Exploration of different constituents of fragmentation potential of a light mass compound nucleus

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Introduction

The hypothesis of compound nucleus was put forwarded by Niels Bohr in 1936 [1] and verified experimentally in 1950 by SN Ghoshal [2]. This process takes places in two steps, firstly, formation of compound nucleus with complete amalgamation of target and projectile, secondly, the disintegration of the compound nucleus. The decay of compound nucleus has been investigated within statistical as well as non-statistical or dynamical approaches. Within dynamical cluster decay model (DCM) [3, 4] fragmentation potential comprises of the sum of binding energies, nuclear proximity potential, Coulomb potential and rotational energy. The investigation of these contributions in the fragmentation potential is the aim of the present work.

It is relevant to mention here that number of compound nuclei formed in low energy heavy ion reactions, in various mass regions, have been successfully investigated with this dynamical approach, based on the quantum-mechanical fragmentation theory (QMFT) [5]. QMFT applies the quantum tunneling concept of probability and shell effects of the reaction partners and decay products to describe the binary fragmentation as collective mass transfer process in the heavy ion collisions. Based on QMFT, the DCM has been developed for hot and rotating compound nuclei in terms of collective coordinates of mass and charge asymmetries.

We have explored the different constituents of the fragmentation profiles of the decay of compound nucleus (CN) ^{20}Ne* formed in heavy ion collision reactions, with the spherical consideration of the fragments. We find that the temperature dependent binding energies play pivotal role in the evolvement of the fragmentation potential of the minimized fragments while nuclear proximity potential, Coulomb potential and the angular momentum dependent potential are competing to contribute in their total value/magnitude.

Methodology:

The DCM is worked out in terms of collective coordinates of relative separation R, and mass (and charge) asymmetries $\eta_A = (A_1 - A_2)/(A_1 + A_2)$ [and $\eta_Z = (Z_1 - Z_2)/(Z_1 + Z_2)$] where A_1 and A_2 are the masses (and Z_1 and Z_2 are charges) of incoming nuclei. In terms of these coordinates, the compound nucleus (CN) decay cross-section for ℓ-partial waves, is defined as

$$\sigma = \frac{\pi}{k^2}\sum_{l=0}^{l_{max}}(2l+1)P_0\,P; \quad k = \sqrt{\frac{2\mu E_{C.M}}{\hbar^2}} \qquad (1)$$

where, P_0 is preformation probability obtained by solving the stationary Schrodinger equation, refers to η- motion and P refers to R-motion.

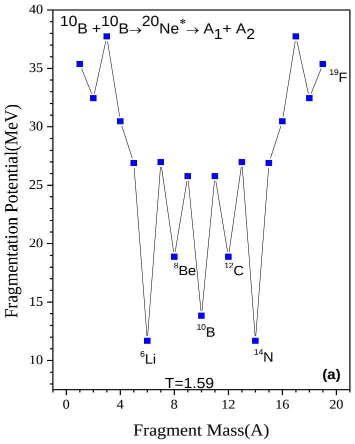

Fig. 1(a) Variation of fragmentation potential with fragment mass A for the radioactive nucleus ^{20}Ne* at T=1.59MeV, for spherical consideration.

However, within the scope of present work, we are focusing on the study of the fragmentation potential only, which is the sum of binding

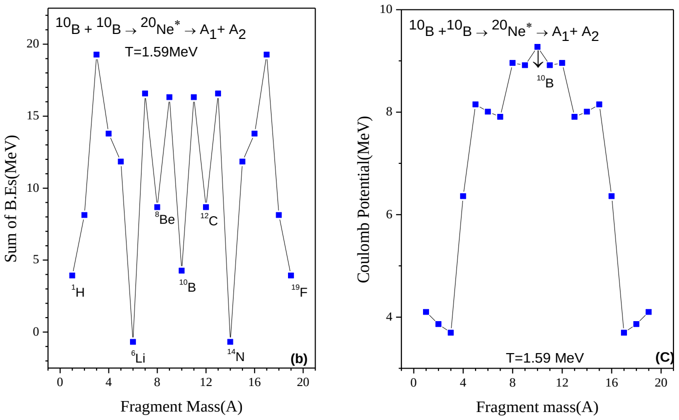

Fig. 1(b-d) b) Sum of B.Es (c) coulomb potential (d) proximity potential with fragment mass A for the compound nucleus ^{20}Ne*, at T=1.59MeV, for spherical considerations.

energies (B_i), Coulomb(V_c), proximity(V_p), centrifugal potential (V_ℓ), all being temperature (T) dependent, represented by

$$V(\eta,R) = -\sum_{i=1}^{2} B_i(A_i,Z_i) + V_c(R,Z_i) + V_p(R,A_i) + V_\ell(R,A_i) \quad (2)$$

Calculations and Discussions:

Fig. 1(a) presents the collective potential energy surface in fragmentation of CN ^{20}Ne* at T=1.59MeV for spherical considerations. From Fig 1(a) we observe that the intermediate mass fragment ^{6}Li with their complementary fragment (C.F.) ^{14}N is more favoured than other fragments. As we move further to higher fragment mass A the fragments ^{8}Be and ^{10}B with corresponding C.F. also starts minimizing but with smaller values of fragmentation potential as compared to ^{6}Li fragment.

The variation in different constitutes of this fragmentation potential that is Sum of binding energies (B.E.s), Coulomb potential, proximity potential with fragment mass A are shown in Figure 1 (b), (c) and (d) respectively. The binding energies in Fig 1(b) shows the minima's for the same fragments, which are minimized in fragmentation plots as shown in Fig. 1(a) i.e. ^{6}Li with their C.F. ^{14}N is more minimized than other fragments. The variation in Coulomb potential and proximity potential with fragment mass A in Figure 1(c) and (d), show their respective behavior , which is opposite to each other, with few minima's for particular fragments in Coulomb potential part.

Further, the variation in different constitutes of this fragmentation potential (Fig. 1(a)) suggests that the structure of the fragmentation potential is mainly due to the sum of binding energies. The other components predominantly contribute to the structure of light particles. For intermediate mass fragments and symmetric mass fragments there is only change in magnitude of fragmentation potential, the structure almost remains same as that of sum of binding energies component. But the fusion-fission fragments get favorable minimized positions due to the effect of, particularly, proximity potential. These trends are clearly reflected in the experimental data/ results studied earlier, within the DCM [3].

References:

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