^{10}Be accompanied ternary fission of ^{252}Cf isotope

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Introduction

Ternary fission is a rare radioactive decay process in which a parent nucleus breaks into three fragments and it was observed for the first time by Alvarez [1], (as reported by Farwell *et al.*,). Usually in a ternary fission process, one of the fragments is very light compared to the main fission fragments. The ternary particle or light charged particle formed in the ternary fission process can be emitted in two different configurations; equatorial or collinear configuration. An equatorial configuration is one in which the ternary particle is emitted in a direction perpendicular to the main fission fragments whereas in the case of collinear configuration, the light charged particle is emitted along the direction of the main fission fragments.

Unified ternary fission model

The light charged particle accompanied ternary fission is energetically possible only if 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 V consists of Coulomb potential V_{Cij} and nuclear proximity potential V_{Pij} of Blocki *et al.*, [2] and is given as,

$$V = \sum_{i=1}^{3}\sum_{j>i}^{3} (V_{Cij} + V_{Pij}) \tag{2}$$

Using one-dimensional WKB approximation, the barrier penetrability P is given as,

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

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 mass parameter is replaced by reduced mass μ and is given as,

$$\mu = m\frac{A_1A_2A_3}{A_1A_2 + A_2A_3 + A_3A_1} \tag{4}$$

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,

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

Results and Discussion

The ^{10}Be accompanied ternary fission of ^{252}Cf isotope has been studied in both equatorial and collinear configuration using the concept of cold reaction valley, which was introduced in relation to the structure of minima in the so called driving potential. The driving potential is defined as the difference between the interaction potential V and the decay energy Q of the reaction. In the ^{10}Be accompanied ternary fission of ^{252}Cf isotope, the driving potential for all possible fragment combinations are calculated and plotted as a function of fragment mass number A_1 as shown in figure 1. Here minima is found for A_1 = ^{4}He, ^{10}Be, ^{14}C, ^{16}C, ^{18}C, ^{20}O, ^{22}O, ^{24}O, ^{26}Ne, ^{28}Mg, ^{30}Mg, ^{32}Mg, ^{34}Mg, ^{36}Si etc. The fragment combination ^{110}Ru+^{10}Be+^{132}Sn shows a deep minimum is due to the presence of doubly magic nucleus ^{132}Sn (N=82, Z=50) and the same fragment combination possess high Q value. Hence the fragment combination around ^{110}Ru+^{10}Be+^{132}Sn may be the most favourable fragment splitting found in the ternary fission, as it possess the presence of doubly magic nuclei and high Q value. This can be clarified only with the calculation of barrier penetrability and the relative yield obtained for every fragmentation found in the ^{10}Be accompanied ternary fission of ^{252}Cf isotope.

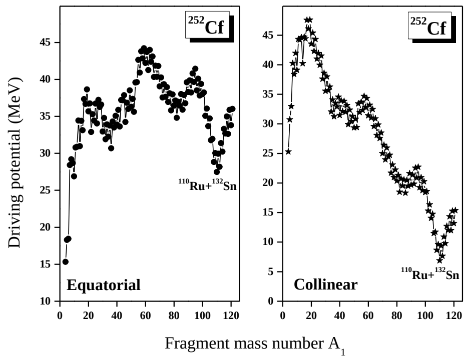

Fig. 1 The driving potential is plotted as a function of fragment mass number A_1 for the ^{10}Be accompanied ternary fission of ^{252}Cf.

The barrier penetrability is calculated for all possible fragmentations found in the cold reaction valley and hence the relative yield is calculated. Figure 2 represents the plot of relative yield versus fragment mass numbers A_1 and A_2. From the figure it is clear that the highest relative yield is found for the fragment combination ^{110}Ru+^{10}Be+^{132}Sn, which is the same fragment combination with a minimum driving potential, high Q value and possess the presence of doubly magic nucleus ^{132}Sn (N=82, Z=50) in the cold reaction valley plot.

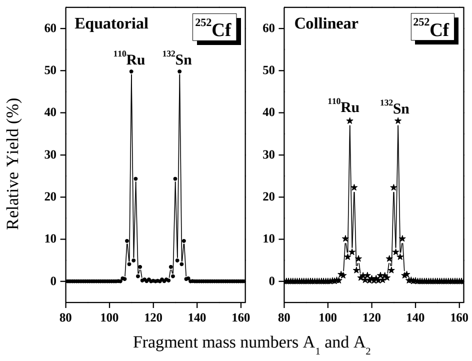

Fig. 2 The relative yield is plotted as a function of fragment mass numbers A_1 and A_2 for the ^{10}Be accompanied ternary fission of ^{252}Cf.

The next highest relative yield is obtained for the splitting ^{112}Ru+^{10}Be+^{130}Sn which includes the presence of doubly magic nuclei ^{130}Sn (N=80, Z=50). The next favoured fragment combinations found in this ternary fission process is for ^{108}Mo+^{10}Be+^{134}Te and ^{114}Ru+^{10}Be+^{128}Sn which includes the presence of near doubly magic nucleus ^{134}Te (N=82, Z=52) and the proton shell closure Z=50 of ^{128}Sn respectively.

A comparative study has been made with the relative yield obtained in the equatorial and collinear configuration of the ^{10}Be accompanied ternary fission of ^{252}Cf isotope with the experimental data [3]. The experimental ternary fission yields are observed for the correlated pairs of ^{96}Sr/^{146}Ba, ^{98}Sr/^{144}Ba, ^{100}Sr/^{142}Ba, ^{100}Zr/^{142}Xe, ^{102}Zr/^{140}Xe, ^{104}Zr/^{138}Xe, ^{106}Mo/^{136}Te, ^{108}Mo/^{134}Te, ^{110}Ru/^{132}Sn, ^{112}Ru/^{130}Sn. Figure 3 shows the comparison of the relative yield with the experimental data found in the ternary fission of ^{252}Cf isotope with ^{10}Be as light charged particle. Here the most probable fragment combinations which are observed in the experiment using Gammasphere facility and that obtained using the Unified ternary fission model are found to the same.

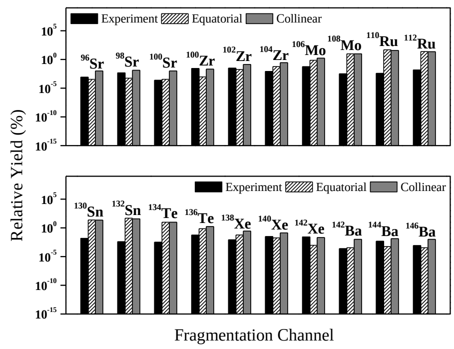

Fig. 3 Comparison of relative yield with the experimental data for the ^{10}Be accompanied ternary fission of ^{252}Cf isotope.

References

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