Determination of $^{55}Mn(n,\gamma)$ reaction cross-section at the neutron energies of 1.12 and 2.12 MeV

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Introduction

Manganese is one of the most abundant element in the earth's crust. It is a grey white metal with a relative mass of 54.938, melting point of 1245ºC and density of 7.43 kg/dm^2. Manganese is used in making steel, shielding material and structural material in reactors. This is because of it has properties like sulphide former, deoxidizer and hardenability. Manganese has one stable isotope ^{55}Mn with 100% abundance.

In a reactor, during chain reaction, some of the neutrons, interact with the manganese, present in the shielding material and produce ^{56}Mn (half-life=2.5789 h) from the $^{55}Mn(n,\gamma)$ reaction. Thus the knowledge of such reaction cross section is essential for better understanding of nuclear reaction mechanism. Besides this, the $Mn^{55}(n,\gamma)^{56}Mn$ reaction cross-section is important for fast reactors, breeder reactors and accelerated driven sub-critical system (ADSs) [1].

IAEA-EXFOR database [2] indicates that the work done so far for the $Mn^{55}(n,\gamma)^{56}Mn$ reaction cross-section at low neutron energies (i.e. within 1 to 5 MeV) has discrepancy. At the neutron energies of 0.2, 0.58, 0.76, 0.97, 2.15 and 4 MeV there are more than one $^{55}Mn(n,\gamma)$ reaction cross section data available. However, there is no experimental data at the neutron energies of 1.12 and 2.12, 3.12 and 4.12 MeV available in literature [2,3].

In the present work, we determine the $Mn^{55}(n,\gamma)^{56}Mn$ reaction cross-section at the neutron energies of 1.12 and 2.12 MeV by using the off-line γ-ray spectrometric technique. The (n,γ) reaction cross-section ^{55}Mn as a function of neutron energy was also calculated using nuclear reaction modular code TALYS-1.6 [4] and compared with the present experimental data at 1.12 and 2.12 MeV as well as the literature data at other neutron energies.

Experimental Details and Calculations

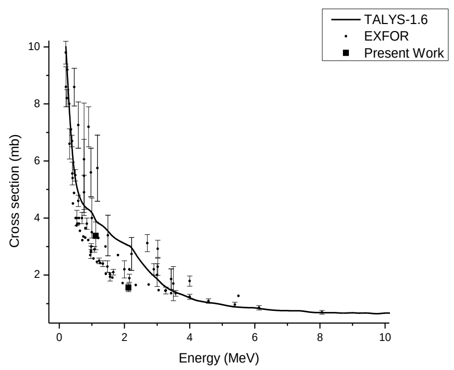
The experiment with the neutron energies of 1.12 and 2.12 MeV was performed using the folded tandem ion beam accelerator (FOTIA) at Van-de-Graff, BARC, Mumbai. The neutron beam energies of 1.12 and 2.12 were produced from the $^{7}Li(p, n)^{7}Be$ reaction by using the proton energy of 3 and 4 MeV. A circular LiF pellet of 1 cm diameter and 3 mm thickness was used for neutron production. It was fixed on a stand inside in a 0^0 angle of the beam exit window. A beam collimator of 10 mm diameter was used before the target. The 3 mm thick LiF pellet is sufficient to stop the proton beam of 3 and 4 MeV. A known amount ~0.0735 gm (for 1.12 MeV) and 0.0973 gm (for 2.12 MeV) of manganese metal foils and 1-mm-thick natural indium metal foils were wrapped separately with 0.025-mm-thick super pure aluminum foil to prevent contamination. The In-Mn stack was also mounted at 0^0 with respect to the beam direction. These samples were irradiated for 8 h 32 min with neutron energy of 1.12 MeV and 7 h 45 min for 2.12 MeV, respectively. The current of incident proton beam during the irradiations was 100 nA for both 3 and 4 MeV. The irradiated samples of Mn and In along with the Al wrapper were cooled for 1-2 h. They were mounted on different Perspex plates and taken for gamma-ray spectrometry [5]. From the photo-peak activity of 846.76 keV γ-ray of ^{56}Mn, the $Mn^{55}(n,\gamma)$

reaction cross-section (σ) was calculated by using the usual decay equation [5]. The ^{115}In(n,γ)^{116m}In reaction was used as the neutron flux monitor.

Results and discussion

The Mn^{55}(n,γ)^{56}Mn reaction cross-section obtained from the present work at the neutron energies of 1.12 and 2.12 MeV are shown in Table 1.The ^{55}Mn(n,γ) reaction cross-section as a function of neutron energy was also theoretically calculated by using the computer code TALYS-1.6 [6]. The data for the two neutron energies are shown in Table 1. The required inputs like nuclear masses, discrete energy levels, optical model potential and level densities of the nuclides involved in the calculations have been taken from latest RIPL-3 [6]. The data from TALYS-1.6 and the experimental data from present work at the neutron energies of 1.12 and 2.12 MeV along with literature data from EXFOR data library [2] at other neutron energies are plotted in Fig. 1. It can be seen from Fig. 1 that the experimental and TALYS values show a similar trend. However, TALYS values are slightly higher than the experimental values within the neutron energy of 1-4 MeV

Figure 1. Comparison of experimental Mn^{55}(n, γ)^{56}Mn reaction cross-sections with the theoretical values of TALYS-1.6 [6].



Conclusion

The ^{55}Mn(n,γ)^{55}Mn reaction cross-section at the neutron energies of 1.12 and 2.12 MeV are determined for the first time. At 2.12 MeV, it is found to be lower than the TALYS values. Thus it is strongly recommended to carry out the nuclear model calculation with reliable parameter set in the high energy range on such type of nuclear reactions, especially when there are no experimental data.

Table 1: Present experimental data and calculated results from TALYS 1.6 [6]

En (MeV)	^{55}Mn(n,γ)^{56}Mn cross-section (σ) in mb	
	Experimental	TALYS 1.6
1.12	3.37±0.49	3.87
2.12	1.56±0.15	3.03

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