Effect of pairing strength on dynamics of ^{118}Xe* nucleus formed in ^{28}Si+^{90}Zr reaction

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Introduction

The heavy ion reactions (HIRs) involving projectile beam heavier than alpha-particle are of great interest as they may effectively aid in producing new isotopes beside providing relevant information related to nuclear structure and associated dynamics. Thus, in the present work, an attempt has been made to study the dynamics of heavy ion reactions involving ^{28}Si projectile beam (having N=Z) induced on ^{90}Zr target nucleus. In the reaction under study, the presence of ^{90}Zr target having neutron shell closure (N=50) and proton sub-shell closure (Z=40) makes it of considerable interest so far as the understanding of heavy ion reaction is concerned.

In a recent experiment [1], the fusion cross sections for the ^{118}Xe* nucleus formed in ^{28}Si + ^{90}Zr reaction were measured at center of mass energy, E$_{c.m.}$=65.7−92.4 MeV. In view of this, the decay of ^{118}Xe* nucleus has been studied using the collective clusterisation approach [2]. Apparently, the fusion cross sections are considered to be sum of evaporation residue ($A_2 \leq 4$) and fission cross sections, however in the present work, the ER decay is found to be dominant decay mode. It is worth noting that in this work, the role of pairing strength (δ) has been examined through the variation of fragmentation potential and the preformation probability, which provide significant information related to structural features at compound nuclear stage.

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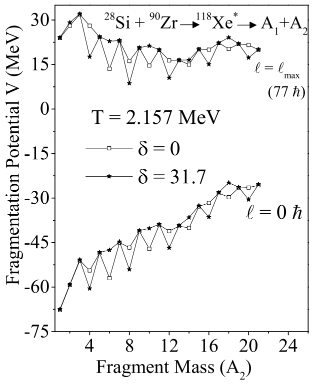

FIG. 1: (a) The variation of fragmentation potential plotted for ^{118}Xe* nucleus at maximum energy and at extreme ℓ-values.

Methodology

The decay analysis of chosen composite system is studied using the DCM [2] which is based on quantum mechanical fragmentation theory (QMFT), 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. The decay cross-sections are calculated in terms of barrier penetrability P and preformation factor (P$_0$). Here barrier penetrability (P) refers to the R-motion and is calculated by using WKB integral and P$_0$ is solution of stationary Schrödinger equation in η-coordinate and is helpful in analyzing the structural information of compound system formed. The Schrödinger equation involves the fragmentation potential as input which is given as:

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

The first and second term represents the liquid drop binding energy and shell corrections, while V$_C$, V$_P$ and V$_\ell$ are respectively the T -dependent Coulomb, nuclear proximity, and centrifugal potentials for deformed, oriented

TABLE I: The DCM calculated evaporation residue (ER) decay cross-sections of ^{118}Xe*, nucleus formed in ^{28}Si + ^{90,92,94}Zr reaction for the use of deformations by using different pairing coefficient (δ), compare with experimental data.

			$\delta(T)=0$		$\delta(T)\neq 0$		
$E_{c.m.}$ (MeV)	T (MeV)	ℓ_{max} ($\hbar$)	ΔR (fm)	σ_{DCM} (mb)	ΔR (fm)	σ_{DCM} (mb)	$\sigma_{Exp.}$ (mb)
65.7	1.605	73	1.048	0.047	0.862	0.049	0.049
68.9	1.680	73	1.217	2.660	1.113	2.010	2.317
88.5	2.085	77	1.739	680.1	1.759	674.0	680.0
92.4	2.157	77	1.729	690.0	1.768	676.0	674.0

nuclei.
The pairing term of liquid drop part of binding energy is given by:

$$Pairing\ \ energy = \delta(T)\frac{f(A,Z)}{A^{3/4}} \qquad (2)$$

where, $f(A,Z)$=(-1,0,1) respectively, for even-even, even-odd and odd-odd nuclei. The pairing strength $\delta(T)$, is cofficient of pairing energy and constrained to be positive definite at all temperature. According to work of Davidson, the δ-values in Eq.2 converge to '0' for T>1.5 MeV. However, recently the pairing strength calculated using Gupta *et al.* gives non zero values of δ for T>1.5 MeV. Thus in present work the comparative study of zero and non-zero values of pairing strength is carried in reference to the values given by Davidson *et al.* [3] and those calculated by Gupta and collaborators [4] respectively.

Results and discussions

In present work, the ER decay analysis of ^{118}Xe* has been carried out using DCM, where the role of zero and non-zero pairing strength ($\delta(T)$) is observed at extreme energies and at corresponding higher temperatures (T>1.5 MeV). It is worth noting that in liquid drop potential used as an input in fragmentation potential (Eq.1), the coefficient of pairing energy term converges to zero for temperatures T>1.5 MeV [3]. Thus, the odd-even effect of binding energy is expected to be negligibly small at T>1.5 MeV. On the other hand as per results of Gupta and colaborators [4], the pairing strength is observed to have significant values even at higher temperature. Thus a relative comparison of zero and non-zero pairing strength seem to be of considerable interest. Fig.1 shows the variation of fragmentation potential as a function of fragment mass for evaporation residue ER and IMF region at E$_{c.m.}$=92.4 MeV (only). It is clearly observed that with the inclusion of non zero pairing ($\delta(T) > 0$) the emission of 4n fragments i.e. A_2=4,8,12,16 is prominent as the fragmentation potential is minimum for these fragments. On the other hand, for the zero pairing strength ($\delta(T) = 0$) taken from davidson *et al* [3]., the fragments with 4n+2 configuration i.e. A_2=6,10,14 are more perceptible towards the decay of ^{118}Xe* nucleus. A similar observation is also drawn from the variation of summed-up preformation probability, P_0, as depicted in Fig.2 and this behavior retains its pattern independent of excitation energy. Thus it may be concluded that pairing strength influences the fragmentation governed in heavy ion induced reaction. One may also observe from Table I that with the inclusion of modified $\delta(T)$, the ℓ_{max} values remain same while the neck length parameter changes when $\delta = 0$ is replaced by $\delta \neq 0$.

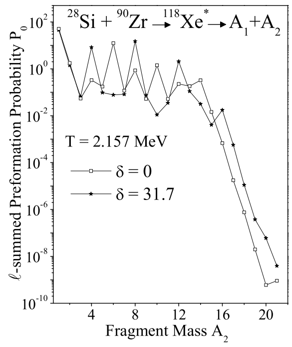

FIG. 2: The ℓ-Summed preformation probability as a function of fragment mass (A$_2$).

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