Average total kinetic energy for different Pb isotopes using fragmentation theory

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Introduction

The dependence of fusion-fission dynamics on the incoming channel mass-asymmetry has been investigated experimentally and theoretically since long in light heavy-ion reactions at above as well as below barrier energies. Depending on the entrance channel mass asymmetry, excitation energy and deformation involved, the dynamical path to fusion-fission process differ significantly. The complex process of fusion of two heavy nuclei can be best understood via the decay products of compound nucleus (CN), such as the fusion-evaporation residue (ER), complex-intermediate mass fragment (IMF) and fusion-fission (ff) process. Experiments [1] were performed at different center-of-mass energies ($E_{c.m.}$) ranging from 107 MeV to 137 MeV in order to measure the ER and fusion cross-section of spherical compound nucleus ^{200}Pb*, formed in reaction with ^{30}Si as a projectile and ^{170}Er as target. We have studied this data in a way to test the entrance channel dependence on the formation and decay of ^{200}Pb* compound system using the dynamical cluster-decay model (DCM) and Wong model. A nice fit to the experimental ER and fission cross-section with spherical as well as deformed choice of fragments for the reactions ^{16}O+^{184}W, ^{19}F+^{181}Ta [2] and ^{30}Si+^{170}Er is obtained. Further in order to study the average total kinetic energy <TKE> of decaying fragments of different isotopes around ^{200}Pb* region, ^{192}Pb* and ^{202}Pb* nuclei formed by using ^{48}Ca+^{144,154}Sm reactions are investigated in the framework of DCM. This work is accepted for publication in Phys. Rev C. In the present article, we intend to address the aspects associated with the <TKE> results calculated in reference to data of [3].

The Model

The dynamical cluster-decay model (DCM) is based on the collective coordinates of mass (and charge) asymmetry η=$(A_1$-$A_2)/(A_1$+$A_2)$ (and η_Z=$(Z_1$-$Z_2)/(Z_1$-$Z_2)$) and relative separation R. In terms of ℓ partial waves, the compound nucleus decay cross-section is

$$\sigma = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_{max}} (2\ell + 1) P_0 P. \qquad (1)$$

Here, P_0 is the preformation probability, which can be obtained by solving the stationary Schrödinger equation in η-coordinate, and P the penetrability calculated in WKB approximation. The deformation and orientation dependent fragmentation potential at a fixed temperature T is

$$V(\eta) = -\sum_{i=1}^{2} B_i + V_C + V_N + V_\ell \qquad (2)$$

where B_i are the experimental binding energies, V_ℓ is the potential due to angular momentum effects and V_C is the Coulomb potential. The V_N is an additional attraction due to nuclear proximity potential. All the terms in Eq. (2) are temprature and deformation dependent. The temperature dependent average total kinetic energy TKE(T) can be defined as,

$$< TKE >= \sum_{\ell=0}^{\ell_{max}} \frac{\sigma_\ell(A_2)}{\sigma(A_2)} TKE(\ell, A_2). \qquad (3)$$

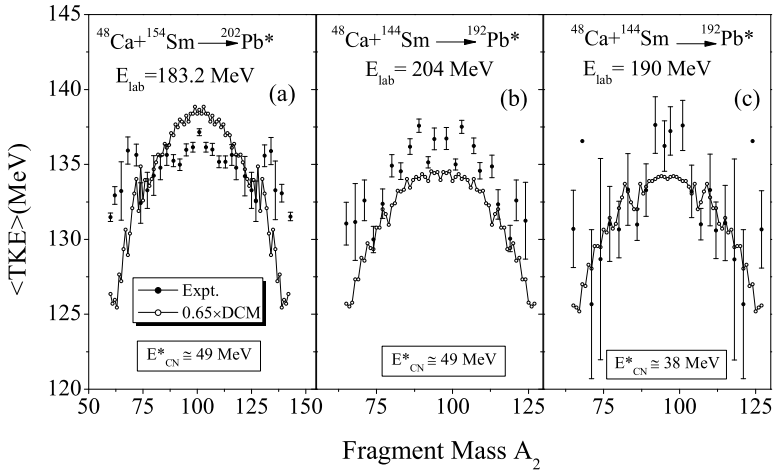

FIG. 1: Calculated average total kinetic energy <TKE> with in the DCM framework and available experimental data plotted as a function of fragment mass A_2. (a) At excitation energy E^*_{CN}=49 MeV for reaction ^{48}Ca+^{154}Sm, (b) same energy as in part (a) but for reaction ^{48}Ca+^{144}Sm and (c) same reaction as in part (b) but at E^*_{CN}=38 MeV.

Here, for each fragments, the TKE for each ℓ is averaged over its corresponding production cross-section σ_ℓ with respect to total cross-section $\sigma(A_2) = \sum_{\ell=0}^{\ell_{max}} \sigma_\ell(A_2)$.

Calculations and Discussion

In this section we have calculated the average total kinetic energy <TKE> using the neck-length parameters ΔR_{ER}= 1.645fm and ΔR_{ff}=0.925fm obtained by fitting the available evaporation residue and fission data [4] of $^{48}Ca + ^{154}Sm \rightarrow ^{202}Pb^* \rightarrow A_1 + A_2$ reaction. Since, no experimental ER data is available for ^{48}Ca+^{154}Sm reaction, so the same neck-length is used. The experimental data of <TKE> is available for ^{48}Ca+^{154}Sm at excitation energy 49 MeV and for ^{48}Ca+^{144}Sm at excitation energy 38, 49 MeV [3]. The <TKE> of two systems is plotted as fragment mass A_2 as shown in Fig.1. The calculated <TKE> is higher in magnitude, which suggests that comparatively smaller ℓ-values contribute towards <TKE> calculations, as also shown in Ref. [5]. So in order to compare the DCM calculated <TKE> values with experimental data, a scaling factor of 0.65 is used as shown in Fig. 1. After rescaling, the calculated <TKE> seem to provide reasonable comparison with the experimental data. The relatively higher values of angular momentum ℓ_{max} are possibly due to the moment of inertia in sticking limit (for further details see Ref. [6]). It will be of further interest to investigate the <TKE> using non-sticking moment of inertia as the corresponding ℓ-values are much lower and one may find better comparison using this approach.

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