Dependence of surface diffuseness parameter on N/Z ratio of colliding nuclei using Skyrme energy density formalism

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Introduction

During last few decades, huge experimental data has been accumulated on the fusion cross-sections and excitation function involving large number of stable (symmetric and asymmetric) as well as unstable colliding nuclei [1]. The enriched experimental data has led to the development of large number of theoretical model. The bench mark of these model is either proximity formalism or Woods-Saxon form of parametrization. More than dozen of such potentials are available in the literature with slight change in the radius, diffuseness, surface energy coefficient and universal function parameter. The outcome of these models are drastically affected by slight change in these parameters. In particular the surface diffuseness parameter significantly affect the shape of nuclear potential. Surface diffuseness parameter used in Woods-Saxon form of potential have been extracted from a large number of experimentally studied neutron-rich fusion cross sections at near barrier energies [1]. The exact value of diffuseness parameter suitable for fusion process is still unknown. Therefore, it is interesting to study experimentally studied nuclei to extract the suitable value of diffuseness parameter. Further it is interested to study the dependence of such parameter on N/Z ratio of colliding nuclei within the framework of Skyrme energy density formalism [2]. To achieve this goal, we employed large number of experimentally studied reactions with N/Z ratio as high as 1.43.

Skyrme Energy Density Formalism

In the Skyrme energy density formalism (SEDF) [2], the nucleus-nucleus interaction potential $V_N(R)$ is defined as the difference between the energy expectation of colliding system at a separation distance R and at complete isolation (i.e. at ∞)

$$V_N(R) = E(R) - E(\infty) \qquad (1)$$

The energy expectation value E for the energy density functional H (r) of Vautherin and Brink [1] is given by

$$E = \int H(\vec{r})d\vec{r} \qquad (2)$$

Where the Hamiltonian $H(\vec{r})$ for an even-even spherical nucleus reads as:

$$H(\vec{r}) = \frac{\hbar^2}{2m}\tau + \frac{3}{8}t_0\rho^2 + \frac{1}{16}t_3\rho^3 + \frac{1}{16}(3t_1 + 5t_2)\rho\tau + \frac{1}{64}(9t_1 - 5t_2)(\vec{\nabla}\rho)^2 - \frac{3}{4}W_0\rho(\vec{\nabla}.\vec{J}). \qquad (3)$$

The Skyrme force parameters t_0, t_1, t_2, t_3 and W_0 have been fitted by different authors to describe the ground state properties of large number of nuclei [2]. These different set of parameters are represented by different Skyrme forces labeled as S, SI, SII, SIII, SIV, SV, SVI, Ska, Skm and Skm* [2].

The total interaction potential is given by

$$V_T(R) = V_N(R) + (Z_P Z_T e^2)/R, \qquad (4)$$

Where Z_P and Z_T are the charge numbers of the projectile and target nuclei respectively and 'R' denotes the distance between the centre of mass of two spherical nuclei in fm and $V_N(R)$ represents the nuclear part of the interaction potential and can be calculated using eq. (1).

Results and Discussion

The present study is conducted within the framework of SEDF by using the above set of Skyrme forces and even-even colliding nuclei. The diffuseness parameter is firstly extracted using SEDF by comparing the outcome with experimental fusion cross section values for the collision of ^{12}C + ^{16,18}O, ^{12}C + ^{28,30}Si, ^{12}C +

^{46,48,50}Ti, ^{16}O + ^{28,30}Si, ^{16}O + $^{7(0,2,4,6)}$Ge, ^{16}O + ^{144,148,154}Sm, ^{28}Si + ^{28,30}Si and ^{32,34,36}S + ^{58}Ni [3]. As a next step the diffuseness parameter is taken here to be a free parameter. We systematically vary the value of '*a*' to best fit the available experimental data on fusion cross-sections. The best suited value we obtained using Skyrme force – SIII is plotted with N/Z ratio in figure 1.

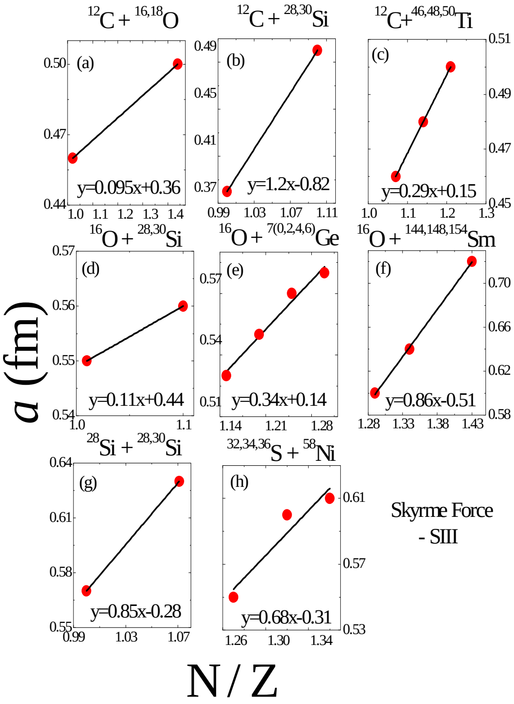

Fig. 1 The variation of surface diffuseness parameter '*a*' with N/Z ratio of colliding nuclei for Skyrme force - SIII. The solid line represents the straight line least square fit over the data points (Preliminary results).

Also noticed that slight changes in the value of diffuseness parameter '*a*' drastically affect the fusion probabilities. Further, the colliding partners having larger N/Z ratio show strong dependence on '*a*'. In figure 2, the variation of surface diffuseness parameter with N/Z ratio of colliding nuclei namely ^{16}O + ^{70,72,74,76}Ge for different Skyrme forces S, SI, SII, SIII, SIV, SV, SVI, Ska, Skm and Skm*.

Our systematic study over large number of colliding nuclei reveals that the surface diffuseness parameter extracted from measured fusion cross sections follow a linear trend with N/Z content of the colliding nuclei for different Skyrme forces. Further, the extracted value of diffuseness parameter is independent of the choice of Skyrme force parameter used.

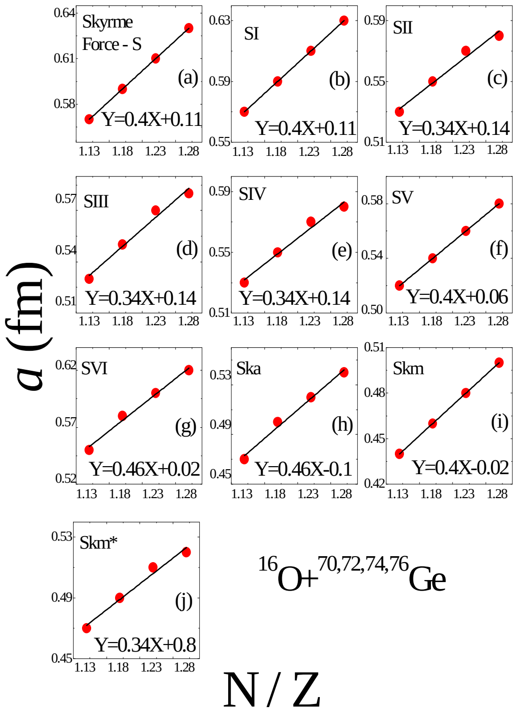

Fig. 2 Same as Fig. 1, but for colliding nuclei ^{16}O+^{70,72,74,76}Ge and using different Skyrme forces (Preliminary results).

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