Role of N/Z in the Pre-scission Neutron Multiplicity for the ^{16,18}O+^{194,198}Pt Systems

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Introduction

The most striking evidence for the effects of nuclear viscosity is the measurement of pre-scission particle multiplicities [l-3] from the fission fragments, which are more than expected from the standard statistical model calculations. Extensive studies have been carried out in the past to determine the dynamical fission time scales from the measurements of the multiplicity of pre-scission neutrons, protons, alpha particles and electric dipole γ - rays, in heavy-ion induced fusion–fission reactions [1–3]. These clear demonstrations of the dynamical constraints to fission time scales are the most potent probes for studying the nature of nuclear viscosity. For instance, calculations of the lifetimes of the excess pre-scission neutrons have been used to estimate the fission delay time, which depends directly on the magnitude of the viscosity. To obtain the information of the dissipation strength beyond the saddle point, i.e., the saddle-to-scission friction strength, it is necessary to employ those observables that can be affected by the saddle-to-scission friction effects. Several of these studies involve measurements of particle multiplicities at various excitation energies, different entrance channel mass asymmetries and as a function of fissility of the compound nuclear reactions [2]. The fission dynamics as a function of **'(N-Z)/A**' and **N/Z**, the effect of the neutron excess from the reaction system chosen and the contribution coming from near scission configuration is not yet studied systematically [4]. Keeping this in mind, we have measured neutron multiplicities from fission fragments for a number of heavy nuclei by populating compound nucleus with same **Z** (proton Number) but with different **N** (Neutron Number). We report here the results of neutron multiplicity measurements for ^{16,18}O+^{194,198}Pt reactions at different set of excitation energies which populate the compound nuclei with same **Z (Z=86, Rn)** but different value of **N** (i.e different N/Z and (N-Z)/A.

Experimental Arrangement

The experiments were carried out at IUAC (New Delhi), using pulsed beams of ^{16}O (E_{lab}=118, 110, 100 and 88 MeV) and ^{18}O (E_{lab} = 120, 116, 108, 112.5, 102, 97.5, 90 and 85.5 MeV) from the 15UD Pelletron plus first module of super-conducting linear accelerator (LINAC).The experiment was done by populating the compound nuclei at 79, 71.7, 61 and 50 MeV excitation energies. Targets used for this experiment are ^{194}Pt (1.75mg/cm^2) and ^{198}Pt (2.15mg/cm^2). Fission fragments were detected by a pair of large area Multi-wire proportional counter (MWPC) (5"x3") kept at fission fragment folding angle. Two silicon surface barrier detectors were placed at ±16^o out of plane for normalization purpose. 16 neutron detectors (NE213 and BC501A), of 5" diameter and 5" depth, from the **NAND array** were kept at 2 meter away from the target at different angles. The threshold of neutron detectors was kept at about 0.5 MeV by calibrating it with standard γ source (^{137}Cs). The efficiency correction for the neutron detectors was performed using the

Monte Carlo computer code MODEFF. Discrimination between neutrons and gamma rays was made by using both neutron time of flight (TOF) and pulse shape discrimination (PSD) techniques. For minimizing gamma background in the neutron spectra, the beam dump was extended about 4 m downstream from the target and the beam pipe was well shielded with lead and borated paraffin. The trigger of the data acquisition was generated by logical OR of the two fission fragments (Cathode of the two MWPC) and it further ANDED with the RF of the beam.

Analysis

A number of laboratory neutron energy spectra, selecting various fission fragment-neutron correlation angles, were constructed. The neutron spectra corrected for the detector efficiency, were simultaneously fitted by assuming three moving sources corresponding to a pre-scission (composite nucleus) and post-scission (two fission fragments). To determine the pre- and post-scission parameters the Watt expression [2] was used for the neutron emission spectra. The pre-scission neutron multiplicity M^{pre}, post-scission fragment neutron multiplicity and temperature M^{post} ,T^{post} respectively (here M^{post} refers to the neutron multiplicity from one of the fragments) were determined from the fits. The temperatures T^{pre} was calculated as $T = \sqrt{(E^*/a)}$, where E^* is the excitation energy and a is the level density parameter, taken as A/10 for compound nucleus. T^{pre} was scaled down by a factor of 11/12 to account for multistep evaporation[2]. Minimum value of chi^2/ (degrees of freedom) on the fitting procedure were in range of 0.001-0.003.

Results and Discussions

The variation of M^{pre} with N/Z is shown in Figure-1. We see an increasing tendency of M^{pre} value with the increase of N/Z.

The total neutron multiplicity (M^{tot}) also represents total available excitation energy, which is given by $E_{ex}+Q_{fiss}$-TKE. Here, Q_{fiss} is the fission Q value. It is seen from the Figure-2, the average number of evaporated neutrons per MeV increases with the increase in N/Z ratio consistent with the change in separation energy of the neutron. The dip observed at the lowest excitation energy for the system $^{18}O+^{194}Pt$ might be perhaps due to the shell closure (N_C=126) of the compound nucleus $^{212}Rn_{86}$ formed by the above reaction. At the lowest excitation energy dissipation effect is minimum and we expect statistical -

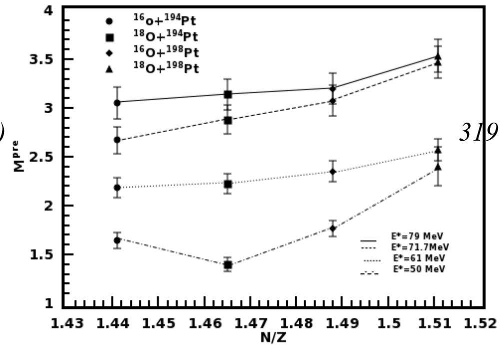

Figure ~1: Variation of M^{pre} with N/Z for $^{16,18}O+^{194,198}Pt$ reactions

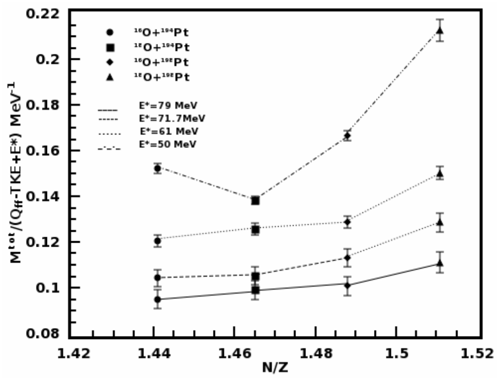

Figure ~2: Ratio of the total neutron multiplicity and available excitation energy for the various systems under study

model to roughly predict the measured neutron multiplicity values. In our measured systems neutron number is also gradually increasing. A PACE calculation was performed taking an acceptable parameter sets tested for a wide range of target projectile systems in this mass region. At the lowest excitation energy (50 MeV), the experimental M^{pre} value for $^{16}O+^{194}Pt$ target was reproduced (Expt.1.64±0.08, PACE 1.62). The same set of parameters at the similar (lowest) excitation energy predicted a M^{pre} value of 1.7 for $^{18}O+^{194}Pt$ (Expt. 1.40±0,07), 1.72 for $^{16}O+^{198}Pt$ (Expt.1.8±0.08) and 1.80 for $^{18}O+^{198}Pt$ (Expt. 2.4±0.07) Systems. With increasing N/Z even at the lowest excitation energy statistical model could not reproduce the measured neutron multiplicity values.

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