Fusion excitation functions around the Coulomb barrier for ^{18}O + ^{61,62}Ni system

Nabendu Kumar Deb[1],* Harun A. Rashid[1], Amar Das[1], Kushal Kalita[1], Subir Nath[2], Pankaj K. Giri[3], Rudra N. Sahoo[4], N. Madhavan[2], J. Gehlot[2], Rohan Biswas[2], N. K. Rai[5], A. Parihari[2], T. Varughese[2], B. J. Roy[6], Saumyajit Biswas[7], Anjali Rani[8]

[1] *Department of Physics, Gauhati University, Guwahati - 781014, Assam, India*
[2] *Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, India*
[3] *Department of Physics, Central University of Jharkhand, Ranchi - 835205, Jharkhand, India*
[4] *Department of Physics, Indian Institute of Technology, Ropar,Punjab - 140001, India*
[5] *Department of Physics, Banaras Hindu University, Varanasi, Uttar Pradesh-221005, India*
[6] *Nuclear Physics Department, Bhabha Atomic Research Centre, Trombay, Mumbai - 400085, India*
[7] *Department of Physics,Visva Bharati, Santiniketan, West Bengal-731235, India*
[8] *Department of Physics & Astrophysics, Delhi University, Delhi-110007, India*

Introduction

Nuclear fusion cross section around the Coulomb barrier reveals varieties of phenomena. One such phenomenon is the enhancement of the sub-barrier fusion cross section as compared to the theoretical predictions of 1-D barrier penetration model (BPM) [1, 2]. Such enhancement occurs due to the coupling of relative motion to internal degrees of freedom of the colliding nuclei such as deformation [3], vibration [4], nucleon transfer [5] and neck formation [6] between the two interacting nuclei.

Neutron transfer plays a vital role in the enhancement, especially, for the systems having positive Q value of few neutron transfer, as it causes a considerable shift in the barrier height [7]. Thus in order to examine this, we measured fusion excitation functions for ^{18}O + ^{61,62}Ni system around the Coulomb barrier, using Heavy Ion Reaction Analyzer (HIRA) at the Inter University Accelerator Centre (IUAC), New Delhi [8]. In these systems the Q-values are positive for two neutron (2n) stripping channel.

Experimental Setup

Pulsed beam of ^{18}O (with 4 μs pulse separation) was bombarded on ^{61,62}Ni target (99.6% and 98.45% enriched respectively) of 150 $\mu g/cm^2$ thickness prepared on 30 $\mu g/cm^2$ carbon backings in the target development laboratory at IUAC [9]. In the target chamber of HIRA, two silicon surface barrier detectors were mounted in the forward direction at 15.5^o in the horizontal plane to monitor the beam and for normalization of cross section. A carbon charge reset foil of 30 $\mu g/cm^2$ thickness was used for charge re-equilibration of evaporation residues (ER), after probable internal conversion processes, coming out of the target. At the focal plane of HIRA, a Multi Wire Proportional Counter of 150 $\times$ 50 mm^2 active area was used for the detection of ER. Time of flight (TOF) was defined for particles reaching the focal plane with respect to RF of beam to separate multiple-scattered beam-like particles and ERs.

The fusion excitation function measurements were performed (in laboratory frame) from 34 MeV to 53 MeV in steps of 1 MeV below the Coulomb barrier, ~1-2 MeV near the barrier and 3 MeV above the barrier. This energy range covers 15% below to 30% above the Coulomb barrier. The solid angle of acceptance for HIRA was 10 mSr. Raw scattered plots for 53 MeV (above barrier) and 34 MeV (below barrier) beam energy are shown in Fig. 1 (for ^{18}O+^{62}Ni as a representative case), with the energy loss along x-axis and the corresponding TOF along y-axis. The

*Electronic address: `nd_globe@yahoo.co.in`

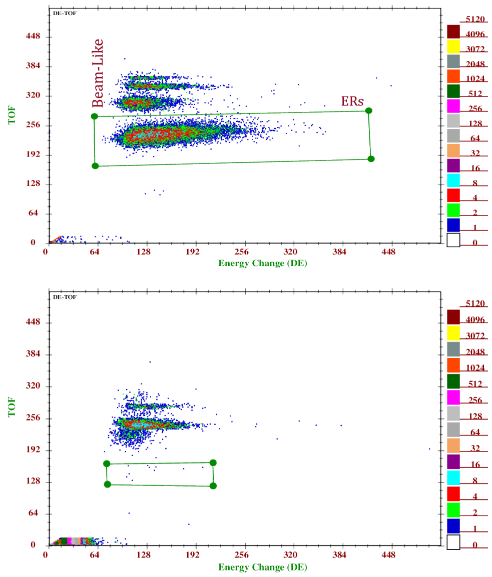

FIG. 1: Energy loss versus TOF spectra for ^{18}O+^{62}Ni at E_{lab} = 53 MeV (top), and E_{lab} = 34 MeV (bottom).

spectra are similar for ^{18}O+^{61}Ni. It is seen clearly that beam-like particles are very well separated from the ERs in both the extreme cases. In the measurement of the fusion cross section, the ER cross section was taken to be the total fusion cross section as the fission contribution in this mass region is negligible.

Results and Discussion

Fig. 2 shows the preliminary ER cross section which is calculated using the equation:

$$\sigma = \frac{1}{\varepsilon}\left(\frac{Y_{ER}}{Y_M}\right)\left(\frac{d\sigma}{d\Omega}\right)_R \Omega_M$$

where the symbols carry usual meaning as is shown in Ref. [10]. Corrections for the loss of beam energy in C-backing and half target thickness were taken into account. For 1DBPM cross-section, calculations were done using the theoretical coupling code CCFULL [11] without implementing inelastic excitations; the ion - ion potential used here is the Woods-Saxon parameterization of Akyuz-Winther potential. It can be seen from the figure that the sub-barrier fusion cross-section is clearly enhanced compared to that of 1DBPM by few orders for both the systems. The role of positive Q-value 2n transfer towards this enhancement needs to be ascertained. Further analysis is in progress and the results will be compared with the various coupling channels using CCFULL to see the behaviour of the sub-barrier fusion cross section and its corresponding fusion dynamics. These analyses will be presented in the symposium.

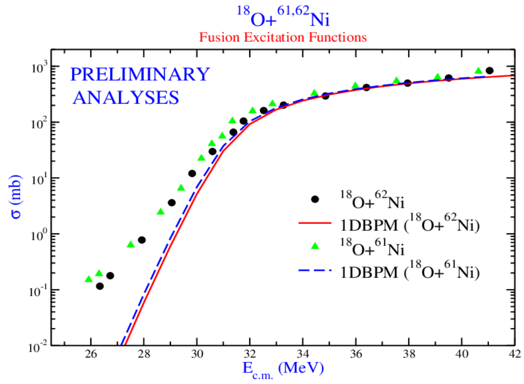

FIG. 2: Fusion excitation functions for ^{18}O+^{61,62}Ni.

Acknowledgments

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