Fusion Barrier Distributions in ^{28,30}Si+^{124}Sn Reactions

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Introduction

The coupling of various degrees of freedom such as static deformation, inelastic excitation and nucleon transfer with the relative motion gives rise to a distribution of barrier in heavy ion induced fusion reactions. The barrier distribution is a fingerprint of the reaction characterizing the important channel couplings. The relative importance of various couplings in fusion reaction is of topical interest. In an earlier study with deformed projectiles ^{28,30}Si on ^{115}In target, it was observed that the barrier distributions get affected due to coulomb reorientation of the deformed projectile nuclei in the field of target nucleus thus giving rise to fusion hindrance at sub-barrier energies[1]. In that study, we considered deformed projectile rotational and positive Q-value transfer channel couplings to relative motion in fusion for investigation of Coulomb reorientation and no inelastic coupling of the ^{115}In target was considered. In the present work, we have extended the measurements with ^{124}Sn target and inelastic coupling of target has been considered in the coupled channel calculations. The fusion barrier distributions for ^{28,30}Si+^{124}Sn systems have been obtained by quasi-elastic scattering measurements at backward angles and the results compared with the predictions of coupled-channel calculations.

Experimental Details

The experiment was carried out at 14UD BARC-TIFR Pelletron facility at Mumbai, using ^{16}O, ^{28}Si, and ^{30}Si beams on a self-supporting ^{124}Sn target of thickness 210 μg/cm^2. The isotopic enrichment of the target was more than 99%. The measurements were carried out in the beam energy range of E_{lab} =90-118 MeV for ^{30}Si+ ^{124}Sn systems in steps of 2.0 MeV and for ^{28}Si+ ^{124}Sn system in the beam energy range of E_{lab} = 90-118 MeV in steps of 2.0/1.0 MeV. Two silicon surface barrier detectors ΔE (15 μm) – E(500 μm), ΔE (25 μm) – E(1 mm) were placed at 160°, 140° to the beam direction to detect the projectile-like fragments (PLF) in the reactions. Two Si(Au) detectors at (±20°) with respect to the beam direction were used to measure Rutherford scattering events for normalization. In the data analysis, the quasi-elastic events were defined as the sum of elastic, inelastic and transfer events.

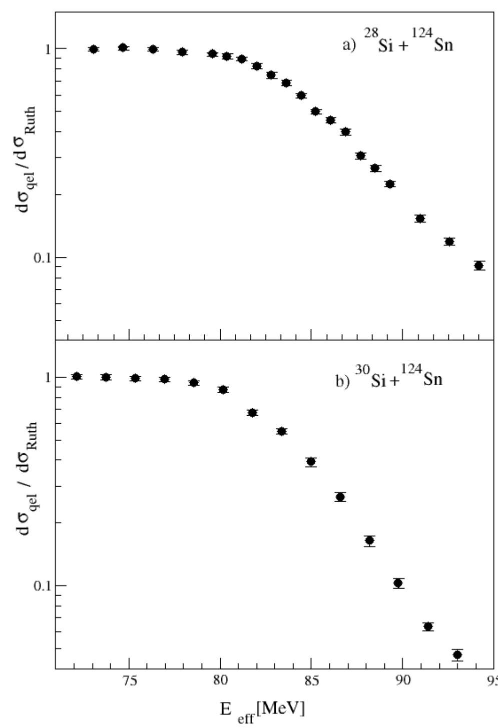

Fig.1: Ratios of the quasi-elastic to the Rutherford scattering cross-section at θ_{lab}=160°.

For most of the bombarding energies the PLF's stopped in the ΔE detectors. The quasi-elastic events were separated from evaporation products form ΔE energy spectrum. An effective energy was introduced to correct for centrifugal effects , where $E_{eff} = 2E_{C.M.}/(1+\mathrm{cosec}(\theta_{c.m.}/2))$[2]. The measured quasi-elastic to Rutherford scattering cross section as a function of E_{eff} at θ_{lab}=160° is shown for ^{8}Si+^{124}Sn and ^{30}Si+^{124}Sn systems in Fig.1.

Results and Discussions

The experimental excitation function data are used to determine the barrier distribution $D_{qel}(E)$ using point difference formula with a step of 2.0 MeV in laboratory frame. The centrifugal corrections are carried out to convert the results of D_{qel} (E,160°) to that of D_{qel} (E,180°) following the procedure described in Ref.[2]. The experimental barrier distributions of ^{28,30}Si+ ^{124}Sn systems along with the predictions of coupled channel code CCFULL[3] for various couplings are shown in Fig.2. In order to investigate the deformation and Coulomb effects of the projectile on fusion barrier distribution, calculations were carried out by taking into consideration coupling of rotational states of ^{28}Si and ^{30}Si projectiles in ^{28}Si+^{124}Sn and ^{30}Si+^{124}Sn fusion reactions with (Nuclear+Coulomb) and only (Nuclear) coupling in the CCFULL code. The deformation parameters ($\beta_2 = -0.408$, E_x = 1.72 MeV, and $\beta_4 = 0.10$) for ^{28}Si and ($\beta_2 = 0.32$, E_x = 2.23 MeV, and $\beta_4 = 0.10$) for ^{30}Si were taken in the CCFULL code for rotational coupling calculations of deformed projectiles. In case of ^{28}Si+^{124}Sn reaction both 4n- and 2n-neutron pickup (+4n,+2n)) channels are positive Q-values of 5.46 MeV and 4.65 MeV respectively. The CCFULL calculation has been carried including most positive Q-value +4n transfer channel coupling as only one transfer coupling option is available in the code. Similarly for ^{30}Si+^{124}Sn system only (+2n) pick up channel is having a positive Q-value of 1.36 MeV. The ^{124}Sn deformation parameters and excitation energies for 2^+ and 3^- vibrational states are ($\beta_{2+} = -0.408$, E_x = 1.72 MeV, and $\beta_{3-} = 0.10$, E_x = 1.72 MeV) respectively. The CCFULL results for uncoupled, (Coulomb + Nuclear+ transfer(+4n/+2n) + target inelastic couplings) labeled as (with Coulomb reorientation) and (Nuclear+ transfer (+4n/+2n) + target inelastic couplings) labeled as (without Coulomb reorientation) are shown for both the systems in Fig.2. It is seen that with inclusion of Coulomb effects of the projectile in the CCFULL calculation the low energy part of the barrier distribution is reduced and the high energy part increased and the agreement between experiment and prediction of CCFULL improves. Above observations suggest that the fusion barrier is redistributed due to the Coulomb effect of the deformed projectile in the field of the spherical target.

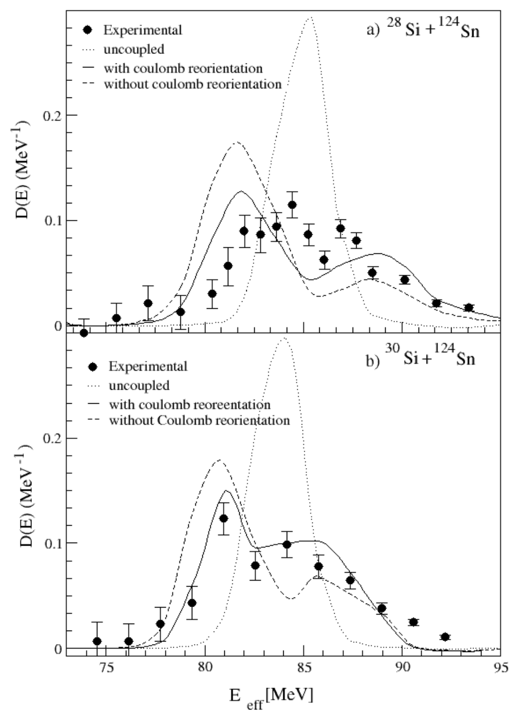

Fig.2. Barrier distributions of ^{28,30}Si+ ^{124}Sn systems, solid circles are the experimental data and the dashed and the solid lines represent the calculations for various coupling.

References

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[2] Timmers H *et al*., Nucl. Phys. A 584, 190 (1995)
[3] K. Hagino *et al.*, Comput. Phys. Commun. 123, 143 (1999).