Fission time study for the fissioning nuclei ^{212}Rn via neutron multiplicity measurements

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Introduction

Study of heavy ion-induced fusion-fission process for a number of compound nuclei has been in progress for the number of years. These studies are devoted to understand the role of viscosity in the fission-fusion process. Due to this viscous nature of compound nucleus, the fission process is hindered. The compound nucleus formed as a result of fusion of two nuclei de-excites by emitting number of light particles such as α, p, ν and γ in addition to fission fragments. These particles emitted during de-excitation contains valuable information about the dynamical nature of compound nucleus. The experimentally measured multiplicities are larger than the values predicted by the statistical model of compound nucleus which confirms that the fission process slows down. The measured multiplicities of these particles is used to extract the total fission time. The total fission time is divided into two parts, the transient time(τ_{tr}) which also include the formation time of the compound nucleus and the saddle to scission time(τ_{ssc}).

In the present work, pre and post-scission alpha and neutron multiplicities have been simultaneously measured for the compound nucleus ^{212}Rn and fission time is extracted using the statistical model code Joanne-2 [1].

Experimental Details

The experiment was performed in the General Purpose Scattering Chamber(GPSC) facility at IUAC, New Delhi. Pulsed beam of ^{16}O from 15UD Pelletron has been bombarded on self-supporting enriched target of ^{196}Pt at energy 93 forming the compound nucleus ^{212}Rn at excitation energy of 56 MeV. The target used was of thickness of 1.8 mg/cm^2 and was placed at an angle of 45^0 with respect to the beam. Two Multi Wire Proportional Counters (MWPC) were placed at the folding angles of 30^0 and 135^0 for detecting fission fragments. Both were placed at a distance of 20.5 cm from the center of target and have an active area of 20cm $\times$ 10cm. In order to separate the fission events from other competing processes, time-of-flight (TOF) information of fission fragments from MWPCs was used. Two Monitor Detectors, passivated implanted planar silicon (PIPS), were also place inside the scattering chamber at $\pm 10^0$.

Neutrons were detected using three liquid organic scintillator detectors (BC501) coupled to 12.7cm XP4512B Photomultiplier tube. These detectors were placed outside the scattering chamber at angles of 30^0, 90^0 and 120^0 w.r.t beam direction at distance of 1.5m. In addition to it, four CsI(Ti) detectors were also used at angles of 70^0, 90^0, 110^0 and

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130^0 for α-particles detection. Energy calibration of Cs(Tl) detectors for α-particles was performed using ^{254}Am and ^{229}Th sources. Also , in-beam calibration of the CsI(Tl) detector was performed using $^{12}C(^{12}C, \alpha)^{20}Ne^*$ $^7Li(^{12}C, \alpha)^{15}N^*$ reactions at 30 Mev and 20 MeV respectively which give discrete α energies ranging from 5 MeV to 25 MeV. The detectors setup used for the experiment is shown in Fig 1.

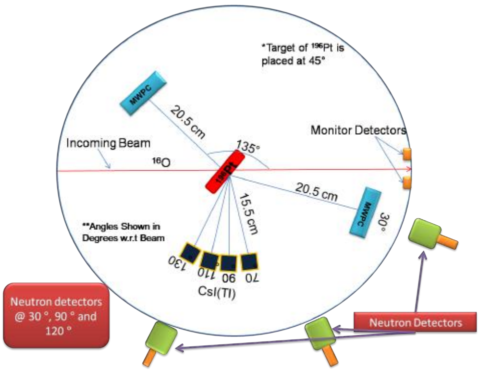

FIG. 1: Systematic of experimental setup.

Data Analysis

In order to differentiate between diferent particles in CsI(Tl) detectors , ballistic deficit pulse shaping technique was used to obtain two decay time (τ_L) and (τ_S). Plotting short decay time to long decay time gives bands corresponding to different particles. The details of the procedure is given in our pervious publication [2]. Since the neutron detector used is sensitive to both gamma and neutrons, so particle identification betweem the two was done using the pulse shape discrimination method. The of flight spectra of neutrons were converted to energy spectra. During offline data analysis, the large angular opening of MWPC was divided into four equal parts to have better angle definations. The alpha and neutron energy spectra so obtained were normalised to the fission events and the solid angle of the detector. Normalised alpha and neurton yield spectra were fitted at various angles using the moving source technique to extact

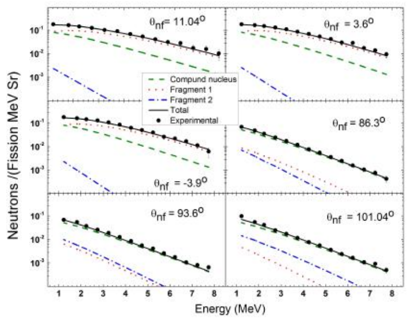

FIG. 2: Normalised neutron multiplicity spectra at 93 MeV, along with fits of moving source formula.

the multiplicities. Neutron and alpha multiplicities were calculated for the three sources: compound nucleus source which is known as pre-scission multiplicity and two fully accelerated fission fragments sources known as post-scission multiplicity using the Watt expression [3]. In case of alpha, fourth source, near scission emission (NSE) was also included. The pre and post-scission contributions for neutrons using moving source along with experimental data at various angle combinations are shown in Fig 2.

Analysis has been done with and without adding delays in JOANNE2 code and it is observed that sufficient fission delay ($\approx$ 50zs) is required to reproduce experimentally obtained neutron and alpha multiplicities simultaneously. The values of multiplicities so obtained are $\alpha_{pre} = (7.20 \pm 0.13) \times 10^{-3}$, $\alpha_{post} = (0.49) \times 10^{-3}$, $\nu_{pre} = (2.30 \pm 0.07)$ and $\nu_{post} = (0.78 \pm .03)$. The temperatures used in the moving source code are T_{pre}=1.46MeV and T_{post}=1.31MeV.

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