Observation of fusion-fission events in ^{19}F + ^{175}Lu system at ≈ 3 MeV/nucleon excitation energies

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Introduction

Nuclear fission has a prominent role in extending the chart of nuclides to super heavy elements, as a terminator of r-process nucleosynthesis in stellar environment, as a source of energy and as a crucial source of mid-mass isotopes to access the part of the nuclear chart at high neutron excess asymmetry. Owing to such huge importance, the phenomenon of heavy-ion induced fission has been extensively studied for various entrance channel parameters [1]. Inspite of considerable theoretical progress, it has so far proven very difficult to explain, within a comprehensive theoretical framework, the evolution of fission or fission-like modes observed [2] for nuclear systems produced with significant transfer of excitation energy, linear and angular momenta, or for nuclei far away from the line of stability [3]. Determining the path followed by the products of a heavy-ion interacting system, in general, and of fission fragments in particular has proven to be a daunting endeavour due to the various possible dynamical paths a heavy-ion reaction can follow. Recently Ghosh *et al.* [4] reported that the behaviour and values of parameters of mass (A) and charge (Z) distributions of the yields of fission fragments as a function of excitation energy act as indispensable probes to map the path followed by the system starting from the reacting nuclei. In a fusion-fission process, the compound nucleus formed via complete and/or incomplete fusion may proceed towards fission depending upon the available excitation energy.

In the present work, 24 ($74 \leq A \leq 133$) fission fragments have been identified and their production cross-sections have been measured at incident projectile energies of 105 and 110 MeV. Some aspects of heavy-ion induced fusion-fission process at low excitation energies have been studied which have important and direct implications on the dynamics of the fusion-fission process.

Experimental Details

The experiments were performed at the Inter University Accelerator Centre, New Delhi using the 15UD pelletron accelerator facility. Beams of ^{19}F with energy 105 and 110 MeV were bombarded on ^{175}Lu (abundance = 97.41%) target foil of thickness ≈ 1.5 mg/cm^2 backed by Al-catcher foils of sufficient thickness. The identification and measurement of production cross-sections were achieved by recoil-catcher activation technique followed by the offline γ-ray spectroscopy of the induced activity in the target sample after the beam irradiation [5]. Further experimental details are given elsewhere [6].

Mass Distribution of Fission Fragments

As a typical example, the measured mass distribution of the fission like residues at 110 MeV is shown in Fig. 1. The distribution is found to be symmetric, broad, single humped and can be fitted with a single Gaussian peak indicating the production of the identified fission products from the fully equilibrated compound nuclear processes (de-excitation of compound nuclei formed in complete fusion and/or incomplete fusion) even at excitation energies as low as ≈ 3 MeV/A. This behaviour of the fission fragment mass distribution is a typical example of the so called fusion-fission reaction. Theoretical considerations of Businaro and Gallone [7] complement the symmetric behaviour of mass distribution of the experimental yields of fission-like residues for the system under study.

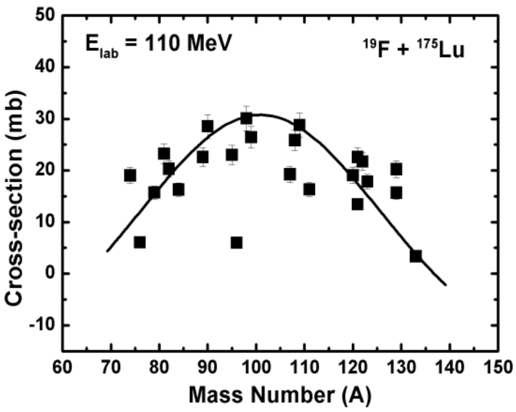

Fig. 1 Measured mass distribution of fission like residues at 110 MeV. The solid line is the Gaussian profile through the data points.

Isotopic and Isobaric Yield Distributions

Isotopic and isobaric yield distributions of the identified isotopes produced as a result of fission have also been studied. They have been found to be well represented by Gaussian functions. The values of the parameters of the isobaric yield distributions are found to be in good agreement with literature values. Also, the values of width parameter ($\boldsymbol{\sigma}_Z$) of isobaric distributions obtained from experiment and by converting the width parameter of isotopic yield ($\boldsymbol{\sigma}_A$) to $\boldsymbol{\sigma}_Z$ by $\boldsymbol{\sigma}_Z = \boldsymbol{\sigma}_A.Z/Ap$ are found to be in good agreement within errors of measurement suggesting the self-consistency [8] of the present analysis. As an example, the isotopic distribution at 110 MeV of four isotopes of Xenon ($^{120, 121, 122, 123}$Xe) is shown in Fig. 2. Further details regarding measurement and analysis will be presented.

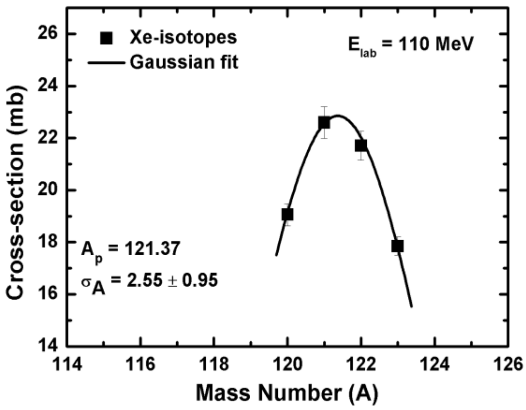

Fig. 2 Isotopic yield distribution of Xe isotopes at 110 MeV. The solid line shows the fitted Gaussian distribution.

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