Determination of Fission Product Mass Distribution in α+^{232}Th Reaction from Short Irradiation using He-Gas Jet Transport System

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Introduction

Measurement of yield of fission products and determination of fission product mass distribution (FPMD) for different fissioning systems have got importance both in fundamental physics as well as applications in isotope production. The mass distribution for fission can be measured off-line (radiochemical method) or on-line. The radiochemical method has an advantage of uniquely identifying fission products. However, off-line measurement usually involves long follow-up of radioactivity of the fission products after irradiation. The on-line measurement is relatively quick, though, it requires much more elaborate experimental set-up and has a mass resolution varying with the technique used and experimental set-up. The present work describes an attempt to obtain fission mass distribution with short irradiation and a small follow-up time.

In the present work, the mass distribution for α-induced fission of ^{232}Th has been determined using the He-gas jet facility of Variable Energy Cyclotron Centre (VECC), Kolkata [1]. Mass distribution for the compound nucleus U^{236*} has been reported to be double-humped as well as triple-humped in different studies [2-4] at an excitation energy of ~30MeV. The excitation energy of the U^{236*} compound nucleus in the present study is 31.0 MeV. In order to get comprehensive information about the mass distribution, measurements involving varying irradiation and follow-up period have been carried out. Here the results obtained from the measurement involving ~ 2min irradiation followed by 30 min counting are presented. This information would also provide a database to the development of Radioactive Ion Beams (RIB) at VECC, Kolkata. The experimental mass distribution has been compared with the calculation of GEF code [5].

Experiment

The α-irradiation of ^{232}Th target was performed in K=130 AVF Cyclotron at VECC with 40MeV α-beam. The projectiles entered into the irradiation chamber through a 25 micron thick Havar window and then passed through a 25 μm super pure aluminum foil placed upstream of the target before bombarding the target. The energy loss of the projectile in the Havar window, in the aluminum foil, and in the target was calculated using the software SRIM [6] and resulted in α beam energy of 36.2 MeV at the centre of the ^{232}Th target. The irradiations were performed for 2 min followed by 30 min counting. Flux mapping was carried out to take care of the fluctuations during the irradiation period. The data acquisition was performed by PC-based, software controlled PCI-bus multichannel analyzer FAST ComTec MCA-3 [7] in the batch mode with spectrum acquisition time of 30 s.

Results and Discussion

A typical γ-ray spectrum of the fission products obtained in 2 min irradiation is shown in Fig. 1 The figure also shows the assignment of different γ-lines in the spectrum to the various fission products.The assignments were made on the basis of γ-ray energies half-lives of the fission products.

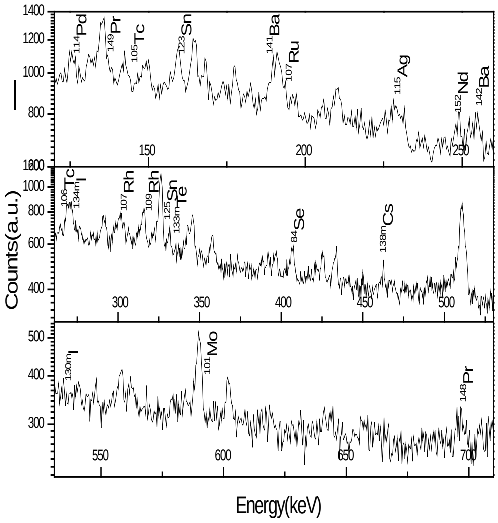

Fig 1: A typical γ-ray spectrum of the fission products obtained after 2 min irradiation followed by 30 s counting.

The γ-ray spectra were analyzed using the peak area analysis software PHAST [8]. The peak areas under the characteristic γ-rays of different fission products were used to obtain their 'end of irradiation activities'. The end of irradiation activities were used to obtain the yields of the fission products using the procedure discussed elsewhere [9]. The MD curve obtained from 2 min irradiation is shown in Fig. 2.

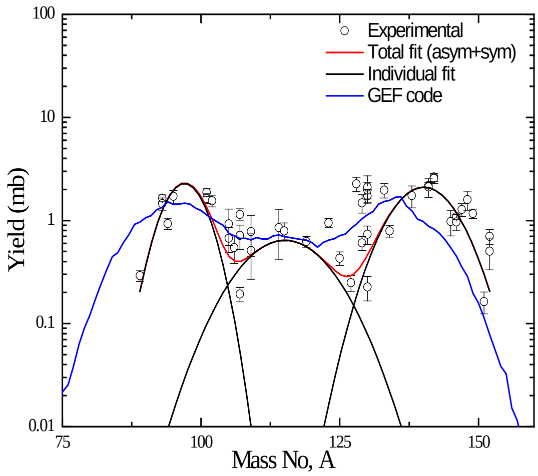

Fig. 2: Mass distribution for α + ^{232}Th reaction at E_α = 36.2 MeV obtained from 2min irradiation

The curve could be fitted to a sum of three Gaussian functions, two for asymmetric fission and one for symmetric fission. The centroid of the symmetric fission is around 115 and asymmetric peaks are centered around 97. and 140. respectively.

Though, the values of the width and centroid of MD curve may have significant uncertainties due to the limited number of data points, the data clearly show the triple humped nature of the MD. It should be mentioned here that the primary feature of the MD does not change even after incorporating the yields obtained from other two irradiations, viz., 10 min and 2 h. The experimental MD curve was also compared with the calculations of the GEF code. It can be seen from the figure that the GEF calculations are in qualitative agreement with the experimental data. However, the GEF calculations underestimate the contribution fm standard II asymmetric fission mode (N-88).

Conclusions

It is evident both from experimental data and theoretical calculations that the shell effect plays a significant role in the fission of ^{236}U at excitation energy of 31 MeV. Thus the present work demonstrates quick determination (~ 30 min) of FPMD by short irradiation using He-gas jet transport system, which gives reasonable and reliable information about the nature of the mass distribution.

References

[1] A. Chakrabarti et al., Nucl. Inst. and Meth. in Phys. Res. **A263,** 421 (1988).
[2] T. C. Roginski, M. E. Davis and J. W. Cobble, Phys. Rev. C **4,** 1361 (1971).
[3] R. Guin et al., Radiochimica Acta **48,** 7 (1989).
[4] A. Chakrabarti et al., Z. Phys. A **345**, 401 (1993)
[5] K. H. Schmidt, B. Jurado, C. Amouroux, and C. Schmitt, Nuclear Data Sheets **131,** 107 (2016).
[6] J. F. Ziegler and J. P. Biersack, TRIM code, version 95.06.
[7] https://www.fastcomtec.com
[8] P. K. Mukhopadhyay, in Proceedings of Symposium on Intelligent Nuclear Instrumentation, Mumbai (2001), Vol. 33, p. 307; INIS Repository 33, 33001318 (2001).
[9] R. Tripathi et al., Phys. Rev. C **88**, 024603 (2013).