interacting potential, V and disintegration energy, Q of the process.

Figure 1 represents the cold valley graph of $^{348,350}120$ isotopes with ^{4}He as the light charge particle, connecting driving potential and mass number A_1 of one of the fragments. For parent isotope $^{348}120$, first dips in the valley are obtained for the cases ^{8}He+^{336}Lv+^{4}He and ^{24}O+^{320}Ds+^{4}He which contains near doubly magic nuclei ^{8}He and proton magic ^{24}O. Further, a deep minimum in the driving potential is observed for the combination of fragments ^{80}Ni+^{264}Th+^{4}He, which is due to the nearly doubly magic behavior of ^{80}Ni nuclei. The next minimum in the driving potential is shown by the combination ^{130}Pd+^{214}Hf+^{4}He, which include near neutron magic nucleus ^{130}Pb. For the parent isotope $^{350}120$, a first minimum is shown by the fragment combination ^{24}O+^{322}Ds+^{4}He, which has the ^{24}O nucleus with a proton shell closure at Z=8. Next prominent dip in the valley is observed for the configuration ^{80}Ni+^{266}Th+^{4}He with proton shell closure at Z=28 and near neutron shell closure at N=52. Further, a deep minimum in the valley is exhibited by the combinations ^{130}Pd+^{216}Hf+^{4}He and ^{131}Pd+^{215}Hf+^{4}He with near neutron magic ^{130,131}Pd nucleus. Additional minima observed in each case are marked in its respective cold valley plot.

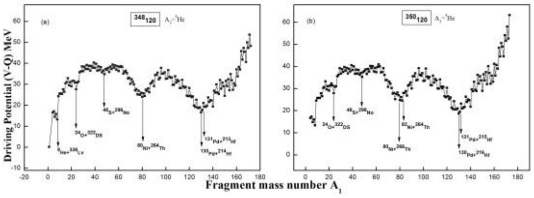

Fig. 1 Driving potential of $^{348,350}120$ isotopes with ^{4}He plotted as a function of fragment mass number A_1.

To find the suitable fission channel, in addition to cold valley, barrier penetrability and relative yield calculations are carried out for each case using equations 3 and 5 respectively. Further the relative yield versus fragment mass numbers A_1 and A_2 is plotted as presented in Figure 2. It is evident from the relative yield plot of $^{348}120$, the maximum relative yield is shown by the fragmentation ^{130}Pd+^{214}Hf+^{4}He due to the presence of near neutron magic nucleus ^{130}Pd. Next highest yields are exhibited by combinations ^{131}Pd+^{214}Hf+^{4}He and ^{128}Pd+^{216}Hf+^{4}He as they possess near neutron magic nucleus ^{131}Pd and neutron magic nucleus ^{128}Pd respectively. In the case of $^{350}120$ parent isotope, the maximum relative yield is observed for ^{130}Pd+^{216}Hf+^{4}He configuration, which have ^{130}Pd with near neutron shell closure at N=84. Second and third highest yields are exhibited by the combinations ^{131}Pd+^{215}Hf+^{4}He and ^{128}Pd+^{218}Hf+^{4}He respectively.

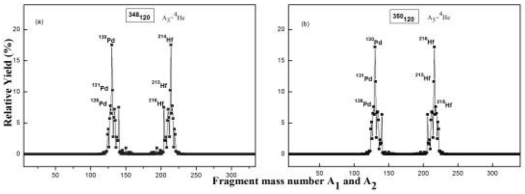

Fig. 2 Relative yield of $^{348,350}120$ isotopes with ^{4}He plotted as a function of fragment mass number A_1 and A_2.

Acknowledgement

One of the authors Amaya Pavithran would like to thank the Council of Scientific and Industrial Research (CSIR) for the financial support provided through the Junior Research Fellowship (JRF), under the file No: 08/0753(19102)/2024.

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