Fission characteristics of the ^{224}Th compound nucleus

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Fission has been studied extensively to understand underlying mechanisms that are responsible for its occurrence [1]. The distribution of masses of fission fragments can be asymmetric or symmetric, depending on various factors such as isospin and excitation energy of the fissioning nucleus. Further, spectroscopy of fragments following spontaneous fission has provided valuable information about the structure of neutron-rich nuclei. For example, studies of ^{252}Cf fission fragments have led to observation of some noteworthy aspects such as octupole shapes and hyperdeformation in barium nuclei [2, 3], cold ternary fission [4], and spin dependence of triaxial deformation in molybdenum isotopes observed in the fission of ^{248}Cm [5]. Recent studies of fission fragments following heavy-ion fusion reactions have revealed fine structure dips in the fragment mass distribution [6, 7]. These dips are interpreted as due to nuclear shell-structure effects causing "shape inhibition" in nuclei near shell closure at the scission point. It was also pointed out in Ref. [7] that more experimental information is desirable for systematic investigation of the above interpretation. In general, compound nucleus fission following heavy-ion fusion has not been particularly exploited for gamma-spectroscopic studies. This work is focused on the fission of the compound nucleus ^{224}Th.

The nucleus ^{224}Th was produced in the fusion of an 86 MeV ^{16}O beam with a self-supporting ^{208}Pb target of 5.5 mg/cm^2 thickness. The beam was provided by BARC-TIFR pelletron located at TIFR, Mumbai. The γ rays following the reaction were detected using Indian National Gamma Array (INGA), which at the time of experiment consisted of 19 clover Ge detectors. The data were recorded to disk using a triggerless digital data acquisition system based on XIA Pixie-16 modules [8].

One of the important characteristics of the fission process is the mass distribution of the fission fragments. Although multiple fission paths are possible, mass symmetric and asymmetric paths dominate the fission process [1]. Furthermore, it is observed that in spontaneous and neutron-induced fission the asymmetric mode is dominant [9], while the symmetric mode is enhanced in fusion-fission reactions [6, 7]. Another interesting aspect of fission is neutron multiplicity. Ter-Akopian *et al.* have observed neutron multiplicities as low as 0, and 10 on the higher side in the spontaneous fission of ^{252}Cf using high-resolution $\gamma-\gamma-\gamma$ coincidence techniques [10]. On the other hand, it was deduced in a recent study that on average 8 neutrons were evaporated in fusion-fission reaction [7].

It is well known that the total intensities of the lowest $2^+ \rightarrow 0^+$ transitions of even-even fission products represent the total independent yields of these isotopes with a high accuracy ($< 5\%$) [10]. We have used this information to obtain relative independent yields of various isotopes following fission of ^{224}Th. The intensity of the lowest $2^+ \rightarrow 0^+$ transition was obtained by putting gates on all transitions which feed the lowest 2^+ state directly. We have also searched for cross-coincidences between various fission partners. Figure 1 shows summed double-gated spectra on various transitions in the ground-state bands of ^{108}Ru, ^{106}Ru, and ^{102}Mo which il-

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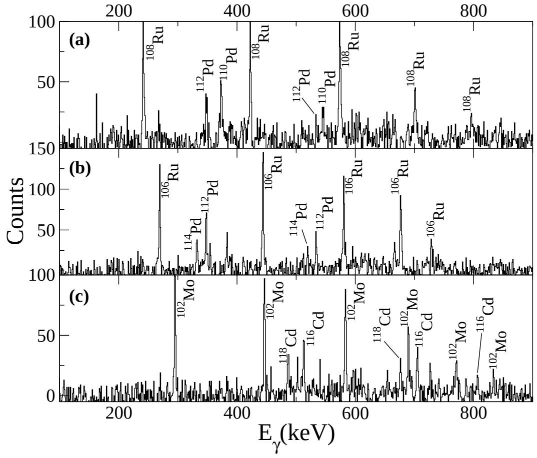

FIG. 1: Spectra illustrating cross-coincidences between fission partners. The spectra are obtained by summing various double gates in (a)^{108}Ru, (b)^{106}Ru, and (c)^{102}Mo.

lustrate cross-coincidences observed with their fission partners. Such cross-coincidences were observed between Ru-Pd, Mo-Cd, Sn-Zr, Te-Sr, and Xe-Kr isotopes, which confirm their origin in the fission process of ^{224}Th. These observations were also used to derive neutron multiplicity. It is found that the multiplicity varies at least from 4 to a maximum observed value of 8.

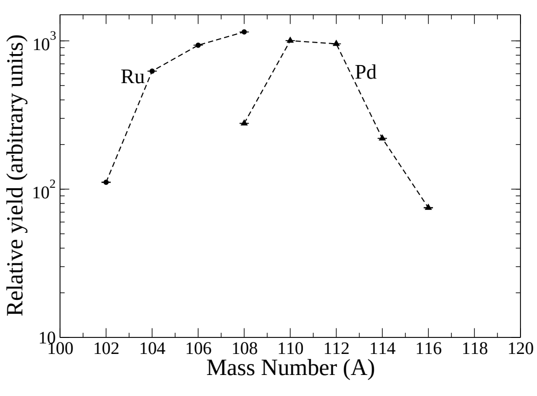

FIG. 2: Relative independent (preliminary) yields of Ru and Pd fragments populated in near-symmetric fission of ^{224}Th following fusion-fission reaction.

The experimental relative yields also indicate that the symmetric fission is enhanced over asymmetric fission, with the peak being at $A \approx 110$. This is consistent with the theoretical calculations based on a two-stage reaction model [11]. Relative yields of near-symmetric fission partners are illustrated in Fig. 2. The preliminary analysis also indicates a dip in the fragment mass distribution at $A = 124$ arising from shell effects, similar to that observed in the fission-fragment mass distributions of ^{226}Th [6] and ^{256}Fm [7].

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