Impact of microscopic temperature-dependent binding energies upon the decay of ^{32}Si* nuclear system

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Introduction

The fusion reactions of neutron-rich oxygen and carbon nuclei are of vast importance to explore the nucleosynthesis in the astrophysical scenarios. Moreover, the fusion reactions of light n-rich nuclei are one of the probable reason to trigger ^{12}C+^{12}C reaction and production of X-ray superburst [1]. The availability of radioactive ion beam facilities act as eloquent tool to explore the different characteristics of exotic nuclei. Different theoretical formalisms such as Hartree-Fock theory, coupled channel model etc. have been developed to investigate the reactions involving exotic nuclei [2]. Here, we use the dynamical cluster-decay model (DCM) [3, 4] to explore the reaction involving n-rich ^{20}O projectile, in reference to available data [5].

Within DCM, the temperature-dependent binding energies (T.B.E.) are one of the important ingredients to evaluate the fragmentation potential. So far, the T-dependent Davidson mass formula [6] had been used for calculation of T.B.E. within DCM. Though, any mass formula cannot be considered as a reliable guide to calculate T.B.E. since the masses of different known regions are used to fit different mass formulae at T = 0 MeV and therefore a good agreement is found. But these mass formulae show divergence in unknown regions where no correlation or common trend is noted using one of the mass formula as reference case [7]. It raises question about their efficacy to correctly predict the T.B.E. To address this issue, we inculcate the microscopic T.B.E. relativistic mean field (RMF) theory [8] within DCM [4]. It is well known that any theory expressed in terms of differential equations has predictive power and hence, RMF theory based T.B.E. calculations are reliable.

In the light of above discussions, it is intrguing to investigate the $^{20}O+^{12}C$ reaction of astrophysical signifiacnce. Also, it is imporatant to explore the role of microscopic T.B.E. upon the fragmentation process and different factors involved in the fusion cross-section calculations of above reaction leading to the formation of $^{32}Si^*$ nuclear system.

Formalism

Within DCM, the decay or fragment production cross-section of the compound nucleus, in terms of ℓ-partial waves, is [3, 4]

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

where P_0 is the preformation probability, given by the solution of stationary Schrödinger equation in η co-ordinate. For this equation the fragmentation potential $V_R(\eta,T)$ is an essential input, as defined below

$$V_R(\eta,T)=\sum_{i=1}^{2}\Big[V_{LDM}(A_i,Z_i,T)\Big] + \sum_{i=1}^{2}\Big[\delta U_i\Big]exp(-\frac{T^2}{{T_0}^2})+V_c+V_P+V_\ell \tag{2}$$

where V_p, V_c, V_l are temperature-dependent nuclear proximity, Coulomb and angular momentum dependent potentials, respectively, for deformed nuclei. $B_i=V_{LDM}(A_i,Z_i,T)+\delta U_i$ are the T.B.E. of two nuclei. $V_{LDM}(T)$ is the T-dependent liquid drop part of the

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*Electronic address: `manpreetphys@gmail.com` binding energy by Davidson et al. and δU_i are the empirical shell corrections of Myers-Swiatecki. In the present work, we have inculcated the T-dependent RMF binding energies with NL3 parameter set [8], by replacing the $V_{LDM}(A_i,Z_i,\mathrm{T})+\delta U_i$ terms of the fragmentation potential $V_R(\eta,T)$ defined in Eq. (2) The fragmentation potential $V_R(\eta,T)$ embodies the nuclear structure effects and hence, the preformation probability P_0 carriers the nuclear structure imprints.

Results and discussion

Fig. 1 presents the impact of macroscopic (mac) and microscopic (mic) T.B.E., calculated using Davidson formula and RMF theory comparatively, upon the fragmentation process of $^{32}Si^*$ nuclear system. The neutrons (1n-5n) are the most probable exit channels in the decay process for mac T.B.E. case (Fig. 1(a)). Whereas, for mic T.B.E. case, besides the neutron channels, the α fragments (^4He, ^5He) with complementary ^{28}Mg, ^{27}Mg fragments are also noted (see Fig. 1(b)). It is in agreement with results of the statistical EVAPOR model [5] which predicts ^5He as most probable light-particle channel. Other α-like fragments (^8Be, ^{24}Ne) are also more favored energetically for mic T.B.E. compared to mac T.B.E. case. The structure of symmetric mass fragments (SMF) also gets changed with the inculcation of mic T.B.E. Quite interestingly,the shape of the potential energy surface changes significantly for light particles and SMF window ($A_{CN}/2\pm5$) for mic T.B.E. case. It is inferred that structure and magnitude of fragmentation potential change significantly along with some changes in Z-distribution with inclusion of mic T.B.E. It portrays that T.B.E. (see Fig. 2) governs the shape of the potential energy surface and it in turn, affects the P_0 which is an important factor in the fusion cross-section calculations. The further details can be found in Ref. [4].

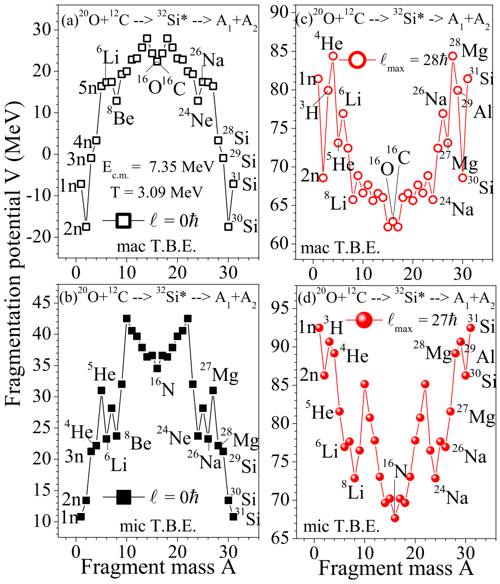

FIG. 1: Fragmentation potential in the decay of $^{32}Si^*$ at T =3.09 MeV for $\ell = 0\ \hbar$ (left panel) and ℓ_{max} (right panel) using (a, c) Davidson formula based mac T.B.E. and (b, d) RMF theory based mic T.B.E.

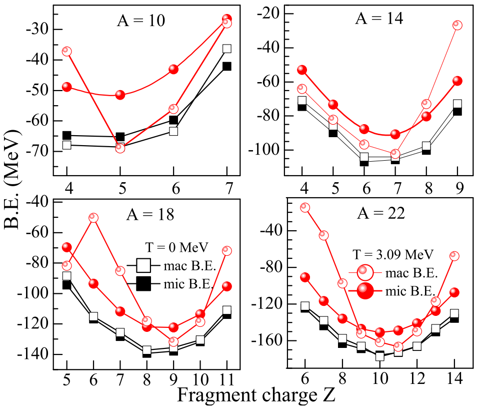

FIG. 2: The mac and mic binding energies for isobars with A = 10, 14, 18, 22 at T=0, 3.09 MeV.

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