Influence of hexadecapole deformation on fusion for ^{16}O + ^{174,176}Yb systems

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Introduction

Fusion cross sections for heavy ion reactions, however, are found to be enhanced, in some cases by several orders of magnitude, over expectations from the one-dimensional barrier penetration predictions near and below the Coulomb barrier [1–3]. The coupling of internal degrees of freedom such as transfer of valence neutron, neck formation, zero point motion and static deformation have been considered in order to explain observed enhancements of the fusion cross setions in sub-barrier energies. The deformation of one or both the partners in a heavy-ion reaction is expected to influence the effect on the fusion cross section at near barrier energies. It has been shown both experimentally and theoretically that the subbarrier fusion of spherical and well-deformed nuclei in the ground state is strongly enhanced by deformation [4, 5]. In the present work we have performed ER excitation function measurement for the systems ^{16}O + ^{174,176}Yb forming compound nuclei ^{190,192}Pt. Evaporation residues (ER) are the unambiguous signatures of CN formation. The ^{174,176}Yb nuclei have large ground state quadrupole and negative hexadecapole deformation value and thus provide an ideal case for our purpose.

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Experimental details

The experiment was performed using 15 UD Pelletron accelerator facility at Inter University Accelerator Centre (IUAC), New Delhi. Pulsed beam of ^{16}O with a pulse separation of 4 μs was bombarded on isotopically enriched ^{174}Yb and ^{176}Yb targets of thicknesses 125 μgcm^{-2} and 170 μgcm^{-2} respectively on carbon backing of thickness 25 μgcm^{-2}. ER excitation function measurements were performed at laboratory beam energies of 64.6 - 103.6 MeV for the systems ^{16}O + ^{174,176}Yb respectively. ERs were separated using the recoil mass spectrometer, Heavy Ion Reaction Analyzer (HIRA) [6] at IUAC. 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. A 30 μgcm^{-2} carbon foil was placed 10 cm downstream from the target to reset the charge state of the ERs. At the Focal Plane (FP) of the HIRA, a two-dimensional position-sensitive multi wire proportional counter (MWPC) with an active area of 150 mm $\times$ 50 mm was used to detect ERs.

Data analysis and results

In the measurement of the fusion cross section, the ER cross section was taken to be equal to the total fusion cross section since the fission contribution in this energy region is negligible. The total ER cross section is given by

$$\sigma_{ER}(mb) = \frac{Y_{ER}}{Y_{norm}} \left(\frac{d\sigma}{d\Omega}\right)_{Ruth} \frac{\Omega_{norm}}{\bar{\epsilon}_{HIRA}} \quad (1)$$

where Y_{ER} is the ER yield at the focal plane of the HIRA, Y_{norm} is the number of scattered beam particles detected by any of the normalization detectors, Ω_{norm} is the solid angle subtended by any of the normalization detectors, $(\frac{d\sigma}{d\Omega})_{Ruth}$ is the differential Rutherford scattering cross section in the laboratory system and $\bar{\epsilon}_{HIRA}$ is the average HIRA transmission efficiency. The transmission efficiency of HIRA was calculated by using the semimicroscopic Monte Carlo code, TERS [7, 8] for each xn-evaporation channel at all E_{lab}. The average ER transmission efficiency for all the ERs through the HIRA was obtained by taking the weighted average of the efficiency for different evaporation channels at each energy. The relative abundance of different exit channels was estimated using the statistical model code PACE3 [9]. The exact coupled-channel (CC) calculations were performed for the present systems using the code CCFULL [10]. The fusion excitation functions and the result of the CC calculations are shown in Fig. 1 and Fig. 2 respectively. We found that the CC calculations including coupling to rotational β_2 (solid line) states of ^{174,176}Yb offer a better fit to the above barrier points. Similarly, the coupling to rotational β_2, β_4 (-ve) (dashed line) states of target nuclei also fails to explain the below barrier data. We, however, note that there is strong enhancement in sub-barrier fusion cross section as compared to that predicted by CCFULL calculations including essential couplings.

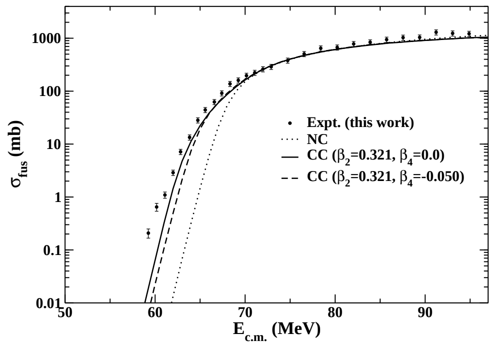

FIG. 1: The experimental fusion excitation functions on ^{16}O + ^{174}Yb system with coupled channel calculations using CCFULL code.

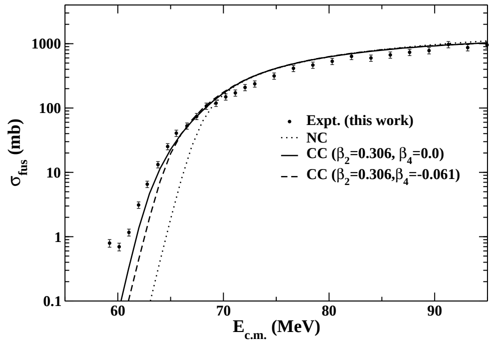

FIG. 2: The experimental fusion excitation functions on ^{16}O + ^{176}Yb system with coupled channel calculations using CCFULL code.

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