Ternary fission studies of Californium (Cf) nuclei and heavy particle emission from ground and excited state of nuclei in transtin region

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The break-up of a radioactive nucleus into three fragments covers a spectrum of fission events from one end in which a scission neutron accompanies two main fission fragments, to the other in which three fragments of about equal masses are emitted. The ternary fission process with three charged particles in the outgoing channel, with the third particle being very light compared to the main fission fragments are situated between these two extremes and are called as light charged particle (LCP) accompanied fission. Though being an exotic process the study of LCP accompanied fission have got increased attention to understand about nuclear structure, fission dynamics, nuclear forces, energy spectrum and angular distribution of fragments. In this thesis work, a new model called "Three Cluster Model" (TCM) has been proposed [1–4] with different degrees of freedom to study the ternary fission of given nuclei. The advantage of this model is that, for a fixed third fragment, we can calculate the fragmentation potential minimized in mass and charge asymmetry coordinate.

Since α-particle being the most probably observed LCP in ternary fission, α accompanied fission of Californium nuclei ($^{238-256}$Cf) is studied using TCM within spherical approximation and equatorial configuration. The charge minimization of the third fragment is shown here for the first time by minimizing the ternary fragmentation potential energy. The most probable ternary fragmentation identified through the potential energy surface and relative yield calculation in α accompanied fission of Californium isotopes reveal that at least one (or two) of the fragments associate itself with the neutron (or proton) closed shell and in some cases even the doubly closed shell nucleus. Among the Cf isotopes studied the neutron rich isotopes ^{252}Cf, ^{254}Cf and ^{256}Cf have maximum probability to observe α accompanied fission. The calculated relative percentage yields of α accompanied fission of ^{252}Cf are in reasonable agreement with that of available experimental data. The preformation factor of ternary fragmentation and their effects in the relative yield are also studied. Apart from α particle as third particle, few other LCP accompanied ternary fission is studied theoretically and experimentally. Hence, it will be interesting to study within TCM, various third particle accompanied fission. One such study for the case of ^{252}Cf for all possible third fragments is carried out within spherical approximation in the equatorial configuration [2] as well as in collinear configuration [4]. Due to large number of ternary fragmentation of given nucleus for different third particles, we imposed the condition of $A_1 \geq A_2 \geq A_3$ and calculated the ternary fragmentation potential energy, relative yields of all possible ternary fragmentation of ^{252}Cf with A_3=1 to 84. The potential energy surface corresponding to collinear configuration exhibits a strong valley around ^{48}Ca and its neighboring nuclei ^{50}Ca, ^{54}Ti and ^{60}Cr, which was not present in the potential energy surface in equatorial configuration. As a consequence of this strong minima in the ternary fragmentation potential the relative yield of ternary fragmentation with ^{48}Ca, ^{50}Ca, ^{54}Ti, ^{60}Cr and ^{82}Ge as third fragment shoots up in magnitude with respect to their neighbors. The results of potential energy and relative

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yield calculation reveal that collinear configuration increases the probability of emission of heavy fragments like ^{48}Ca (doubly magic nucleus) and its neighboring nuclei as third fragment which resemble with the recent experimental result. The results obtained indicates that the equatorial configuration may be a preferred configuration for light particles and collinear configuration is preferred for heavy third fragment emission in particle accompanied fission. The most probable ternary fragmentation of ^{252}Cf with third fragment $A_3 = 1$ to 84, in both equatorial and collinear configuration are predicted. Among the three fragments in the predicted fragmentation, at least one (or two) of the fragments or all the three fragments associate itself with the neutron (or proton) closed shell and in some cases even the doubly closed shell nucleus. The result also indicates that even mass third fragments are more favoured than odd mass third fragments in both equatorial and collinear configuration. The possibility of ternary fission mode in the superheavy mass region is also studied.

The experimentally measured results of α accompanied ternary fission of ^{252}Cf imply that fragments with higher ground state deformation are seem to have more yields compared to other fragment combinations. Hence the effects of deformation and orientation are incorporated in TCM. The sensitivity of potential energy surface (PES) due to the ground state quadrupole deformation (β_2) and the orientation effects (90°-90° and 0°-0°) in ^{4}He and ^{10}Be accompanied fission are analyzed [3]. The most favoured ternary splittings for both ^{4}He and ^{10}Be accompanied fission of ^{252}Cf nucleus are predicted. The predicted channels are the fragmentation that are having the largest yield in the measurement. From our calculations of PES, few fragmentation channels that are not yet observed experimentally are seemed to be probable due to their higher quadrupole deformations, inviting the attention of experimentalists. The present study reveals that the ground state deformation of the fragments and the orientation effects play a major role in identifying the most probable fragments in ternary splitting rather than the closed shell effects alone of the fragments.

Another kind of exotic radioactive decay mode called cluster decay or heavy particle decay from ground and excited parents are also studied in this thesis. A new semi-empirical formula is proposed [5] to calculate the cluster decay half-lives in trans-tin region. The results obtained are found to have a better agreement with the available theoretical results. Further the possible cluster decay modes in ^{127}I using PCM, UFM and the newly proposed formula is studied. The calculated half-lives are compared with recently measured lower limits of half-lives. The calculated values are well above the experimental lower limits and trend of calculated values also matches with experimental values. For heavy cluster emission from the excited compound nucleus one of the important ingredients is the knowledge of temperature dependent binding energies. For this purpose, Krappe's formula is refitted with the experimental binding energies by varying the volume and surface co-efficient's and is used in DCM to study the light particles and intermediate mass fragments emission from the excited ^{116}Ba* formed in the reaction ^{58}Ni +^{58}Ni at different incident energies. The results are in good agreement with the experimental values.

Acknowledgments

The author acknowledges with thanks the financial support in the form of University Research Fellowship granted by Bharathiar University.

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