Effect of Centrifugal potential on the dynamics of ^{6}Li induced reaction

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Introduction

In recent times, the reactions induced by loosely bound projectiles have been a topic of considerable interest. This is because the loosely bound nuclei possess anomalous properties such as, low break-up threshold and extended nuclear structure due to which, many new challenges appear in the investigation of such reactions and their related dynamics. Apart from the nature of projectile and target, the interaction potential involved in a nuclear reaction also plays a crucial role. With this aim, an attempt has been made to observe the role of moment of inertia with sticking limit (I_S), which involves the rotation of two touching spheres about their common center of mass and with the non-sticking limit (I_{NS}) where no intrinsic rotation of fragments is considered due to small separation distance between them, for the ^{6}Li+^{90}Zr reaction [1] using dynamical cluster-decay model (DCM) [2, 3].

In the present work, we choose to apply both the moment of inertia approaches to the intermediate mass ^{96}Tc* nucleus, which decays via evaporation residue (ER), having major contribution from neutron cross-sections, $\sum$xn;x=1-3 [1]. The calculations have been done with the inclusion of quadrupole (β_2) deformations having optimum orientations (θ_i^{opt}) [2]. In this paper, the behavior of fragmentation potential is analyzed at highest (above-barrier) energy, $E_{c.m.}$=28.0 MeV, and the results remain consistent with the variation in energy across the barrier.

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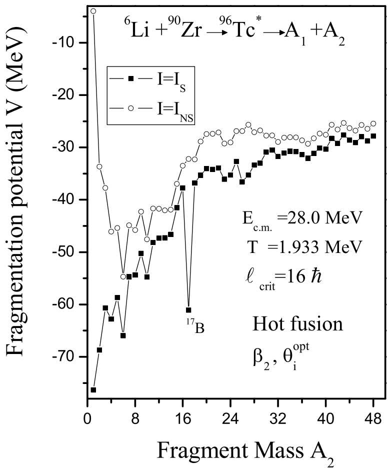

FIG. 1: Fragmentation potential as a function of light fragment mass A_2, for I_S and I_{NS} limit of moment of inertia.

Dynamical Cluster-decay Model

The decay cross-sections are calculated using the DCM [2, 3] which is worked out in terms of the collective coordinates of mass asymmetry $\eta = \frac{A_1-A_2}{A_1+A_2}$ and relative separation R with temperature (T) and deformation ($\beta_{\lambda i}$) effects duly incorporated in it. In terms of these coordinates, using ℓ partial waves, the CN decay cross-section is defined as

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

Here, the preformation probability P_0 is obtained by solving the stationary Schrödinger equation in η coordinate at a fixed R while the penetrability P, refers to R-motion and is calculated using the WKB approximation. Also, ℓ_{max} is the maximum angular momentum up to which the cross-section are fitted, and is defined at a point where $\sigma_{ER}\rightarrow 0$. The role of moment of inertia enters DCM through centrifugal potential given as

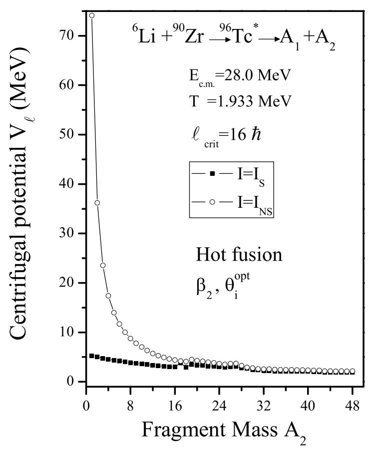

FIG. 2: The centrifugal potential for the energetically favored fragments using I_S and I_{NS} limit.

$$V_\ell = (R, A_i, B_{\lambda i}, \theta_i, T) = \frac{\hbar^2 \ell(\ell+1)}{2I(T)} \qquad (2)$$

with I=I_S=$\mu R^2 + \frac{2}{5}A_1 \mathrm{m} R_1^2(\alpha_1) + \frac{2}{5}A_2 \mathrm{m} R_2^2(\alpha_2)$ for sticking limit and I=I_{NS}=μR^2 for non-sticking limit of inertia.

Results and Discussions

To analyze the effect of moment of inertia in the decay of ^{96}Tc*, the neutron evaporation residue cross-sections have been fitted by using the I_S and the I_{NS} limits of moment of inertia in the framework of DCM. The calculations have been done over a wide range of incident energies across the barrier, using the neck-length parameter ΔR. The calculated ER cross section find nice agreement with extrapolated data for ΔR in range 1.38fm-1.57fm for I_S approach and 1.39fm-2.30fm for I_{NS} approach. However, due to limited scope of space the results here are discussed at above barrier energy only at which the cross-section of 778±37 mb is attained for I_S and I_{NS} approaches at ΔR=1.57fm and ΔR=2.30fm respectively. It is worth mentioning that the value of ℓ_{max} depends on the use of moment of inertia and is relatively higher for I_S limit and lower, for I_{NS} approach. In order to establish the effect of moment of inertia, it is desirable to make the comparative analysis at same ℓ, and hence the results have been discussed at ℓ_{crit}=16ħ (ℓ_{crit}= $R_a\sqrt{2\mu[E_{c.m.} - V(R_a, \eta_{in}, \ell = 0)]}\ \hbar$). The role of I_S and the I_{NS} approach is clearly evident in Fig.1 which shows the variation of fragmentation potential as a function of light fragment mass (A_2). The effect is more prominent in lower mass region (ER), having relatively larger magnitude for I_{NS} as compared to I_S choice. However, with increase in fragment mass A_2, the behavior of I_{NS} is found to be similar to that of I_S approach. Interestingly, a similar result has also been observed for heavy mass ^{241}Pu* nucleus[3]. For the I_{NS} limit, the large magnitude of fragmentation potential in ER region can be understood by analyzing the variation of one of its constituent, the centrifugal potential (V_ℓ) with A_2 (see Fig.2), which shows very large magnitude in the lighter mass region for I_{NS} limit and gradually starts competing with the I_S approach with increase in fragment mass. On the other hand, the proximity potential, in which the role of moment of inertia enters through ΔR, follows a similar trend for both the approaches and hence does not influence the fragmentation potential significantly. It may be noted in Fig.1 that, the emergence of a dip at A_2=17 observed for I_S approach is probably due to the inappropriate choice of β_2 deformation for the minimized fragment ^{17}B. However, for the use of I_{NS} limit, the minimized fragment ^{17}B is replaced by ^{17}O as a result of which there is no such unexpected minima observed. In summary, the choice of moment of inertia is observed to affect the decay of ^{96}Tc* nucleus quite significantly. The I_S approach seems to be more appropriate for ER process in view of smaller magnitude of fragmentation potential and neck-length parameter within 2fm range.

References

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