A comparitive study of α-ternary fission of ^{251}Es nuclei

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Introduction

The formation of three fission fragments through the spontaneous fission of a radioactive nucleus is usually referred to as ternary fission. Out of three ternary fission fragments, one fragments is very light and hence the ternary fission is referred to as light charged particle (LCP). In most cases of ternary fission, the LCP is α particle emitted in a direction perpendicular to the other two fission fragments. Harvey et al.,[1] discovered the isotopes ^{249}Es, ^{250}Es, ^{251}Es, and ^{252}Es at Berkeley Crocker Laboratory cyclotron. A gold foil deposited with atoms of ^{249}Bk was bombarded with 20-40 MeV α-particles and the beta-emitter ^{249}Bk was bombarded with helium ions from 20 to 40 MeV. Such reactions produced the isotopes ^{249}Es, ^{250}Es, ^{251}Es, and ^{252}Es. From the detail study of literature survey it is clear that there are no studies on the alpha ternary fission of Einsteinium isotopes. Hence the aim of present work is to study the α-accompanied cold ternary fission of ^{251}Es isotope within the unified ternary fission model (UTFM). The calculations have been done by taking the interacting barrier as the sum of Coulomb and proximity potential. In the present work, we have calculated the driving potential, probability and relative yield for all possible fragments of ^{251}Es isotopes using different proximity potentials

UNIFIED TERNARY FISSION MODEL USING DIFFERENT PROXIMITY POTENTIALS

The α-accompanied ternary fission is energetically possible only if the Q value of the reaction is positive

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

Here 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 of Coulomb potential and nuclear proximity potential. The interacting potential between two nuclei of fission fragments is taken as the sum of the Coulomb potential and proximity potential.

$$V = \sum_{i}^{3} \sum_{j>i}^{3} (V_{Cij} + V_{Pij}) \tag{2}$$

Here V_{Cij} is due to Coulomb interaction between the fragments and V_{Pij} nuclear proximity potential. Six nuclear proximity potentials are used in the present work viz., **Bass 1973[2],** Prox 1977[3], Prox 1983[4], Prox 1988[5], BW 1991[6] and Prox 2000[7]

According to the WKB theory, barrier penetrability P, the probability with which the ternary fragments cross the three-body potential barrier is given as

$$P = \exp\left\{ -\frac{2}{\hbar} \int_{z_1}^{z_2} \sqrt{2\mu(V-Q)}\,dz \right\} \tag{3}$$

The turning points $z_1 = 0$ represent touching configuration and z_2 is determined from the equation $V(z_2) = Q$, where Q is the decay energy. The potential V is the sum of the Coulomb and proximity potential, are computed by varying the distance between the near surfaces of the fragments. The mass parameter is replaced with reduced mass (μ). The relative yield can be calculated as the ratio between the penetration probabilities of a given fragmentation over the sum of penetration probabilities of all possible fragmentation as follows:

$$Y(A_i, Z_i) = \frac{P(A_i, Z_i)}{\sum P(A_i, Z_i)} \tag{4}$$

Results and discussions

The alpha-accompanied ternary fission of ^{251}Es isotopes is studied by applying unified ternary fission model using different proximity potentials. The Q values are calculated using the recent data of mass excess values from Wang et al. [8]. The calculated driving potential using different proximity functions versus mass numbers A_1 and A_2 for ^{251}Es is as shown in figure 1. In this figure, there is a minima that occur in cold valley for A_1 = ^{8}Be, ^{12}B, ^{18}O, ^{24}F ^{30}Si, ^{36}S, ^{40}Ca, ^{50}Ti, ^{68}Ni, ^{98}Mo, ^{108}Pd, ^{118}Sn etc,. The corresponding reaction is also shown in the figure23. It is observed that the driving potential is minimum for fragment configuration ^{40}Ca+^{205}Ir+^{4}He and is attributable to doubly magic nuclei ^{40}Ca (N=20,Z=20). Second minimum occurs for the fragment configuration ^{68}Ni+^{179}Tm+^{4}He being presence of ^{68}Ni(N=40,Z=28). It is also observed minimum driving potentials for the other fragment configurations viz, ^{8}Be+^{239}Np+^{4}He, ^{12}B+^{235}U+^{4}He, ^{18}O+^{229}Ac+^{4}He, ^{24}F+^{223}Ra+^{4}He, ^{36}S+^{211}Tl+^{4}He, ^{30}Si+^{217}Bi+^{4}He, ^{50}Ti+^{197}Re+^{4}He, ^{98}Mo+^{149}Cs+^{4}He, ^{108}Pd+^{139}Sb+^{4}He, ^{118}Sn+^{129}Ag+^{4}He.

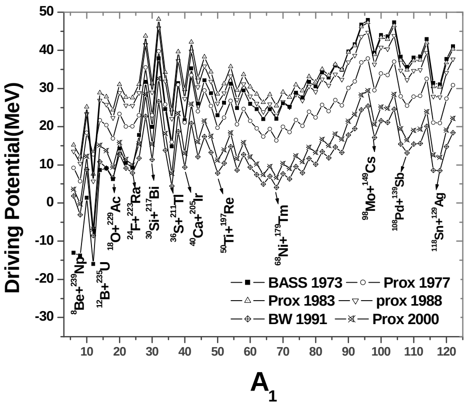

Fig.1: Calculated driving potential using different proximity potentials as a function of mass numbers A_1 and A_2 for the ternary fission of ^{251}Es.

Fission yield is calculated using different proximity potentials treating ^{4}He as a minimized third fragment for ternary fission of ^{251}Es as a function of mass numbers A_1 and A_2 as shown in figure 2. It is clear from the above figure that the fragment configuration ^{40}Ca+^{205}Ir+^{4}He posses highest yield due to the presence of doubly magic nuclei ^{40}Ca (N=20,Z=20). Second highest yield is observed for the fragment configuration ^{68}Ni+^{179}Tm+^{4}He due to the presence of magic nuclei ^{68}Ni(N=40,Z=28).

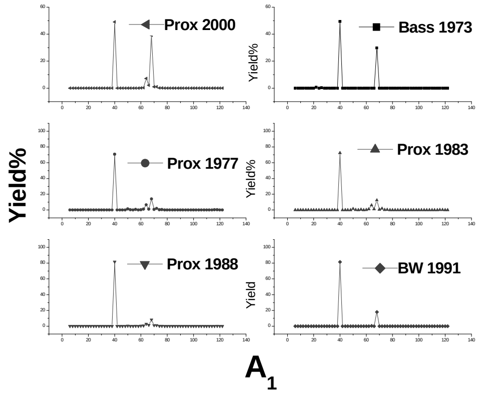

Fig.2: Calculated fission yield using different proximity potentials for the charge minimized third fragment ^{4}He is plotted as a function of mass numbers A_1 and A_2 for the ternary fission of ^{251} Es.

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