Measurements of ^{56}Fe (n, p) ^{56}Mn reaction cross-section at neutron energy of 15.5 MeV

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Structural materials such as zirconium, niobium, aluminum and stainless steel and are important from reactor point of view. Among these stainless steel is used as cladding cladding material of nuclear fuel in fast reactor. Besides this, in reactor stainless steel is used as the calandria vessel and pipe lines of secondary coolant circuit. In stainless steel natural iron is a primary component with isotopic composition of ^{54}Fe (5.845 %), ^{56}Fe (91.754 %), ^{57}Fe (2.119 %), ^{58}Fe (0.282 %). In reactor there is a broad neutron spectrum of energy ranging from 0 to 10 MeV [1]. Therefore different nuclear reactions such as (n, γ), (n, n'), (n, p) and (n, α) etc. occur based on the energy of neutron and isotopic composition of iron. In view of this, in the present work we have determined the (n, p) reaction cross-section of ^{56}Fe with average neutron energy of 18.1 MeV by using off-line gamma ray spectrometric technique.

About 60-170 mg of natural Fe with ^{56}Fe of 91.754 % and 570-990 mg natural uranium were wrapped separately with 0.025 mm thick aluminum foil. A stack of sample was made, which was wrapped with additional Al foil. The uranium metal foil was used to measure the neutron flux. The stack sample was irradiated for 3-5 h with quasi mono-energetic neutron of 15.5 MeV from ^{7}Li (p, n) reaction of 18 MeV proton beam in the 6 meter height main line at BARC-TIFR Pelletron facility. The proton current during irradiation was 250 nA with 9.05 MV terminal voltage. The irradiated sample was cooled for 2 h and the iron and uranium along with wrapper were mounted on two different Perspex plate and analyzed by γ-ray spectrometry. ^{56}Mn from ^{56}Fe (n, p) have a $T_{1/2}$ of 2.58 h with characteristic γ-line of 846.7 keV whereas, fission products from ^{238}U (n,f) have varying half-lives [2]. In view of this, the irradiated Fe and U on Perspex plate were counted for suitable time alternately for their gamma ray activity, using pre-calibrated 45 cc HPGe detector coupled to a PC-based 4K MCA. The resolution of the detector system was 2 keV at 1332 keV γ-line of ^{60}Co.

The observed photo-peak area (A_{obs}) for 846.7 keV of ^{56}Mn and for different γ-lines of fission products (e.g. 743.3 keV of ^{97}Zr) were obtained from their total peak area after subtracting the linear background due to Compton effects. From observed A_{obs} of a particular fission product (e.g. ^{97}Zr), neutron flux (φ) was obtained using decay equation [1]

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

where N is the number of atoms of the isotope of the element and σ is the fission cross-section of ^{238}U [3]. Y is the cumulative fission yield of ^{97}Zr [4]. 'ϵ' is the detector efficiency, which was obtained by using standard ^{152}Eu source. 'a' is the γ-ray abundance [2] and λ is the decay constant of the product nuclide. 't', T and ΔT are irradiation, cooling and counting time respectively.

In the present experiment the proton beam of energy 18.0 MeV was bombarded on Li target to produce neutrons. The neutrons produced in ^{7}Li(p, n) reaction with 18.0 MeV proton beam are quasi mono-energetic with average energy of 15.5 MeV. From the A_{obs} of ^{97}Zr, neutron flux was calculated at 15.5 MeV neutrons using equation (1) and found to be $1.54\pm0.06\times10^{7}$ n cm^{-2} s^{-1}. Using A_{obs} of ^{56}Mn in the above equation, ^{56}Fe(n, p) reaction cross-section (σ) was calculated, which is 76.22±5.25 mb, which is given in Table 1 along with the value from ENDF/B-VII [5] and JENDL-4.0 [6].

Table 1. ^{56}Fe (n, p) reaction cross-section (barns) at 15.5±0.7 MeV neutron energy

Present work	ENDF/B-VII	JENDL-4.0
76.22±5.25	86.25	84

It can be seen from Table 1 that the experimentally obtained (n, p) reaction cross-section of ^{56}Fe (76.22±5.25 barns) from the present experiment is slightly lower than the evaluated data from ENDF/B-VII [5] and JENDL-4.0 [6]. In view of this the ^{56}Fe (n,p) reaction cross-section was also calculated using TALYS 1.0 [7] and EMPIRE-II [8] and plotted in Fig. 1 as shown in solid and dot-dot lines, along with the value from present work (star). It can be seen from Fig. 1 that the experimental value within the range of uncertainty is in good agreement with the value obtained from both TALYS [7] and EMPIRE-II [8]. However at lower neutron energy the EMPIRE-II values are higher than the experimental data. Slight lower experimental present work may be because of the use of quasi mono-energetic neutron. The experimental value of ^{56}Fe(n, p) is important from the point of view of design of fast reactor.

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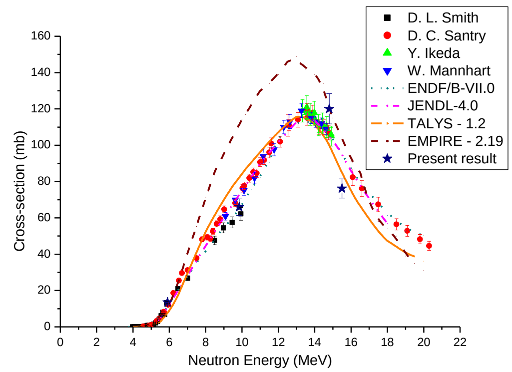

Fig. 1. Plot of ^{56}Fe(n, p) cross-section as a function of neutron energy.

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