Measurement of ^{78}Se(n, p)^{78}As reaction cross-sections at different neutron energies

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Introduction

Neutron activation and off-line γ-rays spectroscopy techniques are used for measurements of neutron induced reaction cross-section. The experimental measurement for (n, p), (n, 2n), (n, γ), (n, α) etc. on various nuclei are useful for testing the validity of the different theoretical nuclear reaction models. In fusion reactor, International Thermonuclear Experimental Reactor (ITER) device the D-T fusion will produce neutrons of 14.6 MeV energies and with scattering the neutron spectra will be from thermal to 14.6 MeV [1]. These neutrons interact with structural materials of the reactor and open (n, p), (n, 2n), (n, γ), (n, α) etc. reaction channels. In EXchange FORmat (EXFOR) data library experimental data is available for several nuclei but there is large inconsistency between experimental and theoretical data [2]. Therefore, the accurately measured neutron data of different reactions cross sections are necessary for development of future fusion devices. The neutron induced cross section data also useful in the development of the Accelerator Driven Sub-critical System (ADS) for nuclear waste transmutation, Advanced Heavy Water Reactor programme (AWHR) as well as in radiation damage estimateon of structural materials [3]. In nature, there are six stable isotopes of selenium exist. The nuclear reaction Se(n, p)As produces arsenic isotopes and arsenic is a very poisonous element. Therefore the study of Se(n, p)As reactions is important for arsenic which produced from the selenium [4]. In present work, we measured ^{78}Se(n, p)^{78}As cross section at 13.52±0.67 and 19.86±0.59 MeV neutron energies and estimates the theoretically from using TALYS-1.8 and EMPIRE-3.2.2 code [5-6].

Experimental Details

The experiment was performed using 14UD BARC-TIFR Pelletron Linac accelerator facility Mumbai, India. The nuclear reaction ^{7}Li(p, n)^{7}Be was used for the production of the quasi-monoenergetic neutron beam in which proton incident on natural Lithium (Li) foil of thickness 6.8 mg/cm^2 and this lithium foil is sandwiched between the two Tantalum (Ta) foils. The front Tantalum foil which facing the proton beam was the thinnest and have thickness 4 mg/cm^2 the back tantalum foil of thickness 0.1mm was used to stop the proton beam. The selenium sample was irradiated with neutron for 5 to 7 hours. The neutron irradiated activated samples emit γ-rays and these γ-rays counted with pre-calibrated 80 cm^3 HPGe detector coupled to a PC based 4096 multi-channel analyser. The energy and efficiency calibration of the HPGe detector determined using the standard ^{152}Eu source. The resolution of the HPGe detector was 1.8 keV at 1332 keV. The neutron flux of the order of 10^6 n/sec calculated from ^{27}Al(n, α)^{24}Mg nuclear reaction which used as a flux monitor. The neutron activation cross section calculated from following equation,

$$\sigma = \frac{A\lambda\left(\frac{C_L}{L_T}\right)}{N\epsilon\varphi I_\gamma\left(1-e^{-\lambda t_{ir}}\right)\left(1-e^{-\lambda t_c}\right)e^{-\lambda t_w}} \qquad (1)$$

Where, A-total area under the gamma peak, λ-decay constant, N-number of target nuclei-$/cm^2$, ϵ-photo-peak efficiency of γ-rays, I_γ γ-ray transition probability, t_w cooling, t_c counting, t_{ir} irradiation time, φ neutron flux C_L and C_T are clock and live time.

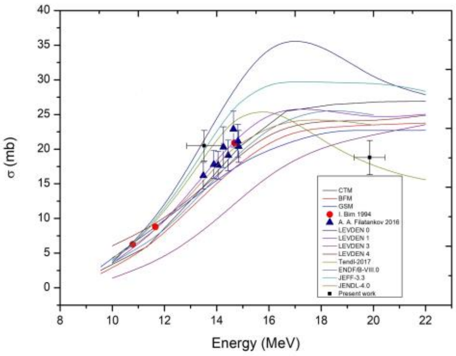

Fig-1 cross section for ^{78}Se(n, p)^{78}As reaction at 13.52±0.67 and 19.86±0.59 MeV neutron energies.

Calculation and data analysis

Theoretical estimation of ^{78}Se(n, p)^{78}As reaction cross section was performed by using TALYS-1.8 and EMPIRE-3.2.2 code from 10 to 22 MeV energies. In TALYS-1.8 code level density model are available namely Constant Temperature Model (CTM), Back-shifted Fermi gas Model (BFM) and Generalized Super-fluid Model (GSM) Similarly in EMPIRE-3.2.2 code, GSM, Gilbert & Cameron, HFB parity dependent level density model are available and these model used for cross-section calculation [5-6]. The neutrons produced from reaction are quasi-monoenergetic with long tail of low energies and peak around Ep-1.88 MeV. This lower energies tail region also contributed in reaction cross-sections. The tailing correction of low energy neutron was done using method given in literature [7].

Results and Discussion

The cross section for ^{78}Se(n ,p)^{78}As reaction measured at 13.52±0.67 and 19.86±0.59 MeV neutron energies from equation (1) and it is found to be 20.49±2.225 and 18.81±2.453 as shown in the Fig-1. The measured data compare with ENDF-B/VIII, JENDL-4.0, JEFF-3.3, TENDL-2017 data libraries and with experimental data. The measured data agree with JEFF-3.3, TENDL-2017 library and LEVDEN 0 model of EMPIRE-3.2.2 in low energy region and with TENDL-2017 in high energy region.

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