Dynamics of ^{92}Zr and ^{108,110}Sn nuclei formed in ^{16,18}O-induced reactions

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Introduction

In recent times, the dynamics of reactions involving magic nuclei has been a topic of considerable interest in low energy heavy ion reactions. This is because, the presence of shell closure effects in the interacting nuclei or the compound nucleus formed has a significant influence on the subsequent decay patterns. In view of this, an attempt has been made to address the dynamics of deformed magic ^{92}Zr nucleus formed in ^{16}O+ ^{76}Ge and ^{18}O+ ^{76}Ge reactions. In addition to this, the role of ^{16}O and ^{18}O projectile have also been explored in the dynamics of spherical magic ^{108,110}Sn isotopes. In reference to experiments performed by [1], the calculations have been carried out in framework of the dynamical cluster decay model (DCM) [2]. It is worth noting that, DCM gives better description of evaporation residue (ER) and fusion-fission (ff) cross-section by empirically fitted neck-length parameter "ΔR". The calculations have been carried out with inclusion of qaudrupole deformation β_2 within optimum orientation approach. The effect of entrance channel is analyzed for ^{92}Zr nucleus and the role of projectile mass is explored in the dynamics of ^{108,110}Sn nuclei by studying the variation of fragmentation potential and preformation probability.

The experimentally observed fusion cross-sections of ^{92}Zr and ^{108,110}Sn nuclei are addressed in DCM by estimating the total decay cross-sections as the sum of light particles (LPs) which dominate at lower angular momentum (ℓ), and fission fragments which contribute significantly at higher ℓ-values.

Methodology

The DCM is a two step model involving preformation probability P_0 of the decay products or clusters formed in the mother nucleus and Penetration (P) of the fragments or clusters through the interaction barrier. The preformation probability P_0 is obtained by solution of stationary Schrödinger equation, whereas the penetrability P is calculated through WKB approximation. The fragmentation potential $V_R(\eta,T)$, at fixed R, used as stationary Schrödinger equation in η is defined in DCM as

$$V(\eta,T) = \sum_{i=1}^{2}[V_{LDM}(A_i,Z_i)] + \sum_{i=1}^{2}[\delta U_i]\exp(-T^2/T_0^2) + V_C + V_P + V_\ell. \quad (1)$$

where V_C, V_P and V_ℓ are, respectively, the T-dependent Coulomb, nuclear proximity and centrifugal potentials for deformed and oriented nuclei.

Using both P_0 and P, the compound nucleus (CN) decay cross-sections can be calculated using partial wave analysis by using

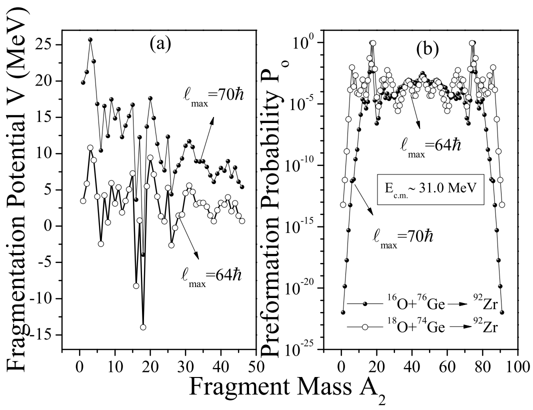

FIG. 1: (a) Fragmentation Potential V (MeV) and (b) Preformation Probability P_0 varying as fragment mass A_2 for plotted for decay of ^{92}Zr nucleus formed in ^{16}O+^{76}Ge and ^{18}O+^{74}Ge reactions.

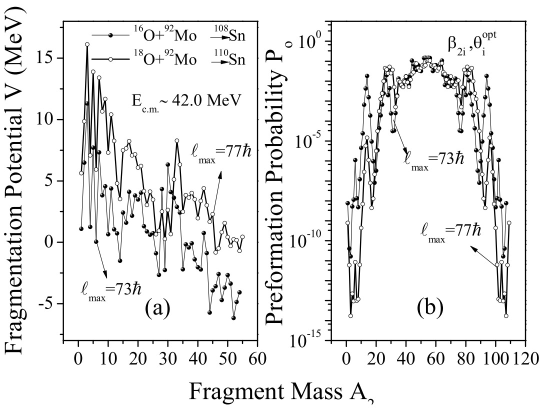

FIG. 2: Same as Fig. 1 but for $^{16}O+^{92}Mo$ and $^{18}O+^{92}Mo$ reactions.

the collective coordinates of mass (and charge) asymmetry $\eta = (A_1 - A_2)/(A_1 + A_2)$ [and $\eta_Z = (Z_1 - Z_2)/(Z_1 + Z_2)$], relative separation R, the multipole deformations $\beta_{\lambda i}$ and orientations θ_i (i=1,2) of two nuclei in the same plane.

Calculations and Results

In order to study the entrance channel effects in framework of DCM, the calculations have been done for deformed magic nucleus ^{92}Zr, formed using $^{16}O+^{76}Ge$ and $^{18}O+^{74}Ge$ reactions. Fig. 1(a) illustrates the variation of fragmentation potential V (MeV) as a function of fragment Mass A_2. It is observed that the magnitude of fragmentation potential is different for both the channels, being higher for ^{16}O induced channel possibly due to larger ℓ-value. However, the structure of potential energy surface is almost identical irrespective of the choice of incoming reaction partners. This is further emphasized in Fig. 1(b) showing variation of preformation probability P_0 as a function of fragment Mass A_2. It is evident from the figure that mass distribution of ^{92}Zr is similar for $^{16,18}O$-induced reactions. These observations seem to indicate the entrance channel independence in the decay of deformed magic nucleus ^{92}Zr. It is worth noting that at lower ℓ-values, LPs have high preformation probability, indicating large contribution (not shown in figure) whereas at ℓ=ℓ_{max}, the fission fragments possess higher probability and hence dominate the contribution towards decay cross-sections. For the use of different neck-length parameter ΔR, the DCM calculated cross-sections for decay of ^{92}Zr nucleus find nice agreement with experimentally observed data [1].

In addition to this, we further aim at analyzing the role of projectile mass in the dynamics of spherical magic $^{108,110}Sn$ [3] compound systems, formed in ^{16}O and ^{18}O induced reactions. In order to investigate the effect of projectile mass, Fig. 2(a) showing fragmentation potential is plotted for $^{16}O+^{92}Mo$ and $^{18}O+^{92}Mo$ reactions. Except from difference in structure of potential energy surfaces for intermediate mass region, the fragmentation potential is almost identical for both the reactions. The α- nucleus structure is present in both the channels and also for ^{92}Zr fragmentation depicted in Fig. 1(a). The variation of preformation probability plotted in Fig. 2(b) illustrates near symmetric mass distribution for both the incoming channels. It indicates that, projectiles with different mass do not effect the mass distribution of fragments in the decay of $^{108,110}Sn$ compound systems. Thus, it may be concluded that the decay of deformed magic ^{92}Zr system is independent of entrance channel and the fragmentation path of spherical magic $^{108,110}Sn$ nuclei, is not influenced much by the presence of different projectile.

Acknowledgment

Financial support form University Grant Commission (UGC), New Delhi is greatly acknowledged.

References

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