Ternary breakup of $^{298}_{114}X$

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Introduction

The breakup of heavier nuclei into three, four and even five becomes energetically more favourable than binary fission. Based on this, many theoretical and experimental studies were made to study ternary fission in trans-actinide and superheavy region. In superheavy mass region mainly the ternary to binary ratio has been reported. Grumann *et al* reported [1] that superheavy nuclei undergo ternary fission through oblate deformation and predicted ternary fission as the dominant decay mode of superheavy nuclei. Later Diehl and Greiner [2] have shown that in $^{298}_{114}X$ the barrier for oblate ternary fission is more than 50 MeV high whereas the prolate liquid drop barriers almost vanish and it has equal heights for binary and ternary fission of the superheavy nuclei with mass number of about 300 [2]. Hence they suggested that oblate ternary fission can be ruled out since the shell energy of nearly magic nuclei can hardly reduce this barrier.

Schultheis *et al* within LDM calculated [3] the barrier for ternary fission of superheavy nuclei and reported that the barriers for binary and ternary fission are equal within 10% and also calculated the relative cross-section (σ_T/σ_B) of ternary to binary spontaneous fissions which is much higher in the superheavy nuclei than in the actinide region. This was justified by the fact that in binary fission of superheavy nuclei many nucleons would be outside the closed shell (Z=50, N=82) of both the fragments, hence it might be energetically favourable to form a closed shell third fragment among these nucleons (say for example ^{132}Sn+^{132}Sn+^{34}Si in $^{298}_{114}X$). In actinides less number of nucleons are available outside the closed fragment shells. Minimum excess of the ternary barrier height over the binary one occurs in the region below the doubly magic nucleus $^{298}_{114}X_{184}$, where the total life time is high with respect to spontaneous fission, α and β decay. This result implies that the ratio of ternary to binary will be large for highly stable superheavy nuclei. And hence the high ternary to binary ratio is considered as a characteristic property of superheavy nuclei and it is advocated as a test for superheavy elements.

Very recently Zagrebaev *et al* studied [4] the possibility of true ternary fission in superheavy nuclei and reported that it is quite possible for superheavy nuclei to undergo ternary fission, with formation of a heavy third fragment because of the strong shell effects leading to a three body clusterization with the two doubly magic Sn like cores (for example ^{132}Sn+^{132}Sn+^{32}S in $^{296}_{116}X$). All these theoretical and experimental studies imply that ternary fission might be a competing decay mode to alpha decay in superheavy mass region. Hence, it would be of interest to see the possibilities of observing heavy light charged particles with doubly magic Sn like main fission fragments in spontaneous ternary fission of highly stable superheavy nuclei.

In this direction earlier we reported [5], α and a few heavy third particle accompanied ternary breakup of $^{298}_{114}X_{184}$ considering the third particle to come out from the lightest of the other two fission fragments after the binary division within the three cluster model (TCM) proposed by one of us [6, 7]. Other earlier studies also considers the sequence of breakup in this manner. However, the three fragments can be arranged in three different ways as $A_1 + A_2 + A_3$, $A_2 + A_3 + A_1$ and $A_3 + A_1 + A_2$ i.e. the lightest fragment A_3 is

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considered at the middle of the other two fragments or either at the two ends. We present in this work the potential energy surface of the ternary breakup of ${}^{298}_{114}X_{184}$ for all possible third fragments in three different configurations in collinear geometry within TCM.

In order to consider all possible third fragments in TCM we impose the condition that $A_1 \geq A_2 \geq A_3$ in the selection of fragmentation to avoid repetition of fragment combinations. Here the subscripts 1 and 2 stand respectively for heavy and light fragments and the third fragment is denoted by 3. With the implementation of the above condition in ternary fragmentation of ${}^{298}_{114}X_{184}$ the third fragment can have mass numbers from A_3=1 to 99. For all the possible 99 third fragment masses the ternary fragmentation potential energy is calculated (for three different positions of the fragments) and charge minimized with respect to their charge asymmetry.

Results and Discussion

Figure 1 presents the ternary fragmentation potentials of ${}^{298}_{114}X_{184}$. The open squares, solid circles and stars corresponds to the arrangements $A_1 + A_2 + A_3$ (Case-I), $A_2 + A_3 + A_1$ (Case-II) and $A_3 + A_1 + A_2$ (Case-III) respectively. Of the three cases, Case-II has the least potential energy for all third fragments. For third fragment mass numbers at least upto 50, Case-I and Case-III gives similar results and beyond that the potential for Case-III lies higher than Case-I. The potentials for third fragment mass numbers beyond 80, Case-I and Case-III gives similar results and all the three cases converges as the size of the three fragments becomes almost equal. For true ternary fission (with comparable mass of three fragments) the fragment combination ^{86}Se+^{80}Zn+^{132}Sn seems to be a probable one. However, there are other pronounced valleys such as ^{132}Sn+^{22}O+^{144}Ba,^{132}Sn+^{32}Mg+^{134}Te and ^{132}Sn+^{34}Si+^{132}Sn in the potential energy surface corresponding to Case-II as marked in the figure. These combinations in the minima of the potential contains atleast two closed shell fragments. To conclude, the ternary breakup with the lightest fragment at the middle has more probability than the other two combinations. But the available Q-value would remain the same for all the cases. The strong decrease in the potential for Case-II is due to the fact that, the Coulomb potential between the other two fragments reduces considerably as they are separated at least by the diameter of the lightest fragment.

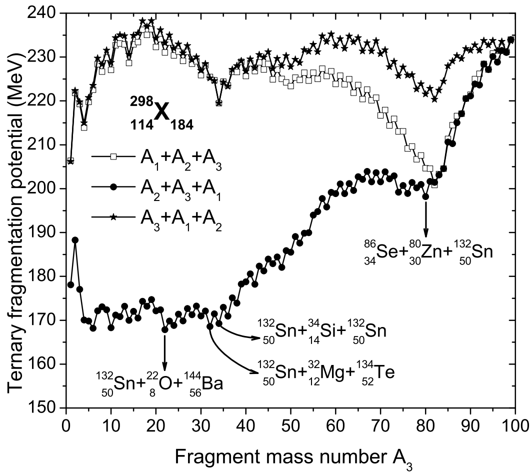

FIG. 1: Potential energy surface of nucleus ${}^{298}_{114}X$.

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References

[1] J. Grumann, U. Mosel, B. Fink and W. Greiner, Z. Physik **228** 371 (1969).

[2] H. Diehl and W. Greiner, Nucl. Phys. **A 229** 29 (1974).

[3] H. Schultheis and R. Schultheis, Phys. Lett. **49B** 423 (1974)

[4] V. I. Zagrebaev, A. V. Karpov and W. Greiner, Phys. Rev. C **81** 044608 (2010)

[5] K. Manimaran and M. Balasubramaniam, *Proceedings of DAE-BRNS Int. Symp. on Nucl. Phys.* **54**, (2009) p455.

[6] K. Manimaran and M. Balasubramaniam, Phys. Rev. C **79** 024610 (2009).

[7] K. Manimaran and M. Balasubramaniam, Eur. Phys. J. A **45** 239 (2010).