Investigation of surface diffuseness of colliding nuclei with respect to N/Z ratio

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Introduction

In the low energy heavy-ion collision, fusion of colliding nuclei and related phenomena has always been of central interest. Lot of research work is being carried out in order to best describe the value of the measured fusion cross section by fitting the nucleus-nucleus interaction potential parameters [1]. The nucleus-nucleus interaction potential can be described with large variety of models based on microscopic/macroscopic concept [1, 2]. The most often choice of the nucleus-nucleus interaction potential is Woods-Saxon form of the potential [1, 2] given as

$$V_N(r) = -V_0/\left[1 + exp\left((r - R_0)/a\right)\right] \text{ MeV}. \quad (1)$$

Where V_0 is the depth, R_0 is the radius and a is the surface diffuseness parameter. Several authors used these parameters to best fit their data and hence to extract barrier parameters [1, 2]. In this potential, the value of the diffuseness parameter play significant role in deciding the shape of the potential, height of fusion barrier and ultimately the fusion cross section at near barrier energies. At the same time, in Ref. [1] a very large values of diffuseness parameter (= 0.75 to 1.5 fm) is employed to fit adequately the measured fusion cross section. On the other hand, relatively lesser value of diffuseness parameter is required to fit elastic scattering data [3]. The extracted values of surface diffuseness parameter and the possible explanation for its high value is still not clear. We are interested in this paper to study the dependence of diffuseness on the N/Z ratio of the colliding nuclei. To achieve this goal, we employed large number of colliding partners with N/Z ratio as high as 1.43 and three potentials based on the proximity formalism.

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The Model

The total ion - ion interaction potential is given by,

$$V_T(r) = V_N(r) + Z_P Z_T e^2/r \text{ MeV}. \quad (2)$$

Where Z_P and Z_T are the charge numbers of projectile and target nuclei respectively and 'r' denotes the distance between the center of mass of two spherical nuclei in fm. Here, $V_N(r)$ represents the nuclear part of the interaction potential and can be calculated using Woods-Saxon parameterization due to Winther and collaborators [2,3] represented by eq. (1). The different versions of Winther potential differ either in the value of radius parameter or the surface diffuseness parameter. These different versions are labeled as CW 76, BW 91 and AW 95 [2].

Results and Discussion

We have systematically analyze the fusion of large number of colliding partners such as ^{12}C + ^{16,17,18}O, ^{12}C + ^{28,29,30}Si, ^{32,34,36}S + ^{58}Ni, ^{16}O + ^{28,29,30}Si, ^{16}O + ^{70,72,73,74,76}Ge, ^{27}Al + ^{70,72,73,74,76}Ge, ^{16}O + ^{144,148,154}Sm and ^{28}Si + ^{28,29,30}Si using above stated potentials. Firstly, we calculate the barrier parameters and cross sections for all the colliding series. Secondly, we vary the diffuseness parameter so that it fit the experimental fusion cross section value within near barrier region $V_B \pm$ 5MeV by using Wong model [2]. It has been observed while fitting the fusion cross section that the original value of surface diffuseness parameter used in all models along with the value extracted from elastic

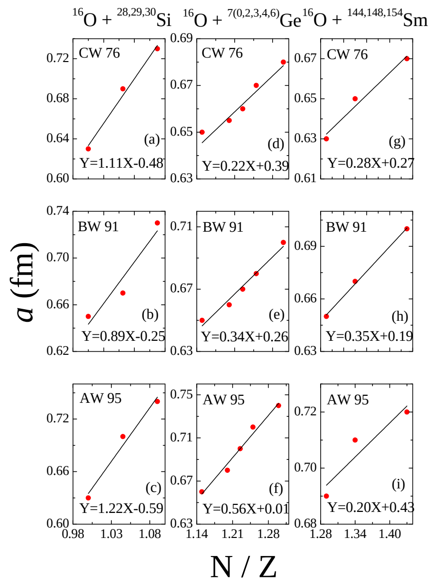

FIG. 1: The variation of surface diffuseness parameter 'a' with N/Z ratio of colliding nuclei namely ^{16}O + ^{28,29,30}Si, ^{16}O + ^{70,72,73,74,76}Ge and ^{16}O + ^{144,148,154}Sm for three different potentials.

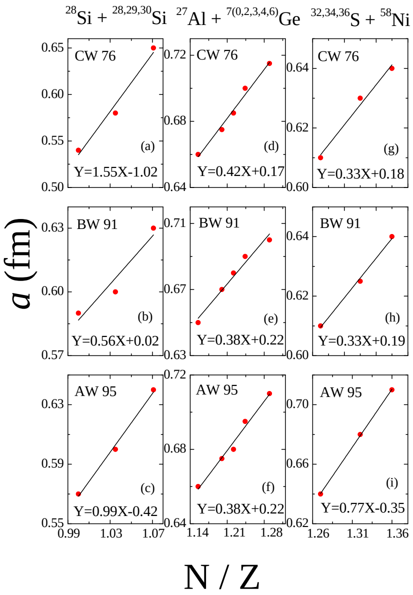

FIG. 2: Same as figure 1, but for the colliding nuclei ^{28,29,30}Si, ^{27}Al + ^{70,72,73,74,76}Ge and ^{32,34,36}S + ^{58}Ni.

scattering data is not sufficient to reproduce the experimental data within near barrier region. Whereas, slight change in the value of diffuseness parameter nicely fit the experimental data within near barrier region.

Interestingly, As we increase the neutron content of a particular colliding series the value of diffuseness parameter is also increased. For more clarity, the extracted values of diffuseness parameter for ^{16}O + ^{28,29,30}Si, ^{16}O + ^{70,72,73,74,76}Ge, ^{16}O + ^{144,148,154}Sm and ^{28}Si + ^{28,29,30}Si, ^{27}Al + ^{70,72,73,74,76}Ge, ^{32,34,36}S + ^{58}Ni is plotted as a function of N/Z ratio for different potentials in figures 1 & 2. Here the straight line represents the best fit over the data points. It is clear from the figures that the extracted values of surface diffuseness shows a linear variation with N/Z ratio of the colliding partners. All reaction series stated above follow the similar pattern and the extracted value of diffuseness parameter vary from 0.62 fm to 0.77 fm.

Our systematic study reveals that the surface diffuseness parameter follow linear variation with N/Z content of the colliding partners and its value is significantly differ from the commonly accepted value a = 0.63 fm from elastic scattering data.

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