Investigation of dissipation in fission of ^{220,222,224}Th isotopes formed in ^{16}O+^{204,206,208}Pb fusion reactions.

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Introduction

The dynamics of fusion-fission process in nucleus-nucleus collisions has been extensively investigated, both experimentally and theoretically, in recent years. It is a well-established fact now that fission is a slow process dominated by nuclear viscosity. The surplus emission of pre-scission light particles with respect to the predictions of standard Statistical Model [1] is the most striking experimental evidence of this behavior. This means that in order to explain the phenomenon, it is necessary to use a diffusion model which includes nuclear viscosity as a parameter. To investigate the mechanism of nuclear fission, the emission of light particles, especially neutrons works as a clock to measure the fission time scale.

A systematic analysis of the fission hindrance for the ^{16}O+^{204,206,208}Pb systems has been performed over a wide range of beam energies above the Coulomb barrier using neutron multiplicity as a probe. Moreover, shell effects on particle emission were also investigated as functions of excitation energy and viscosity. The experiment was performed at Inter University Accelerator Centre (IUAC) using National Array of Neutron Detectors and the experimental set-up is given in Ref [2]. In order to extract the experimental pre- and post- scission neutron multiplicity contributions, energy spectra of all the neutron detectors were fitted simultaneously using χ^2 minimization process at various angles using the Watt expression [3]. Fig.1 shows the fits to the double differential neutron multiplicity spectra at various angles for ^{16}O+^{208}Pb at 99.4 MeV. The value of experimental M_{pre} and M_{tot} for the three isotopes of Th at various excitation energies are plotted in Fig.2.

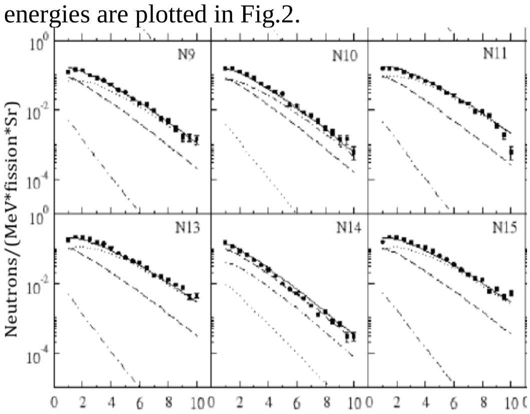

Fig.1. Neutron Multiplicity (filled squares) for the ^{16}O+^{208}Pb at 99.4 MeV along with the fits for the pre-scission (dot curve) and post-scission from one fragment (dot-dash curve) and second (dash curve). The solid line represents the total contribution.

In the present paper we are reporting the theoretical interpretation of the experimental data which was reported earlier [2].

Theoretical Calculations

The experimentally measured values of pre and post scission neutron multiplicities were compared with the statistical model predictions. In the standard statistical model calculations the emission of neutrons, protons, alphas and GDR γ-rays along with fission are considered as possible decay channels of excited compound nuclei. The light particle and GDR γ-rays partial widths were obtained from the Weisskopf formula [4]. In the present work fission width was taken from the work of Kramers [5] and is given as

$$\Gamma = \frac{\hbar\omega_g}{2\pi}\Gamma_{BW}\left[\sqrt{1+\left(\frac{\beta}{2\omega_s}\right)^2} - \frac{\beta}{2\omega_s}\right]$$

where

$$\Gamma_{BW} = \frac{1}{2\pi\rho_g(E_i)}\int_0^{E_i-V_B}\rho_s(E_i - V_B - \varepsilon)d\varepsilon$$

where β is the reduced dissipation coefficient, ω_g and ω_s are the frequencies of the harmonic oscillator potentials which have same curvatures as the LDM nuclear potential at the ground-state and saddle configuration, respectively. Transient and saddle to scission times were also taken into account [6]. The level density parameter was taken from the work of Ignatyuk *et al.* [7], which incorporates the nuclear structure at low excitation energy.

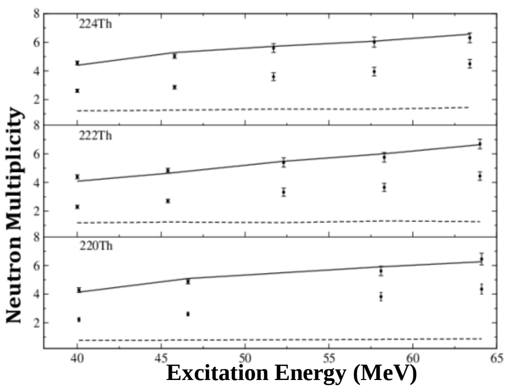

Fig.2. Experimental excitation functions of M_{pre} and M_{tot} (solid squares) with statistical model predictions for β=0 (M_{pre}-dotted lines and M_{tot}-solid lines).

Statistical model calculations were performed with β = 0 which reduces the Kramer's fission width to the Bohr-Wheeler transition state fission width. The calculated value of M_{pre} and M_{tot} were compared with the experimental values in Fig.2. It was observed that pre-scission neutron multiplicities were under-predicted by the statistical model though the total neutron multiplicities were reasonably well reproduced.

Pre-scission multiplicities were next calculated with different values of β in the Kramer's fission width. The value for which the calculated value of M_{pre} matches the experimental value is taken as the best-fit β value for a given system. Fig.3 shows the variation of the best-fit values of β with excitation energy for different compound nuclei.

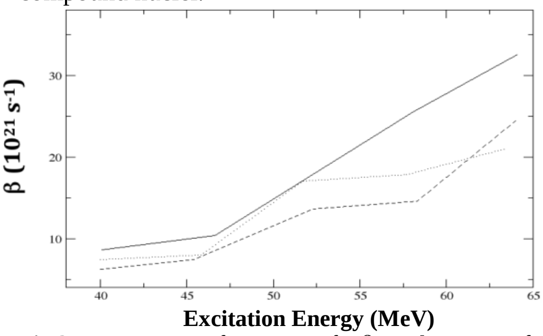

Fig.3. Excitation function of β values to fit experimentally obtained M_{pre}. (^{224}Th – dotted line, ^{222}Th – dashed line and ^{220}Th – solid line).

Discussion and Conclusion

It is observed that the dissipation strength increases with the excitation energy of the Compound Nucleus (CN). The excitation energy dependence may reflect certain limitations of the present model including neglect of higher order terms in dissipation and use of shape independent dissipations. Further, the shell structure of the CN is already taken into account through the level density formula and the ground state masses. Thus β, which is a bulk nuclear property, does not show any strong isotopic dependence.

References

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