Decay of $^{56}Ni^*$ system formed in ^{16}O+^{40}Ca reaction

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Introduction

Hot nuclear systems formed in low energy heavy ion collisions are studied extensively by experiments as well as by theoretical methods. Dynamical cluster-decay model (DCM) based on fragmentation theory by Gupta and collaborators [1], a non statistical approach, explains the de-excitation of hot and rotating compound systems as the dynamical collective mass motion of preformed fragments, with different preformation probabilities for the light particles (LPs) and intermediate mass fragments (IMFs), tunnelling the barrier, with the structure effect entering through the preformation factor. Binding energies of hot nuclei are major inputs in the model.

In the earlier works on DCM the liquid drop part of Davidson et al., were used and which were refitted for two of its constants (for each isotopic chain) so as to give the g.s. experimental binding energies. Among the different temperature dependent binding energy formulae available in the literature the one due to Guet et al., [2] gives a quadratic dependence of the coefficients of binding energy terms on temperature. They used extended Thomas-Fermi density functional at finite temperature, to find the coefficients for the free energy of a hot nucleus with symmetric and asymmetric parts for the volume and surface energies and Coulomb energy. Since this formula is proposed to give the T-dependence of the leading LDM and droplet model coefficients it does not have terms like pairing and Wigner terms. However, in this work in addition to the liquid drop energy proper, the role of the pairing and Wigner terms due to Krappe [4] are also studied in the Guet et al., formula. In this work, the temperature dependent liquid drop proper due to Guet et al., without any refitting of the coefficients along with the shell corrections due to Myers and Swiatecki is used in DCM to study the decay of hot and rotating $^{56}Ni^*$ system formed in the ^{16}O+^{40}Ca. Experimentally this reaction is studied [3] at the incident energies $E_{c.m.}$ = 49.5, 52.71, 54.93, 57.57, 58.5, 59.14 and 62.36 MeV and light particles and fission like fragments cross sections are reported. The fragmentation potential in DCM is .

$$V(\eta,T) = -\sum_{i=1}^{2}[BE_{LDM}(\eta,T)] + \sum_{i=1}^{2}\delta U_i(T) + V_c(T) + V_p(T) + V_\ell(T) \quad (1)$$

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The first two terms are the liquid drop proper and shell corrections. The remaining terms are the Coulomb, nuclear and centrifugal po

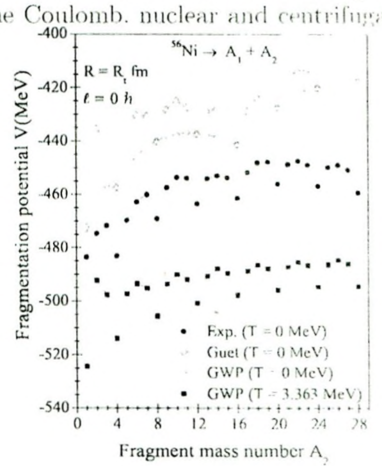

FIG. 1: Fragmentation potential of ^{56}Ni, for T=0 MeV, for the use of experimental BEs and Guet et al., BEs with and without the inclusion of pairing and Wigner terms. Potential at T=3.363 MeV is also shown.

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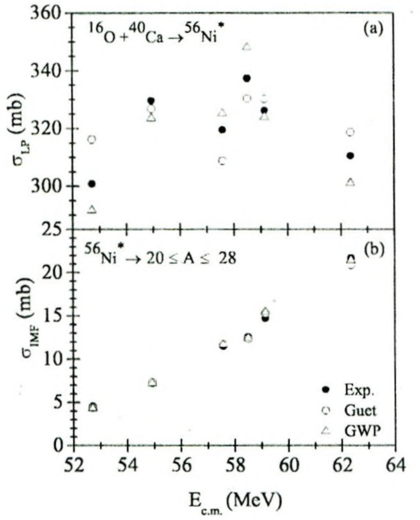

FIG. 2: (a) Cross sections for LPs and (b) Cross sections for the IMFs, compared with the experimental values [3] for different incident energies.

tential. In DCM the decay cross section, is given by,

$$\sigma = \frac{\pi}{k^2} \sum_{\ell=0}^{\ell_{max}} (2\ell+1) P_0 P; k = \sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \quad (2)$$

where P_0, the preformation probability referring to η motion and P, the penetrability referring to R motion, calculated as in [1].

Results and discussions

Fig. 1 shows the fragmentation potentials calculated using Eq. (1) for the binary decay of the compound system ^{56}Ni formed in the reaction $^{16}O+^{40}Ca$ for T=0 MeV and T=3.363 MeV at $R = R_t$ and $\ell = 0\hbar$. Line with solid circle corresponds to the use of ground state (T=0 MeV) experimental binding energies of Audi and Wapstra, which shows explicit preference for the four α-nuclei. Line with open circle represents the calculation due to the Guet et al., formula (without any fitting of the binding energy coefficients), showing no minima for all the four nucleon structure but exhibiting a small minima for the fragments ^4He and ^{16}O. The line with up triangle represents the effect due to the inclusion of the Wigner and pairing terms in the Guet et al., formula. Even though the Wigner and pairing energies are zero for the four-α nuclei, due to the contribution from non-α nuclei, strong minima is present for α-nuclei. Line with solid square represents the T-effects (T=3.363 MeV) in the fragmentation potential with the inclusion of Wigner and pairing energies in the Guet et al., formula.

Calculated LPs cross sections (Panel(a)) and IMF cross sections (Panel(b)) at different incident energies mentioned above, for the use of Guet et al., formula with and without Wigner and pairing energies are compared with the experimental values are shown in Fig.2. In Panel(a), we notice that with the inclusion of Wigner and pairing terms in the Guet et al., formula the agreement with the experimental data at different energies is better. The fission like fragments cross sections are nicely reproduced at all the energies considered.

In this work it is shown that the explicit preference of α structure is shown not to vanish with the inclusion of temperature and rather it is shown as the inherent property of the form of the binding energy formulae used. Also it is shown that the refitting of the coefficients of the original forms of the binding energy formulae is not required.

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