Fragmentation analysis of the binary, ternary and quaternary fission of U and Fm isotopes

Chahat Jindal[1],* Nitin Sharma, and Manoj K. Sharma
[1]*School of Physics and Materials Science*
Thapar Institute of Engineering and Technology, Patiala-14007, Punjab, INDIA

Introduction

The process where a radioactive nucleus decays into fragments of comparable size is known as the spontaneous fission. Swiatecki *et al.* [1] suggested that the nuclei with fission parameter 30.5 < Z^2/A < 43.3 may undergo into multi fragment emission. Beside this, nuclear shape effects are studied [2], and it is emphasized that the two or three necks are probable as one goes from lighter to heavier nuclei. Henceforth, one may conclude that the probability of three or four body emission increases as we approach towards heavy and superheavy nuclei. The radioactive splitting of the parent nucleus into two, three and four fragments is termed as the binary, ternary and the quaternary fission. The main reason for this radioactive splitting is the shell closure effect associated with the parent or the daughter nucleus [3]. Hence, it will be of interest to explore the fragmentation behaviour of such decay modes, and make a comparative analysis of the probable fragmentation pattern. In the present work, a comparative analysis of binary, ternary and quaternary fission of U and Fm isotopes is made using the Quantum Mechanical fragmentation Theory(QMFT) based model.

Methodology

In the present work the fragmentation analysis is carried out using QMFT based models. The fragmentation potential is calculated as in [4, 5]:

$$V = \sum_{i=1}^{4}\sum_{j>i}^{4} B_i + V_{Cij} + V_{Pij} \qquad (1)$$

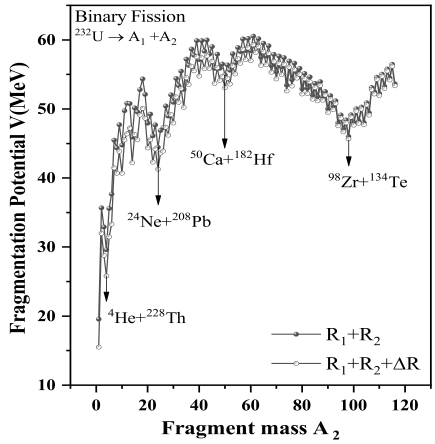

FIG. 1: Calculated fragmentation potential of ^{232}U nucleus as a function of fragment mass A_2 for touching configuration and at optimized neck length (ΔR).

Here, B_i are the binding energies of the fragments, V_{Cij} is the Coulomb potential and V_{Pij} is the short range proximity potential. The relative separation among the fragments is R_{ij} = R_i+R_j+s_{ij}. Here R_i and R_j are the radius vectors of decaying fragments and s_{ij} is the surface separation between them. It is relevent to mention here that the s_{ij} is taken in reference to collinear configuration.

Results and Discussion

In the present work, the decay analysis of ^{232}U,^{238}U,^{246}Fm,^{256}Fm nuclei is made using fragmentation structure. The minima in the fragmentation structure gives the most probable fission fragments. In view of this, the probable fission fragments are identified for binary, ternary and quaternary fission. Initially, the fragmentation potential for binary decay of

*Electronic address: jindalchahat11@gmail.com

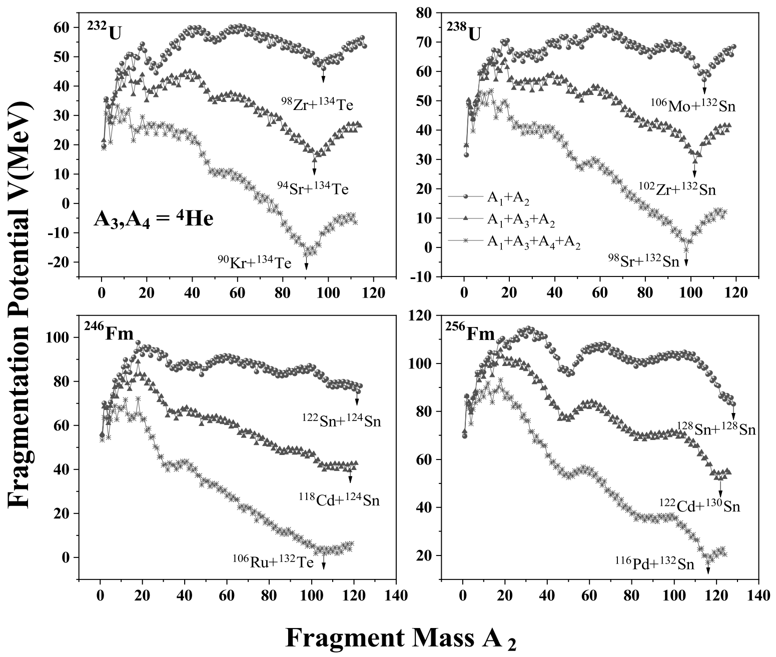

FIG. 2: The calculated fragmentation potential V(MeV) as a function of fragment mass A_2 for binary, ternary and quaternary fission of (a) ^{232}U (b) ^{238}U (c) ^{246}Fm (d) ^{256}Fm nuclei.

^{232}U nucleus is estimated with and without including neck length parameter in Fig.(1). The dips in the fragmentation structure depict the most probable decay fragments. In general, one of these fragments is associated with neutron or proton shell closure. One may see the emergence of Z=2,20,82 and N=82,126 magicity in Fig(1). It can be noticed that the overall fragmentation structure is almost similar for both cases in Fig(1). Therefore, the touching configuration is employed to work out the comparative analysis of the fragmentation potential for binary, ternary and quaternary decay channels. The comparison of fragmentation structure of the three decay modes is made in Fig.(2) and the most probable fission fragments are identified for each channel. It can be observed from this figure that the fission region changes from asymmetric to symmetric configuration, when one goes from U to Fm nucleus for all the decay channels. Beside this, it is observed that one of the fragment is associated with neutron or proton shell closure (Z=50,N=82). Hence, the shell closure effects play a significant role in the considered decay modes. The comparison among the relative yield of the such decay channels would be of future interest.

References

[1] WJ Swiatecki, *et al.* , Nucl. Phys. **46**, 639 (1963).

[2] DN Poenaru, *et al.* , Phys. Rev. C **59**, 3457 (1999).

[3] DN Poenaru, RA Gherghescu, W Greiner, Nucl. Phys. A **747**, 182 (2005).

[4] KP Santhosh, A Cyriac, Phys. Rev. C **101**, 044613 (2020).

[5] K Manimaran, M Balasubramaniam, Phys. Rev. C. **83**, 034609 (2011).