Cross sections of ^{79}Se (p,n) reaction for nuclear transmutation

M. Hemalatha[1],* A. Patel[1], N. Maladkar[1], S. Kailas[1,2], S. G. Wahid[1], D. Negi[1], S. K. Tandel[1]
S. V. Suryanarayana[2], H. Naik[2], S. Santra[2], G. Mahanto[2], B. K. Nayak[2], A. Saxena[2]
[1]UM-DAE Centre for Excellence in Basic Sciences, Mumbai - 400098, INDIA
[2]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA
** email: hema@cbs.ac.in*

Introduction

Long-lived fission products (LLFP) such as ^{79}Se constitute waste burden from a power reactor. For safe storage in containers, it is important to transmute LLFP to short-lived nuclei. It is necessary to transmute significant amount of LLFP in each irradiation process. Therefore, the conversion time should be relatively small. Hence, it is crucial to choose transmutation reactions such that both nuclear cross section and the intensity of projectile are high. Choice of nuclear reaction should be such that it should not lead to creation of isotopes with long half-lives. Protons, neutrons, and photons can be considered as suitable projectiles for this programme. While neutrons, both slow and fast, are not useful because there are problems due to neutron capture on the other isotopes present along with ^{79}Se. For example, while neutron capture of ^{79}Se will lead to stable ^{80}Se, the isotope ^{78}Se will capture neutrons leading to ^{79}Se, the long-lived isotope that we would like to transmute. However, the proton-induced reactions at low energy are suitable for transmutation of long-lived fission fragments ^{79}Se ($T_{1/2}=2.95\times10^5$ years). These reactions convert ^{79}Se to short-lived ^{79}Br, while transmuting other isotopes to either stable or short-lived Br isotopes [1][2]. While (p,n) data exist for stable Se isotopes over a limited energy range, there are no data for radioactive ^{79}Se. We have measured cross sections for ^{74,76,77,78,80,82}Se (p,n) reactions at several energies with protons bombarding on natural Se targets. We then compare the measured cross sections with these from the statistical model code TALYS [3]. The parameters of the calculation can be chosen to give best agreement with data. The calculations can then be extended to the radioactive ^{79}Se isotope. This information is essential in dealing with the transmutation of radioactive ^{79}Se isotope. The preliminary experimental results have been presented in this abstract.

Experimental Details

The production yield of nuclei ^{76,77,78,80,82}Br have been measured in the reaction of proton with ^{nat}Se target using heavy-ion fusion evaporation reactions. We have measured the cross sections of (p,n) reactions on ^{78,80,82}Se using natural Se targets from (p,n) threshold energies to 18.5 MeV and for ^{74,76,77}Se cross-sections from (p,n) threshold energies to (p,2n) threshold energies. Several targets were irradiated, the irradiation time was chosen to be from about 2 hours to 14 hours depending on the half-lives of the isotopes. Due to low melting point of Se, care was taken to keep proton beam current at ~7 nA. Se targets were prepared by electro-deposition of Se (~600 μg/cm^2) on Al foil of thickness of about 2.5 mg/cm^2. The target thickness of both Se and Al are required in the measurement of cross section and beam energy. The Rutherford Back Scattering (RBS) technique was used in determination of the thickness for both Se and Al. A proton beam of 4 MeV from FOTIA, Mumbai was utilized for RBS measurements. Stacked-foil activation technique was used, and the stack was formed by positioning the Al foils immediately after the Se targets. Al foils were used as energy degrader and also as catcher foils. After the irradiation, the targets were removed and the beam induced γ-activities in individual foils were counted in off-line γ counting mode using two HPGe detectors [4].

Results and Discussion

Spectra were recorded at suitable time intervals to enable the corelation of the half–lives of various residual nuclei and their respective transition. The beam energy and counting time were optimized to obtain residual nuclei of interest. The γ-rays from a standard ^{152}Eu source were used for the efficiency and the energy calibration of the both HPGe detectors. The efficiency of the detector was interpolated to the required energy on the measured efficiency curve.

The observed γ-ray spectrum obtained in production of ^{78,80}Br via ^{nat}Se (p,n) reaction at E_p ~14 MeV is shown in Fig. 1. As indicated the γ-rays of energy of 613.8 keV are emitted from the residual nucleus, ^{78}Br ($T_{1/2}$= 6.45 min), while the 616.3 keV is from ^{80}Br ($T_{1/2}$=17.68 min). These close lying peaks were suitably convoluted using the software "Radware" to obtain the counts under peak required for absolute cross section analysis.

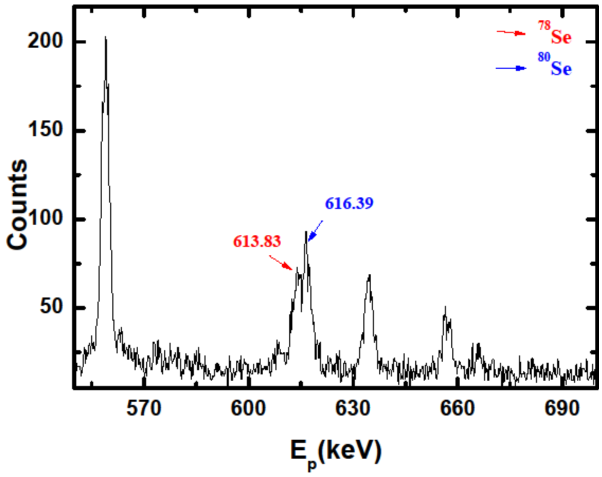

Fig. 1 The observed γ-ray spectrum obtained in production of ^{78,80}Br via ^{nat}Se (p,n) reaction at E_p ~17 MeV.

The observed γ-ray spectrum obtained for production of ^{76,77,82}Br via ^{nat}Se (p,n) reactions at E_p~ 12 MeV is plotted in Fig. 2.

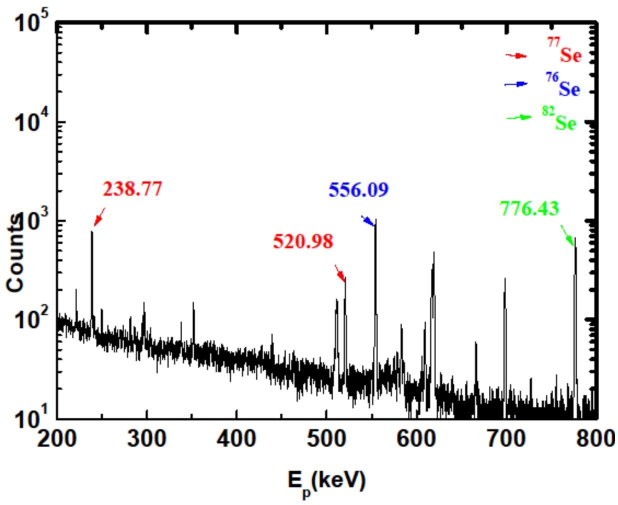

Fig. 2 The observed γ-rays spectrum obtained for production of ^{76,77,82}Br via ^{nat}Se (p,n) reactions at E_p~ 12 MeV.

The γ-rays corresponding to production of ^{74,76,77,78,80,82}Br have been observed. On completion at our analysis of proton induced reactions on natural Se isotopes, we would obtain excitation functions of ^{74,76,77,78,80,82}Se(p,n)^{74,76,77,78,80,82}Br. A statistical model analysis using the TALYS-1.6 code would be performed with parameters optimized to obtain good agreement with existing data. The calculations would then be extended to obtain the cross section for unstable ^{79}Se. Using this proton-induced cross section on ^{79}Se, the transmutation time which is much smaller than the half-life of ^{79}Se, can be obtained. It is interesting to note that the proton-induced reactions of Se isotopes present in waste burden lead to short-lived products. The amount of ^{79}Se that would be transmuted would be decided by the effective range of protons of given energy in the target medium. Low energy protons cannot be chosen as the range of protons in material is small and hence amount of material that can be transmuted in a given campaign is limited. High intensity of proton beam cannot be used as Se has low melting point. The choice of intensity and energy are crucial and decides the amount of ^{79}Se which can be effectively transmuted.

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