Fusion excitation function studies in the reactions forming ^{158,166}Er

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Introduction

Nuclear fusion is a complex process involving a complete re-arrangement of quantum systems with many degrees of freedom. Heavy ion fusion exhibits a strong entrance channel dependence at near fusion barrier energies and could be reasonably explained by coupled channels formalism [1] that explicitly includes the effects of internal degrees of freedom. Though tremendously successful in describing the data at near barrier energies, coupled channels theories fail to describe fusion at deep sub barrier and well above the fusion barrier energies [2]. Alternate theories [3, 4] proposed recently also could not give a reasonable explanation to the experimental observations till date. It is pointed that instead of a coherent coupled channels approach, a model with a gradual onset of decoherence [5] between the superposed states may be required to describe fusion.

Experimental Setup

The experiment was carried out at Inter University Accelerator Centre (IUAC), New Delhi, using the 15 UD Pelletron accelerator. Pulsed beams of ^{16}O, with a pulse separation of 4 μs, was used to bombard the isotopically enriched ^{142}Nd and ^{150}Nd targets. The measurements were performed in the beam energy range of 60 to 104 MeV and 56 to 104 MeV, for the ^{16}O+^{142}Nd and ^{16}O+^{150}Nd reactions, respectively.The low energy ERs produced in the fusion reactions were separated from other possible scattered particles using the Heavy Ion Reaction Analyser (HIRA) [6] and are detected in the focal plane using a two-dimensional position-sensitive multi wire proportional counter (MWPC) with an active area of 150 mm x 50 mm. Two silicon surface barrier detectors were placed inside the target chamber to measure elastically scattered beam particles and to get absolute normalization of ER cross sections. The time interval between two successive pulses were slightly more than the time of flight (TOF) of ERs, from the reaction point to the focal plane of HIRA. The ERs were selected through the two-dimensional spectrum of ER energy loss (ΔE) vs ER TOF as shown in Fig1.

Results and discussion

The fusion cross section at different energies is estimated by using the standard expression [7]. Coupled channels code CCFULL has been used to analyse the measured fusion cross sections for the two reactions. Nuclear potential parameters V$_0$, r_0 and a were first fixed using the Akyz-Winther parameterisation [9]. The measured excitation function is found to be significantly enhanced relative to the one-dimensional barrier penetration model (1-DBPM). Vibrational coupling of 2^+ and 3^- states of ^{142}Nd is found to explain the sub-barrier fusion enhancement in

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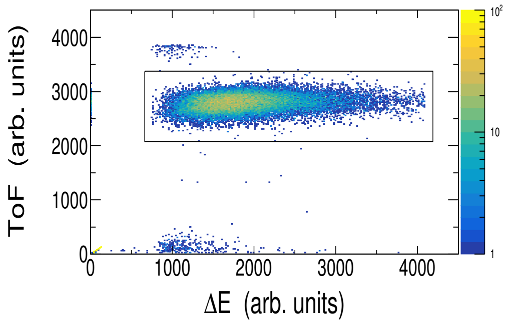

FIG. 1: Energy loss versus TOF spectra for ^{16}O+^{142}Nd showing clear separation.

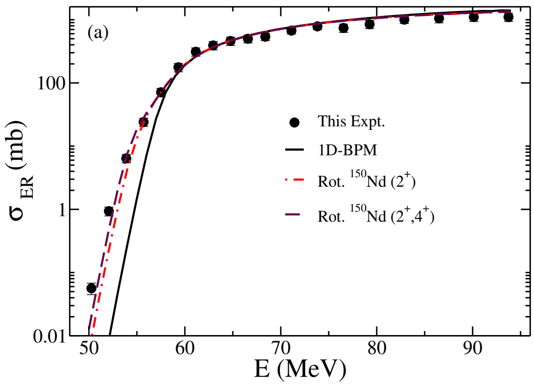

FIG. 3: The experimental fusion cross section for the ^{16}O+^{150}Nd reaction along with CC calculations.

^{16}O+^{142}Nd reaction. Vibrational effects of ^{16} seem to play no role in sub-barrier fusion in this reaction. The degree of fusion enhancement is larger for the ^{16}O+^{150}Nd reaction, compared to ^{16}O+^{142}Nd. Rotational couplings of (2^+ and 4^+ states) of the deformed target reproduced the fusion cross sections reasonably well in ^{16}O+^{150}Nd reaction at sub- and near barrier energies.

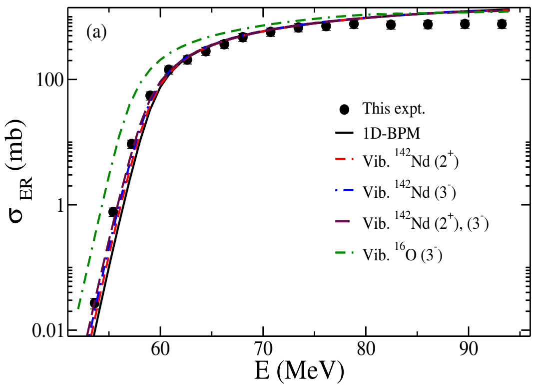

FIG. 2: The experimental fusion cross section for the ^{16}O+^{142}Nd reaction along with CC calculations.

Though CC calculations assuming AW potential parameters reasonably reproduce the fusion cross sections at below barrier energies, they overpredict fusion at energies well above the barrier. This difference is observed to increase with increasing beam energy. Careful analysis indicates that the observed difference is not due to fission or particle emission. Diffuseness parameter in the range 1.0 - 1.1 fm is required to fit the cross sections. These values are significantly larger than the values obtained from elastic scattering measurements. The inadequacy of AW potential parameters hints the role of dynamical effects in fusion at higher energies.

Acknowledgments

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