Scaling of heavy ion fusion excitation functions with regard to Wongs expression

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Introduction

Cross sections for heavy ion reactions below the Coulomb barrier is characterized by a marked enhancement of the fusion cross sections over the predictions of the one dimensional barrier penetration model, as also the associated isotope dependence. A large number of experimental data has accummulated over the years for such sub-barrier fusion enhancements[1].

The fusion enhancements is usually ascribed to coupling of the fusion channel with other degrees of freedom such as nuclear deformation, low lying collective excitations as well as by nucleon transfer etc. An alternative approach applied to many cases has been the distribution of barriers[2].

With the accummulation of large volume of experimental data it would be desirable to have a general scaling of appropriate parameters describing the fusion excitation functions. Some attempts have already been reported[3].

Here we describe one such attempt.

Wong's formula

The one dimensional barrier penetration model predicts the following expression, given by Wong [4] for the fusion cross section :

$$\sigma = \frac{\pi R_B^2 \hbar\omega}{2E_{cm}} ln\left[1 + e^{2\pi(E_{cm}-V_B)/\hbar\omega}\right] \quad (1)$$

The above formula is obtained by replacing the partial fusion probabilities by the transmission coefficients through an inverted parabolic barrier formed by the Coulomb, nuclear and centrifugal potentials. The parameters refer to the position (R_B), barrier magnitude (v_B) and the barrier curvature ($\hbar\omega$) at r = R_B.

Along the lines of the scheme of barrier distributions for describing the near barrier experimental fusion excitation functions we suggest that the effect of coupings can be accounted for by using a mean effective barrier, again described by three parameters similar to the ones in the Wong formula. These parameters are obtained by a non linear least squares fit to the Wong formula through the experimental data points.

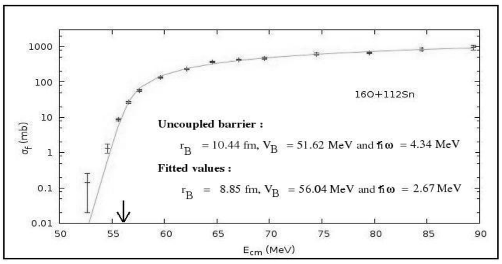

FIG. 1: **Plot of fusion cross section vs. E_{cm} for ^{16}O + ^{112}Sn system.**

Results and discussion

We have collected near barrier experimental data for about 500 heavy ion systems from the Nuclear Reaction Videos web site [1] and applied the above procedure to them.

Fig 1 shows a typical plot of the excitation function, illustrating the goodness of the fit through the experimental data points for the ^{16}O + ^{112}Sn system[5]. The parameter values are shown therein.

The systems have then been filtered to select only those cases which have correlation co-

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efficients >0.9. The following parameters for the different systems have been considered:
1. Coulomb potential at touching radius. 2. Distance of closest approach in a head on collision under Coulomb field alone 3. Neutron excess 4. Fissility 5. Neutron separation energy in the compound nucleus 6. Grazing angular momentum at the barrier energy.

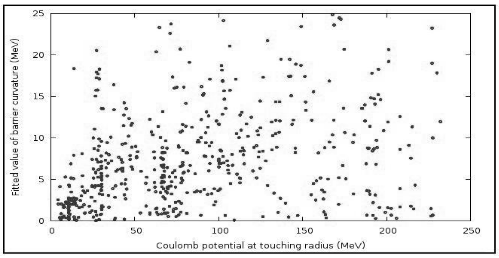

FIG. 2: **Plot of barrier curvature vs. Coulomb potential at touching radius for various systems.**

The dependent parameters plotted against the above quantities are the 1D BPM parameters of the uncoupled barrier and the fitted parameters for the effective mean barrier. The plots were observed to fall into three categories: a) Randomly scattered plots b) Plots showing a linear correlation and c) Plots wherein the systems cluster into groups, each group showing linear variation. Example plots are given in figures 2 - 5.

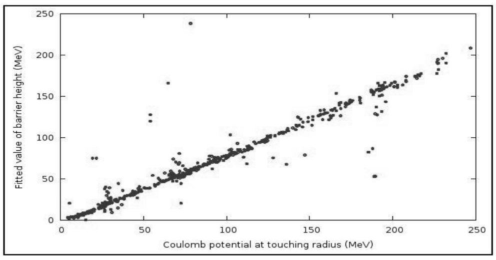

FIG. 3: **Plot of Fitted values of the barrier height vs. Coulomb potential at touching radius for various systems.**

When the third category is considered, the individual groups are found to have either the same projectile or the same target. It is hoped

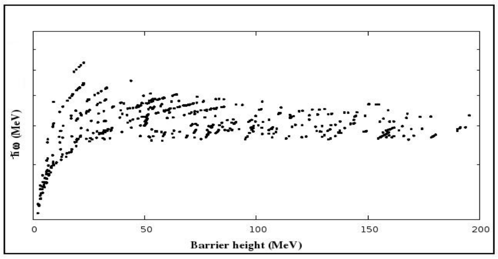

FIG. 4: **Plot of the barrier curvature vs. barrier height for various systems.**

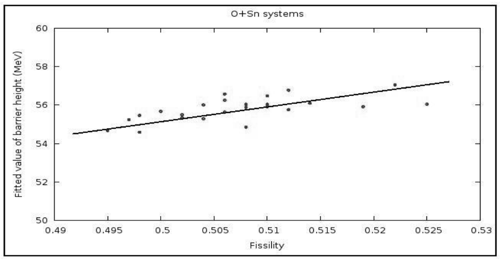

FIG. 5: **Plot of Fitted values of the barrier height vs. Fissility for O+Sn systems.**

that such plots can be used to predict the fusion excitation function parameters for any arbitrary system.

References

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