Production of medically relevant radionuclides through heavy-ion interactions

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Introduction

The investigation of fusion dynamics in the heavy ion (HI) interactions has been a topic of interest in recent years. These reactions are important particularly at projectile energies in the range of 4-7 MeV/nucleon above the coulomb barrier [1]. The Complete fusion (CF) and Incomplete fusion (ICF) are the two competing processes in this energy range [2]. In ICF reactions a part of projectile fuses with the target and hence the transfer of the partial angular momentum from the projectile to the target takes place. Whereas in CF processes, projectile is captured completely by the target and complete transfer of the angular momentum takes place. These reactions are followed by the populations of evaporation residues after the formation of the compound nucleus.

The application of heavy ion reactions above the Coulomb barrier with medium mass targets is an area of resurgent interest. The residues populated in the reactions of 4-7 MeV/nucleon energy region have many usages. There are several potentially important residues that can be very useful in various clinical applications. Radioisotopes like ^{161}Er, ^{157}Dy are some of the important residues for auger therapy and radio imaging purposes. Above mentioned radionuclide can also be produced via proton or other light ion projectiles. But through that method radionuclides produced contain isotopic impurities which make them difficult to separate.

In the present study we propose the production ^{161}Er and ^{157}Dy radioisotopes, employing ^{16}O beam and ^{156}Gd targets using target activation technique.

Experimental details

The experiment was conducted at the Inter University Accelerator Centre (IUAC), New Delhi, using the General Purpose Scattering Chamber (GPSC) facility. Using the 15UD Palletron accelerator beam of $^{16}O^{7+}$ is used for excitation measurement technique on the target of ^{156}Gd at projectile energy ≈ 100 MeV, irradiation was done for ≈ 5 hours. The corresponding beam current was ≈ 15 nA. The stacked foil activation technique has been used which is followed by offline analysis of γ- spectrum.

Preparation of target ^{156}Gd was done using the rolling machine whose thicknesses ≈ 1.2 to 2.5 mg/cm² is deposited on Al-catcher foil of variable thicknesses ≈ 1.2 to 2.2 mg/cm². The thickness of the materials used was measured by α–transmission method. Once the target is irradiated with the beam then activity of the samples are recorded. In order to reduce the time elapsed between irradiation and the start of counting the GPSC is equipped with the In-Vaccum Transfer Facility (IVTF). To estimate the beam flux, the total charge collected at the Faraday cup situated behind the stack assembly of target and catcher was employed. Following the irradiation, the assembly containing the irradiated target and catcher was extracted from the scattering chamber. Induced activity within every Al-catcher foil is recorded using a pre-calibrated, high-resolution HPGe detector with an active volume of 100 c.c. This detector was linked to a PC through CAMAC-based CANDLE software [3].

Result and discussions

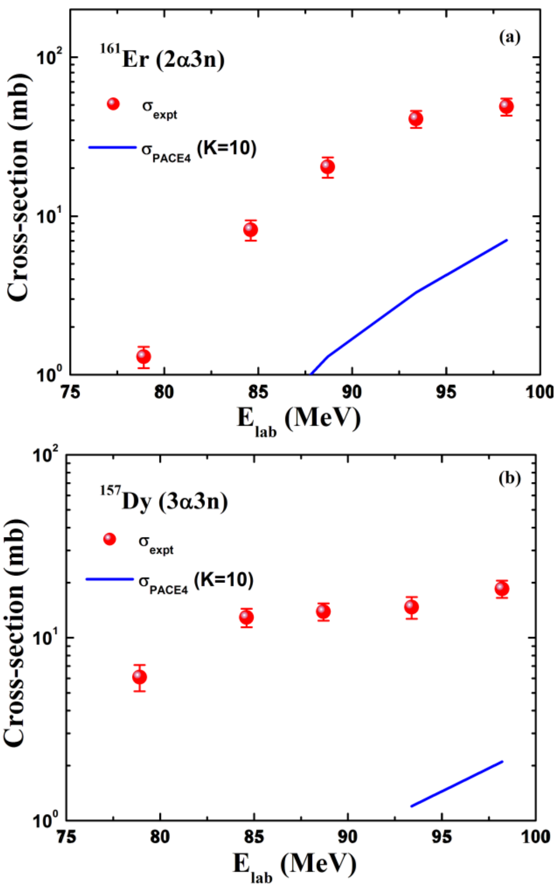

Fig. 1. Measured excitation function along with the theoretical predictions of PACE4 code for ERs (a) ^{161}Er and (b) ^{157}Dy

Different residues populated in the interaction of ^{16}O and ^{156}Gd at energy range of 4-7 MeV/nucleon. These residues are produced through xn/pxn and αxn/ αpxn channels. All the residues are populated via CF and/or ICF processes. Of all the different evaporation residues which are produced for the system, few of the radionuclides like ^{161}Er and ^{157}Dy are of utmost importance in nuclear medicine and imaging [4]. These evaporation residues are identified from their distinctive γ-rays emerging from those particular residues which are then further confirmed by analysing their decay curve.

The measure excitation function of radio-nuclide ^{161}Er and ^{157}Dy populated in the system ^{16}O + ^{156}Gd is displayed in Fig. 1 (a)-(b). Here we studied their prediction of theoretical cross section through statistical model code PACE-4 of the ERs populating for the ^{16}O + ^{156}Gd which are then compared with the experimental cross section.

From Fig. 1 (a)-(b), it can be seen that for both the residues, there is significant enhancement in the experimental cross-section values from the theoretical predictions of PACE-4. As PACE-4 values only shows us the CF cross section. So the enhancement in the observed cross-section is primarily due to its formation via ICF process. These results indicate that the radionuclides ^{161}Er and ^{157}Dy are formed not only through CF but also through ICF process.

Acknowledgments

Authors express their thanks to Director and Convener, AUC, Inter-University Accelerator Centre (IUAC), New Delhi, India, for providing all necessary facilities to carry out the experiment. The authors are also thankful to the Head of Department of Physics, Aligarh Muslim University, Aligarh for the motivation and support.

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