Complete and incomplete fusion cross section measurement for the $^{9}Be+^{93}Nb$ system

S. Rathi[1],* Arati Chavan[1], V. V. Parkar[2,3], K. Mahata[2,3], S. K. Pandit[2,3], K. Ramachandran[2], A. Shrivastava[2,3], Prasanna M[4], Satbir Kaur[2,3], Sangeeta Dhuri[2,3], V.Kumar[2], A. Kumar [2], Tarunsagar Prajapati[1], Amitha Ganeshan[1], Prabhat Mishra[2,3], and R. Tripathi[5]

[1] *Vivekanand Education Society's College of Arts, Science and Commerce (Autonomous), Mumbai - 400071, India*
[2] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, India*
[3] *Homi Bhabha National Institute, Anushaktinagar, Mumbai 400094, India*
[4] *Rani Channamma University, Belagavi - 591156, India and*
[5] *Radiochemistry Division, Bhabha Atomic Research Centre, Mumbai - 400085, India*

Introduction

Recently, fusion with weakly bound stable/ radioactive nuclei and the influence of breakup on complete fusion has received a great amount of attention in nuclear physics [1,2]. These studies are important in understanding the nucleosynthesis process, and in the production of nuclei near the drip line. Several experimental and theoretical studies of fusion reactions with weakly bound projectile like ^{6}Li,^{7}Li, ^{9}Be have been performed over the last two decades. The main issues in these in these studies is to determine, if the weak binding leads to enhancement or hindrance of the complete fusion cross sections. There are theoretical calculations that predict either suppression of the complete fusion (CF) cross sections due to breakup of loosely bound nucleus or enhancement of the same due to coupling of the relative motion of the colliding nuclei to the breakup channel. In general, from the data of stable weakly bound nuclei on heavy targets, it can be said that the suppression in complete fusion increases with (a) target atomic number (Z_T) and (b) decrease of projectile break-up threshold (E_{th}). But there is not any empirical expression for the suppression as a function of Z_T and E_{th} . Complete fusion suppression is a well known phenomenon observed with ^{5,6}Li, ^{9}Be weakly bound projectiles on various targets [3]. Also the fusion suppression is found to be target independent for a particular projectile. There are very scarce measurements on the fusion cross section of stable weakly bound projectiles on the medium mass targets around mass region 100, to draw any conclusion on suppression/hindrance on fusion cross section. So, we have performed fusion cross section measurements in this mass region.

Experimental Details

The experiment was carried out at BARC-TIFR Pelletron LINAC Facility, Mumbai. Self-supporting, rolled, natural foils of ^{93}Nb, with thickness 1.02-1.9 mg/cm^{2} were irradiated by beams of ^{9}Be, in the energy range E_{beam} = 20-46 MeV. The aluminium catcher foils of thickness 2 mg/cm^{2} were mounted behind the target foils to stop the recoiling reaction residues. Targets were irradiated for 4 hrs. for the energies above barrier and 6-8 hrs. for below barrier energies with typical beam current of 40-100 nA. The beam current was recorded at regular intervals of 1 min. using CAMAC scaler. The γ rays from irradiated samples were counted offline using two efficiency calibrated HPGe detectors. The target-catcher foil assembly was placed either at a distance of 10 cm from the face of the detector or on the face of the detector, depending on the activity of the irradiated sample. Both the HPGe detectors were shielded with Cu-

*Electronic address: sarla.rathi@ves.ac.in

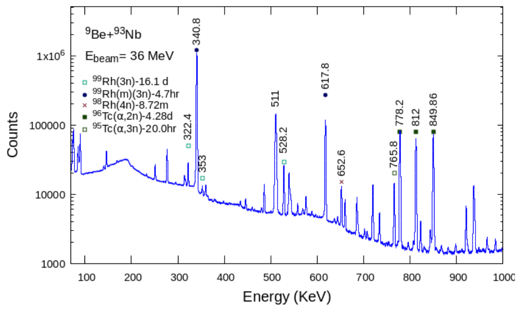

FIG. 1: A typical gamma spectra from ER detected in HPGE detectors at E_{beam} = 36 MeV.

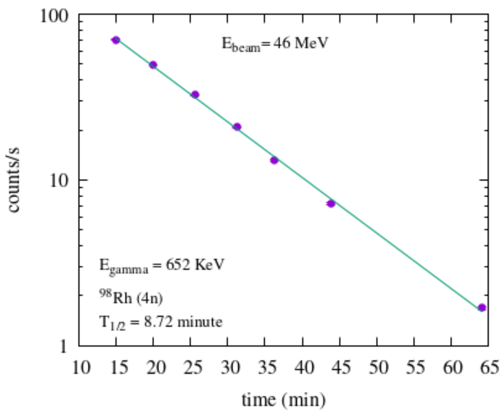

FIG. 2: Activity of the ^{98}Rh evaporation residue as a function of time at E_{beam}=36 MeV. Line corresponds to activity obtained by fitting the data.

Cd Pb shielding for reducing the background radiation. The efficiency and energy calibration of the HPGe detectors were done using standard ^{152}Eu and ^{133}Ba γ-ray sources. Data were recorded in VME based data acquisition system for below barrier energies. The compound nucleus ^{102}Rh produced in the reaction decays to $^{98-101}$Rh by evaporating successive neutrons (1n-4n), over the energy range of measurement.

Analysis and Result

A typical gamma spectra from evaporation residues (ER) detected in HPGe detector at beam energy of E_{beam}=36 MeV is shown in fig.1. The residues from CF and incompete fusion (ICF) were identified by their character-

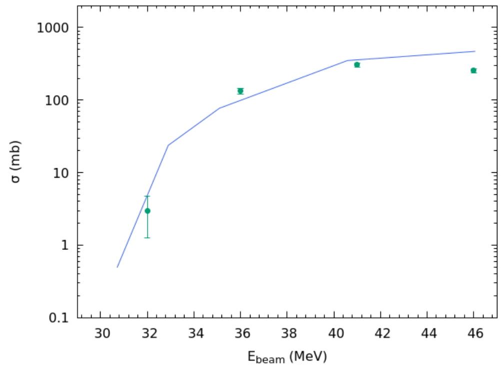

FIG. 3: Comparison of ^{98}Rh ER cross section at various energies with pace calculations [5].

istic γ rays and are marked in the figure along with thier half-lives. The identification of γ rays was confirmed by half-life measurement as shown in Fig. 2. In the CF channel, ^{100}Rh (2n), ^{99}Rh (3n) and ^{98}Rh (4n) residues are dominant. In the ICF ^{96}Tc(α,2n), ^{95}Tc(α,3n) residues were identified. The cross sections of the residues were estimated from the standard expression used in the offline γ-ray counting [4] considering the yield, half-life, cooling, counting time, efficiency of detector and branching ratio etc. Fig. 3 shows comparison of ^{98}Rh evaporation residue (ER) cross section at various energies with pace calculations [5] (shown in line). Further analysis is in progress. We will be presenting the results of contributions of CF and ICF in ^{9}Be+^{93}Nb system.

Acknowledgments

We thank PLF accelerator staff, Mumbai for providing steady and uninterrupted beam and P. Patale for help during the experiment.

References

[1] L. F. Canto et al. Phys. Rep. 424, 1 (2006).

[2] N. Keeley et al., Prog. Part. Nucl. Phys. 59, 579 (2007).

[3] V. Jha, V. V. Parkar, S. Kailas, Phys. Rep. 845, 1 (2020)

[4] V. V. Parkar et al.,Phys. Rev. C 97, 014607 (2018).

[5] A. Gavron, Phys. Rev. C 21 (1980) 230