^{238}U(n, γ) and ^{238}U(n, 2n) reaction cross-section measurements at E_n=17.28 MeV

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We present the measurements of ^{238}U(n, γ) and ^{238}U(n, 2n) cross sections at an average neutron energy of 17.28 MeV from the ^{7}Li(p, n)^{7}Be neutron source generated at the 14UD BARC-TIFR Pelletron facility at Mumbai. The experimentally determined ^{238}U(n, γ) `and ^{238}U(n, 2n) reaction cross-sections from present work were compared with the evaluated data of ENDF/BVII and JENDL-4.0, JEFF-3.1 and CENDL-3.1. The ^{238}U(n, γ) and ^{238}U(n, 2n) reaction cross-sections were also calculated theoretically using the TALYS 1.2 computer code and were found to be in good agreement with the experiment.

The experiment was carried out at TIFR-BARC Pelletron facility at the 6 meter height main line [1]. About 0.2750g of natural U 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 γ-ray spectrometry of the sample was done using a 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 fission product (e.g. ^{97}Zr) from ^{238}U (n, f) reaction was used as a flux monitor. For ^{238}U(n, γ) reaction, the half-life of ^{239}U is 23.54 min., which decays 99.6% to ^{239}Np within 3 h. In view of this, ^{238}U(n, γ) reaction cross-section (σ) can be calculated from the γ-ray activity of ^{239}Np ($T_{1/2}$ = 2.355 d) measured after sufficient cooling time. Similarly, the ^{238}U(n, 2n) reaction cross-section was calculated from the γ-ray activity of ^{237}U obtained from the γ-ray spectrum measured after sufficient cooling time. 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 [1].

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

where N is the number of target atom, σ is the ^{238}U (n, f) fission cross-section [2] and Y is the yield of the fission products [3]. ‘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 [4].‘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 be (9.16 ±0.17) x 10^7 n cm^{-2} s^{-1}. Then the ^{238}U(n, γ) cross-section was calculated from the 277.9 keV γ-rays activities (A_i) of the reaction product ^{239}Np, which is 1.276±0.07 mb. The neutron flux above ^{238}U(n, 2n) threshold energy was obtained as (7.7 ±0.17) x 10^7. Then the ^{238}U(n, 2n) cross-section was calculated from the 208.0 keV γ-rays activities (A_i) of the reaction product ^{237}U, which is 1001.58±25.6 mb. The neutrons from ^{7}Li(p, n) reaction for proton energy of 20 MeV are not mono-energetic but have a tailing part. So the contributions to ^{238}U(n, γ)and ^{238}U(n, 2n) cross-section due to the tail region are 0.73 mb and 544.8

mb, respectively. Thus the experimentally determined actual ^{238}U(n, γ) and ^{238}U(n, 2n) cross-sections are 0..55±0.07 mb and 456.78± 25..6 mb, respectively. The experimental ^{238}U(n, γ) and ^{238}U(n, 2n) cross-sections are shown in Fig.1 and Fig.2 along with literature data [1,2] at lower energy.. The experimental cross-sections were also compared with the evaluated data of ENDF/B-VII [6], JENDL-4.0 [7] and JEFF-3.1 [8]. The cross-sections were also calculated theoretically using the TALYS 1.2 computer code [9] and was found to be in good agreement with the experimental data, which shows the correctness of the present approach. These accurate data are important from nuclear waste formation and destruction point of view in Uranium fuel reactors and future ADS.

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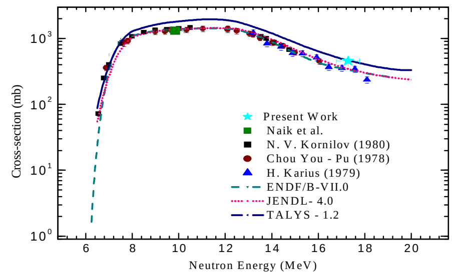

Fig-2

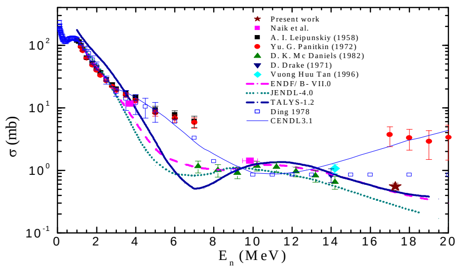

Fig-1