Prescission and postscission neutron multiplicities in the $p+^{238}$U reaction

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Introduction

Nowadays, there is an increasing interest in studying nucleon-induced fission of actinides at intermediate energies, i.e., between 20 and 200 MeV due to worldwide interest in accelerator-driven systems (ADS) for nuclear applications. Such systems consist of subcritical reactors driven by neutrons produced in a spallation subactinide target irradiated with energetic protons. This spallation process produces also energetic secondary protons which will still significantly contribute to the overall induced reactions. Neutron- and proton- induced reactions in this energy range are among the very important ones for the ADS design [1, 2]. The most probable process resulting from these reactions is fission, which will be accompanied by non-negligible pre- and post-scission neutron emission which will surely affect the subcriticality aspect of the proposed ADS reactor. Therefore, it is important to study neutron multiplicities and compare them with evaluations and predictions presently used for establishing the subcriticality concept and criteria of a reactor design. Here we report our measurements on the prompt fission neutron spectra in ^{238}U fission induced by proton at energies 14, 18 and 23 MeV

Experimental Details and Data Analysis

The experiment was performed using a proton beam, obtained from the Bhabha Atomic Research Centre-Tata Institute of Fundamental Research 14UD Pelletron accelerator. A self-supporting thin metallic foil of ^{238}U of thickness 2.08 mg/cm^2 was used as the target. Measurements have been carried out at three bombarding energies 14 MeV, 18 MeV and 23 MeV of proton. Two silicon surface barrier detectors F_1 (450mm^2) and F_2 (50mm^2) were placed at backward angles of 150° and -123° respectively. A thin-walled (3 mm) scattering chamber was used to minimize multiple neutron scattering. The neutrons emitted in the reaction were detected by four EJ301 neutron detectors (2 inch thick and 5 inch in diameter) positioned outside the scattering chamber at a distance of 1.0 meter from the target. The neutron detectors N1,N2,N3,N4, subtends an angles of 180°,151°,118°, 84° w.r.t. fission detector F1 and 94°, 67°, 34°, 180° w.r.t. fission detector F2 respectively. A pulse shape discrimination technique is used to discriminate neutron and gamma rays in the neutron detector. The neutron energy has been measured using time of flight(TOF) technique. The TOF signal of each neutron detector was obtained with reference to the start pulse derived from either of the two fission detectors. The time calibration was done using a precision time calibrator. The position of the gamma-ray peak in the TOF spectrum was used as the reference for calibrating the TOF spectrum.

Results and Discussion

The laboratory neutron energy spectra were determined from the observed TOF spectra after correcting for the neutron detection efficiency for each neutron detector. In order to obtain the prescission and postscission neutron components, the observed neutron energy spectra were fitted with three moving-source evaporation components (the prescission component corresponding to emission from com-

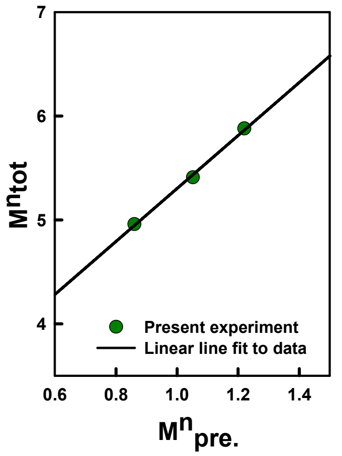

FIG. 1: Average prescission versus average total neutron multiplicity for the present measurements
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posite nucleus and the postscission components corresponding to emission from the two fission fragments) using the Watt expression:

$$Y(E_n) = \sum_{i=1}^{3} \frac{M_n^i \sqrt{E_n}}{2(\pi T_i)^{3/2}} \times exp\left(\frac{-(E_n - 2\sqrt{\epsilon_i E_n} cos\phi + \epsilon_i)}{T_i}\right); \quad (1)$$

where ϵ_i ;,T_i, and M_n^i are the energy per nucleon, temperature, and multiplicity of each neutron emission source i. E_n is the laboratory energy of the neutron, and ϕ_i is the neutron detection angle with respect to the source i. The ϵ_i values for the two fission fragments and the angle of emission of the complementary fragment were determined by applying the reaction kinematics using the Viola's systematics for total kinetic energy release for the symmetric division. The postscission parameters M_n^{post} and T_{post} for both fragments were assumed to be equal. The temperature for the prescission component T_{pre} was also fixed using a Fermi gas relation between temperature and excitation energy. The remaining parameters M_n^{pre},M_n^{post} and T_{post} were obtained by fitting the observed spectra with Eq.1 by the χ^2 minimization procedure. The values of the M_n^{pre} and M_n^{post} obtained from the four sets corresponding to four neutron detection angles are found to be consistent with each other, which implies that there is no appreciable dependence of M_n^{pre} and M_n^{post} on the neutron detection angle with respect to the beam direction. The total neutron multiplicity was derived as $M_n^{tot} = M_n^{pre} + 2M_n^{post}$ from the fitted values of M_n^{pre} and M_n^{post}. The Fig.1 shows the the correlation between the values of M_n^{pre} and M_n^{tot}. The present data agree with the overall trend indicated by the straight line with a slope of 2.55± 0.12 and an offset for M_n^{pre}=0.0 corresponding to M_n^{tot} = 2.76±0.13. The Fig.2 shows the variation of M_n^{tot} with excitation energy of the compound nucleus along with the results obtained from NRV project. The M_n^{tot} values, calculated using NRV project are found to be somewhat lesser than the present data. It is seen from this figure that as expected M_n^{tot} increases with excitation energy. Detailed results will be presented during the symposium.

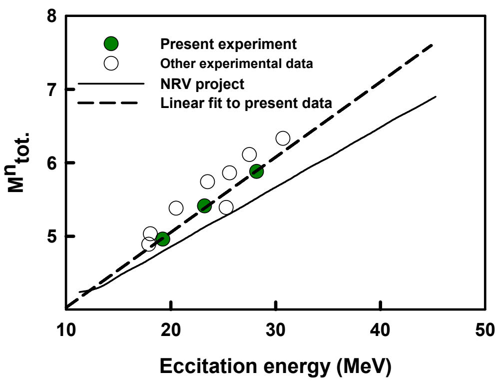

FIG. 2: Experimental average total neutron multiplicity as a function of the excitation energy of the compound nucleus.

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