Decay analysis of ^{9}Be induced reactions using stable and non deformed targets

Shilakha Dawar, Neha Grover, Gurvinder Kaur, and Manoj K. Sharma*
School of Physics and Materials Science,
Thapar University, Patiala - 147004, Punjab, INDIA

Introduction

The pursuit of investigation of decay of compound and non compound nuclear reactions inscribes the cogitation of various processes subsequent to collision between projectile and target nuclei. Hitherto extensive studies have been devoted to understand the structure aspect associated with numerous dominant reaction mechanisms of nuclei. One of the major concern is to study the effect of exotic structure of projectile, target and composite system and consequently to address the form of evaporation residue (ER) and fission etc. In the recent experiment [1], ^{9}Be was incident on spherical (non-deformed) targets ^{208}Pb and ^{209}Bi leading to the formation of ^{217}Rn* and ^{218}Fr* nuclei. The neutron evaporation and fission cross-sections were measured and the complete fusion cross-sections were estimated for both the reactions. It was concluded that the two reactions behave almost identical and there is no evidence of significant influence of additional proton when ^{208}Pb target is replaced by ^{209}Bi.

In the present contribution, The Dynamical cluster decay model (DCM)[2] has been used to investigate the decay mechanism of ^{217}Rn* and ^{218}Fr* nuclei formed via loosely bound projectile, ^{9}Be and spherical targets, ^{208}Pb and ^{209}Bi respectively. The main focus of current work is to (i) find the contribution of ER and Fission decay mode . (ii) see the effect of target mass on fragmentation profile. (iii) predict the cross-sections at higher incident energies. (iv) study related role of deformations, angular momentum and temperature effects etc.

*msharma@thapar.edu

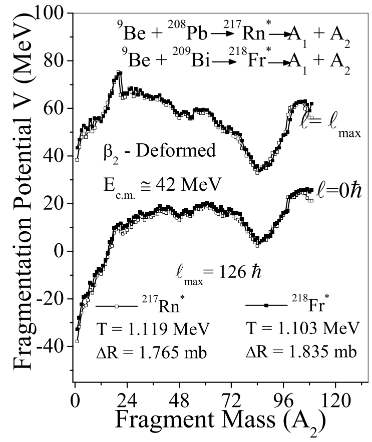

FIG. 1: Fragmentation potential plotted as a function of A_2, for the decay of ^{217}Rn* and ^{218}Fr* nuclei for β_2-Deformed choice.

Dynamical Cluster-decay Model

In present study, the decay cross-sections of chosen composite systems are calculated using the dynamical cluster decay model (DCM)[2] based on quantum mechanical fragmentation theory (QMFT), which is worked out in terms of collective coordinates of mass asymmetry, $\eta_A = (A_1 - A_2)/(A_1 + A_2)$ (1 and 2 represents, heavy and light fragments respectively) and relative separation R. Decay cross-sections are calculated as:

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

The preformation probability (P_0) refers to η-motion and penetrability (P) refers to the R-motion. The preformation probability (P_0) used in eqn. (1) is obtained by solving the stationary Schrödinger equation and is given as:

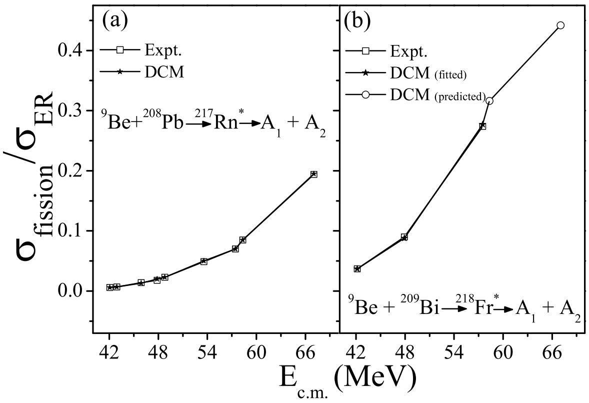

FIG. 2: Variation of ratio of fission to the evaporation residue cross-section as a function of centre of mass energy for (a)^{217}Rn* (b)^{218}Fr*

$$P_0 = \mid \psi(\eta(A_i)) \mid^2 \sqrt{B_{\eta\eta}} \frac{2}{A_{CN}} \quad (2)$$

The penetrability (P) is calculated by using WKB integral as:

$$P = \exp\Big[-\frac{2}{\hbar} \int_{R_a}^{R_b} \{2\mu[V(R) - Q_{eff}]\}^{1/2} dR \Big] \quad (3)$$

where R_a is the first turning point of the barrier penetration. The multipole deformations $\beta_{\lambda i}$ (λ=2, 3, 4), and orientations θ_i (i=1,2) of two nuclei or fragments are incorporated in DCM along with temperature (T) effect.

Results and Discussions

The Decay cross-sections of ^{217}Rn* and ^{218}Fr* formed in reactions ^{9}Be+^{208}Pb and ^{9}Be+^{209}Bi have been studied in framework of DCM at energies varying from E$_{c.m}$=(42.0-67.0) MeV where both the targets have same neutron magicity (N = 126) effect. All calculations have been done for β_2-deformed choice of fragmentation and optimum orientation approach. The variation of fragmentation potential V (MeV) as a function of fragment mass (A$_2$) at neck length parameter for the evaporation residue choice of decay mode is shown in Fig.1, which comprehensively describes the comparative fragmentation analysis of both compound nuclei at same center of mass energy E$_{c.m.}$≈42 MeV. It is clearly evident from the figure that, at two extreme angular momentum values, the target mass hardly makes any difference in the fragmentation pattern and hence the associated potential energy surfaces (PES). Similar behavior has been observed at neck length parameter (ΔR) for the fission decay mode, except for some arbitrary minimas in intermediate mass fragment (IMF) and heavy mass fragment (HMF) region due to inappropriate deformations (not shown here).

According to experiment [1], there is some contribution of fission cross sections in addition to evaporation residue. Thus an attempt has been made to address the possible decay modes of ^{217}Rn* and ^{218}Fr* nuclei. The evaporation residue and fission cross-sections are calculated for both the reactions and the ratio $\sigma_{Fission}/\sigma_{ER}$ is plotted as a function of center of mass energy (E$_{c.m.}$) as shown in Fig. 2. Fig.2(a) and 2(b) represent the relative contribution of fission respectively for ^{217}Rn* and for ^{218}Fr*. It can be seen from Fig.2 that the fission contribution increases with increase in center of mass energy (E$_{c.m.}$). The calculated cross-sections find nice agreement with the available data. In addition to this an attempt has been made to predict the fission and ER cross-sections for ^{218}Fr* at two highest energies with the help of neck length systematics observed at lower incident energies and the predicted cross-sections are shown via open circles in Fig.2(b). The deformation, angular momentum and temperature effects are duly incorporated in above results.

References

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[2] R. K. Gupta, S. K. Arun, R. Kumar, and M. Bansal, Nucl. Phys. A **834**, 176c (2010).