Measurement of the neutron capture cross-section of ^{238}U using the neutron activation technique

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Significant effort has been aimed at generating nuclear power based on the concept of fast reactor [1-2] and advanced heavy water reactor (AHWR) [3]. In AHWR ^{232}Th-^{233}U in the oxide form is the primary fuel, whereas in the fast reactor ^{238}U-^{239}Pu in the form of carbide is used as the primary fuel. The ^{239}Pu is first generated in a research reactor from ^{238}U(n, γ)^{239}U reaction and by successive two beta decays. Then the fissile material ^{239}Pu along with ^{238}U is used as a fuel in fast reactor for power generation. The ^{238}U is used as the breeding material to regenerate the fissile material ^{239}Pu. In the fast reactor, there is a fast neuron spectrum. Thus for the production of ^{239}Pu, it is necessary to have knowledge about ^{238}U(n, γ) reaction cross-section at various neutron energies. In the present work we have determined the ^{238}U(n, γ) reaction cross-section using the neutrons from ^{7}Li(p, n) reaction and by activation technique followed by off-line γ-ray spectrometry.

The experiment was carried out using the 14UD BARC-TIFR Pelletron facility at Mumbai, India. The neutron beam for irradiations of U was obtained from the ^{7}Li(p, n) reaction by using the 12 MeV proton beam of 400 nA at main line at 6 m above the analyzing magnet of the Pelletron facility. After irradiation and sufficient cooling, the γ-rays of fission/reaction products from the irradiated U sample were counted in an energy and efficiency calibrated 80 c.c. HPGe detector coupled to a PC-based 4K channel analyzer. From the observed photo-peak activity (A_{obs}) for 743.3 keV γ-line of ^{97}Zr the neutron flux (Φ) of 1.3 x10^{7} n cm^{-2} s^{-1} was obtained by using Eq.1, as explained in ref. [4]. Eq.1 can be used for estimating σ when Φ is known or vice versa.

$$A_{obs}(CL/LT)=N\sigma\Phi a\varepsilon(1-e^{-\lambda t})e^{-\lambda T}(1-e^{-\lambda CL})/\lambda \qquad (1)$$

The neutrons from Li(p,n) reaction are not mono-energetic, and their energy spectra were obtained from literature as shown in ref. [4]. The contribution to the neutron flux from the tail region is 49 % at the proton energy of 12.0 MeV. The average energy of neutrons under quasi mono-energetic peak is 9.85±0.38 MeV for 12 MeV protons after removing the tail of the spectrum.

The ^{238}U(n, γ) cross-section (σ) was calculated from the observed activity of 277.85 keV of ^{239}Np in the γ-ray spectrum of the un-separated sample, which is 2.333±0.123 mb. The contribution from the tail region to ^{238}U(n, γ) reaction has been estimated using the ENDF/B-VII [5] and JENDL-4.0 [6] by folding the evaluated cross-sections with neutron flux distributions The contribution from the above evaluation at E_P = 12 MeV are 1.023 and 0.614 mb from ENDF/B-VII and JENDL-4.0 respectively. The true value of ^{238}U(n, γ) reaction-cross section due to the neutrons from the quasi mono-energetic peak consisting of the n_0 and n_1 groups of the neutron spectrum is obtained by subtracting these average cross-section due to neutron tail region from the above measured total cross section data. Thus the actual experimentally obtained ^{238}U(n, γ) reaction cross-sections at average neutron energies of 39.85±0.38 MeV corresponding to proton energy of 12 MeV is 1.42 ± 0.09 mb.

The present experimental ^{238}U(n, γ) cross-sections are within the range of evaluated data of ENDF/B-VII and JENDL 4.0. However, the evaluated value from JEFF-3.1 [7] and CENDL-3 [8] are not in agreement with the present experimental value. In order to examine this aspect, the ^{238}U(n, γ) reaction cross-sections from the present work and similar data from EXFOR [9] are plotted in Fig. 1. It can be seen from Fig. 1 that the ^{238}U(n, γ) reaction cross-section from present work at 9.85±0.38 MeV is in agreement with the value of McDaniels et al taken from EXFOR. Further, the ^{238}U(n, γ) reaction cross-section decreases from 100 keV to 7 MeV. Thereafter it decreases from neutron energy of 7 MeV to 15 MeV. Beyond this, it increases suddenly from neutron energy of 17 MeV to 20 MeV. In order to examine this, the evaluated data from ENDF/B-VII [5], JENDL-4.0 [6], JEFF-3.1 [7], CENDL [8] and INDC (VN)-8 [10] were plotted in Fig. 1. Similar data based on activation technique from the review article of Ding et al [11] were also plotted in Fig. 1 which agrees with evaluations only at low energies. The ^{238}U(n, γ) reaction cross-section at different neutron energy beyond 1 keV was also calculated theoretically using computer code TALYS of version 1.2 [12] and shown in Fig.1 . The trend of evaluated ^{238}U(n, γ) reaction cross-section is well reproduced by TALYS. However, they are slightly higher than the experimental and evaluated data.

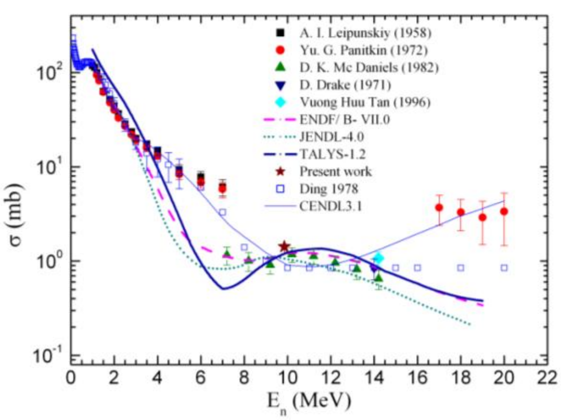

Fig. 1. Plot of experimental, evaluated and TALYS ^{238}U(n,γ) reaction cross-section as a function of En=1 keV to 20 MeV.

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