Role of hexadecapole deformation of ^{28}Si in fusion mechanism of ^{28}Si+^{90}Zr system

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Gaining insight into the role of nuclear intrinsic degrees of freedom in fusion, has been the motivation of many experimental studies in the current nuclear research [1]. The intrinsic degrees of freedom such as inelastic excitation, neutron transfer, static or dynamic deformation gets coupled to the relative motion of the interacting nuclei and affect the fusion dynamics. Experimental signatures of these coupling have been observed in fusion cross-section measurements via fusion enhancement and structure in fusion barrier distribution [2]. Comparison of these experimental results with coupled channel predictions has established the role of various couplings in heavy ion fusion mechanism.

Recently, the fusion barrier distribution derived from quasi-elastic backscattering has been investigated by our group for the ^{28}Si + ^{154}Sm system [3]. Despite the well-established rotational nature of ^{28}Si (having both quadrupole and hexadecapole deformations), we found that a coupled-channel calculation with vibrational coupling to its first 2^+ state reproduces the barrier distribution structure rather well. Later we observed that the resolution of this anomaly lies in the hexadecapole deformation of ^{28}Si; the contributions to the reorientation coupling ($2_1^+ \rightarrow 2_1^+$) from the quadrupole deformation is largely canceled out by that from the hexadecapole deformation. Hence an almost identical result is found with two coupling schemes if one considers the large positive hexadecapole deformation of the projectile. A large value leads to a strong cancellation in the re-orientation term that couples the 2^+ state back to itself, hence making the rotational state look vibrational in this process.

In a paper by Newton et. al [4] the experimental barrier distribution for the fusion of ^{28}Si + ^{90}Zr system has been studied. From their calculations, they have observed that treating the 2^+ state in ^{28}Si as a phonon state rather than as an oblate rotor gives a somewhat better fit. Moreover, treating the 2^+ state in ^{28}Si as a prolate rotor give poor representations of the data. For the better fit to the experimental data they have reported that there is not strong evidence to distinguish between ^{28}Si being vibrational or oblate.

To check the influence of hexadecapole deformation of ^{28}Si on the fusion of ^{28}Si + ^{90}Zr system, we have performed the coupled channel calculations with both the excitation modes of ^{28}Si. Fig. 1 shows the barrier distribution obtained from coupled channel calculations with different values of β_2 and β_4. Interestingly we noticed that an almost identical result is found for ^{28}Si + ^{90}Zr system also

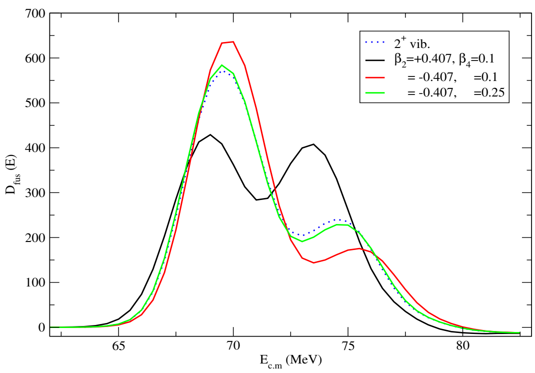

FIG. 1: Results of coupled channel calculations for fusion barrier distribution of ^{28}Si + ^{90}Zr system with vibrational (dotted line) and rotational excitation (solid lines with deformation values) of ^{28}Si.

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with the rotational and vibrational coupling scheme if one considers the large positive hexadecapole deformation of the projectile. The only qualitative difference between the rotational and vibrational coupling schemes is the absence of a re-orientation term when the 2^+ state is treated as a phonon. That is, there is no $2_1^+ \rightarrow 2_1^+$ coupling. In the rotational scheme this coupling is present and it is important here to note that the 2^+ state may be coupled to itself by both quadrupole and hexadecapole deformations. The coupling strength will, therefore, depend on the value of β_4 that one uses. There is a range of positive values of this parameter in the literature for ^{28}Si. The best theoretical value is probably that due to Möller and Nix [5], $\beta_4 = 0.25$. When we perform the calculations using this value we see (Fig. 1) that the new rotational results are barely different from those for the vibrational calculation. In other words, the hexadecapole contribution to the re-orientation coupling practically cancels out the quadrupole contribution.

Hence similar observation is appeared here as observed for the ^{28}Si + ^{154}Sm system, showing a sensitivity of fusion process to the ^{28}Si hexadecapole deformation. Thus, we conclude that its the rotational excitation of the ^{28}Si projectile playing role in the fusion mechanism and due to its large β_4 value it seems that its vibrational excitation is giving better explanation to the experimental data.

References

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