Fission fragment mass distribution around $A = 136$ in ^{239}Pu(n$_{th}$, f) reaction

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Introduction

Dynamical evolution during nuclear fission involves a large scale collective rearrangement of the nuclear matter. Fission fragment (FF) mass distributions are important from understanding the fission dynamics as well as from the various nuclear energy applications point of view. A large number of experiments have been carried out in this field during the last decades and are generally incorporated into the main evaluated nuclear data libraries such as JEF - 2.2, JEFF - 3.1.1, ENDF/B - VII.0, and JENDL - 4.0 as reminded in Ref. [1]. Nevertheless, strong efforts are needed to reduce fission yield uncertainties as well as to understand differences observed between these evaluated nuclear data libraries. In case of ^{239}Pu(n$_{th}$, f) fission, anomalies in the mass distribution around A=134 have been observed. Revised data library JEFF-3.1.1 [2] shows a 10% dip in comparison to the JEF-2.2 [3] in the case of ^{239}Pu(n$_{th}$, f) fission. The independent mass yield for $A = 134$ roughly corresponds to the ^{134}Xe cumulated fission yield. Since Xenon is released in irradiated Mox fuel, its accurate production information is very important in the nuclear energy reactors.

Recently, FF mass distributions have been measured from the study of fission fragment spectroscopy in heavy-ion fusion reactions; ^{208}Pb(^{18}O, f) and ^{238}U(^{18}O, f) [4]. These experiments are performed at large excitation energy (∼50 MeV) of the fissioning nuclei. It has been observed that the mass distributions show fine structure dips at A=124 and 136. The observed dips in the fragment yield distribution have been interpreted due to "shape inhibition" of close shell (Z=50 and N=82) fragment nuclei at the scission point [4]. It would be of interest to investigate these fine structures in mass distribution from thermal neutron induced fission.

In the present paper, we report the results obtained for mass distribution in the range of A = 132-145 from ^{239}Pu(n$_{th}$, f) reaction, measured using the Lohengrin recoil mass spectrometer located at the Institut Laue-Langevin in Grenoble (France).

Experimental Details

The Lohengrin recoil-mass spectrometer is a nuclear physics instrument that uses low-energy fission reactions for fission fragment production [1]. The target used for this experiment was a highly enriched (99.5%) ^{239}Pu deposited as oxide on a titanium backing. Owing to the high enrichment and to the high ^{239}Pu thermal fission cross section, contributions from other fissioning nuclei are negligible. This sample (300 μg/cm^2) was placed close to the core of ILL's high-flux reactor in a thermal-neutron flux of 5×10^{14} n/(cm^{2}s). Fission products emerging from the target are created with an ionic charge state q (ranging from about 15 to 30) and kinetic energy E$_k$ from about 50 to 120 MeV (depending on their masses). The selection of these fission products is performed by a combination of a magnetic and an electric sector fields, whose deflections are perpendicular to each other. At the exit slit of this parabola spectrometer, the combined action of the two fields separates

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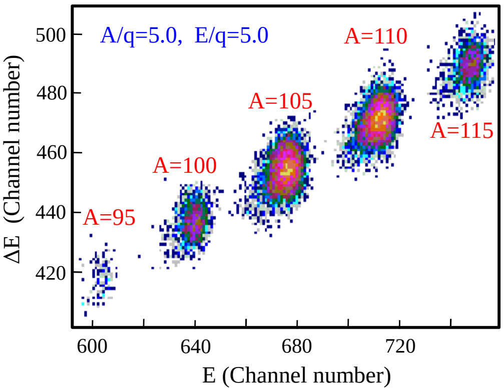

FIG. 1: A two dimensional plot of ΔE vs E for a typical setting of the spectrometer A/q=5.0 and E_k/q=5.0.

ions according to their A/q and E_k/q ratios.

At the exit slit of the spectrometer, an ionization chamber is kept where different mass fragments are separated in the ΔE vs E-plot as shown in the Fig. 1. The E_k and q distributions can be assumed to be independent to each other at least to a first order approximation. Therefore, measuring the E_k distribution at the optimum q (q_m) and knowing what fraction of the total intensity is contained for a given (q_m), by dividing the integration of E_k distribution by the q_m-fraction, the total yield is determined.

Data Analysis and Results

Because of the large thermal neutron flux at the position of the source and very high (n, f) and (n, γ) cross sections (total∼1000 b) for ^{239}Pu, source (target) strength reduces quite appreciably with time. In order to determine absolute mass yields, the change of the source strength with time has to be taken into account. For this purpose, measurements of the mass yield for A=136 were carried out periodically in every eight hours, resulting to the 'burn-up' curve.

For each mass in the range of 132-145, the kinetic energy distributions were measured at an optimum value of q_m. The fraction of q_m was determined from the q-distribution for each mass. By dividing the integration over E_k by the q_m-fraction, the yield $Y(A,t)$ for mass number A was determined at a time t. After normalizing the mass yield $Y(A,t)$ with the burn-up yield (A=136 at time t), the absolute mass yields $Y(A)$ were obtained as shown in the Fig 2.

Obtained results in the range of A=132-145 have been compared with evaluated data libraries JEFF-3.1.1 [2] and JEF-2.2 [3]. In the Fig. 2, data from evaluated libraries are scaled to a A=136 yield of 1.00. Present data, are consistent with the old version of the evaluated data library JEF-2.2, whereas JEFF-3.1.1 shows a 10% dip at A=134 as shown in the Fig. 2. Present data do not reveal any dip at the mass A=136 as claimed earlier [4], however the latter are obtained at high excitation energy (∼50 MeV) using fission fragment spectroscopy in ^{208}Pb(^{18}O, f) and ^{238}U(^{18}O, f) reactions.

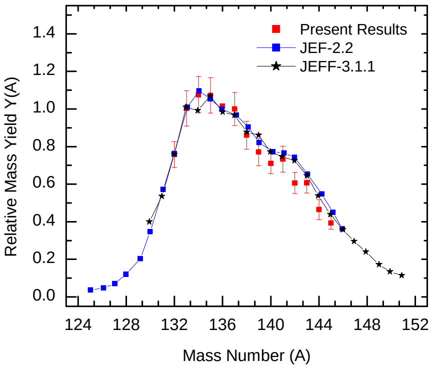

FIG. 2: Mass distribution around A=136 from ^{239}Pu(n_{th}, f) fission. Data from evaluated libraries JEF-2.2 (solid squares) and JEFF-3.1.1 (stars) are scaled up with a factor of 14.5.

References

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