Comparison of different approaches used to calculate the fusion barriers

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Introduction

The study of fusion barriers and corresponding fusion cross sections has seen a renewed attention in recent years [1, 2]. This renewed interest is mainly due to the fact that above understanding is a gateway for the synthesis of superheavy elements, production of new neutron-rich nuclide as well as understanding of nuclear structure effects [1, 2].

As is clear from the literature, lot of experimental data is available on fusion barriers since 1970 [2–4]. One should keep in the mind that no experiment measures the barrier of a reaction directly. In all experiments involving the fusion mechanism, one often measures the differential cross sections and then using suitable theoretical approach, one can extract the height and position of a barrier [2–4]. This procedure also adds uncertainty in the experimental values. On the other hand, various parametrized pocket formulas have been derived either using experimental data as guideline or using some firm theoretical approach [1, 3–5]. Most of the approaches are based on the direct parametrization technique [1, 4].

In this technique [1, 4], the fusion barrier heights and positions are depends only on the charge and mass numbers Z_1, Z_2, A_1, and A_2. This means that once the colliding partners are known, one can calculate the fusion barrier positions and heights instantaneously. The main advantage of this technique is that it is not restricted to one particular shell. Therefore, it is an universal parametrization because shell effects are washed out. It is therefore necessary to compare the different forms available to calculate the fusion barrier heights and positions with the available experimental data. This will certainly helpful in deciding which expression is closer to the experimental data and should be used in further fusion barriers calculations.

Methodology

We firstly calculate the fusion barrier heights using the analytical expressions presented by Vaz *et al.* [3], Royer *et al.* [5], Puri *et al.* [4] along with three recent parametrizations presented by Dutt and Puri [4] using well known proximity potentials [1]. These are labeled as Vaz 1981 [3], Royer 2001 [5], Puri 1992 [4], Prox 1977, Prox 1988, and Prox 2000, respectively [1]. In total, six such expression are confronted with the available experimental data on fusion barriers. From the above discussion, it is clear that the common among all above stated parametrizations is that the final outcome is in terms of simple quantities like charges Z_1, Z_2 and/or masses A_1, A_2 of the colliding nuclei. Therefore, the detailed comparison of such parametrizations is of central interest.

Results and Discussion

In the present study, total 150 reactions with combined mass (A_1+A_2) varies between 20 (^{10}B + ^{10}B) and 294 (^{86}Kr + ^{208}Pb) are taken into account. This comparison covering almost the entire periodic table will give us unique possibility to compare various pocket formulas for fusion barriers.

In figure 1, we plotted the analytical fusion barrier heights V_B^{anal} (MeV) verses the corresponding experimental values V_B^{expt} (MeV). The experimental values are taken from the Refs. [2–4]. Here, only six different analytical approaches are used and compared with

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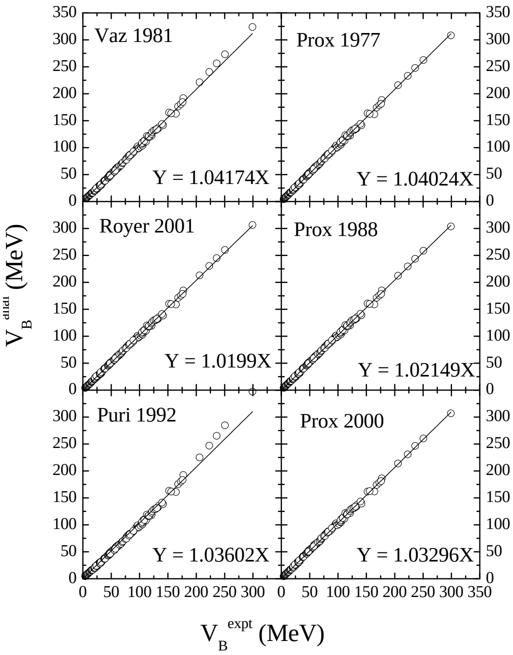

FIG. 1: A comparison of analytical fusion barrier heights $V_B^{\rm anal}$ and corresponding experimental fusion barrier heights $V_B^{\rm expt}$. Solid lines represent the straight-line least-squares fit over the data points. The experimental data are taken from Refs. [2–4].

available experimental data. All six expressions reproduces the experimental data within ±5%. In particular, Royer 2001 and Prox 1988 are closer to the data i.e. within 1.99% and 2.15%, respectively. Whereas, the approaches due to Vaz 1981, Puri 1992, Prox 1977, and Prox 2000 are far from the experimental data. However, for fusion barrier positions no clear picture is emerges out [6]. This is due to large uncertainty in the measurements of fusion barrier positions.

Further, we shall extend our work to study and compare the cross sections of different colliding nuclei for these parametrized expressions [6].

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