Comparative analysis of Skyrme interactions in the decay of $^{136}Nd^*$ nucleus

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Introduction

The Skyrme interactions based on microscopic approach of Skyrme Energy Density Formalism (SEDF) are oftenly used for calculating nuclear proximity potentials. Variety of Skyrme forces are available within the SEDF approach that cover a range of barrier characteristics. Recently, Dutra *et.al.* [1] single out few Skyrme forces that satisfy microscopic as well as macroscopic constraints applied on them. From the set of best selected forces, SKT1 force is chosen to make comparative analysis with earlier studied GSkI force. Owing to the fact that different Skyrme forces have different barrier characteristics, we aim to test their role in the dynamics of $^{40}Ca +^{96} Zr$ reaction. In reference to experimental data [2], the coupled-channel analysis shows underestimation of fusion cross-section at below barrier region. Thus, sub barrier mechanism in ^{40}Ca induced reaction is of great interest that need to be explored. Moreover, the fusion cross-section in [2] is expressed as fusion evaporation cross-section, where evaporation residues contribute the most, having negligible participation of fission fragments.

Using Dynamical Cluster-decay Model (DCM) [3], the decay of $^{136}Nd^*$ compound nucleus formed in ^{40}Ca+^{96}Zr reaction is studied under the influence of two different Skyrme forces. The experimental data is addressed by varying the only parameter in DCM i.e. neck length parameter (ΔR). The specific role of Skyrme forces is studied exclusively within DCM based calculations and their effect is examined via the fragmentation structure. In addition to this, the effect of these forces is tested in view of barrier characteristics which is extremely desirable to address nuclear behavior across the Coulomb barrier.

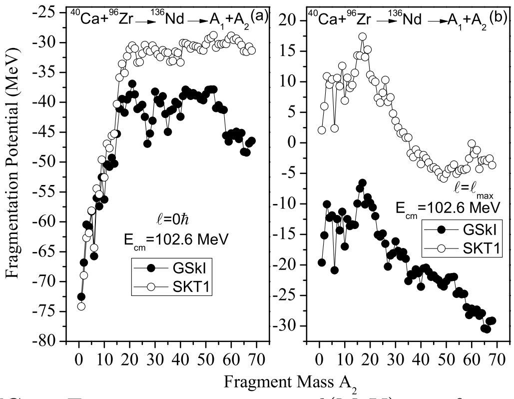

FIG. 1: Fragmentation potential(MeV) as a function of fragment mass A_2 calculated using GSkI and SKT1 force at $E_{c.m.}$=102.6 MeV for ℓ=0 and ℓ=ℓ_{max} with in DCM.

Methodology

In DCM, the compound nucleus decay cross-section using partial wave analysis is studied in terms of preformation probability P_0 and penetrability P and is given as

$$\sigma = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_{max}} (2\ell+1)P_0P; \; k = \sqrt{\frac{2\mu E_{c.m}}{\hbar^2}} \quad (1)$$

where preformation probability P_0 refers to η motion and is calculated by solving Schrodinger equation in η-coordinates. The structure information enters via fragmentation potential used to solve Schrodinger equation. The fragmentation potential comprises

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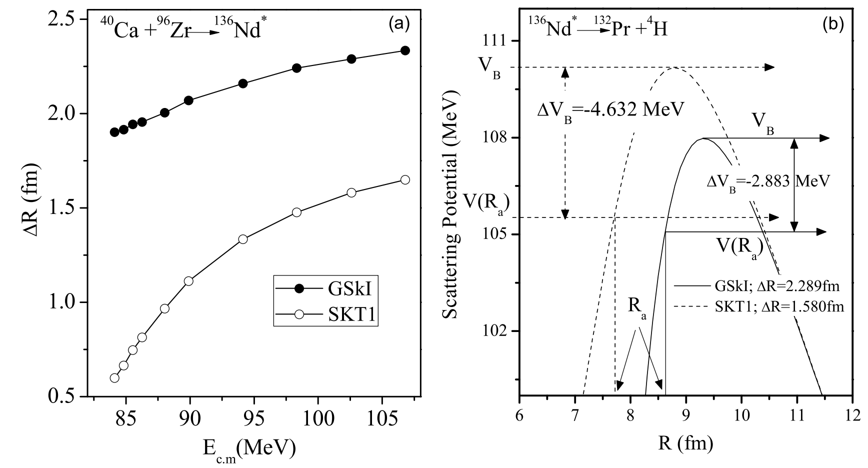

FIG. 2: (a)Variation of Neck length parameter ΔR with $E_{c.m.}$ studied using GSkI and SKT1 force. (b) Scattering potential plotted as a function of range R showing the barrier lowering parameter ΔV_B=$V(R_a)$-$V(B)$ for both the forces.

of binding energy, shell correction, Coulomb excitation, proximity potential and rotational energy term. The penetrability P is obtained by using WKB approximation in reference to R motion and is given by

$$P = \exp\Big[-\frac{2}{\hbar}\int_{R_a}^{R_b}\{2\mu[V(R) - Q_{eff}]\}^{1/2}dR\Big] \quad (2)$$

Calculations and Results

The fragmentation potential is plotted as a function of fragment mass A_2 for SKT1 and GSkI forces at $E_{c.m.}$ = 102.6 MeV shown in Fig 1, where (a) represent fragmentation values at ℓ=0 $\hbar$ and (b) refers to values at ℓ_{max}. From the figure, it is clear that the structure of potential energy surface (PES) for GSkI and SKT1 forces is quite comparable for light mass fragments while for heavy mass fragments, significant variation in structure as well as magnitude of fragmentation potential is observed. The GSkI force has low magnitude of fragmentation potential as compare to SKT1. This shows that GSkI force will perform better in the decay study of $^{136}Nd^*$. Evidently, Fig 1(a). suggest that light mass fragments are more favorable at ℓ=0 $\hbar$. However at higher ℓ-values as shown in Fig 1(b), the contribution of fission fragments start superseding to light fragmentation. The experimental data is addressed using SKT1 and GSkI forces over the energy range $E_{c.m.}$= 84.11 to 106.2 MeV by optimizing neck length parameter ΔR which is plotted as a function of $E_{c.m.}$ for both the choice of Skyrme forces in Fig 2(a). It is noticed that ΔR increases with increase in $E_{c.m.}$ and both the forces follow almost similar trend. However, GSkI force has high magnitude of ΔR as compare to SKT1. This modifies the first turning point R_a of barrier penetrability and hence influence the barrier lowering parameter ΔV_B as shown in Fig. 2(b). As the magnitude of ΔV_B for GSkI force is less in comparison to SKT1 force, so GSkI force seems more suitable to address the below barrier phenomena.

References

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