Barrier distribution of ^{18}O + ^{92}Mo system at sub-barrier energies

Rishi Pal Chahal[1],* Vijay[1], Manjeet Singh Gautam[2],# Sukhvinder Duhan[3], and Hitender Khatri[4]
[1]Department of Physics, Chaudhary Bansi Lal University, Bhiwani (Haryana) - 127021, INDIA
[2]Department of Physics, Government College Alewa, Jind (Haryana) - 126102, INDIA
[3]Deptartment of Applied Sciences and Humanities, Set Jai Parkash Mukand Lal Institute of Engineering Technology, Radaur, Yamunanagar (Haryana) - 135133, INDIA
[4]Department of Physics, Government College for Women, Gharaunda, Karnal (Haryana) - 132114, INDIA
. * email: rishipal.phy@cblu.ac.in, #gautammanjeet@gmail.com

It has been well-established that the coupling of intrinsic degrees of freedom like inelastic surface vibrational states, neck formation and/or nucleon transfer channels to the relative motion of participants plays a crucial role in the fusion dynamics at sub-barrier domain. Because of the active participation of channel couplings, nominal barrier splits into distribution of barriers [1-4]. In the barrier distribution (BD), original barrier gets modified into more than one barrier of different heights and weights. According to Rowley *et al.* [5], one can extract barrier distribution by taking double derivative of quantity $(E_{c.m.}\sigma_F)$ with respect to center-of-mass energy $(E_{c.m.})$. The idea of barrier distribution is quite fruitful to identify the nature of dominant coupling participated in the fusion process. By using the concept of barrier distribution, one can also analyze the fusion data at deep sub-barrier energies with considerable accuracy.

Present work examined the barrier distribution data for the ^{18}O + ^{92}Mo system by using symmetric-asymmetric Gaussian barrier distribution (SAGBD) approach [6-8]. To entertain the multi-dimensional aspect of the barrier distribution, we follow the idea of authors given in the Ref. [9], and the fusion excitation function is given as

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

σ_F denotes the fusion cross-sections and $\sigma^{Wong}(E_{c.m.},V_B)$ is the Wong's formula [10]. $D_f(V_B)$ is the effective fusion barrier which obeys the normalization condition. The $D_f(V_B)$ is given by following relation

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

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

here, V_{B0} and Δ represents mean barrier height and standard deviation, respectively. Due to the contributions from various intrinsic channels, the actual barrier height which is termed as effective barrier (V_{eff}) will always come out to be small in comparison to the nominal barrier (V_{CB}). The effective fusion barrier can be approximately given by the following relation

$$V_{eff} \approx (0.95 \pm 0.03)\,V_{CB} \qquad (3)$$

The cumulative effects of various dominant channels are quantitatively obtained in terms of channel coupling parameter (λ) and V_{CBRED}.

$$\lambda = V_{CB} - V_{eff} \qquad (4)$$

The V_{CBRED} measures the percentage decrease of fusion barrier in comparison with the uncoupled Coulomb barrier V_{CB}.

In order to obtain the theoretical outcomes from the adopted approach, the spherical Woods-Saxon Potential (WSP) form of the nuclear potential has been opted. The WSP parameters like depth (V_0), range (r_0) and diffuseness (a_0) for the ^{18}O + ^{92}Mo system are 130 *MeV*, 1.04 *fm* and 0.66 *fm* respectively. These potential parameters are used to extract barrier parameters like barrier position, height and curvature which are 9.81 *fm*, 45.93 *MeV* and 4.07 *MeV*, respectively. The aforementioned parameters are used in the present calculations and the results are shown in Fig. 1.

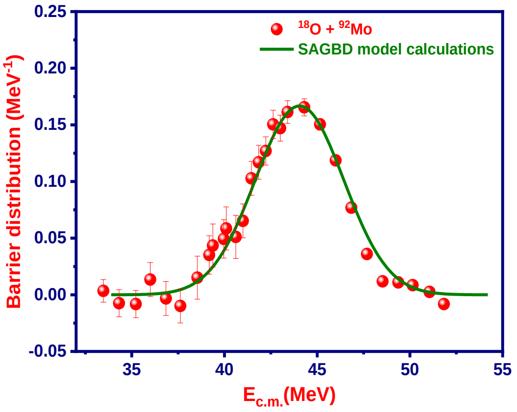

Fig. 1 The barrier distribution data of ^{18}O + ^{92}Mo system [11] are compared with theoretical barrier distributions obtained from the SAGBD calculations.

Monteiro et al. [11], suggested that the barrier distribution data of ^{18}O + ^{92}Mo reaction was quite distinct from the uncoupled theoretical distribution. The authors also concluded that only inelastic channels were not sufficient to address the BD data and hence the transfer channels were mandatory to retrieve the shape of BD data [11]. On the other hand, theoretical results estimated by using the SAGBD method are able to retrieve the shape of barrier distribution at sub-barrier energies (see Fig. 1).

The influences of dominant channel couplings are quantitatively ascribed in terms of λ and V_{CBRED}. The λ describes the impacts of nuclear structure linked with the colliding partners in the sub-barrier domain. Furthermore, the V_{CBRED} directly measures the percentage reduction in the barrier height with reference to the uncoupled Coulomb barrier (V_{CB}) due to active participation of dominant channel couplings. For the ^{18}O + ^{92}Mo system, the values of λ is 1.69 and V_{CBRED} is 3.68% of V_{CB}. The positive and non-zero values of these parameters clearly suggested the significant impacts of internal structure of participants in the fusion process of ^{18}O + ^{92}Mo system. This further suggests that barrier modification effects are mandatory to reproduce the BD data of studied system.

In summary, the experimental BD for the ^{18}O + ^{92}Mo system are examined by using the SAGBD formalism. The large positive values of λ & V_{CBRED} clearly indicate that the intrinsic structure of the participants display significant impacts on the fusion process of ^{18}O + ^{92}Mo reaction. For present case, the close resemblance between estimated and experimental data demonstrates that the SAGBD calculations fairly entertain the influences of neutron transfer and inelastic channels.

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