The role of surface diffuseness in heavy-ion fusion barriers studies

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Introduction

The study of heavy-ion fusion barriers and cross sections has attracted a lot of attention in recent years because it is quite useful for the understanding of structural effects, production of superheavy elements and cluster-decay studies [1–3]. At the same time, it is closely related with nucleus-nucleus interaction potential. Therefore, a systematic study of fusion barrier is of great importance to check the various theoretical nucleus-nucleus interaction potentials and to explore the global features of fusion barriers.

As is clear from literature [1–3], lot of experimental data is available on fusion barriers and cross sections. One should keep in mind that no experiment measures the barrier of a reaction directly [1–3]. In all experiments involving the fusion mechanism, one often measures the differential cross sections and then using suitable theoretical approach, one can extract barrier parameters. Recently, many authors used bare potential due to Akyüz-Winther (AW) to extract barrier parameters [1]. The nuclear potential taken in these studies is of Woods-Saxon (WS) form;

$$V_N(r) = -\frac{V_0}{1+\exp\left(\frac{r-r_0A_1^{1/3}-r_0A_2^{1/3}}{a}\right)}, \quad (1)$$

where A_1 and A_2 are the mass numbers of target and projectile nuclei, V_0 is the depth, r_0 is the radius parameter, and a is diffuseness of the nuclear potential. Newton *et al.* [1], used this method and varied the values of a for 47 measured fusion excitation functions. The diffuseness parameter of WS potential varied in the range from 0.75 to 1.5 fm to fit the above barrier fusion excitation functions. At the same time, it was also found that the deduced value of a showed strong increase with increasing charge product Z_1Z_2. On the other hand, the elastic scattering cross sections are generally described by the WS form of the potential with $a = 0.63$ fm [1, 3]. So it is quite interesting to see the effect of variation of surface diffuseness on barrier parameters.

Methodology

Christensen and Winther derived the nucleus-nucleus interaction potential by analyzing the heavy-ion elastic scattering data, based on the semiclassical arguments and the recognition that optical model analysis of elastic scattering determines the real part of the interaction potential only in the vicinity of a characteristic distance. The nuclear part of the empirical potential due to Christensen and Winther is written as [3];

$$V_N(r) = -50\frac{R_1R_2}{R_1+R_2}\exp\left(-\frac{r-R_1-R_2}{a}\right). \quad (2)$$

Here R_i is radius parameters and a is diffuseness parameter. This model is labeled as CW 76 [3].

A refined version of the above potential was derived by Broglia and Winther [3], by taking WS parametrization with subsidiary condition of being compatible with the value of the maximum nuclear force predicted by the proximity potential [3] as;

$$V_N(r) = -\frac{16\pi\frac{R_1R_2}{R_1+R_2}\gamma a}{1+\exp\left(\frac{r-r_0A_1^{1/3}-r_0A_2^{1/3}}{a}\right)}. \quad (3)$$

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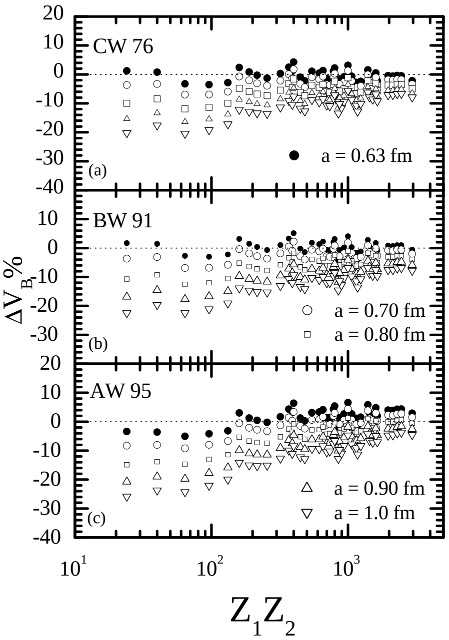

FIG. 1: The percentage deviation ΔV_B % as a function of the product of charges $Z_1 Z_2$ using different values of diffuseness parameter a in different versions of Winther potential.

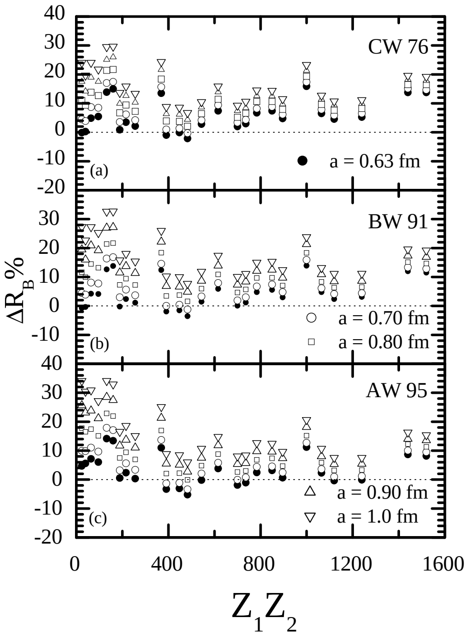

FIG. 2: Same as fig.1 but for ΔR_B %.

This potential is labeled as BW 91 [3]. The third potential used in the present study is given by Eq. (1) and is labeled as AW 95 [3].

The most sensitive parameter in all above potentials is diffuseness parameter a as far as the fusion barrier is concerned. Now the question arises as to whether higher values of a relate to the actual shape of the nuclear potentials, since they are much larger than the values of $a = 0.63$ fm extracted by fitting elastic scattering data.

Results and Discussion

In the present study more than 150 experimentally studied reactions are taken into account. Firstly, fusion barriers are calculated using different potentials with surface diffuseness 0.63 fm. Secondly, the barrier parameters are calculated using different values of surface diffuseness i.e. 0.70, 0.80, and 0.90 fm. Finally, the combine effect of surface diffuseness is analyzed on fusion barriers.

Figs. 1 and 2 show the effect of variation of diffuseness parameter on fusion barrier heights and positions, respectively. This clearly indicate a strong deviation from experimental value as one moves from lower to higher values of a. Here the results are consistent with the lower value of a because these potentials were based on elastic scattering data. So one must be very careful while varying the value of surface diffuseness to fit experimental data also.

References

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