Fission fragment mass distribution in ^{6,7}Li+^{238}U reaction

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Introduction

The shape of the mass distribution of the fission fragments from the actinides induced by proton or neutron is known to change with the incident energy. At low energies, it shows a double humped distribution which changes slowly to a single humped distribution as energy increases[1]. However, for a reaction involving a weakly bound projectile (i.e., ^{6}Li+^{232}Th), a sharp change in the shape of the mass distribution with energy has been observed [2]. The ratio of the fission yield at the peak ($M \sim 137-140$) to the yield at its valley ($M \sim A/2$) is a measure of nuclear heating. The more is the value of P/V, less is the nuclear excitation. The sharp increase in the P/V value in the fission fragment mass distribution in ^{6}Li+^{232}Th reaction was concluded to be due to reduced momentum transfer caused by alpha or deuteron induced fissions. A large probability of breakup of ^{6}Li into α and d made a substantial contribution to the breakup induced fission and thus the average excitation energy was much lower than the case of complete fusion (CF) followed by fission.

To investigate the above observation further fission measurements were made for two more reactions involving a different target (^{238}U) and two weakly bound projectiles ^{6}Li and ^{7}Li with different breakup probabilities. Since ^{7}Li has a higher breakup threshold (hence lower breakup probability), one can expect that P/V ratio for the ^{7}Li induced reaction should be smaller than that of ^{6}Li, specially at lower energies.

Measurements and analyses

The experiment was performed using ^{6,7}Li beam from the 15-UD pelletron facility in Inter University Accelerator Centre, New Delhi. The ^{238}U target of thickness $\sim 100\ \mu$g/cm^2 sandwiched between two layers of ^{12}C of thickness $\sim 15\ \mu$g/cm^2 was used. Two multi-wire proportional counter (MWPC) detectors were used to detect fission fragments. Both the MWPCs have an active area of 20x10 cm^2 and provide position signals in horizontal (X) and vertical (Y) planes, timing signal for time of flight measurements and energy signal giving the differential energy loss in the active volume. The start of the timing was taken from a small area (3.7 x 3.7 cm^2) transmission type fast timing multi-wire proportional counter and the stop was taken from the large area MWPCs. The combination of small MWPC and any one of the large MWPCs provide absolute timing of the fission fragments. Time of flight signal in combination with differential energy loss signal gives a clean separation of fission fragments from projectile and target like particles.

Fig. 1 shows typical yield of fission fragments of different masses detected in the ^{7}Li+^{238}U reaction at three energies: 31.4, 40.4 and 51.4 MeV. It can be observed that the double humped structure in the mass distribution is more prominent at 31.4 MeV compared to that at 51.4 MeV. At higher energies, it gradually approaches to become a single hump

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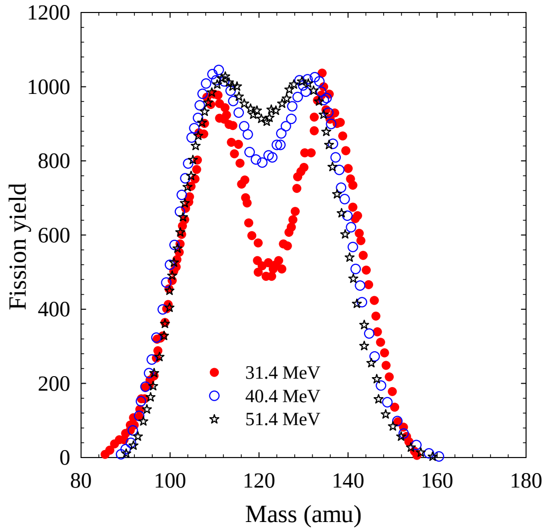

FIG. 1: Yield of fission fragments as a function of mass obtained from the reaction ^{7}Li+^{238}U at beam energies of 31.4 (filled circles), 40.4 (hollow circles) and 51.4 MeV (stars), showing the change in the shape of mass distribution with energy.

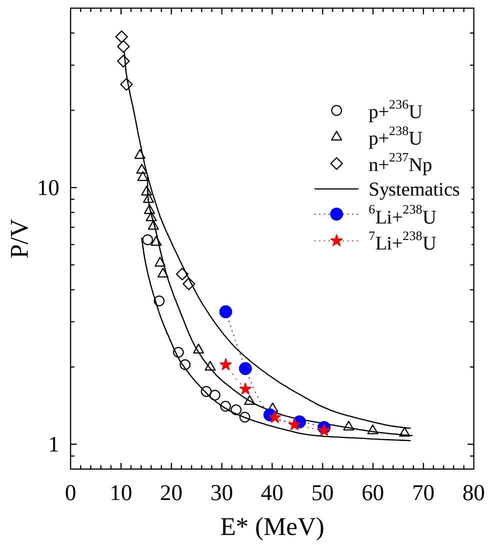

FIG. 2: Ratio of peak to valley (P/V) of the fission fragment mass distribution for ^{6,7}Li+^{238}U along with literature data for n and p induced fission of the actinides. Results of systematics are shown as solid lines. See text for details.

with symmetric mass distribution. The mass distributions obtained from the measured fission data for ^{6}Li+^{238}U reaction at slightly different energies (but with same excitation energies) also showed a similar behaviour.

The ratio of the peak to valley of the fission fragments mass distribution are calculated for ^{6,7}Li+^{238}U reactions at different energies and plotted in Fig. 2 as filled circles and stars respectively. The P/V values from the literature[3] data for p and n-induced fissions of Uranium and Neptunium targets along with the calculations from systematics are also shown in the above figure to compare the present results. It is interesting to observe that although the P/V values for ^{7}Li+^{238}U (stars) follows the trend similar to the systematics in the measured energy range, the values for ^{6}Li+^{238}U (filled circles) at lowest two energies are very large compared to the rest of the systems. The larger value of P/V for ^{6}Li+^{238}U implies that the average excitation energy of the compound nuclei formed in this reaction must be smaller, due to incomplete fusion (ICF) contribution, than the one we have calculated assuming complete fusion only. However, for ^{7}Li+^{238}U, the ICF contribution seems to be much less compared to the case of the former. This observation is consistent with the fission cross section data[4] as well as the results of the coupled-channels calculations [5] where it was observed that the total fusion (CF+ICF) for ^{6}Li+^{238}U is much larger than ^{7}Li+^{238}U at sub-barrier energies.

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