Observation of preequilibrium emission of neutrons in α-induced reaction on ^{93}Nb

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Introduction

Measurement of excitation functions in α-induced reaction on intermediate or heavy mass region is important for reactor technology, specially in accelerator driven system (ADS) used for energy production and transmutation of nuclear waste and in nuclear medicine. Moreover, measurement of excitation functions play a significant role to understand the fundamental reaction mechanisms such as compound and precompound processes or to check the applicability of different nuclear reaction models.

In view of the above, an attempt has been made to analyze preequilibrium emission of neutrons over compound reaction mechanism in α-induced reaction on natural niobium (^{93}Nb) in 30 - 50 MeV energy range. Although a large number of investigations have already been done for this reaction over a wide energy range, but, they suffer from the large systematic divergence as reported by different group of scientists [1]. In recent experimental measurements, T*árkányi* et. al. [1], Amanuel et. al. [2], Sharma et. al. [3], observed significant preequilibrium emission in the high energy tail of excitation functions upto 10 MeV/A. Mukherjee et. al. [4] measured isomeric cross section ratio and excitation function of ^{95m,g}Tc upto 30 MeV/A for preequilibrium study.

Experimental

The experiment was carried out at the Variable Energy Cyclotron Center (VECC), Kolkata, India. α beam was allowed to incident on the pure ^{93}Nb foils of thickness 1.84 mg/cm^2 between 30-50 MeV energy range. ^{93}Nb foil was backed by aluminum foils of suitable thickness, worked as a catcher foil as well as energy degrader foil. Beam intensity was measured by total charge collected at the Faraday cap, situated at back side of the foil assembly. After the end of bombardment (EOB), γ-spectroscopic studies were carried out to analyze the residues by using a p-type HPGe detector coupled with a digital spectrum analyzer (DSA) and GENIE-2K software (Canberra). The known activation formula was used for the calculation of cross section of the identified residues. Fig 1 shows the γ-ray spectrum of all produced residues at 30 MeV incident energy.

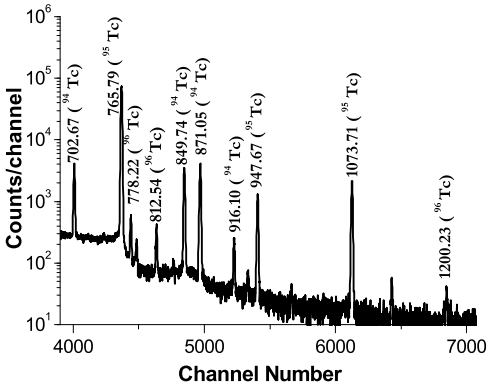

FIG. 1: The γ-ray spectrum of the 30 MeV α-induced reaction on ^{93}Nb foil after 1.4 h of the EOB.

Results and discussion

To understand the reaction mechanisms involved in α+^{93}Nb system, cross sections of

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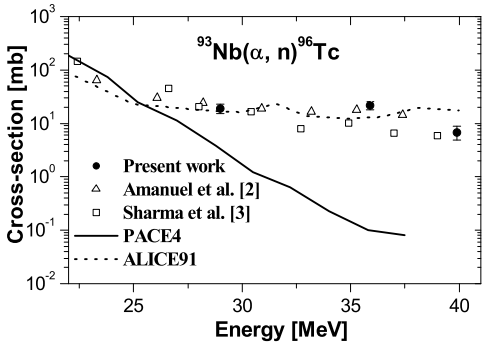

FIG. 2: Comparison of measured cross sections of ^{96}Tc with other measurements and theoretical calculation.

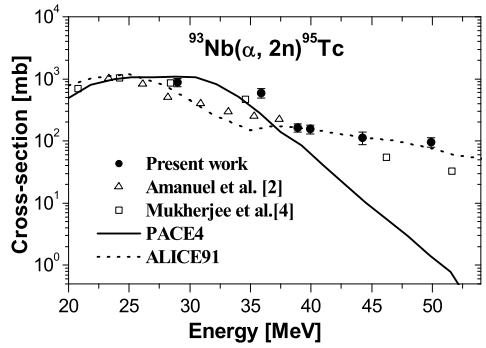

FIG. 3: Comparison of cross sections of^{95}Tc with other measurements and theoretical calculation.

the residues were estimated theoretically using PACE4 and ALICE91. PACE4 calculation is based on the Hauser-Feshbach formalism with Gilbert-Cameron level density parameter. ALICE91 uses Weisskopf-Ewing model and geometry dependent hybrid (GDH) model for compound and precompound processes, respectively; Fermi gas level density with level density parameter = A/9 was selected. Initial exciton number, $n_0 = 4$ (2p,2n,0h) was chosen for α particle in GDH model.

Table I lists the measured cross section of ^{96}Tc and ^{95}Tc at various incident energies. Measured excitation function of ^{96}Tc and ^{95}Tc are compared with PACE4 and ALICE91 calculations and with the recent literature results, shown in Fig 2 and Fig 3, respectively.

TABLE I: Measured cross section at various incident energies

Energy (MeV)	**Cross-section (mb)**	
	^{96}Tc(4.28 d)	^{95}Tc(20.0 h)
29.0	19.1 ± 3.6	875.3 ± 127.4
35.9	21.7 ± 3.7	595.0 ± 101.0
38.9	–	164.6 ± 25.8
39.9	6.8 ± 1.9	156.2 ± 25.0
44.3		113.0 ± 23.9
49.9		96.6 ± 16.6

Overall, experimental data are in good agreement with ALICE91 calculation as well as earlier measured data. However, prediction of PACE4 fails to reproduce the cross sections at higher energy indicating the significant emission of preequilibrium neutrons over compound reaction evaporated neutrons. As seen in Fig 3 the present measurement reproduces the ALICE91 estimation quite well within experimental uncertainties at the high energy region compared to [4].

Conclusion

This study confirms the preequilibrium emission of neutrons upto 12 MeV/A over the compound reaction at the high energy tail of excitation functions as observed by other investigators. Experimental cross sections are explained by admixture of equilibrium and preequilibrium processes in both the neutron emission channels.

Acknowledgment

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References

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