Fission Fragment Mass Distribution measurement in $^{238}U(^{18}O,f)$ system from γ-spectroscopy studies

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Introduction:

In nuclear fission the shape of the nucleus evolves in the multidimensional space of relative separation, neck opening, mass asymmetry and shape of the fragments [1-3]. Nuclear fission also offers unique conditions to study the interplay of the structure and dynamics of the fissioning nuclei [4]. The fission fragment mass distribution can strongly be influenced by the nuclear shape evolution of the composite system. We have investigated the role of shell closure on the fission fragment mass distribution in obtained $^{238}U(^{18}O,f)$ reaction. The yield of the fragments were determined using the γ-γ coincidence technique.

Experimental details and data analysis:

The experiment was carried out at 15UD IUAC Pelletron facility, New Delhi, using ^{18}O beam of energy 100 MeV to bombard a self supporting ^{238}U target of thickness ~ 15 mg/cm^2. The gamma rays emitted by the fission fragments were detected using Indian National Gamma Array (INGA) comprising of eighteen Compton suppressed Clover detectors, each having intrinsic photo peak efficiency ~ 0.2 [5,6]. The Compton suppressed data were collected in an event-by-event mode with the minimum requirement of three-fold prompt γ-ray coincidence, for which the event rate was 1.6 K/sec with the beam current ~ 3 pnA.

The E_γ-E_γ matrix constructed from the prompt γ coincidence data using RADWARE software. The independent yield of a particular fragment nucleus has been determined from the coincidence of gamma rays of $2^+\rightarrow0^+$ and $4^+\rightarrow2^+$ transitions. The yields of several even-even isotopes, $^{90-96}$Sr, $^{96-102}$Zr, $^{98-108}$Mo, $^{104-112}$Ru, $^{108-116}$Pd, $^{114-122}$Cd, $^{116-128}$Sn, $^{124-134}$Te, $^{130-138}$Xe, $^{136-144}$Ba, $^{142-148}$Ce, $^{146-152}$Nd and $^{150-158}$Sm have been determined from the γ-γ coincidence matrix as shown in Fig.1. It is observed that the isotopic yield of the fragments follow a bell shape distribution, which implies that the yield of a particular fragment depends on the N/Z ratio.

Results and discussions:

The fission fragment mass distribution is obtained by adding the yields of various nuclei corresponding to a particular mass as shown in Fig. 2. It is found that the fragment mass distribution is symmetric about ^{124}Sn (half of the compound nuclear mass is $A_{CN}/2=128$) and the missing mass is due to the evaporation of 8 neutrons. We also observe some dips in the mass distribution curve, corresponding to fragment masses A=112, 124, and 136, where the yield is significantly reduced. In an earlier measurement Bogachev *et al.* reported the mass distribution of the fission fragments for the $^{208}Pb(^{18}O,f)$ [7]. Comparing their results with the present work, it is observed that the dips at the closed shell nuclei for A=124 (Z=50 shell) and for A=136 (N=82 shell) are seen in both cases. The other dips at A=112 in the present work and at A=84 and 98 for ^{208}Pb (^{18}O,f) system [Ref. 7], are due to the complementary fragment masses of A= 124 and 136 fragments. It is clearly evident that the structures/dips in the mass distribution is because of these A= 124 and 136 closed shell nuclei.

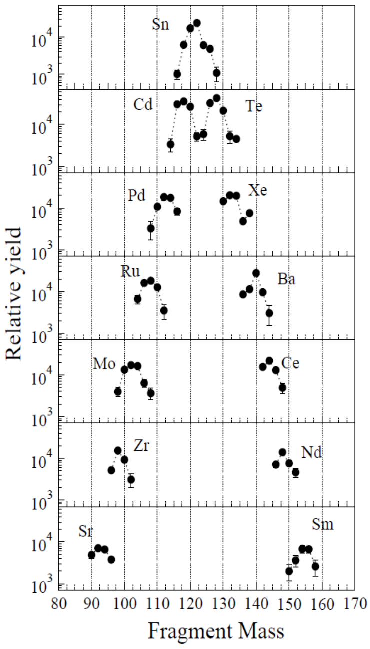

Fig. 1. Relative yield distribution of various fission fragments produced in ^{18}O+^{238}U reaction.

In the present analysis, the reduction in the fragment mass yield due to the presence of long lived isomeric states has been corrected from the known lifetime and intensity data; except for the Sn isotopes due to the lack of detailed spectroscopic information. In some nuclei, the side-bands directly feeding to the 2^+ state of the g.s. band are populated with significant intensity and their contribution is excluded in the yield determination, if we consider only coincidence between $2^+\rightarrow0^+$ and $4^+\rightarrow2^+$ transitions. After incorporating the above corrections the fission fragment mass distribution obtained for the even-even fission fragments is shown in Fig.2. The average behavior of the mass distribution is found to be in agreement with the systematics of the energy dependent mass width measured for ^{16}O+^{238}U system [8]. The calculations were done for the thick target, after averaging the mass distributions over the energy range by weighing the cross sections obtained using the CCFUS code. The width of the theoretically calculated mass distribution is obtained to be about $\sigma_M \approx 20.5$ amu, which compares well with the overall experimental mass distribution as shown by dashed line in Fig. 2.

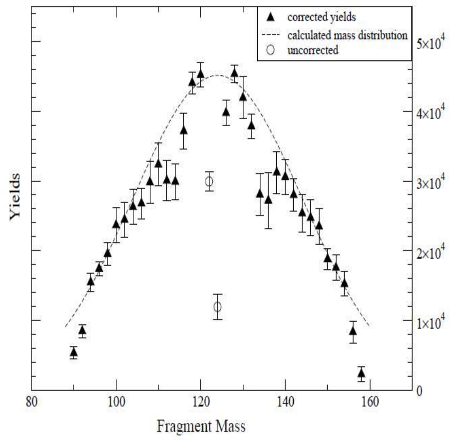

Fig. 2. Fission fragment mass distribution produced in ^{18}O+^{238}U along with calculations, (dashed line).

In summary, the fission fragment yield distribution in ^{238}U (^{18}O, f) system has been measured by employing the γ-γ coincidence technique. Fine structure dips are observed in the mass distribution, which seem to be related to the shell closure of the individual fission fragment nuclei for Z=50 and N=82 shells, where the yields are depleted. We interpret the fine structure dips in the mass yields to be due to "shape inhibition" of close shell fragment nuclei at the scission point.

Acknowledgement: We acknowledge the support and help of pelletron operation staff and Electronics group of IUAC, New Delhi. We also thank T. Trivedi, G. Jnaneswari, D. Negi and Kumar Raju for their contribution during the experiment.

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