Statistical model analysis for α + ^{209}Bi system

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It is well established that the presence of shell correction around the saddle point results in double humped fission barriers for actinide nuclei [1]. Experimental as well as theoretical knowledge about the influence of shell corrections at the saddle point in nuclei of A ∼200, where the ground state shell corrections are strongest, is scarce. Although, shell correction may not lead to any significant secondary minima in the steeply varying liquid drop surface in these nuclei, a significant shell correction may be present as indicated by some calculations, e.g. [2].

In case of actinide nuclei, fission barriers are smaller and can be directly measured experimentally. However, most of the measurements of fission cross sections for A ∼200 are performed at energies much higher than that of fission barrier, where there are other competing channels open and statistical description become essential. In the statistical model for the decay of compound nucleus, the competition between fission and light particle emission is determined by the relative density of levels available. The density of levels depends upon available excitation energy (U_x) and level density parameter (a_x). Here, $x = n$ or f corresponding to equilibrium or saddle point deformation.

Although a number of studies have been carried out, there are still ambiguities in choosing various input parameters for the statistical model analysis. In earlier attempts to extract fission barrier heights from the fits to the measured fission excitation functions, excitation functions of evaporation residues (ER) and prefission neutron multiplicities (ν_{pre}) were not considered. It has been shown that the fission cross sections, which are cumulative, can be explained by several sets of correlated pairs of fission barrier (B_f) and ratio of level density parameter ($\tilde{a}_f/\tilde{a}_n$) [3]. However, simultaneous fits to the excitation functions of fission, evaporation residue and pre-fission neutron multiplicities can be obtained by unique set of parameters.

In Ref. [3], we have carried out simultaneous analysis of the excitation functions of fission, evaporation residue and pre-fission neutron multiplicities for a numbers of compound nuclei formed in heavy ion, i.e. ^{12}C, ^{16}O and ^{19}F, induced reactions. In this paper, we present the analysis for α+^{209}Bi system.

In the analysis, fission barrier is expressed as $B_f(J) = B_{LD}(J) - \Delta_n + \Delta_f$, where $B_{LD}(J)$, Δ_n and Δ_f are the J dependent liquid drop component of the fission barrier, the shell correction at the ground state and the shell correction at the saddle point, respectively. The values of $B_{LD}(J)$ are taken from rotating finite range model [6]. The shell correction at the ground state is taken as the difference between the experimental and liquid drop mass. The shell correction at the saddle point is assumed to be $k_f \times \Delta_n$. The value of k_f is to be determined from the fit to the experimental data.

An energy dependent shell correction to the level density parameter $a_x = \tilde{a_x}[1 + (\Delta_x/U_x)(1 - e^{-\eta U_x})]$ is employed with $x = n$ or f corresponding to equilibrium or saddle deformation. The asymptotic liquid drop values $\tilde{a_n}$ and $\tilde{a_f}$ are taken to be $A/9$ and $\tilde{a_f}/\tilde{a_n} \times \tilde{a_n}$, respectively. The value of $\tilde{a_f}/\tilde{a_n}$ is varied to fit the data.

Initial excitation energy as well as the particle separation energies at various decay steps are calculated using experimental masses. The intrinsic excitation energy at the equilibrium deformation is defined as

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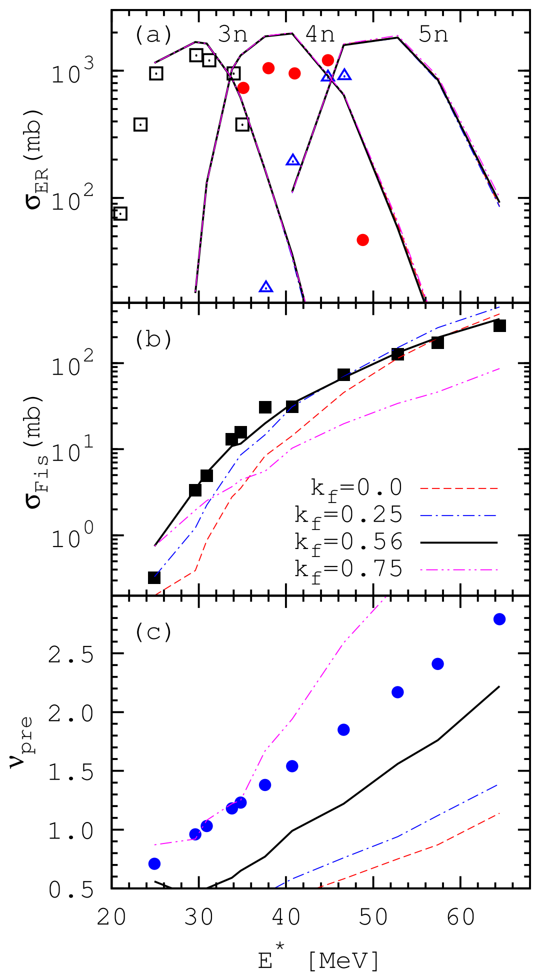

FIG. 1: Results of statistical model calculations for α +^{209}Bi systems for different values of k_f (see text) are compared with (a) the experimental evaporation residue cross sections (σ_{ER}), (b) the experimental fission cross sections (σ_{Fis}) [4] and (c) the pre-fission neutron multiplicities (ν_{pre}) from systematics [5].

$U_n = E^* - E_{rot}(J)$. The rotational energies, $E_{rot}(J)$, are taken from Ref. [6]. The intrinsic excitation energy at the saddle deformation is taken as $U_f = U_n - B_f$. The initial J distributions of the decaying compound nuclei are obtained using the code CCDEF.

Fig. 1 shows the results of four different values of k_f. For each values of k_f, value of $\tilde{a_f}/\tilde{a_n}$ have been varied to get the best fit to the experimental fission and ER cross sections [4]. As can be seen from Fig. 1(a), statistical model calculations with different values of k_f produces indistinguishable results for ER cross sections. However, the resulted fission excitation functions for different values of k_f are significantly different. In the present analysis, the ν_{pre} data from systematics [5], derived from measurements of ν_{pre} in heavy ion induced fusion-fission reaction, has not been included in the simultaneous fitting. Predicted ν_{pre} values are compared with the systematics [5] in Fig. 1(c).

The shape of the fission excitation function can be best reproduced with $k_f = 0.56$ and $\tilde{a_f}/\tilde{a_n}$ =1.00. The corresponding values of fission barrier height and shell correction at the saddle point are 12.8 MeV and -3.6 MeV, respectively. The value of the fission barrier height estimated earlier from the fit to fission excitation function without considering the multichance nature of fission for the same system is 20.1 MeV [7]. Measurement of ν_{pre} for the present system will elucidate further.

References

[1] P. Möller *et al.*, Phys. Rev. **C 79**, 064304 (2009)
[2] M. Bolsterli *et al.*, Phys. Rev. **C 5**, 1050 (1972).
[3] K. Mahata *et al.*, Phys. Rev. **C 74**, 041301(R) (2006).
[4] Yu. E. Penionzhkevich *et al.*, Eur. Phys. J. **A 13**, 123 (2002) and references therein.
[5] H. Baba *et al.*, J. Phys. Soc. Jpn. **66**, 998 (1997).
[6] A. J. Sierk, Phys. Rev. **C 33**, 2039 (1986).
[7] L. G. Moretto, Phys. Rev. Lett. **75**, 4186 (1995).