Mass distribution in photon induced fission of ^{232}Th

H.Naik[1,*], V.T.Nimbje[2], D.Raj[3], A.Goswami[1], Sarbjit Singh[1], S.N. Acharya[2], K.C.Mittal[2], S.Ganesan[3], V.K. Manchanda[1] and V. Venugopal[4].

[1]*Radiochemistry Division,,* [2] *Applied Prototype Physics Division.* [3]*Reactor Physics Design Division,*
[4]*Radiochemistry and Isotope Group, BARC, Mumbai - 400 085.*
[*]*e-mail : naikh@barc.gov.in*

Yields of fission products in fast neutron and photon induced fission of ^{232}Th, ^{238}U and long-lived minor actinides (^{237}Np, ^{240}Pu, ^{242,243}Am & ^{244,245}Cm) are needed for the decay heat calculation [1] and are important from the accelerated driven sub-critical system (ADS) [2,3] point of view. This is because in ADS higher energy (GeV) proton from accelerator strikes a heavy element like Pb, Bi, Th or U target, which yields large number of neutrons by Spallation reaction. The Spallation target becomes a source of neutrons, which can achieve self-sustaining fission chain in a sub-critical core. However, during the Spallation processes, along with high-energy neutrons, high-energy photons are also produced, which can cause fission of the Spallation source and long-lived minor actinides. Thus it is important to measure the yields of the fission products in the photon and fast neutron induced fission actinides. The yields data of fission products are also needed for mass and charge distribution studies, which can provide information about the understanding of the process of nuclear fission. In view of this in the present work yields of various fission products in the 10 MeV bremsstrahlung induced fission of ^{232}Th were determined for the first time in India by using recoil catcher and off-line gamma ray spectrometric technique.

The experimental work was carried out in the 10 MeV electron LINAC of electron beam centre at Kharghar, Navi-Mumbai, India. For this purpose about 0.969 gm of ^{232}Th metal targets of 0.025 mm thick and 2.25 cm^2 area was wrapped with 0.025 mm thick super pure Al catcher. The target assembly was placed below a tantalum foil of 1 mm thick, which was kept at a suitable stand facing the electron beam aperture. It was then irradiated for 4-5 hours with the bremsstrahlung produced by impinging the 10 MeV electron beam on tantalum metal foil. The current of the electron beam during irradiation was 50 mA at 400 Hz with a beam width of 10 μs. The irradiated target assembly was cooled for 1.5 hours. Then the target along with Al catcher was mounted on a Perspex plate. The γ-ray activities of fission products at fixed geometry were measured by using an energy and efficiency calibrated 80 c.c. HPGe detector couple to a PC based 4K channel analyzer. The resolution of the detector system was 2.0 keV at 1332.0 keV of ^{60}Co. The dead time of the detector system during counting was always kept less than 5% by placing the sample at a suitable distance from the detector to avoid pile up effect. The γ-ray counting of the sample was done in live time mode and was followed as a function of time.

The net photo-peak areas of different γ-rays of nuclides of interest were calculated by subtracting the linear Compton background from their gross peak areas. From the γ-rays activities (A_i) of the fission products their yields (Y) relative to ^{135}I were calculated by using usual standard decay equation [4]

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$$A_i = N\sigma\Phi a\varepsilon Y\,(1-e^{-\lambda t})\,e^{-\lambda T}(1-e^{-\lambda\Delta T})/\lambda \qquad (1)$$

where N is the number of target atom and σ is the fission cross-section of the target nuclei at bremsstrahlung spectrum with end point energy of 10 MeV. Φ is the photon flux. t, T and ΔT are irradiation, cooling and counting time respectively. 'a' is the abundance of γ-ray energy for the fission product of interest [5]. 'ε' is efficiency of the γ-ray in the detector system, which was obtained by using standard ^{152}Eu source. From the relative yield data, mass yield distributions were obtained by using charge distribution correction and normalizing the total yield to 200 %. The mass yields data in the 10 MeV bremsstrahlung induced fission of ^{232}Th from present work along with 1.9 MeV neutron induced fission of ^{232}Th [4] of comparable excitation energy are plotted in Fig. 1and 2 in log and linear scale to examine the yield profile in the valley and peak position respectively..

From Fig. 1 it can be seen that mass yield distribution in ^{232}Th (γ,f) is triple humped similar to ^{232}Th (n,f) [4]. This is due to well known dip in the outer symmetric barrier. It can be also seen from Fig.2 that yields of fission products are higher around mass number 133-135, 138-140 and 143-145 and their complementary mass number. The oscillation in the interval of five mass units is due to even-odd effect. Besides this, higher yield around mass number 133-135 and 143-145 due to the presence of spherical 82n and deformed 88n shell respectively. These observations indicated the effect of nuclear structure effect in photon induced fission similar to neutron induced fission of actinides.

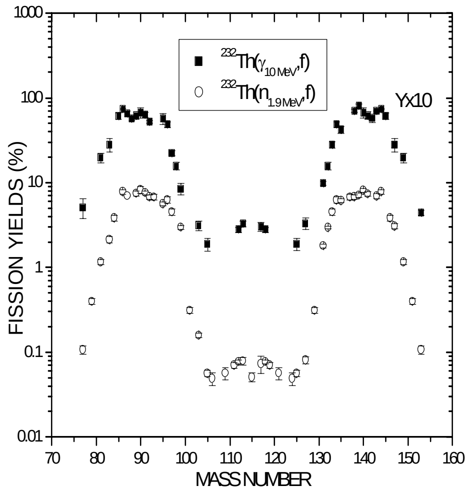

Fig. 1. Mass yield distribution in ^{232}Th (γ,f) and ^{232}Th(n,f).

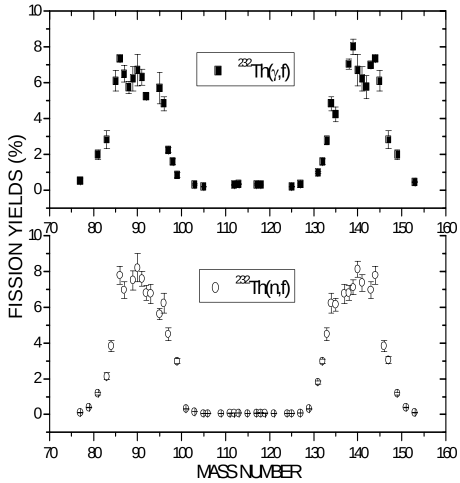

Fig.2. Mass yield distribution in ^{232}Th(γ,f) and ^{232}Th(n,f).

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