Non-compound nucleus contribution in ^{105}Ag* formed in ^{12}C+^{93}Nb reaction using various nuclear potentials.

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Introduction

In a recent work [1], we considered the observed emission of both the light particles (LPs; A_2=1-4), representing evaporation residue (ER) and the intermediate mass fragments (IMFs; 5$\leq A_2 \leq$13), together with the so far unobserved fusion-fission (ff) channel, in the decay of hot and rotating compound nucleus (CN) ^{105}Ag* formed in ^{12}C+^{93}Nb reaction at below barrier energies [2]. For a best fit to the data, the dynamical cluster-decay model (DCM) of Gupta and collaborators [1, 3], using pocket formula for nuclear proximity potential, showed a large non-compound nucleus (nCN) contribution at some of the near and below barrier energies. In the following, we extend this work to the use of various Skyrme forces in the Skyrme energy density formalism (SEDF), and to the use of extended-Wong model [4] where only the total fusion cross-section (sum of ER, IMFs and ff) is considered. Deformation and orientation effects of nuclei are included in both cases. It is important to note here that the nCN contribution in ^{105}Ag* is more recently [5] found to be of the same order as in superheavy nuclei Z=112 ^{286}Cn* and Z=114 ^{292}Fl*; for the three systems, the compound nucleus formation probability P_{CN} $\sim$0.2.

Methodology

The SEDF in Extended Thomas Fermi method: SEDF defines the nuclear interaction

$$V_N(R) = E(R) - E(\infty) = \int H(\vec{r})d\vec{r} - \left[\int H_1(\vec{r})d\vec{r} + \int H_2(\vec{r})d\vec{r}\right]. \qquad (1)$$

H is the Skyrme Hamiltonian Density, a function of nuclear, kinetic energy, and spin orbit densities (the later two being the functions of the nucleon/ nuclear density), written in terms of the, so-called, Skyrme force parameters obtained by fitting ground state properties of various nuclei. There are many such forces, and we use here two old (SIII and SIV) and two new (GSkI and KDE0v1) forces.

The DCM and extended-Wong model: The DCM is based on collective coordinates of mass (and charge) asymmetries η (and η_Z) [$\eta = (A_1 - A_2)/(A_1 + A_2)$, $\eta_Z = (Z_1 - Z_2)/(Z_1+Z_2)$], and relative separation R, with multipole deformations $\beta_{\lambda i}$ (λ=2,3,4; i=1,2), and orientations θ_i. In terms of these coordinates, we define the CN decay cross section for ℓ partial waves as

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

where P_0 is preformation probability, referring to η- and P, the penetrability, to R-motion, both dependent on angular momentum ℓ and temperature T. The same formula is applicable to the nCN decay process where P_0=1.

In Wong model [6], the fusion cross-section is also given by Eq. (2) with P_0=1, and P calculated alone for the incoming channel. Wong carried out the l-summation approximately, using only the l=0 barrier. Noting that the ℓ-dependent potentials contribute significantly, Gupta and collaborators [4] carried out the ℓ-summation explicitly, for the ℓ_{max} determined empirically for a best fit to measured cross-section, and the angles θ_i and azimuthal Φ integrated to give the fusion cross-section

$$\sigma(E_{c.m.}) = \int_{\theta_i,\Phi=0}^{\pi/2}\sigma sin\theta_1 d\theta_1 sin\theta_2 d\theta_2 d\Phi. \qquad (3)$$

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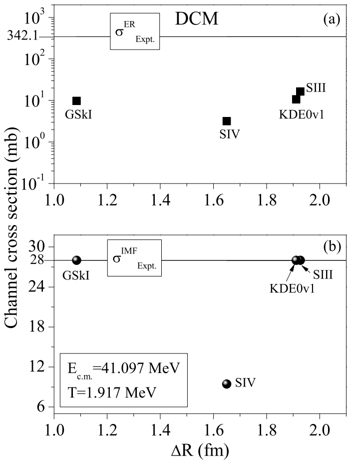

FIG. 1: DCM-calculated ER and IMFs cross-sections compared with experimental data [2].

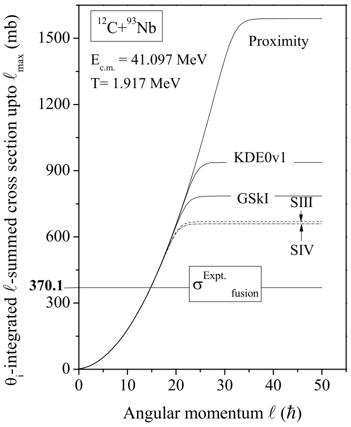

FIG. 2: Extended-Wong model calculated θ_i-integrated (Φ=0 case) cross-section summed up to ℓ_{max} as a function of ℓ itself for ^{12}C+^{93}Nb at fixed $E_{c.m.}$, compared with experimental data [2].

Calculations and Results

Fig. 1 shows the DCM-calculated σ_{ER} and σ_{IMFs} for best fitted ΔR's for some Skyrme forces (SIII, SIV, GSkI, KDE0v1) at $E_{c.m.}$=41.097 MeV (T=1.917 MeV), compared with experimental data for ER and IMFs, respectively, in (a) and (b). We notice that σ_{IMFs} fit nicely, except for SIV which is under-estimated, but σ_{ER} is stronly under-estmated for all the four Skyrme forces. Since the difference between the experimental and calculated σ's is taken as the empirical nCN component, like for proximity pocket formula [1], the DCM calculations using Skyrme forces in SEDF also support a large nCN contribution (more so in σ_{ER}) in the ^{12}C+^{93}Nb reaction at below barrier energy.

Fig. 2 gives the results of using the extended-Wong model, where θ_i integrated cross-section, summed up to ℓ_{max}, is plotted against ℓ itself, for different Skyrme forces, compared with the proximity pocket formula results and experimental data for total cross-section ($\sigma_{ER}+\sigma_{IMFs}$) at $E_{c.m.}$=41.097 MeV. Here, all the forces give an almost exact fitting of data, rather over-estimate the total cross-section which may be due to the missing (not-yet measured) ff component.

Concluding, the extended-Wong model, giving nice fit to data, show no nCN contribution, rather over-estimate it, but the DCM calculations using different Skyrme forces support our earlier result [1] of large nCN content in total cross-section (more so in ER), using the proximity pocket formula.

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