Barrier distributions analysis for the fusion of ^{32}S with ^{89}Y

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Introduction

During the fusion process, it has been well recognized that the kinetic energy linked with the kinematics of fusing pairs can be partially absorbed by the internal static and dynamical effects of participants [1-5]. The influences of the nuclear structure of fusing pairs on fusion can be studied by measuring the distribution of fusion barriers [6,7]. When intrinsic nuclear structure effects (static & dynamical) of reaction partners are considered then the uncoupled barrier gets splitted in more than one barrier and this is called distribution of barriers. In general, the height of some barriers are smaller than the uncoupled Coulomb barrier and such effects cause movement of incoming flux into non-elastic channel like fusion channel. Since the shape of the barrier distributions may be connected directly to the coupling of essential inherent channels that regulate the fusion process at below barrier energies, studying fusion barrier distributions enables a much deeper understanding of fusion kinematics. Hence, in present work, calculations based on SAGBD approach are able to identify the quantitative influences of dominant channels which are crucial in fusion dynamics of ^{32}S + ^{89}Y reaction in terms of channel coupling parameter λ & V_{CBRED}.

SAGBD model

K. Wilczynska & J. Wilczynska [8] and P. Stelson [9] pointed out that the multidimensional aspect of quantum tunneling can be originated by using a Gaussian type of weight function. So, in the SAGBD formalism [10-17], the interplay of internal structure in sub-barrier domain are considered via aforesaid weight function and overall fusion cross-section is:

$$\sigma_F = \int_0^\infty D_f(V_{CB})\,\sigma^{Wong}(E_{c.m.},V_{CB})\,dV_{CB} \qquad (1)$$

In Eq. (1), normalized and continuous in nature and it is mathematically defined by Eq. (2). Where, V_{CB} and $\sigma^{Wong}(E_{c.m.},V_B)$ are the Coulomb barrier and Wong formula [18], respectively. $D_f\left(V_{CB}\right)$ is effective fusion barrier distribution which is symmetric, normalized & continuous in nature and it is mathematically defined by Eq. (2).

$$D_f(V_B) = \frac{1}{N}\exp\left[-\frac{(V_B - V_{B0})^2}{2\Delta^2}\right] \qquad (2)$$

with $N = \Delta\sqrt{2\pi}$

wherein, Δ denotes standard deviation and V_{B0} denotes and mean barrier height. In SAGBD method, we quantify the impacts of nuclear structure on fusion process in terms of λ and V_{CBRED}. Mathematical expression for λ is given by Eq. (3).

$$\lambda = V_{CB} - V_{eff} \qquad (3)$$

where, effective fusion barrier is denoted by V_{eff}. The parameter V_{CBRED} mathematically denotes the percentage decrease in the effective fusion barrier relative to the nominal barrier.

Result and discussion

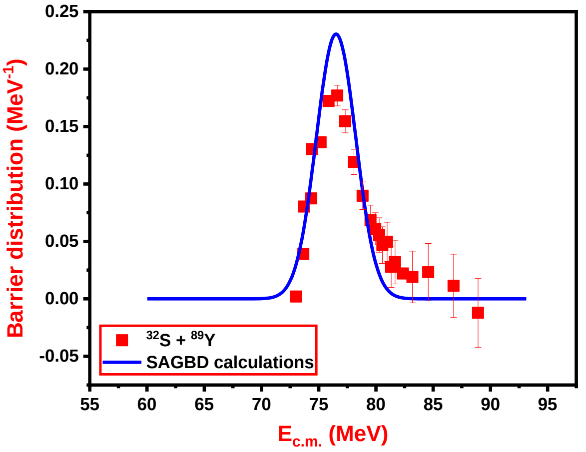

Fig. 1: Theoretical barrier distributions obtained from SAGBD model is compared with the experimental results [19] for ^{32}S + ^{89}Y reaction as a function of $E_{c.m.}$.

In this work, Woods-Saxon form of potential is used for the nuclear part of the nuelus-nucleus potential. For this reaction, the value of potential depth of nuclear potential has kept constant at $100\, MeV$, while the other parameters diffuseness (a_0) and range (r_0) are varied in such a way that the shape of experimental data can be retrieved. For present system, the extracted values of above-mentioned parameters are $a_0 = 0.98\, fm$ & $r_0 = 1.01\, fm$. The barrier characteristics such barrier height $(81.05\, MeV)$, barrier curvature $(2.88\, MeV)$ and barrier position $(9.86\, fm)$ have been obtained which in turn are used in SAGBD method.

Since, in one-dimensional models the physical effects originated due to structure of fusing nuclei are ignored and hence shape of barrier distribution cannot be retrieved by such models. The SAGBD model results appropriately retrieve the shape of experimental data qualitatively as evident in Fig. 1. This clearly suggest that the influences of dominant intrinsic channels associated with structure of fusing nuclei are included into the SAGBD calculations. The influences of such couplings in adopted model are extracted quantitively in terms of λ. The value of λ for present system is found to be 4.52. Furthermore, the parameter V_{CBRED} is also extracted from SAGBD calculations, which highlight also signified the role of internal structure effects associated with fusing nuclei and the value of V_{CBRED} for ^{32}S + ^{89}Y reaction is $5.57\,\%$ of V_{CB}. Form Fig. 1, one can easily noticed that SAGBD outcomes fairly addressed the experimental barrier distribution for the ^{32}S + ^{89}Y reaction.

Conclusion

In short, we have analyzed the fusion of ^{32}S + ^{89}Y reaction using SAGBD model. The SAGBD calculations fairly replicate the shape of barrier distributions data of the ^{32}S + ^{89}Y system, which clearly suggest that the role of internal structure of fusion participants have been intrinsically included in adopted approach. The contribution from the inherent degrees of freedom of fusion participants in SAGBD approach are mathematically obtained in terms of λ & V_{CBRED}. The large positive values of aforesaid parameters suggested that internal structure of fusing pairs plays a very effective role and displayed their impression on the fusion dynamics of the studied system.

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