Measurement ^{232}Th(n, γ) reaction cross-section at E_n=17.28 MeV

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Studies on ^{232}Th(n, γ) and (n, xn) reaction cross-sections besides fission products yields at higher energy neutrons are important from the point of ADS [1] and AHWR [2]. This is because ^{232}Th-^{233}U fuel in connection with ADS is one of the possibilities for power generation besides transmutation of long-lived fission products and incineration of long-lived minor actinides. The ^{232}Th-^{233}U fuel in ADS [1] and AHWR [2] has an advantage over the present reactors based on uranium fuel from the point of thousand times less radio toxic wastes production and the higher percentage of availability of ^{232}Th in the earth crust compared to ^{238}U. In the thorium-uranium fuel cycle, the fissile nucleus ^{233}U is generated by two successive β-decays after a neutron capture by the fertile nucleus ^{232}Th. In ADS high energy (GeV) proton from accelerator strikes a heavy element like Pb and Bi yielding large number of neutrons by spallation reaction. The spallation target becomes a source of neutrons, which drives fission chain in a sub-critical core. Thus it is important to measure the ^{232}Th(n, γ) and (n, xn) reaction cross-sections besides yields of fission products at higher neutron energy. In view of this in the present work we have determined the ^{232}Th(n, γ) reaction cross-section at average neutron energy of 17.28 MeV for the first time using activation and off-line γ-ray spectrometric technique.

The experiment was carried out at TIFR-BARC Pelletron facility at the 6 meter height main line [3]. About 0.3228 g of natural Th metal foil of area 1.0 cm^2 doubly wrapped with 0.025 mm thick Al foil was irradiated for 6 hours at 17.28 MeV quasi mono energetic neutrons by using ^{7}Li(n, p) reaction of 20 MeV proton beam. The proton current during irradiation was 300 nA. After 3 hours of cooling, the irradiated sample along with Al wrapper was mounted on Perspex plate. The fission products (e.g. ^{97}Zr) from ^{232}Th(n, f) reaction and ^{233}Pa ($T_{1/2}$=26.975 d) from ^{232}Th(n, γ) reaction followed by β-decay were analyzed by γ-ray spectrometry using pre-calibrated HPGe detector, coupled with PC based 4K MCA. The resolution of the detector system during counting was 2 keV at 1332 keV γ-line 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 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.

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. The 743.4 keV γ-rays activities (A_i) of the fission products ^{97}Zr is related to the neutron flux (Φ) by standard decay equation [3].

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

where N is the number of target atom, σ is the ^{232}Th(n, f) fission cross-section [4] and Y is the yield of the fission products [5]. '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 [6].'ε' is efficiency of the γ-ray in the detector system, which was obtained by using standard ^{152}Eu source.

The neutron flux was calculated from eq (1) by using γ-ray activities (A_i) of ^{97}Zr and other terms from respective refs. [4-6]. The neutron flux at average neutron energy of 17.28 MeV was obtained to be1..006x10^7 n cm^{-2} s^{-1}. Then the ^{232}Th(n, γ) cross-section was calculated from the 311.9 keV γ-rays activities (A_i) of the reaction product ^{233}Pa using eq (1) and found to be 1.569±0.141 mb. The neutron energy from ^{7}Li(p, n) reaction for proton energy of 20 MeV is not mono-energetic but have tailing part. So the contribution of 1.019 mb to ^{232}Th(n, γ) cross-section due to the tail part of the neutron spectrum [7] from 3.2 MeV to 14.6 MeV was corrected using evaluated data from ENDF/B-VII [8]. Thus the experimentally determined actual ^{232}Th(n, γ) cross-section is 0.550±0.141 mb. The experimental ^{232}Th(n, γ) cross-section is shown in Fig.1 along with literature data [3,4] at lower energy. In Fig. 1 the experimentally determined ^{232}Th(n, γ) cross-sections were also compared with the evaluated data of ENDF/B-VII [8], JENDL-4.0 [9] and JEFF-3.1 [10]. The experimental data is in good agreement with the evaluated data from JENDL-4.0. However, the evaluated data from ENDF/B-VII is on the lower side and JEFF-3.1 data is on the higher side of the experimental data. In view of this the ^{232}Th(n, γ) reaction cross-sections were also calculated theoretically using the TALYS 1.2 computer code [11] and was found to be in good agreement with the experimental data, which shows the correctness of the present approach. The data on ^{232}Th(n, γ) reaction cross-section is thus important from the point of view of testing models of calculation as well as to test the evaluation procedure. Besides these, experimental data on ^{232}Th(n, γ) are useful for the design of ADS and AHWR.

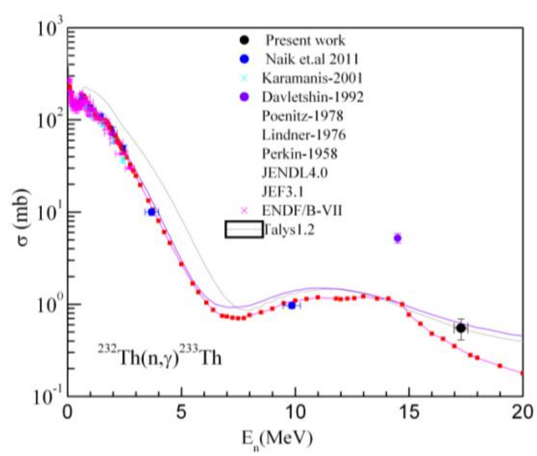

Fig. 1. Plot of the ^{232}Th(n, γ) reaction cross-sections as a function of neutron energies.

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