LCP-accompanied fission to symmetric tripartition of heavy and superheavy nuclei

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Introduction

Break-up of a nucleus into three fragments, known as ternary fission covers a spectrum of three particle fission events from a scission neutron accompanying the two main fission fragments, to the three fragments of about equal masses. The ternary fission process with three charged particles in the outgoing channel, with a very light third particle compared to the main fission fragments is situated between these two extremes and is called as light charged particle (LCP) accompanied fission. This very asymmetric ternary fission is a competing decay mode for binary fission and is observed in spontaneous and induced ternary fissions of various actinides.

The break-up into three nuclei of about equal masses has not been unambiguously detected but there is a strong theoretical indications that such modes can be looked into experimentally. Also, in a series of recent experiments Pyatkov et al., [1] have claimed the observation of true ternary events within missing mass method. α particle is one of the overriding light charged particles accompanying the process of ternary fission apart from the isotopes of H, He, Li, Be and C which were observed as ternary particles but in small traces. But only ^{4}He, ^{10}Be and ^{14}C alone were confirmed as light charged particle accompanying the spontaneous ternary fission. From the experimental signature it is seen that the fission fragments in ternary fission associates with either spherical or deformed closed shell, consequently, study of this exotic decay mode will give structural information of nuclear species.

Further, the branching ratio of ternary fission and/or light charged particle accompanied fission with respect to binary fission is very small and being an exotic process, a theoretical understanding of this process is not completely exploited. A study of this process is very important for the understanding of fission mechanism since the analysis of ternary fission will enable to understand the information on the conditions of the nucleus at scission. In particular, the evaluation of the energy of the fragments just after scission should be extremely important since velocity of the fragments at the instant of their separation provides information on the dynamics of the process. Earlier theoretical attempts made were in the direction of trajectory calculations with the known observables to understand the mechanism as well as yield calculations to compare with the available data.

Methods and Results

We have been studying the ternary fission process of heavy and superheavy nuclei within the three cluster model proposed by us [2–5] and also using statistical theory [6, 7]. The three cluster model takes into account the complete charge minimization of the ternary fragmentation potential of any nucleus. In a later work, the model has been incorporated with deformation and orientation degrees of freedom. It has been identified that for light charged particle accompanied fission deformation and orientation degrees of freedom plays a vital role in the yield calculations. Further, the kinetic energies of the ternary fission fragments corresponding to a particular ternary fragmentation of Sn+Ni+Ca for various mass combinations are studied [8] assuming a two

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step process of the ternary event. This particular combination has been identified experimentally as a most favourable one within missing mass method.

It has been identified that the positioning of the three fragments also plays a significant role. In this direction, we have studied the competition between collinear geometry (wherein all the three fragments lie along the same line and plane) and equatorial geometry (wherein all the three fragments's surface touch each other resulting in a triangular configuration) [9]. The obtained results revealed that the equatorial configuration is the favourable one for light charged particle accompanied fission whereas, if the third fragment mass increases, collinear configuration seems to become a probable configuration.

Further, in order to study all possible ternary fragmentation of a given nucleus we have developed a two dimensional minimization procedure. Incorporating this idea, ternary plots (a four dimensional plot) of the ternary fragmentation potential are made as a function of either the three possible charge numbers or the three possible neutron numbers to locate different region of ternary modes. This study revealed that, the α-accompanied fission remains a favourable one for the actinides within collinear geometry for the arrangement of increasing mass number of the fragments [10]. However, if the lightest fragments is considered to be positioned at the centre of the other two fragments, the scenario changes. For this arrangement, though, α-accompanied fission seems a favourable mode, in addition, there are other strong minima seen in true ternary region leading to symmetric tripartition. Interestingly, the true ternary fission region is found to enhance with increase in size of the parent mass number.

Encouraged by this results we have extended the studies to superheavy nuclei [11]. In general, the superheavy nuclei are identified through the α decay chains. The α decay remains the dominant decay than anyother possible disintegration, thought theoretically cluster decay has also been proposed to be a favourable decay to look for in superheavy region. Our studies revealed some interesting results *viz.,*, the ternary breakup of superheavy nucleus indicates a very strong preference for heavy particle accompanied fission and true ternary fission. We find very less signature for α accompanied fission though α decay remains a dominant one.

In addition, within statistical theory we have studied the complete mass distribution (involving all possible third fragments) of heavy nuclei following the works of Rajasekaran and Devanathan [6, 7]. The results obtained clearly indicated Sn+Ni+Ca fragmentation as a favourable one as has been observed in the experiments.

In this talk an overview of our results will be discussed.

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