Activation cross-section of $^{78}Se(n, p)^{78}As$ reaction over 13.73 MeV to 14.77 MeV neutron energies

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Introduction

The measurement of the activation cross-sections for different neutron induced nuclear reactions have remained a field of interest for the past few decades. For fusion reactors, accurate values of the cross-sections for the (n, p) reaction are required in assessing and predicting radiation damage of materials. The total reaction cross-sections for the (n, p) and (n, α) reactions are also of interest in the study of damage in materials as well as for estimation of the production of hydrogen and helium gas respectively in the accelerator and reactor walls. The advantage of measuring activation reaction cross-sections in the medium mass elements is that these measurements are able to give information about mechanisms by which the interaction between the incident neutrons and the target nucleus proceeds.

In the present work, total cross-sections of (n, p) reaction for one of the selenium isotope were measured over the neutron energy range 13.73 MeV to 14.77 MeV. The present results were compared with the previous data [1, 2] and also with the cross-sections estimated using computer codes based on statistical model calculations. The statistical models mainly EMPIRE-II [3] code and TALYS [4] code were used for calculating the cross-sections of the reactions studied over the neutron energy range 10 MeV to 20 MeV. The activation cross-sections for $^{78}Se(n, p)^{78}As$ reaction having negative Q-value [5] were measured at 13.73 MeV, 14.07 MeV, 14.42 MeV, 14.68 MeV and 14.77 MeV neutron energies.

Experimental

The neutron irradiation was carried out using the 14 MeV neutron generator at the Department of Physics, University of Pune, Pune. The deuterium ions of energy 175 keV and current ~ 100 μA were bombarded on a 8 Curie tritium target. The selenium samples were made by high purity SeO_2(99.%) in powder form to study the $^{78}Se(n, p)^{78}As$ reaction. Similarly, Fe-56 in the form of metal powder was used as monitor. For the experiment, five samples were mounted at 0^o, 30^o, 60^o, 90^o and 120^o angular positions on the vertical rods fixed to the plexiglass plate attached to the tritium target holder of the neutron generator. In this manner, each sample could be placed at a distance of 50 mm from the centre of tritium target. All the five samples were irradiated with neutrons simultaneously for a period of 2400 seconds. The decay data of the reaction products produced in $^{78}Se(n, p)^{78}As$ and $^{56}Fe(n, p)^{56}Mn$ reactions after neutron irradiation are given in Table 1.

Table-1: The decay data of radioisotopes produced in different reactions.

Reaction	Half-life of radioisotope	E_γ (MeV)	f_d (%)
$^{78}Se(n, p)^{78}As$	90.7 m	0.61	54
$^{56}Fe(n, p)^{56}Mn$	2.57 hr	0.84	99

The induced gamma-ray activities of the irradiated samples were measured with a HPGe detector. The gamma-ray detection efficiency of this detector was measured with a Canberra make Multi Gamma Standard MGS-3 source in separate experiment. After the end of the irradiation period, the sample was transferred to the gamma-activity counting room. The induced gamma-ray activities from ^{78}As and ^{56}Mn radioisotopes produced in the sample were measured for a period of 900 seconds. Initially the gamma-ray activity of sample irradiated at 0^o position was measured. Later on the gamma-ray activities of the samples irradiated at 30^o, 60^o, 90^o and 120^o angular positions were measured in sequence. Figure 1 shows gamma-ray spectra of ^{78}As and ^{56}Mn radioisotopes. The activation cross-sections for the reaction were determined at 13.73 MeV, 14.07 MeV, 14.42 MeV, 14.68 MeV and 14.77 MeV neutron energies using the activation formula. The uncertainties in the measurement of each parameter were considered.

Nuclear Model Calculations

The cross-sections for $^{78}Se(n, p)^{78}As$ reaction were estimated using statistical nuclear models EMPIRE-II code and TALYS code over neutron energy range 10 MeV to 20 MeV using those options for which the theoretical cross-sections are close to the present measured cross-sections.

Results and Discussion

In the D-T reaction, the neutron energy depends on the angle of emission. By using expression energies of the neutrons emitted at 0^o, 30^o, 60^o, 90^o and 120^o were estimated and found to be 14.77 MeV, 14.68 MeV, 14.42 MeV, 14.07 MeV and 13.73 MeV respectively. The recorded gamma-ray activities due to ^{78}As and ^{56}Mn produced in $^{78}Se(n, p)^{78}As$ and $^{56}Fe(n, p)^{56}Mn$ reactions respectively are shown in Figure 1. The activation cross-sections for $^{78}Se(n, p)^{78}As$ reaction were measured at 13.73 MeV, 14.07 MeV, 14.42 MeV, 14.68 MeV and 14.77 MeV neutron energies. These cross-sections were also estimated theoretically over 10 MeV to 20 MeV neutron energies using EMPIRE-II and TALYS codes. The variations in the measured and theoretically estimated cross-sections of $^{78}Se(n, p)^{78}As$ reaction with neutron energy are shown in Figure 2. For comparison, a few literature values of the cross-sections are also plotted in Figure 2. It is observed in Figure 2 that the measured activation cross-sections for formation of ^{78}As through $^{78}Se(n, p)^{78}As$ reaction vary from 15.6 mb to 22 mb over the neutron energy range 13.73 MeV to 14.77 MeV. Moreover, the measured cross-sections are close to the corresponding theoretical cross-sections estimated in the present work. In the case of EMPIRE-II code, the cross-sections obtained using the HFBCS level density and nucleon potentials given by Koning are very close to the measured cross-sections as compared to those obtained using other options of the level density and the nucleon potentials. However, in the case of TALYS code, the cross-sections obtained using Fermi gas level density are close to the corresponding cross-sections measured in the present work and also with the literature values as compared to those obtained using other options of the level density. Moreover, the cross-sections obtained theoretically and the literature values of the cross-sections decrease with neutron energy above 16 MeV. This decrease in the cross-section is mainly due to the initiation of $^{78}Se(n, pn)^{77}As$ reaction channel having threshold energy ~10.5 MeV.

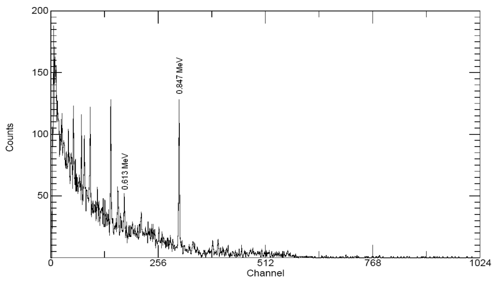

Figure-1: Gamma- ray spectra of ^{78}As and ^{56}Mn.

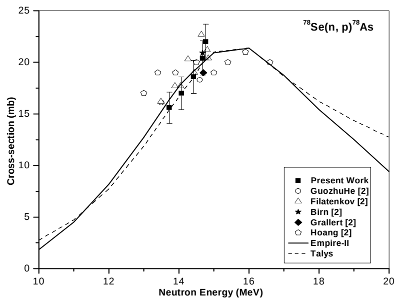

Figure-2: Variation of cross-sections for the $^{78}Se(n, p)^{78}As$ reaction with neutron energy.

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