An attempt to estimate the pre- and post-saddle fission rates in fusion-fission dynamics

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Introduction

Although the fusion-fission process is known from more than 70 years, still the understanding of fusion-fission dynamics is an active field of research. In past two decades, a number of attempts have been made to estimate the strength of nuclear dissipation in fusion-fission dynamics. Most of these measurements are carried out using neutron multiplicity, charged particles multiplicity, evaporation residue cross-section etc. as probes. Based on these studies, the existence of nuclear dissipation is well established at nuclear temperature above 1 MeV [1]. Also it is observed that the excitation energy dependent nuclear dissipation is required for explaining the experimental results. These measurements give the strength of nuclear dissipation or the fission rate between equilibrium and scission points. However these studies could not quantize the fission rate in pre and post saddle regions. The information of pre and post saddle fission rate is important to understand the theoretically predicted deformation dependence of nuclear dissipation [2].Estimation of pre and post saddle fission rate can be obtained from a systematic measurement of neutron multiplicity (which is sensitive to the fission rate between equilibrium and scission point) followed by fission and Evaporation Residue (ER) cross-section measurement (which is sensitive to fission rate between equilibrium and saddle point).

Recently our group has carried out a systematic measurement of neutron multiplicity, ER cross-sections and fission cross-sections [3] for ^{19}F + ^{194,196,198}Pt systems which can be used to estimate pre and post saddle fission rates. In the present work, an attempt has been made to quantize the pre and post saddle fission rate.

Statistical model calculations

In the present calculation, it is assumed that the compound nucleus can decay by the emission of light particles like neutron, proton, α-particle etc, giant dipole resonance (GDR) γ-rays or can undergo fission. The decay width of light particles and GDR γ-rays is obtained from Weisskopf formula whereas the fission width is obtained using integral form of Bohr-Wheeler and Kramer (included dissipation as free parameter)formula. The fission barrier is calculated using the potential obtained from Sierk's model [4]. Since the compound nuclei populated in present study has either neutron shell closure or are close to the shell closed nuclei hence it is important to include the shell correction in calculations. An excitation energy dependent shell correction is taken into account for fission barrier. The level density is taken from work of Ignatyuk et al. [5]. The experimentally obtained fusion cross-section is fitted with coupled channel calculations based code CCDEF. The spin distribution obtained from CCDEF is used as input for the statistical model calculations.

It is observed that the Bohr-Wheeler fission width under predicts the experimental neutron multiplicity and Kramer fission width (which include nuclear dissipation) is necessary to explain the experimental neutron multiplicity. Fig. 1 shows the dissipation strength required to explain the experimental neutron multiplicity as a function of excitation energy.

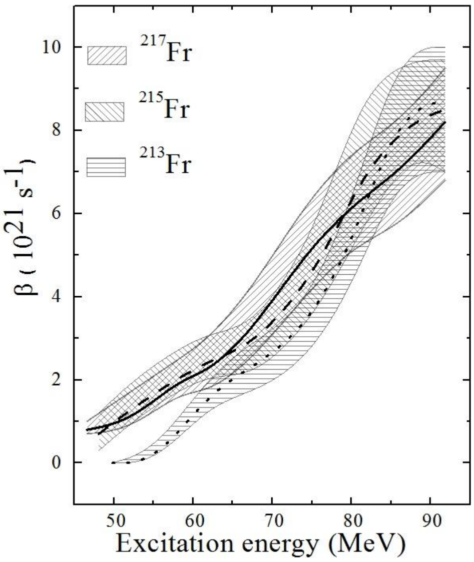

Fig. 1: Dissipation strength as a function of excitation for all the three CN under study.

On the other hand Bohr-Wheeler fission width over predicts the experimental ER cross-sections whereas under predicts the experimental fission cross-sections. The lowering of Finite Rotating Liquid Drop Model (FRLDM) fission barrier ($V_B(l,E^*)= k_f VLDM(l) - \Delta V_{shl}(l)$) is required to explain the experimental ER and fission cross-sections as shown in Fig. 2.

The above results show that while a lowering of fission width by invoking dissipation is essential to reproduce pre-scission neutron multiplicity data, an enhancement of fission width by reducing the fission barrier is required to fit ER data. This discrepancy points to inadequacies in the fission model which requires further investigations. However, even at this stage, one can make the following observation. Since ER data is sensitive to fission dynamics up to the saddle and pre-scission neutron number is determined by fission dynamics up to the scission point, the pre-saddle fission dynamics is faster than the post-saddle dynamics.

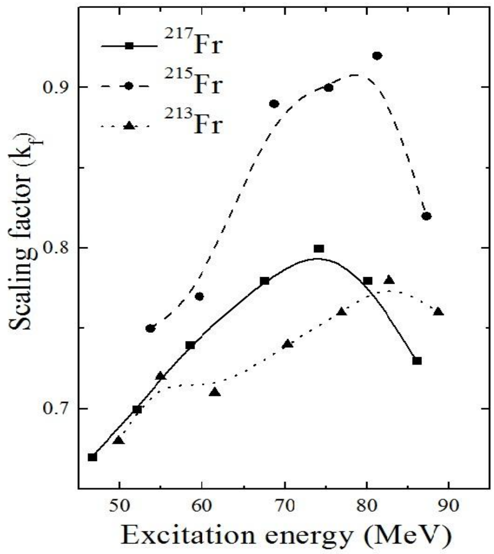

Fig. 2: Relative lowering of FRLDM as a function of excitation for all the three CN under study.

Conclusions

The present work shows that a full understanding of fission process is yet to be achieved. To this end, in addition to shell effects, the spin orientation effect on fission width, enhancement of level density due collective motion and deformation-dependence of particle decay widths are some of the areas which require further investigations. Further, inclusion of energy and deformation dependence of various parameters may help to explain experimentally measured neutron multiplicity, fission and ER cross-sections simultaneously.

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