Systematic investigation to estimate the magnitude of nuclear dissipation in fission dynamics

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Introduction

Fusion-fission process is full of surprises since its discovery. A number of attempts have been made to determine the fission barrier, shell effects and magnitude of nuclear dissipation. The understanding of these effects is a key for the production of super heavy elements and achieve the theoretical predicted island of stability. Recently a number of authors have attempted to estimate the magnitude of nuclear dissipation using neutron multiplicity, charge particle multiplicities, GDR multiplicity, fission cross-sections and evaporation residue (ER) cross-sections as a probe. In our previous studies aiming to explore the effect of shell closure on fission dynamics and estimating the magnitude of nuclear dissipation by measuring neutron multiplicities and ER cross-sections for ^{19}F + ^{194,196,198}Pt [1] , it was observed that nuclear dissipations is lower for shell closed system in comparison to the non-shell closed systems. However dissipation is necessary to explain the experimental neutron multiplicities whereas lowering in the fission barrier (i.e no dissipation) is required to reproduce ER cross-sections. Hence a consistent picture about the magnitude of nuclear dissipations is still missing.

The fission cross-sections for ^{19}F + $^{194.198}$Pt at near barrier energies have already been measured by Mahata *et al.* [2]. Our group has measured the fission cross-sections for ^{19}F + $^{194.198}$Pt at higher beam energies and same are measured for ^{19}F + ^{196}Pt at energy range from near to well above the barrier. Also the statistical model has been modified to include the collective enhancement of level density (CELD), orientation effect and shell corrected level density and fission barrier [4]. The present work contains the re-analysis of the experimental data with the latest statistical model to paint a consistent picture about role of nuclear dissipation in fission dynamics.

Experimental set-up

Experimental fission cross-section has been obtained by measuring the fission angular distribution for energy range from 90.5 to 118.7 MeV. The measurements were carried out using General Purpose Scattering chamber (GPSC) using ^{19}F beam from Pelletron accelerator. The details of the experimental setup and data analysis are discussed in [3].

Statistical model calculations

The experimentally measured fission and ER cross-sections have been used to get the fusion cross-sections. Fusion cross-sections are fitted using coupled channel calculations to obtain the spin distribution which has been used as an ingredient for statistical model calculations. The statistical model has been modified to include the effect of collective en-

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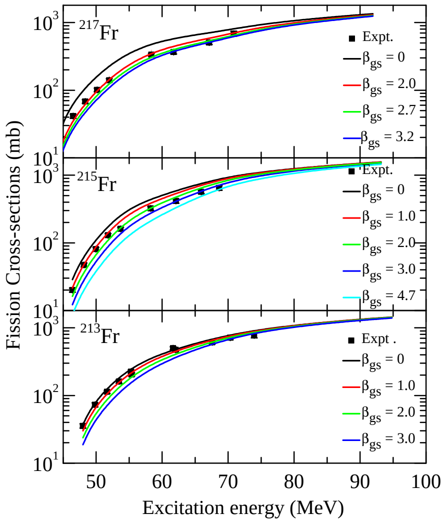

FIG. 1: Experimental fission cross-sections (solid square) along with the statistical model predicted cross-section for different β_{gs} (lines).

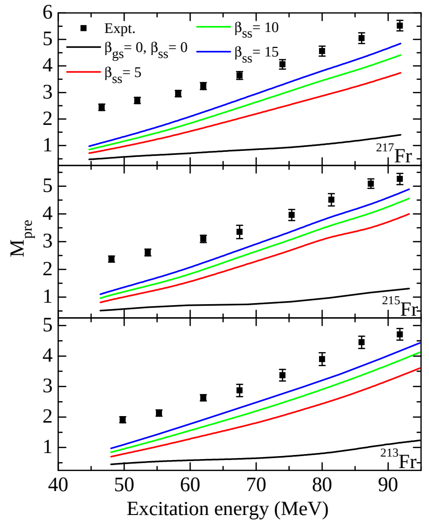

FIG. 2: Experimental neutron multiplicities (solid square) along with the statistical model prediction for different β_{ss} (lines) with β_{gs} as used to reproduce fission cross-sections.

hancement in level density, orientation effects and shell effect in various parameters such as fission barrier, level density, nuclear masses etc [4]. Nuclear dissipation in pre and post saddle regime is considered separately. Experimental fission cross-sections has been reproduce using pre-saddle nuclear dissipations (β_{gs}) as free parameter. Fig. 1 shows the experimental fission cross-sections along with the statistical model prediction for different values of β_{gs}. Experimental neutron multiplicity has been explained using β_{gs} obtained from fission cross-sections along post-saddle nuclear dissipations (β_{ss}) shown in Fig. 2.

Conclusions

It has been observed that a small pre-saddle dissipation is 1×10^{21} sec^{-1} for ^{213}Fr (shell closed compound nucleus (CN)) is necessary to explain the fission/ER cross-sections, whereas the same for ^{217}Fr is 3×10^{21} sec^{-1}. The lowering of dissipation for ^{213}Fr may be correlated to shell effect on dissipation. On the other side post-saddle dissipation as high as 15×10^{21} sec^{-1} is not sufficient to reproduce the neutron multiplicity data. The inability of reproducing the experimental data may be attributed to dynamical effects associated with fusion-fission process. Also the magnitude of pre and post saddle dissipations indicates that nuclear dissipation depend on deformation. The magnitude of dissipation is small when CN is near the equilibrium and it increases as the nucleus become more and more deformed. Also from Fig. 2, it is observed that the deviation of experimental data from statistical model predictions is minimum for ^{213}Fr whereas maximum for ^{217}Fr. These observations may be due to the effect of shell closure on nuclear dissipations which may result in the lowering of dissipation, which is consistent with results obtained from cross-section measurements.

References

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