# Ternary fission of $^{466,476}_{184}$X giant nuclear systems

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## Introduction

The term ternary fission, a rare process relative to binary fission, is commonly used to denote the process of emission of third particle along with the main fission fragments.

After the earlier reports on ternary fission, extensive experimental and theoretical works have been carried out. One such study [1] is the collision of two heavy actinide nuclei (U+U) where they have predicted two lead-like doubly magic fragments along with the heavy third fragment. In the present work, we have studied same giant systems within the level density approach.

## Methodology

Rajasekaran and Devanathan [2] have obtained binary fission fragment combinations by considering charge-to-mass ratios of the parent nucleus and the fissioning fragments. In this work, we have extended this idea to ternary fission as,

$$\frac{Z_P}{A_P} \approx \frac{Z_i}{A_i}, \qquad (1)$$

where, ($Z_P$, $A_P$) and ($Z_i$, $A_i$, $i$ = 1, 2 and 3) correspond to charge and mass numbers of the parent nucleus and three fission fragments respectively.

Ternary fission yield is calculated by,

$$Y(A_j, Z_j) = \frac{P(A_j, Z_j)}{\sum P(A_j, Z_j)}. \qquad (2)$$

According to statistical theory of Fong [3], the relative fission probability is

$$P(A_j, Z_j) \propto \prod_{i=1}^{3} \rho(A_i, Z_i). \qquad (3)$$

The nuclear level density ($\rho$) is

$$\rho = \frac{1}{12}(\pi^2/a)^{1/4} E^{-5/4} \exp(2\sqrt{aE}), \qquad (4)$$

where $a$ ($= E/T^2$) is the level density parameter and $E$ ($= E_{tot} - E_0$) is the excitation energy. Here the ground state energy ($E_0$) and the total energy ($E_{tot}$) are calculated from

$$E_{tot} = \sum_k n_k^Z \epsilon_k^Z + \sum_k n_k^N \epsilon_k^N, \qquad (5)$$

$$E_0 = \sum_{k=1}^{Z} \epsilon_k^Z + \sum_{k=1}^{N} \epsilon_k^N, \qquad (6)$$

where $n_k^Z$ and $n_k^N$ are the occupation probabilities of $Z$ protons and $N$ neutrons.

$$Z = \sum_k n_k^Z = \frac{1}{1 + \exp(-\alpha^Z + \beta\epsilon_k^Z)}, \qquad (7)$$

$$N = \sum_k n_k^N = \frac{1}{1 + \exp(-\alpha^N + \beta\epsilon_k^N)}, \qquad (8)$$

are numerically solved to determine the Lagrangian multipliers $\alpha^Z$ and $\alpha^N$ at a given temperature, $T$=1/$\beta$. For the calculations, the necessary single particle energies of protons $\epsilon_k^Z$ and neutrons $\epsilon_k^N$ are retrieved from the Reference Input Parameter Library (RIPL-3). These single particle energies are calculated using the finite range droplet model (FRDM).

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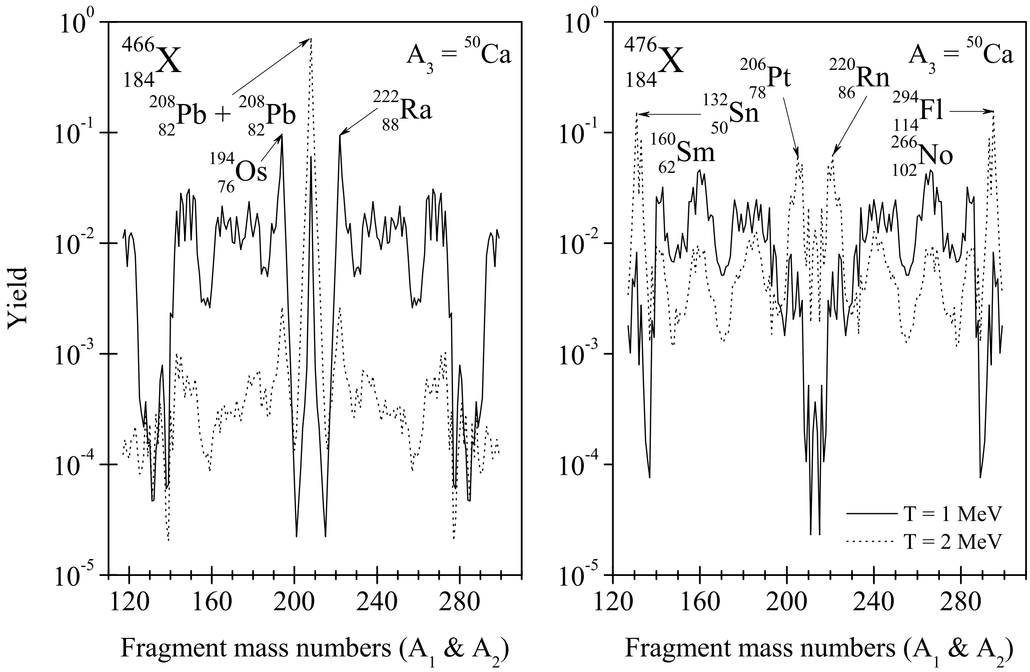


FIG. 1: Ternary fission of $^{466,476}_{184}$X with $A_3 = {}^{50}$Ca at $T = 1$ and 2 MeV.

## Results and discussion

Within the level density picture, recently we have studied the ternary fission of $^{252}$Cf for a fixed third fragment $A_3 = {}^{48}$Ca [4] and for various even mass third fragments from $A_3 = 16$ to 84 [5] at different temperatures. From this study, the importance of closed shell nature of any one of the fragments (mainly the heavier fragment) in the favourable ternary fragmentation is noted.

Here, we have studied the ternary fission of $^{466,476}_{184}$X with $A_3 = {}^{50}$Ca at $T = 1$ and 2 MeV and is presented in Fig. 1. At $T = 1$ MeV, $^{194}$Os+$^{222}$Ra and $^{160}$Sm+$^{266}$No are the most favorable configurations for $^{466}$X and $^{476}$X respectively. At $T = 2$ MeV, $^{208}$Pb+$^{208}$Pb and $^{132}$Sn+$^{294}$Fl configurations are having the most prominent yield values for $^{466}$X and $^{476}$X respectively. In addition to this, for $^{476}$X, $^{206}$Pt+$^{220}$Rn configuration has also pronounced larger yield values. The most prominent peaks are labeled in Fig. 1. Here, the configurations which pronounced larger yield values are having the closed shell structure in either one or both the fission fragments.

## Conclusion

An interesting result obtained from this work indicate $Ca$ accompanied breakup as a favorable ternary mode for two lead-like doubly magic fragments from the ternary fission of $^{466,476}$X.

## References


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