Pre-existence probability in the ternary breakup of ^{252}Cf

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Introduction

Understanding the mechanism of nuclear fission is a field of continuous activity from the beginning of its discovery. Ternary fission is a relatively rare phenomenon, compared to binary fission. Ternary fission is a process in which, besides the two main fission fragments a third charged particle is ejected. The Coulomb fields of heavy fragments repel the light particle and it is interpreted to be emitted from the neck region. The spontaneous ternary fission of Cf has been widely studied both experimentally and theoretically [1]. Experimental results indicate that the light charged particles were usually emitted perpendicular to the fission axis.

Preformed cluster model (PCM) of Gupta and collaborators has been widely used to predict the binary mass distribution or the preformation probability P_0. In PCM, the stationary Schrödinger equation is solved in collective fission degrees of freedom for the binary decay of the compound nucleus. The wave function obtained from the solution of Schrödinger equation is used to evaluate the probability as, $P_0 = |\psi(\eta)|^2$ and is a measure of a particular fragment to be preformed inside the parent nuclei. Poenaru *et al.* [2] interpreted that, the penetration of the overlapping part of the potential is equivalent to the preformation probability of the fragments. They used the analytical superasymmetric fission model to give an expression for preformation probability. An empirical relation was proposed relating the preformation probability and the mass number of the emitted cluster. Rajeswari *et al.* [3] have reported the preexistence probability for the complete binary decay of ^{56}Ni, ^{116}Ba, ^{226}Ra and ^{256}Fm as the WKB integral of the overlapping part within the Unified Fission Model. A second-order polynomial was used to approximate the potential energy of the overlapping part. In the present work, this idea is extended to study the pre-existence probability of ternary fission of ^{252}Cf.

Methodology

For ternary breakup, the possible mass fragmentations are generated using the condition $A_1 \geq A_2 \geq A_3$ and $A_1 + A_2 + A_3$. The third fragment mass number A_3 is taken as fixed and the charge spectrum of the remaining system is considered. The three fragments are assumed to be in the equatorial arrangement with the surfaces of the fragments being separated by a distance of 1 fm. The ternary fragmentation potential between the three fragments are evaluated using,

$$V_\eta(R) = \sum_{i=1}^{3} M_i^x + \sum_{i=1}^{3}\sum_{j>i}^{3} \left(V_C^{ij} + V_P^{ij}\right). \quad (1)$$

M_i^x are the mass excess of the three fragments, V_C and V_P are the Coulomb and nuclear potential evaluated between the three fragments as:

$$V_C^{ij} = \frac{Z_i Z_j e^2}{R_{ij}} \qquad (i,j = 1,2,3) \text{ and } \qquad i > j, \quad (2)$$

$$V_P^{ij} = 4\pi \bar{R_{ij}} \gamma b \phi(\varepsilon). \quad (3)$$

The fragmentation potential is then charge minimized with respect to the mass number of the fragments and then the respective scattering potential is evaluated using,

$$V(R) = \sum_{i=1}^{3}\sum_{j>i}^{3} \left(V_C^{ij} + V_P^{ij}\right). \quad (4)$$

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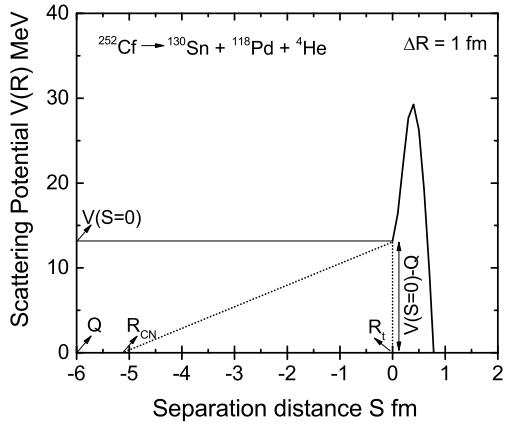

FIG. 1: Scattering potential for the ternary decay of ^{252}Cf with ^{4}He as third fragment as a function of separation distance between the fragments

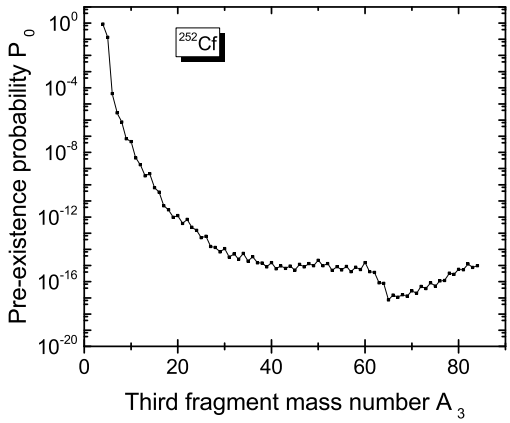

FIG. 2: The pre-existence probability as a function of third fragment mass number for the ternary fragmentation of ^{252}Cf

The scattering potential obtained for a particular exit channel with Q- value of 229.22 MeV is shown in Fig. (1). The separation distance is evaluated using $R_{CN} - (R_1 + R_2 + \Delta R)$, with ΔR as 1 fm. R_t corresponds to the saddle point and a linear approximation is used to connect the position of compound nucleus (R_{CN}) to R_t. The area of the overlapping region from R_t to R_{CN} can be taken as pre-existence probability and is evaluated with known boundary conditions. The pre-existence probability is then evaluated for all the minimized mass fragmentations and the normalized pre-existence value is obtained using,

$$P^i_{ov} = \frac{(Area)_i}{\sum_i (Area)_i}. \quad (5)$$

Results and Discussion

All possible ternary fragmentation of ^{252}Cf nucleus is considered without restricting the choice of A_3. The fragmentation potential is evaluated for all the fragmentations and is charge minimized with respect to the mass number of the third fragment A_3. Then for the charge minimized fragmentations, the scattering potential is evaluated and is then used to evaluate the pre-existence probability as described above. The distribution thus obtained is shown in Fig. (2).

The behaviour of pre-existence probability is similar to that of the experimental observation; it decreases with increase in the mass number of the third fragment. Thus, the general behaviour of the ternary mass distribution can be analyzed with this simple analytical approach. In addition, the results for individual N=Z and N≠ Z third fragments as a function of neutron number of the parent nucleus will also be presented.

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References

[1] K. Manimaran, Ph. D. Thesis, Department of Physics, Bharathiar University (2011) (and references therein).

[2] D. N. Poenaru, and W. Greiner, Physica Scripta **44**, 427 (1991).

[3] N. S. Rajeswari, K. R. Vijayaraghavan and M. Balasubramaniam, Eur. Phys. J. A **47**, 126 (2011).