Production of ^{157}Dy from ^{14}N induced reaction

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Introduction

The study of heavy ions (HI) induced reactions has become a rich and growing area of interest in nuclear physics. It provides the opportunity to probe the mechanism of various reactions [1-3]. It has been observed that complete fusion (CF) and incomplete fusion (ICF) are dominant reaction modes at energies above the coulomb barrier ($E_{C.B.}$). In the CF process entire projectile fuses with the target nucleus and forms an excited compound nucleus (CN), which decays by evaporation of low-energy nucleons [3]. In this process entire linear and angular momentum of the projectile is transferred to the excited compound nucleus. In the ICF process, only a part of the projectile fuses with the target, and the remaining behaves as a spectator and moves in the forwarding cone [3]. In this process incomplete linear and angular momentum of the projectile transfer to the excited composite system. Nuclear reactions have numerous applications in both fundamental as well as in applied fields i.e., medical physics, energy production, astrophysics, etc.

The application of heavy ion reactions above the coulomb barrier with medium mass targets, in the energy regime of 3-7 MeV/nucleon is an area of resurgent interest. The residues populated in the reactions of this energy region have many usages. There are several potentially important residues that can be very useful in various clinical applications. Specifically, radio-nuclides like ^{149}Tb, ^{152}Tb, ^{155}Tb, ^{161}Tb, and ^{157}Dy are of utmost importance based on their applications in nuclear medicine and medical imaging [4]. The fusion reaction, transfer reaction, and many other routes can be adapted to produce the radio-nuclides of interest. However, to produce ^{157}Dy radio-nuclide the ^{14}N + ^{148}Nd system has been used in the present study. The ^{157}Dy has populated via the p4n channel followed by CF.

The radio-nuclide ^{157}Dy is important for its application in skeletal imaging. The two most intense γ-rays of ^{157}Dy are 326.16 keV (branching ratio= 92%) and 182.2 keV (branching ratio=1.84%). The advantages of using ^{157}Dy are that (i) it emits no primary particles, (ii) a γ-ray of 326.16 keV with a 92% branching ratio can produce a better camera image and the radio-nuclide has a decent half-life of 8.14 hours.

Taking into account the importance of ^{157}Dy, this paper aims to measure the cross-section of ^{157}Dy residue using the target activation technique.

Experimental Details

The production cross-sections of the ^{157}Dy(p4n) radio-nuclide in the interaction of ^{14}N projectile with ^{148}Nd target at energy above the Coulomb barrier have been measured. This experiment was performed by our group using General Purpose Scattering Chamber (GPSC) at Inter-University Accelerator Centre (IUAC), New Delhi, India. In the experiment, the stack-foil activation technique was used followed by offline γ-ray spectrometry. The $^{14}N^{6+}$ ion beam incident on ^{148}Nd target of energy ≈85 MeV was produced by 15UD pelletron accelerator at IUAC, New Delhi, India. The irradiation of a stack consisting of seven sandwiched targets (^{27}Al-^{148}Nd-^{27}Al) was performed. The ^{148}Nd target was prepared using the vacuum evaporation technique and by depositing on ^{27}Al thick foils. The enrichment of the ^{148}Nd target used was ≈95.44 %. The thickness of the ^{27}Al capping was 10μg/cm^2, ^{148}Nd target was ≈100-320 μg/cm^2 in range and ^{27}Al catcher was of thickness ≈1.4-2 mg/cm^2. The α-transmission technique was utilized for the measurement of ^{148}Nd target foils.

After the irradiation, the target stack was removed using an in-vacuum transfer facility (IVTF). A pre-calibrated high purity germanium (HPGe) detector coupled with a PC-based data acquisition system has been used for the detection of γ-ray activity induced in target foils along with catcher foils [5]. The efficiency of the HPGe detector was measured using a ^{152}Eu source of known strength. The ER was identified by its characteristic γ-rays along with an analysis of its decay curve.

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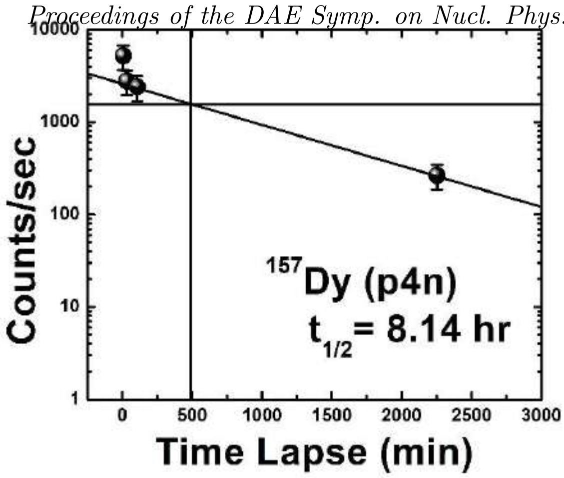

Fig.1(a) Decay curve for the residue ^{157}Dy (p4n)

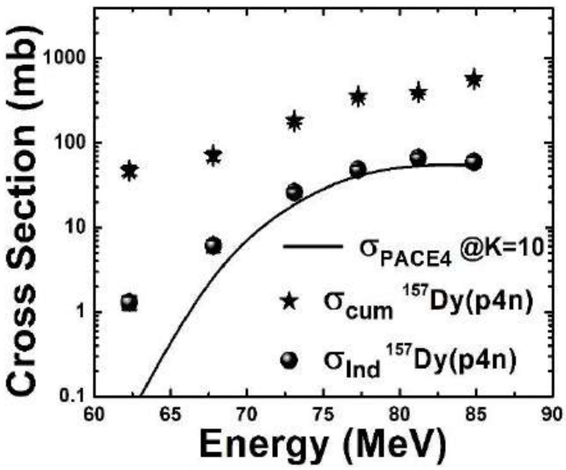

Fig.1 (b) Measured excitation function along with the theoretical predictions of PACE4 code for ^{157}Dy (p4n)

Results and Discussion

A typical decay curve of radio-nuclide ^{157}Dy detected at beam energy ≈ 85 MeV for the system ^{14}N + ^{148}Nd is displayed in Fig. 1 (a). It can be seen from the figure that the half-life of radio-nuclide is found to be $t_{1/2}$ = 8.14 hrs which corresponds to the ^{157}Dy. The measured excited functions of this radio-nuclide populated via emission of p4n channel have been plotted along with its theoretical predictions of PACE4 code and shown in Fig.1(b). The level density parameter a= A/K MeV^{-1} is an important parameter and varying this parameter the measured excitation function can be reproduced. It can be seen in Fig.1(b). The contribution of the precursor decay ^{157}Ho ($t_{1/2}$=12.6 min) has been separated from measures of cumulative cross-section and the corresponding independent cross-sections have been deduced using the standard formulation [6]. It can be seen from Fig.1(b) that the measured independent cross-sections of radio-nuclide are satisfactorily reproduced with the theoretical predictions of PACE4 (K=10) hence it confirms that the radio-nuclide is produced via CF as the PACE4 [7] code only can predict the cross section for CF reaction. From this figure, it has been noticed that the maximum cross-section of ^{157}Dy radionuclide is found to be 573.486 mb corresponding to the beam energy E_{lab} ≈ 84.6 MeV. This yield is sufficient to extract ^{157}Dy from the irradiated sample. Analysis of the present data is in progress.

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