Fission Products Yield In the Neutron-Induced Fission of ^{232}Th Using Neutrons Source From ^{7}Li(p, n)^{7}Be Reaction at Incident Proton Energy of 20 MeV.

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I. Introduction

This paper presents the measurement of fission product yields from the neutron induced fission of ^{232}Th. These measurements were carried out using the neutron source from ^{7}Li (p, n) reaction at TIFR-BARC Pelletron facility. The yields were obtained using activation and off-line gamma ray spectroscopic technique. The fission yields values are reported for twelve fission products. Activated targets were counted in highly shielded HPGe detectors over a period of several weeks to identify decaying fission products. The results obtained from the present work were compared with the similar data of mono-energetic neutrons of comparable energy from literature and are found to be in good agreement.

II. Experimental Procedure

The experiment was carried out at TIFR-BARC Pelletron facility at the 6 meter height main line [1]. The neutron beam was generated from ^{7}Li (p, n) reaction by using a stack of Ta-Li-ta stack. About 1.0 cm^2 of ^{232}Th metal foil with thickness 30.0 mg/cm^2 doubly wrapped with 0.025 mm thick Al foil was mounted at zero degree with respect to the beam direction at a distance of 2.1 cm from the location of the Ta-Li-Ta stack. The ^{232}Th metal foil was irradiated for 12 hours at quasi mono energetic neutrons from ^{7}Li (p, n) reaction using proton beam of 20 MeV. The proton current during the irradiations was around 200 nA. After irradiation, the sample was cooled for one hour. Then the irradiated target of ^{232}Th along with Al wrapper was mounted on Perspex plate and taken for γ-ray spectrometry. The γ-rays of fission products from the irradiated ^{232}Th sample was counted in energy and efficiency calibrated 80c.c. HPGe detector coupled to a PC-based 4K channel analyzer. The counting dead time was kept always less than 5% by placing the irradiated ^{232}Th sample at a suitable distance from the detector to avoid pileup effects. The γ-ray counting of the sample was done in live time mode and was followed as a function of time

III. Data Analysis

1. Calculation of Neutron Energy

For the proton energies of 20.0 MeV, the neutron spectrum have been generated [2,3] using the neutron energy distribution given by J.W. Meadows et al [4] for a typical neutron spectrum from ^{7}Li (p, n) reaction for proton energies of 20 MeV. Based on the neutron spectrum, the flux-weighted average neutron energy has been calculated as 12.52 MeV for the proton energy of 20 MeV.

2. Calculation of fission product yields

The net photo-peak areas of different γ-rays of interest were calculated by subtracting the linear background from their gross peak areas. The number of γ-rays detected (A_{obs}) under the photo-peak of each individual fission products is related to the cumulative yield (Y_c) with the following relation,

$$A_{obs}(CL/LT)\lambda = N\sigma_f(E)\varphi I_\gamma \varepsilon Y_c(1-e^{-\lambda t})e^{-\lambda T_c}(1-e^{-\lambda LT}) \quad (1)$$

Where, N= number of target atoms,
$\sigma_f(E)$ = fission cross-section as a function of neutron energy (E) for ^{232}Th with average neutron flux (φ).
I_γ = branching intensity and ε = efficiency of the detector system for the γ-ray of the fission product.
t = irradiation time, T_c = cooling time
CL and LT = clock time and live time of counting, respectively

The nuclear spectroscopic data such as the γ-ray energy, branching intensity and half-life of the fission products are taken from ref. [5]. The cumulative yields of the fission product relative to fission rate monitor ^{97}Zr were calculated using eq. (1). The yield of fission rate monitor ^{97}Zr was chosen from the point of view of the constant yield with change of neutron energy.

The cumulative yields of various fission products relative to ^{97}Zr in the neutron-induced fission of ^{232}Th at flux weighted average neutron energies of 12.52 MeV is shown in Fig 1 along with the data at 14 MeV [6].

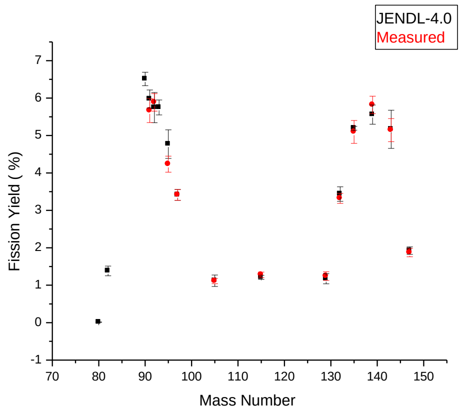

Fig.1. Fission yield of fission products for ^{232}Th(n, f) at En = 12.52 MeV compared to 14 MeV, values taken from literature [6].

IV. Results and Conclusion

In Table 1, the yields of the fission products in the neutron induced fission of ^{232}Th at an average neutron energy of 12.52 MeV from present work were compared with the literature data at 14 MeV [6]. The fission yields for fission products in ^{232}Th(n, f) at neutron energy of 12.52 MeV is measured for the first time. The fission products yields data are plotted in Fig. 1. It can be seen from the Fig. 1 that the yields are comparable for asymmetric products and are slightly lower for symmetric product. The mass yield distribution is triple humped for ^{232}Th(n,f) fission at 12.52 MeV, which is due to the different types of potential barrier [7] in ^{233}Th* known as Thorium –anomaly.

Table 1. Fission products yields in ^{232}Th(n, f) at average En = 12.52 MeV, taking Zr-97 as reference yield for 14 MeV incident neutrons.

Nuclides	Measured	JENDL 4.0 (14 MeV)
Sr-91	5.66 ± 0.32	5.98±0.24
Sr-92	5.89 ± 0.23	5.74±0.40
Zr-95	4.23 ± 0.21	4.77±0.38
Zr-97	3.41±0.15	3.41±0.15
Ru-105	1.12± 0.15	1.11±0.07
Cd-115	1.21 ± 0.53	1.28±0.07
Sb-129	1.17±0.14	1.24±0.12
Te-132	3.44±0.19	3.32±0.13
I-135	5.20±0.05	5.10±0.31
Ba-139	5.56±0.26	5.82±0.23
Ce-143	5.17± 0.15	5.14±0.31
Nd-147	1.93-±0.57	1.87±0.11

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