Measurement of ^{58}Ni(n,p) reaction cross-section at quasi mono-energetic neutron energy of 9.85 MeV

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Structural materials such as zirconium, stainless steel and aluminum are important from reactor point of view because they are used as cladding materials. In stainless steel Ni is one of the component with isotopic composition ^{58}Ni(67.76%), ^{60}Ni(26.42%), ^{61}Ni(1.16%), ^{62}Ni(3.71%), ^{64}Ni(0.95%) respectively. In reactor there is a broad neutron spectrum of energy from 0 to 10 MeV [1]. So it is worth while to determine the reaction cross section of Ni with various neutron energies. In view of this in the present case we have determined the ^{58}Ni(n, p) reaction cross-section with 9.85 MeV quasi mono-energetic neutron using off-line γ-ray spectroscopic technique. The neutrons beam was obtained from the Li(n, p) reaction by using 12 MeV proton beam at BARC-TIFR facility.

Experimentally about 0.1813 g of natural nickel with ^{58}Ni of 67.76% and 29.3 mg/cm^2 of natural Th metal foil of area 1.0 cm^2 were doubly wrapped separately with 0.025 mm thick Al foil and a stalk was made. The samples stalk were irradiated for 4 hours at 9.85 MeV quasi mono energetic neutrons by using ^{7}Li(n, p) reaction of 12 MeV proton beam at the 6 meter height main line of BARC-TIFR Pelletron facility. The proton current during irradiation was 400 nA. After irradiation the samples were mounted on two Perspex plates. ^{58}Co ($T_{1/2}$=70.78 d) from ^{58}Ni(n, p) reaction and the fission products (e.g. ^{97}Zr) from ^{232}Th(n, f) 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 observed photo-peak area (A_{obs}) for 811 keV of ^{58}Co and 743.4 keV for ^{97}Zr were obtained from their total peak area after substituting the linear background due to Compton effect. From the A_{obs} ^{97}Zr, neutron flux (φ) was obtained using decay equation [1]

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

Where N is the total number of target atoms, σ is the ^{232}Th(n, f) cross-section [2], whereas Y is the yields of ^{97}Z [3]. ‘a’ is the γ-ray abundance, taken from the ref. [4]. ε is the efficiency of the γ-ray for the detector system, which was determined by using ^{152}Eu source. λ is the decay constant of the product nuclide. t, T and ΔT are irradiation, cooling and counting time respectively.

From the A_{obs} of ^{97}Zr neutron flux was calculated at 9.85 MeV neutrons using equation (1) and found to be 1.3x10^7 n cm^{-2} s^{-1}. Using A_{obs} of ^{58}Co in the above equation, ^{58}Ni(n, p) reaction cross-section (σ) was calculated, which is 870.02±0.05 mb. The neutron energy from ^{7}Li(p, n) reaction for proton energy of 12 MeV is not mono-energetic but have tailing part. So the contribution of 255.357 mb to ^{58}Ni(n,p) cross-section from the tail part of the neutron spectrum [5] from 5.178 MeV to 6.578 MeV was corrected using evaluated data from ENDF-B VII [6]. Thus the experimentally determined actual ^{58}Ni(n, p) cross-section of 615.72±0.05 mb is given in Table 1 along with the value from EXFOR [2].

The overall uncertainty represents contribution from random and systematic errors as well as precession from three measurements. The experimentally obtained (n, p) reaction cross-section of ^{58}Ni was compared with the data from EXFOR [2] and are found to be in good agreement within errors (Table 1). The ^{58}Ni (n,p) reaction cross section was also calculated theoretically using TALYS 1.2 [7] and plotted in Fig. 1 along with the value from literature and present experiment (square). Theoretical value of 830 mb at mono-energetic neutron energy of 9.85 MeV is also given in Table 1, which is systematically higher than the experimental value. This is because the value from TALYS is based on mono-energetic neutron. However the experimental data is based on quasi mono-energetic neutron. The experimental ^{58}Ni (n,p) reaction cross section are important for design of fast reactor.

Table 1. ^{58}Ni (n, p) reaction cross-section in milli-barns at 9.85 MeV neutron energy

Present work	EXFOR	TALYS
610 ± 49.95	630	830

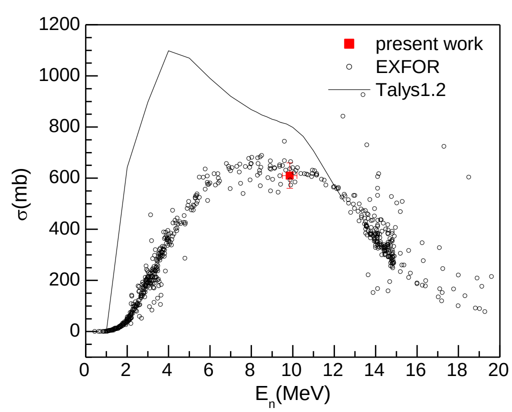

Fig. 1 Plot of ^{58}Ni (n,p) cross-section as a function of neutron energy

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