Decay of ^{132}Sn+^{64}Ni→$^{196}Pt^*$ using Skyrme energy density formalism in dynamical cluster-decay model

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Introduction

The fusion excitation functions for ^{132}Sn on ^{64}Ni are observed experimentally [1] both at above and below the Coulomb barrier energies. The dynamical cluster-decay model (DCM) of preformed clusters [2] was recently applied to the study of decay of compound nucleus ^{196}Pt* formed in this reaction and nice comparisons were obtained for both the observed evaporation residue (ER) and fission cross-sections, except that the fission cross-section showed some contribution of the quasi-fission (qf) process at the highest two energies [3]. Besides qf at higher energies, the barrier modifications was shown to be an essential requirement for fitting the data of both ER and fission at below-barrier enegies. Note that in this work, the pocket formula of Blocki *et al.* was used for calculating the nuclear proximity potential. In the present work, we study the same reaction, based on the DCM, using the nuclear proximity potential obtained from the semiclassical extended Thomas Fermi (ETF) approach of Skyrme energy density formalism (SEDF) [4]. We find that for all the three illustrative Skyrme forces used here, namely, SIII, GSkI and SSk, just as for the case of nuclear potential from Blocki *et al.* [3], nice fits to data (both ER and fission cross-sections) are obtained, with barrier modiffication effets added at sub-barrier energies, and the qf contribution required at higher center-of-mass energies $E_{c.m.}$, where the later (the qf component) is found to increase as the nuclear potential becomes more attractive.

Theory

The dynamical cluster-decay model (DCM) is based on the collective co-ordinates of mass (and charge) asymmetry $\eta=(A_1+A_2)/(A_1+A_2)$ (and $\eta_Z=(Z_1\text{-}Z_2)/(Z_1\text{-}Z_2)$) and relative separation R. In terms of ℓ partial waves, the compound nucleus decay cross-section is

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P. \qquad (1)$$

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 T-dependent. Here, we calculate the nuclear proximity potential by using the ETF approach of SEDF [4]. The energy density formalism defines the nuclear interaction potential as

$$V_N(R) = E(R) - E(\infty) \qquad (3)$$

where, $E = \int H(\vec{r})d\vec{r}$ with H as the Skyrme Hamiltonian density. For nucleon densities, we use the two-parameter Fermi distribution [5], which for the compound system are added under frozen approximation [6].

Calculations and Results

Fig. 1(a) shows the fragmentation potential for ^{196}Pt* at $\ell = 0$ and ℓ_{max} values for the

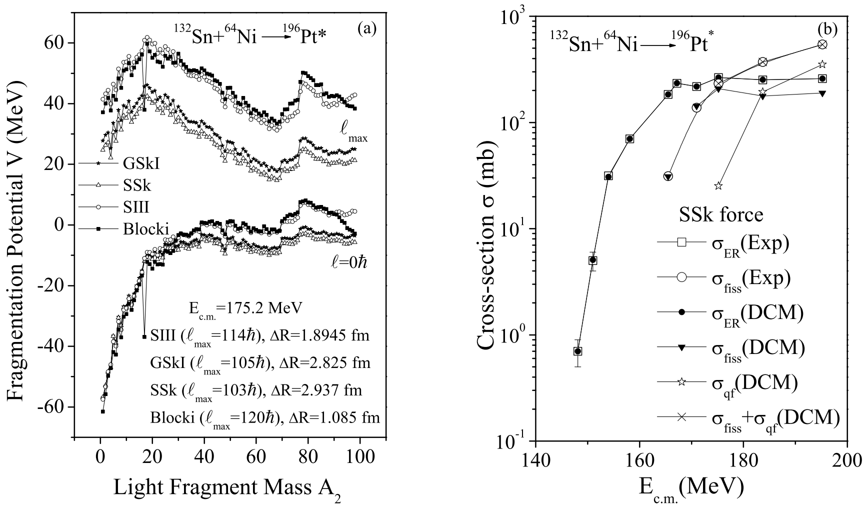

FIG. 1: (a) Fragmentation potentials $V(A_2)$ for the decay of ^{196}Pt* nucleus at $\ell = 0$ and ℓ_{max} values using ETF-based proximity potential from SEDF with different Skyrme forces GSkI, SSk and SIII and the pocket formula of Blocki *et al.* (b) Experimental evaporation residue (σ_{ER}) and fission cross-section (σ_{fiss}) compared with DCM calculations using the SSk force, for ^{132}Sn+^{64}Ni reaction.

three Skyrme forces GSkI, SSk and SIII and for Blocki *et al.*'s pocket formula. We notice that the GSkI and SSk forces show identical fragmentation potentials for both $\ell = 0$ and ℓ_{max}, and the same is true for SIII and Blocki *et al.* interactions, except that Blocki *et al.* also favors a contribution from symmetric mass distribution (relatively deeper minimum at A/2). In any case, for all the four cases, the potential energy minima are stronger at the asymmetric fragments rather than the symmetric fragments. One may also notice that at $\ell = 0$, the contribution of ER is more prominent as compared to the symmetric or asymmetric fragments for all the four interactions, and that, at $\ell = \ell_{max}$, the fission fragments start competing.

Fig. 1(b) shows our results of calculations, illustrated for SSk force, compared with experimental data for both the ER and fission cross-sections. Apparently, our use of the ETF-based SEDF proximity potential, in the framework of DCM, gives a nice description of all the data for all the three Skyrme forces, similar to that was obtained for Blocki *et al.* potential [3]. The lowering of barriers at sub-barrrier energies is required in each case, and a quasi-fission contribution is also found essential to explain correctly the fission cross-sections at the highest two-three energies. Furthermore, we find that the quasi-fission content is relatively higher for the force where the nuclear potential becomes more attractive.

In conclusion, the role of different Skyrme interactions in ETF-based SEDF is studied within DCM, for the decay of ^{196}Pt* formed in radioactive ^{132}Sn beam on ^{64}Ni target. Both barrier-lowering at sub-barrier energies, and quasi-fission (qf) component at above barrier energies are found important, and the qf component is found to increase with the increase in depth of nuclear interaction potential.

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