Effect of modified proximity potential on heavy ion fusion cross-section

Rajni Bansal
Physics Department, Panjab University Chandigarh-160014, INDIA
**email: rajnijain88@gmail.com*

Introduction

Large number of theoretical as well as experimental efforts is under way to study the fusion of heavy ion nuclei leading to several new phenomenons. It includes the understanding of the nuclear structure and formation of neutron rich and super heavy elements. At low incident energies, the fusion of colliding nuclei s the main process for head on collisions. At low incident energies, real part of the interaction potential dominates the dynamics [1-2]. So the precise knowledge of ion –ion interaction potential plays an important role in understanding of these processes.

Large number of theoretical effects has been put forward to give simple and most comprehensive form of ion-ion interaction using various microscopic /macroscopic theories. Among such attempts proximity potential [1] is well known for it simplicity and numerous applications. At the same time it is also clear from the literature that original proximity potential overestimate the experimental data by 4%. Recently a new form of the proximity potential is also suggested to remove the above discrepancy between theory and data. But results are not in good agreement. We try to modify the proximity potential keeping the original form of the proximity potential unaltered by using up to date knowledge of the universal function, surface energy coefficient and nuclear radius.

The Model

The proximity potential is the backbone of all the heavy ion fusion studies. All the proximity potential based on the proximity theorem, according to that, “the force between two gently curve surface in the close proximity is proportional to the interaction potential per unit area between two flat surfaces”.

According to the reference [1], nuclear part of the interaction potential between two flat surfaces can be written as

$$V_N(r) = 4\pi b\gamma R\Phi(s)$$

Where $\phi(s)$ the universal function and R is the reduced radius and γ (in MeV/fm^2) is the surface energy coefficient as function of isospin. For the present study we use the proximity potential in which the universal function, surface energy coefficient and reduced radius are given by

$$\Phi(\xi) = \begin{cases} -1.7817 + 0.9270\xi + 0.143\xi^2 \\ -0.09\xi^3, \text{ for } \xi \le 0 \\ \left.\begin{array}{l} -1.7817 + 0.9270\xi \\ + 0.01696\xi^2 - 0.05148\xi^3 \end{array}\right\} \text{for } 0.0 \le \xi \le 1.9475 \\ -4.14\exp(-\xi/0.7176), \quad \text{for } \xi \ge 1.9475 \end{cases}$$

$$\gamma = 1.25284\left[1 - 2.345 I^2\right]$$

$$R = 1.2332 A^{1/3}\left\{1 + 2.348443/A - 0.151541(I)\right\}$$

Where I = N-Z/A and N ($=N_1+N_2$) and Z ($=Z_1+Z_2$) represent total neutron and proton content. With the help of γ the neutron excess dependence was introduced in this potential.

Using the above set of parameters we construct a new proximity potential labelled as Prox 10 keeping the original form of the proximity potential unaltered.

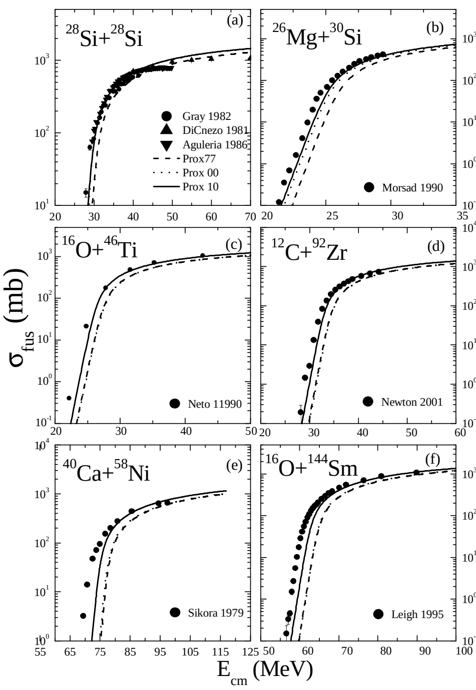

Fig 1: The fusion cross section σ_{fus} (mb) as a function of centre of mass energy $E_{c.m}$ using older versions of proximity potential (Prox 77 and Prox 00) along with new version (Prox 10). Experimental [3] data is also shown.

Results and discussion:

Here we have calculated fusion cross-section σ_{fus} (mb) as a function of centre of mass energy $E_{c.m}$ (MeV) for the large number of the reactions $^{28}Si+^{28}Si$, $^{26}Mg+^{30}Si$, $^{16}O+^{46}Ti$, $^{12}C+^{92}Zr$, $^{40}Ca+^{58}Ni$, $^{16}O+^{144}Sm$ ranging from lighter to the heavier one using older version of proximity potential Prox 77, Prox 00 and with our new modified version Prox 10. Fusion cross section is calculated using well known Wong formula given by

$$\sigma_{fus}\left(E_{cm}\right)=\frac{\pi}{k^2}\sum_{\lambda=0}^{\lambda_{max}}\left(2\lambda+1\right)T_{\lambda}\left(E_{cm}\right)$$

We also display the corresponding experimental data for these reactions [3]. It is clearly visible from the figure that, the results obtained with our modified version i.e. prox10 reproduce the data nicely in comparison to other proximity potential. We see that large part of disagreement at sub barrier fusion energies can be explained with the use of our new modified proximity potential. In other words, our new modified approach is suitable for the fusion of heavy ion studies.

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