Role of Z = 82 shell closure in the decay of ^{194}Hg*, ^{200}Pb*, ^{203}Bi* and ^{207}At* compound nuclei

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Introduction

The compound nucleus (CN) resulting from heavy ion reactions are perceptive towards the entrance and exit channels aspects such as excitation energy, entrance channel mass asymmetry, pairing energy, shell corrections, etc. The shell corrections being the microscopic component of fission barrier, there are speculations that proton shell closure at Z=82 may lead to survival probability of CN against fission [1].

In the present work, we have investigated the decay of compound nuclei ^{194}Hg*, ^{200}Pb*, ^{203}Bi* and ^{207}At* formed in ^{19}F+^{175}Lu, ^{19}F+^{181}Ta, ^{19}F+^{183}W and ^{19}F+^{188}Os reactions, respectively, at $E_{lab} \sim 85$ MeV. The evaporation residues, ERs, cross sections (σ_{ERs}) in the decay of CN ^{203}Bi* have been calculated at six different center-of-mass energies $E_{c.m.}$ and compared with the available data [2]. An attempt has been made to understand the stability of the proton shell closure using the dynamical cluster decay (DCM) of Gupta and collaborators [3]. The decay of CN ^{203}Bi* has been compared with decay of other compound nuclei having Z near and around proton shell closure Z=82.

Methodology

The DCM is worked out in terms of collective coordinates of relative separation R, with deformations β_2 and orientations θ_i of two fragments (i = 1, 2) and mass (and charge) asymmetries η_A = (A$_1$-A$_2$)/(A$_1$+A$_2$) [and η_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 outgoing nuclei. In terms of these coordinates, the compound nucleus (CN) decay cross-section for ℓ- partial waves, is defined as

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

where, P_0 is preformation probability obtained by solving the stationary Schr$\acute{}$odinger equation, refers to η- motion and P, the barrier penetrability, calculated as the WKB tunneling probability, refers to R- motion, both dependent on T and ℓ. The reduced mass $\mu = [A_1A_2/(A_1+A_2)]$ and ℓ_{max} is the maximum angular momentum. The ℓ_{max} is fixed for vanishing LPs/ERs cross-section (σ_{ERs}), i.e., $\sigma_{ERs} \to 0$.The deformations of the interacting nuclei are taken here upto quadruple deformations. It is relevant to mention here that the DCM gives a good description of the ERs or LPs emissions and their excitation functions within a single parameter description, i.e., the neck length parameter ΔR.

Calculations and Discussion

Fig. 1 (a-d) present preformation profile of the favoured fragments in the compound nucleus decay of hot and rotating nuclear systems ^{194}Hg*, ^{200}Pb*, ^{203}Bi* and ^{207}At*, respectively. The calculations have been made within collective clusterization approach of the DCM. Fig. 1 presents very interesting interplay between LPs decay and asymmetric fission fragments. As we move from Fig. 1(a) to Fig. 1(d) we see that the symmetric fission goes out of favour, i.e., asymmetric fission fragments gradually take over.

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TABLE I: DCM calculated σ_{ERs} for the compound nuclei presented in Fig. 1 and their comparison with the experimental data [2].

Compound Nucleus Decay	E_{lab} (MeV)	$E_{c.m.}$ (MeV)	E^*_{CN} (MeV)	Temp. (MeV)	ℓ_{max} ($\hbar$)	ΔR (fm)	σ_{ERs}(mb) DCM	Expt.
$^{194}Hg^* \rightarrow A_1 + A_2$	85.00	76.67	52.20	1.579	109	1.612	45.452	$not-available$
$^{200}Pb^* \rightarrow A_1 + A_2$	85.25	77.15	53.47	1.574	129	1.612	78.153	78.528
$^{203}Bi^* \rightarrow A_1 + A_2$	84.17	76.29	50.62	1.521	125	1.421	6.245	6.3±1.2
$^{207}At^* \rightarrow A_1 + A_2$	85.63	77.77	48.37	1.472	120	1.622	28.023	29.16±4.12

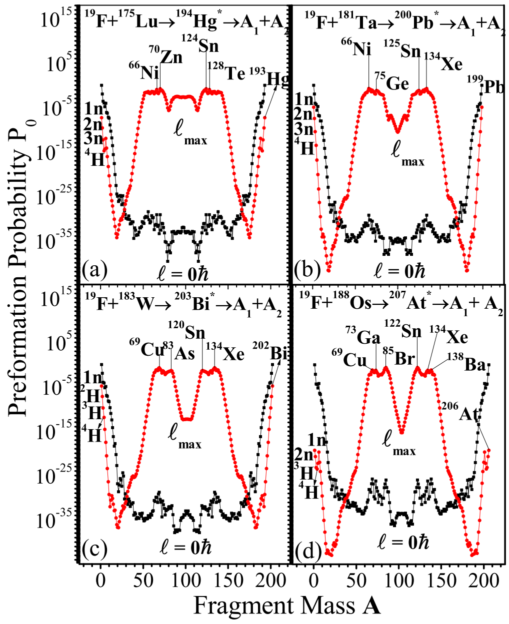

FIG. 1: The preformation probability as a function of fragment mass A at ℓ =0 and ℓ=ℓ_{max} for CN (a) $^{194}Hg^*$ (b) $^{200}Pb^*$ (c) $^{203}Bi^*$ (d) $^{207}At^*$, at $E_{lab} \sim 85$ MeV.

Most importantly, LPs which are highly dominant at lower ℓ-values are superseded by the asymmetric fission fragments at the respective ℓ_{max} values of different compound nuclei (see Table I). However, as we see for compound nuclei ^{200}Pb* (Fig. 1 (b)) and ^{203}Bi* (Fig. 1 (c)) LPs are comparatively strongly preformed. Quite interestingly, Fig. 1 (d) shows that CN ^{207}At* is having weakly preformed LPs in comparision to asymmetric fragments, perhaps due to the fact that it's Z=85 is away from the proton shell closure Z = 82.

Another observation for the decay of CN ^{203}Bi*, there is presence of proton rich LPs

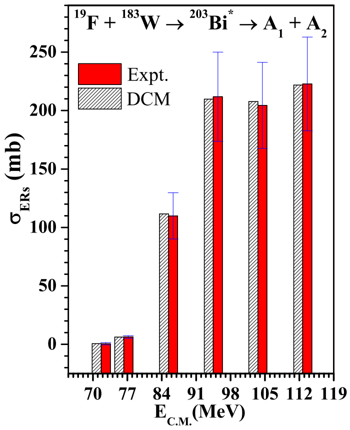

FIG. 2: The calculated evaporation residue cross section σ_{ERs} for $^{203}Bi^*$ compound system at different $E_{c.m.}$, compared with the data.

and having complimentary fragments near Z=82. It is to be noted here that compound nuclei under study are having strongly preformed asymmetric fission fragments having Z=50 i.e. Sn.

Table I presents the DCM calculated σ_{ERs} in good comparison with the experimental data [2]. Fig. 2 presents DCM calculated ERs excitation function, having good comparison with the data. The calculations for the ERs excitation function for other compound systems are in progress.

References

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