Ternary Fission of ^{304}120 isotope with ^{3}H and ^{4}He as light charge particle

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Introduction

Nuclear fission is a process in which a radioactive nucleus breaks in to two or more smaller nuclei known as fission products. In ternary fission, the radioactive nuclei break in to three fragments and often the third particle emitted is very light compared to other two fragments. So, this type of ternary fission process is known as light charge particle accompanied ternary fission. In 1941 R. D. Present [1] predicted the probability of tripartition on the basis of liquid drop model. In 1943, the first emission of light charge accompanied fission was reported by Alvarez [2] and simultaneously by Tsien san-Tsiang et al [3].

Unified Ternary Fission Model

The ternary fission accompanied by light charged particle is energetically possible only if Q value of reaction is positive. i.e.,

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

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 Vc_{ij} and nuclear proximity potential Vp_{ij} of Blocki *et al*[4], The interacting potential barrier is given by,

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

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

$$P = \exp\left\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V-Q)}dz\right\} \tag{3}$$

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,

$$\mu = \frac{m\mu_{12}A_3}{\mu_{12} + A_3}, \quad \mu_{12} = \frac{A_1A_2}{A_1 + A_2} \tag{4}$$

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 probabilities of a given fragmentation over the sum of penetration probabilities of all possible fragmentation as follows,

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

Results and Discussion

The ternary fission of ^{304}120 isotope with ^{3}H and ^{4}He as light charged particle for the equatorial configuration is studied using the concept of cold valley, which was introduced in relation to structure of minima in the driving potential. Driving potential is defined as the difference between interacting potential V and the decay energy Q of the reaction. Here the Interacting potential V is taken as the sum of Coulomb potential and Nuclear Proximity potential. Light charge particle (A_3) is kept fixed in each case and the driving potential is calculated for all possible fragment combination as a function of mass and charge asymmetries given as, $\eta = \frac{A_1 - A_2}{A_1 + A_2}$ and $\eta_Z = \frac{Z_1 - Z_2}{Z_1 + Z_2}$ respectively at touching configuration. A pair of charges is singled out for every fixed mass pair (A_1, A_2) in which driving potential is minimized.

The Driving potential for ^{3}H and ^{4}He accompanied ternary fission of ^{304}120 (Z=120 &N =184) isotope is computed, which is plotted as a function of fragment mass number A_1 and is shown in figure 1. The minima obtained in the cold valley by keeping ^{3}H fixed are at ^{4}He, ^{5}Li, ^{8}Be etc. and for ^{4}He fixed, the minima obtained are at ^{1}H, ^{3}H, ^{4}He, ^{6}He, ^{8}Be etc.

It is obvious from the figure that the minima found around fragment combination ^{134}Te+^{167}Ho+^{3}H is due to the presence of near doubly magic nucleus ^{134}Te (N=82, Z=52). The minima found around fragment combination ^{135}I+^{166}Dy+^{3}H is due to the presence of near doubly magic nucleus ^{135}I (N=82, Z=53). The minima found around fragment combination ^{134}Te+^{166}Dy+ ^{4}He is due to the presence of near doubly magic nucleus ^{134}Te (N=82, Z=52).

The fragment combination giving minima may possess highest yield and this can be verified through the computation of barrier penetrability and the relative yield of fragments obtained in the cold reaction valley. The barrier penetrability and hence relative yield of all fragment combination found in the cold valley plot is calculated for each fixed light charge particle cases and graph is plotted as shown in figure 2. From the graph it is clear that highest yield is obtained for ^{134}Te+^{166}Dy+^{4}He, ^{134}Te+^{167}Ho+^{3}H and ^{135}I+^{166}Dy+^{3}H combinations. It is due to the presence of neutron and proton shell closure of the near doubly magic nucleus ^{134}Te at N=82 and Z=52 and ^{135}I.

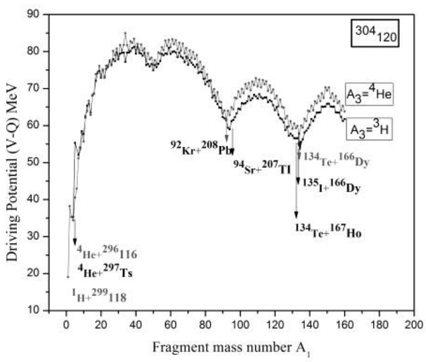

Fig 1. The driving potential for ^{304}120 isotope with ^{3}H and ^{4}He as light charge particle plotted as a function of mass number A_1

The ternary fission of ^{304}120 with ^{3}H and ^{4}He as light charge particle, the maximum yield obtained in the fragment combination having ^{4}He as light charge particle. From this work we can conclude that in the ternary fission of ^{304}120 isotope with ^{3}H and ^{4}He as light charge particle, the presence of nearly doubly magic nucleus plays an important role.

Table 1 represents the computed half-lives of alpha decay chain of ^{304}120 isotope using Coulomb and Proximity potential model [5] and is compared with Viola Seaborg [6] empirical formula. Which indicates the possibility of the sequential series of transformations of the ^{304}120 isotope.

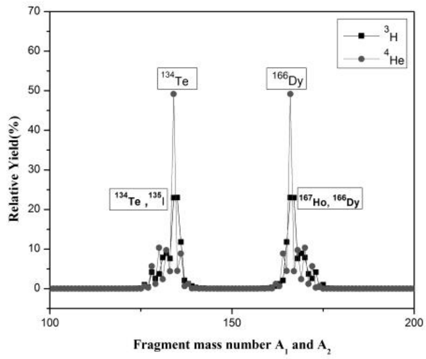

Fig 2. The relative yield of ^{304}120 isotope plotted as a function of mass numbers A_1 and A_2. The fragment combination with highest yield is labeled.

Parent	Q Value (MeV)	$\log_{10}(T_{1/2})$		Decay constant
		CPPM	VSS	
^{304}120	11.51	-1.29	-1.91	13.58
^{300}118	11.03	-0.65	-1.29	3.16
^{296}116	10.71	-0.41	-1.07	1.78
^{292}114	8.17	7.45	6.33	2.40e-08

Table 1: Computed alpha decay chain and spontaneous fission half-life of ^{304}120 isotope.

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