Coupled channel effects in quasi-elastic barrier distributions of ^{16,18}O + ^{206}Pb systems

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Introduction

The heavy-ion collisions at energies around the Coulomb barrier are known to be strongly affected by the couplings of relative motion with the internal structure of colliding nuclei. These couplings that arise primarily due to the inelastic excitation and the nucleon(s) transfer processes, lead to an enhancement of fusion cross sections at sub-barrier energies [1] and a variation of the interaction potential in the scattering process at near-barrier energies. The effect of these couplings may be depicted as a single barrier arising from the nucleus-nucleus potential being replaced by a number of distributed barriers. The resulting barrier distribution is expected to be a sensitive probe of the intrinsic structure of the participating nuclei. The barrier distributions can be extracted experimentally directly from the fusion excitation functions by taking the second energy derivative of the energy weighted fusion cross section. In a complementary way, measurement of the quasi-elastic scattering process at backward angles can be used to derive the quasi-elastic barrier distribution (QEBD) that can provide the similar information. The QEBD is obtained as the first derivative of the ratio of the backward quasi-elastic scattering cross section to the Rutherford cross section with respect to center-of-mass energy [2].

The fusion barrier distribution and QEBD for the ^{16}O + ^{208}Pb have been studied in great detail [3]. The couplings due to the collective excitations of the colliding nuclei are found to have the dominant effect as deduced by the conventional coupled-channels calculations used to explain the experimental QEBD and fusion barrier distributions. In contrast, for the ^{18}O + ^{206}Pb system, the role of single neutron stripping (Q-value= -1.308 MeV) and neutron pair transfer (Q-value = + 1.917 MeV) are expected to be significant. In the present work, the QEBD measurements for the ^{18}O + ^{206}Pb system are performed for the investigation of these aspects.

Experiment

The experiment is carried out using the ^{16,18}O beam from the BARC-TIFR Pelletron facility at Mumbai. The enriched target of ^{206}Pb isotope of thickness 250 μg/cm^2 on ^{12}C backing with a thickness of 30 μg/cm^2 is used in the experiments. The beam energy range was varied from E_{lab} = 67.0 to 86.0 MeV, in the steps of 1 MeV for the ^{18}O + ^{206}Pb system. In addition, measurements for ^{16}O + ^{206}Pb system in the energy range from 76 to 84 MeV are also performed. The reaction products are detected and identified by means of telescopes consisting of silicon surface barrier detectors in the conventional ΔE- E configuration. Three such telescopes were placed at θ_{lab} = 170 deg, 160 deg. and 150 deg. to check the consistency of the backward angle data. In addition, a monitor detector was placed at forward angle θ_{lab} = 40 deg. for the normalization purposes. In the data analysis, quasi-elastic scattering is defined as the sum of all elastic, inelastic and transfer processes. Apart from the one and two neutron transfer, $Z = 6$ and $Z = 7$ channels are also included for the determination of quasielastic excitation function. The measured quasi-elastic excitation functions for both the systems are shown in Fig. 1(a), as a function of E_{lab}. The exper-

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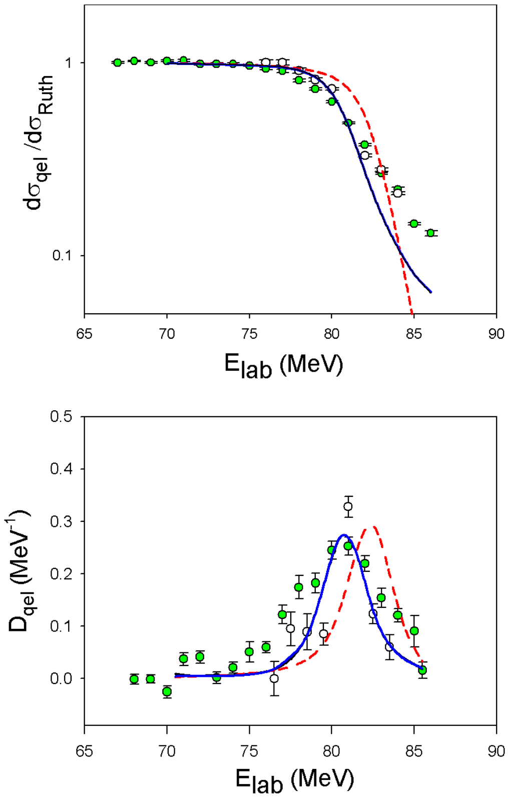

FIG. 1: The measured quasi-elastic excitation function and the quasi-elastic barrier distributions are shown in Fig.1a and Fig.1b respectively, for the ^{16}O + ^{206}Pb (empty circles) and ^{18}O + ^{206}Pb (filled circles) systems. The results of calculations (for the ^{18}O + ^{206}Pb system) are shown by the dashed lines for the bare potential only and with the solid lines that include couplings due to inelastic excitations and one neutron stripping to the single particle states in ^{207}Pb nucleus.

imental QEBDs are extracted using a point-difference approximation, with energy steps of E_{lab} = 2.0 MeV for the ^{18}O + ^{206}Pb system and in E_{lab} = 1.0 MeV steps for the ^{16}O + ^{206}Pb system. As shown in Fig. 1(b), the QEBD for the ^{18}O + ^{206}Pb system has a less barrier height and has a shape that is more wide specially on the lower energy side as compared to the ^{16}O + ^{206}Pb system.

Calculations

The experimental data are compared with the preliminary theoretical calculations performed using the coupled reaction channels (CRC) method with the code FRESCO, for the ^{18}O + ^{206}Pb system. A Woods-Saxon parametrization of the nuclear potential with standard parameters for the real part and an internal potential for the imaginary part is used in the calculations. The interior imaginary potential accounts for the fusion, which is calculated as the absorption following the barrier penetration. The real part of the potential has parameters V_0 = 64.44 MeV, r_0=1.179 and a_0=0.662, while the imaginary part with parameters W_i =10 MeV, r_i=1.0 and a_i=0.4 is used. The coupling to the collective excitations of the colliding nuclei, namely, the vibrational 3^- state at 2.61 MeV, 5^- state at 3.20 MeV and 2^+ state at 4.07 MeV in ^{206}Pb nucleus as well as the 2^+ state at 1.98 MeV in ^{18}O nucleus are included in the calculations. One neutron stripping reactions from $1d\frac{5}{2}$ and $2s\frac{1}{2}$ single particle states of ^{18}O to the $3p\frac{1}{2}$, $2f\frac{5}{2}$, $3p\frac{3}{2}$, $1g\frac{9}{2}$ and $1i\frac{11}{2}$ single particle states in ^{207}Pb are included in the calculations. While the centroid and height of the barrier distribution is well reproduced by the calculations, the width of the QEBD data is not reproduced by the calculations. The coupling of other relevant channels, such as the two neutron transfer may be needed for the correct description of the data. In order to correctly reproduce the data without altering the standard potential paremeters, the efforts are in progress to include all such relevant channels in the coupling scheme.

References

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