Fission fragment γ-spectroscopy of ^{7}Li+^{232}Th system

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Introduction

Study of fission induced by weakly bound nuclei provides an interesting physics problem. Low breakup threshold energies of these nuclei leads to their breakup in the field of the target. Effect of this process on elastic scattering and fusion channels is known to be significant [1]. However, its effect on the fission channel is less explored. In these reactions, along with the complete fusion-fission (CFF), in which the whole projectile fuses with the target followed by fission of the resultant compound nucleus (CN), an additional process of incomplete fusion-fission (ICFF) can occur, in which only one of the breakup fragments fuses with the target to form the CN followed by its subsequent fission. Investigating the influence of these two process on the mass distribution properties is the aim of the present work. In addition, a systematic comparison of these with the corresponding values for fission of the same CN induced by tightly bound nuclei, within similar excitation energy (E^*) range, can provide further confirmation of the effect of the breakup channel on the mass distributions. With this motivation, mass distributions have been obtained for the ^{7}Li+^{232}Th system, using the the less used technique of γ-spectroscopy of fission fragments.

Experimental Details

γ-spectroscopy of the fission fragments resulting from the fission of ^{239}Np, formed in the fusion of the weakly bound ^{7}Li with ^{232}Th, was carried out at the 14UD Pelletron-LINAC facility, TIFR, Mumbai, India, employing the INGA spectrometer [2]. ^{7}Li beam of energies 38 and 45 MeV was bombarded onto a 12 mg/cm^2 self supporting ^{232}Th target with an average beam current of $\sim$3 enA. Energies at the center of the target after energy loss correction are 36.6 and 43.8 MeV. γ-rays emerging from the de-excitation of the fission fragments were detected using the INGA spectrometer. Two or higher fold coincidence events were recorded, in list mode along with its time stamp, using a fast digital data acquisition system based on the PIXIE-16 modules of XIA LLC [3]. Energy calibration and relative efficiency of the spectrometer were determined using a mixed ^{133}Ba-^{152}Eu source.

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Analysis and Results

The data was sorted with a prompt coincidence window of 200 ns, to generate E_γ-E_γ-E_γ cube, using the program MARCOS developed at TIFR. Analysis of the resultant projected spectra was done using the software RADWARE [4]. For each identified even-even fission fragment, a gate on its $4^+ \rightarrow 2^+$ γ transition was set and total counts for the $2^+ \rightarrow 0^+$ γ transition were extracted. These were corrected by the efficiency of the spectrometer to estimate their individual yields. These were then summed for each A to generate the mass distribution, shown in Fig. 1.

The mass distributions were compared with the corresponding values from model calculations of GEF 2015/2.2 code [5]. The shape of the distribution is observed to be in reasonable agreement to the calculations. In order to investigate the effect of the breakup channel, full width at half maximum (FWHM) and peak to valley (P/V) ratio of the experimental distributions were extracted. The distributions were fitted with two Gaussians to extract their FWHM and were compared with

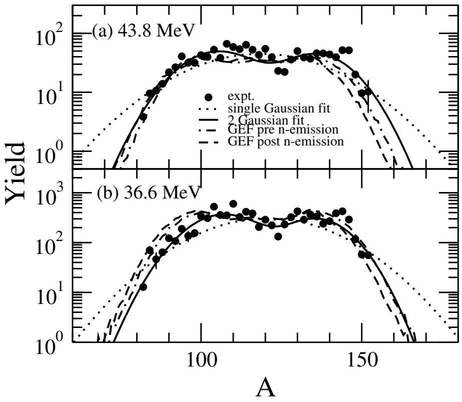

FIG. 1: Fission fragment mass distribution for ^{7}Li+^{232}Th system obtained (a) 43.8 and (b) 36.6 MeV ^{7}Li beam energies respectively.

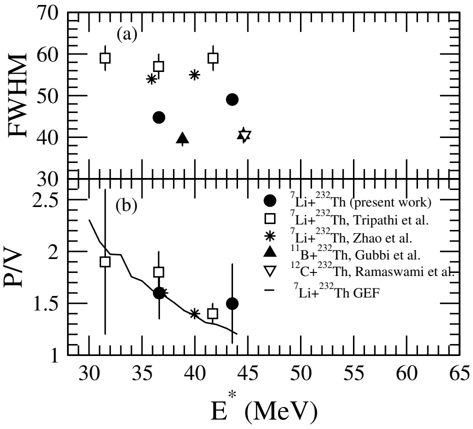

FIG. 2: (a) FWHM and (b) P/V ratio as a function of E* obtained from mass distributions corresponding to fission of ^{232}Th induced by different projectiles.

the corresponding values from previous works [6] and those of ^{11}B+^{232}Th [7] and ^{12}C+^{232}Th [8] systems, involving fission of ^{232}Th induced by tightly bound nuclei (Fig. 2(a)). P/V ratios were obtained by taking an average of the peak yields and dividing them with the lowest yield within the A range of the two peaks and are shown in Fig. 2(b).

The FWHM values from the present work are smaller (by ∼22% at E*=36.6 MeV) than those obtained in the previous work [6] but are systematically higher compared to those for ^{11}B+^{232}Th [7] and ^{12}C+^{232}Th [8] systems. P/V values extracted in the present work are consistent within errors to the previous measurements [6]. They are also in reasonable agreement with the corresponding values of GEF calculations within the E* range of the present measurement.

Conclusions

Comparison of the FWHM values for ^{7}Li+^{232}Th system with those of tightly bound nuclei indicates negligible effect of the breakup channel on the mass distribution in the E* range studied in the present inclusive measurement. This is supported by the agreement of the experimental P/V ratio with GEF calculations which does not take breakup of the weakly bound nuclei into account. Exclusive measurements employing particle-γ coincidence measurement over a wider E* range are required to disentangle the relative effect of the breakup of ^{7}Li on the fission channel.

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