Production of ^{187}Pt radionuclide from ^{11}B-induced reaction on ^{nat}Ta

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Introduction

Investigation of the nuclear reaction processes like direct emission, pre-equilibrium (PEQ) and compound evaporation or equilibrium (EQ) is necessary to understand the experimental and theoretical aspects of the heavy-ion fusion mechanism. It is also important to understand the enhancement in the sub-barrier region and hindrance in the deep sub-barrier [1], suppression [2] and PEQ emission [3, 4] in the above barrier region. To understand these phenomena we need to understand the different degree of freedom of the colliding nuclei like deformation, collective motions, angular momentum distribution, transfer of nucleons, etc. The PEQ emission of neutrons was reported in the $3n$ channel of ^{12}C and ^{16}O, induced reactions on ^{128}Te, ^{169}Tm, and ^{159}Tb, ^{169}Tm, ^{181}Ta, respectively [3]. Later on, the production cross-section of different radionuclides and PEQ emission in $3n$ channel was also reported from ^{11}B+^{89}Y and ^{11}B+^{93}Nb reactions in the energy range $\sim$ 4-5.5 MeV/A [4]. However, the compound reaction mechanism is a favourable route for the production of residues for any application; as an example, production of no-carrier-added ^{97}Ru (2.83d) was investigated from ^{89}Y(^{11}B, $3n$)^{97}Ru reaction as it has various applications in the field of medicine [5]. In this series we have reported an analysis of the production of neutron deficient $^{184-191}$Pt radionuclides from different projectile-target combinations [6]. In the above barrier region, cross-section of fission and α-active heavy reaction products were reported from the ^{10,11}B+^{209}Bi reactions, and it was found that complete fusion (CF) cross-section without breakup was suppressed by 15% for ^{10}B and 7% for ^{11}B [2]. Hindrance of fusion cross-section was also observed, at above barrier energies of ^{11}B, ^{19}F induced reactions on lower mass targets ^{27}Al and ^{19}F due to the entrance channel mass asymmetry [7].

In this article, we report an experimental study of the ^{11}B induced reaction on ^{nat}Ta target within $\sim$ 4.8-5.7 MeV/A energy range that leads to the production of ^{187}Pt.

Experimental details

The experiment was carried out at the BARC-TIFR Pelletron facility, Mumbai, India. The ^{11}B beam was bombarded on a stack of foils of ^{nat}Ta having thickness $\sim$ 1.25-1.8 mg/cm^2, supported by the aluminum catcher foils of thickness $\sim$ 1.5-1.8 mg/cm^2 within 53-63 MeV range of energy. After the end of bombardment, the activity of product radionuclides was measured with the help of γ-ray spectrometry and the cross-sections were calculated using the activation formula. Error associated with the cross-sections are estimated considering all possible sources and the data is presented upto 95% confidence level.

TABLE I: Spectroscopic data of ^{187}Pt

Nuclide	$T_{1/2}$ (h)	E_γ [I_γ] (keV)[%]	E_{th} (MeV)
^{187}Pt	2.35	201.52 [6.4]	46.08
		304.71 [4.3]	

Results and discussion

The measured cross-sections of ^{187}Pt radionuclide populated via $5n$ channel, presented in Fig.1, are compared with the theoretical model calculations obtained from

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ALICE-14 and PACE-4. Both the codes are based on statistical approach and consider the de-excitation of the excited compound nucleus followed by the multi-step Monte-Carlo procedure. PACE-4 considers the angular momentum projections at each stage of the de-excitation. This process allows measuring the angular momentum distribution of the emitted particles in PACE-4. CF cross-section is estimated using one-dimensional barrier penetration model considering Bass barrier potential in PACE-4. The models Hauser-Feshbach and Weisskopf-Ewing have been used for the EQ in PACE-4 and ALICE-14, respectively. Hybrid Monte-Carlo simulation model is considered to investigate the effect of PEQ in ALICE-14 while PACE-4 does not consider the PEQ emission. Furthermore, ALICE-14 can be used for light-heavy ion induced reactions upto 200 MeV. The Gilbert-Cameron level density has been used with level density parameter a = (A/K), where A is the mass number of the compound nucleus and K is a free parameter known as level density parameter constant. K = 9, 10, 11 are considered in the PACE-4 calculation. The Fermi gas level density is adopted in ALICE-14. It shows that at low energy, below 57 MeV, PACE-4 underpredicts the experimental cross-sections while ALICE-14 overpredicts them within the whole energy range. In the higher energy range (∼ 58-63 MeV) experimental cross-sections are in good agreement with PACE-4. It is observed that variation in the level density parameter does not influence the theoretical cross-sections below 68 MeV. The enhancement in experimental cross-sections near barrier could be due to the entrance channel effect of the fusion of ^{11}B to the Ta nucleus. The compound reaction mechanism is dominant in the 5n channel.

Conclusion

The production cross-section of ^{187}Pt from the ^{11}B+^{nat}Ta reaction within ∼ 4.8-5.7 MeV/A has been reported. Hauser-Feshbach formalism grossly reproduces the experimental cross-sections as compared to the Weisskopf-Ewing formalism. Over the measured energy range EQ emission is the dominant mechanism. Therefore, an estimate of the quantity of the product isotope could be made from this study. However, more experimental data are required at higher energies to understand the reaction mechanism.

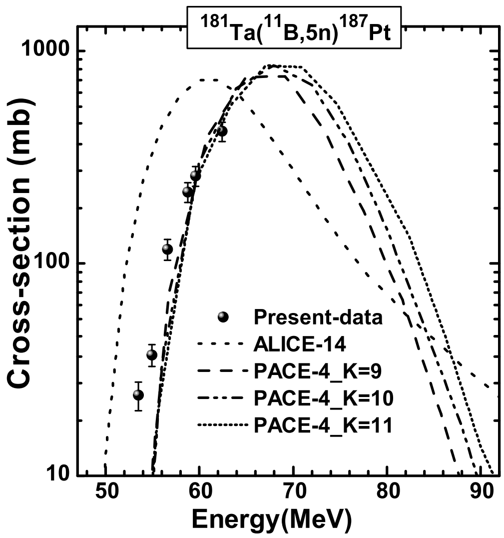

FIG. 1: Comparison of experimental and theoretical excitation functions of ^{187}Pt.

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