Mass resolved angular distribution of fission products in ^{20}Ne+^{232}Th reaction

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Introduction

Fission fragment angular distribution is a sensitive probe to investigate the contribution from non-compound nucleus fission. Investigation of the contribution from non-compound nucleus fission for systems with low $Z_P Z_T$ (Z_P and Z_T are the atomic number of projectile and target respectively) has been an active area of study in the recent past. For compound nucleus fission, anisotropy of fission fragment angular distribution can be estimated from the statistical theory [1,2]. In the case of non-compound nucleus fission, fission occurs before complete equilibration of *K*-degree of freedom, leading to larger angular anisotropy compared to that calculated using statistical theory [1,2] Pre-equilibrium fission model of Ramamurthy and Kapoor [3,4] and entrance channel dependent (ECD) *K*-state model by Vorkapic and Ivanisevic [5] were proposed to explain the anomalous fission fragment angular distribution for the systems having contribution from non-compound nucleus fission. Hinde et al. [6] explained anomalous fission fragment angular distribution in ^{16}O+^{238}U reaction using orientation dependent quasi-fission model. For reaction systems forming heavy composite system (A~>250), significant contribution from non-compound nucleus fission may be present due to the compact saddle point as well as small fission barrier. In addition to the contribution from pre-equilibrium fission in ^{16}O+^{232}Th reaction, Vorkapic and Ivanisevic observed a dependence of angular anisotropy on asymmetry of mass division, which was attributed to the difference in symmetric and asymmetric fission barriers [7]. Mass asymmetry dependence of angular anisotropy in ^{16}O+^{232}Th reaction was also observed by John et al. [8].

In the present work, mass resolved angular distribution of fission products was measured in ^{20}Ne+^{232}Th reaction at E_{lab}=120 MeV (E_{cm}/V_B=1.09, where E_{cm} is the projectile energy in centre of mass frame and V_B is the entrance channel Coulomb barrier. Angular distribution of fission products has been measured by off-line radiochemical method involving recoil catcher technique followed by off-line gamma-ray spectrometry.

Experimental

Experiments were carried out at VECC, Kolkata, India. Self-supporting target of ^{232}Th having thickness 2.86 mg/cm^2 was placed at 45° with respect to the beam direction and bombarded with 145 MeV ^{20}Ne beam. A super pure aluminium foil of thickness 3.38 mg/cm^2 was placed before the target so that the average energy in the target was 120 MeV. For the measurement of fission product angular distribution, a cylindrical irradiation chamber of length 135 mm and inner diameter of 155 mm was used. Aluminium catcher foil of thickness 6.75 mg/cm^2 was mounted on the inner wall of the cylinder covering an azimuthal angle of 180° and θ_{lab} from 90° to 30°. In the forward direction catcher foil was placed on the inner flat surface of the front cover of the chamber covering θ_{lab} from 30° to 0.3°. Irradiation was carried out for about 36 hrs. After the irradiation, the catcher foils were removed and cut into different strips with an average angular width of about 9°. The strips of catcher foils corresponding to different laboratory angles were folded to same geometry and assayed for the gamma ray activity of various fission products using a HPGe detector coupled to a multi-channel analyzer.

Results and Discussion

In the gamma-ray spectra, fission products were identified by their characteristic gamma-rays. From the peak areas under the characteristic gamma-rays, yield of fission products in different strips were determined, which were divided by the solid angle subtended by the strip 'π [$cos(\theta_{1\ lab})$-$cos(\theta_{2\ lab})$]' to obtain lab angular distributions of different fission products. The laboratory angular distributions were transformed into the center of mass frame of reference assuming full momentum transfer to the compound nucleus, and using kinetic energies calculated using the prescription of Rossener *et al.* [9]. Fig. 1 shows centre of mass (CM) angular distributions of some of the fission products, obtained in our preliminary analysis. In order to deduce the angular anisotropy 'W(0)/W(90)', CM angular distributions were fitted using statistical theory expression [1] with the K_0^2 (K_0^2 is the variance of K distribution, K being the projection of total angular momentum J along the symmetry axis) as a free parameter. Fitted curves are shown as solid lines in Fig. 1. Angular anisotropies deduced from the fitted curves are shown in Fig. 2. Solid line in Fig. 2 shows the error weighted average. Average anisotropy was obtained as 2.11±0.11, which was higher than the value of 1.44 calculated using statistical theory, obtained without including the coupling of excited states of projectile or target. A signature of the rise in anisotropy near symmetry, as observed earlier in $^{16}O+^{232}Th$ reaction [7,8] can also be seen in Fig. 2. However, conclusive information on this aspect requires detailed analysis of angular distribution data including more fission products, which is under progress. The results on experimental anisotropies will be compared with statistical theory calculations using fusion *l*-distribution obtained from coupled channel calculations.

In conclusion, mass resolved angular distribution of fission products was measured in $^{20}Ne+^{232}Th$ reaction at beam energy of 120 MeV. A preliminary analysis of the angular distribution data of fission products shows higher average anisotropy compared to that calculated using statistical theory. A signature of rise in anisotropy near symmetry, as reported in earlier studies in literature, is also seen. Further study is in progress to get more detailed information about the contribution from non-compound nucleus fission and dependence of angular anisotropy on asymmetry of mass division.

References

[1] R. Vandenbosch and J. R. Huizenga, *Nuclear Fission* (Academic Press, 1973) London.

[2] I. Halpern and V. M. Strutinsky, in *Proceedings of the Second United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, 1958*, Vol. 15, p. 408.

[3] V. S. Ramamurthy and S. S. Kapoor, Phys. Rev. Lett. **54**, 178 (1985).

[4] V. S. Ramamurthy et al., Phys. Rev. Lett. **65**, 25 (1990).

[5] D. Vorkapic and B. Ivanisevic, Phys. Rev. C 52, 1980 (1995).

[6] D. J. Hindeet al., Phys. Rev. Lett. **74**, 1295 (1995).

[7] D. Vorkapic and B. Ivanisevic, Phys. Rev. C 55, 2711 (1997).

[8] B. John et al., Phys. Rev. C 51, 165 (1995).

[9] H. H. Rossner, J. R. Huizenga, and W. U. Schröder, Phys. Rev. Lett. **53**, 38 (1984).

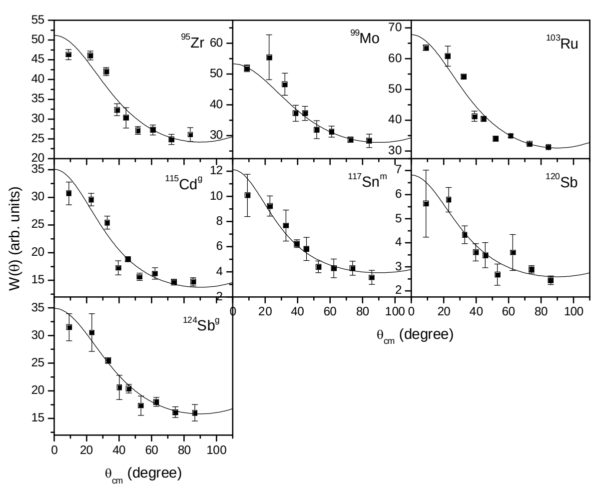

Fig. 1. Plot of centre of mass angular distributions of fission products in $^{20}Ne+^{232}Th$ at E_{lab}=120 MeV

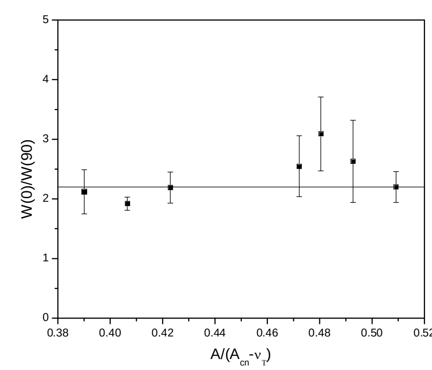

Fig. 2. Plot of angular anisotropy as a function of asymmetry of mass division for $^{20}Ne+^{232}Th$ reaction at E_{lab}=120 MeV. 'A' represents fission product mass number, A_{cn} is the compound nucleus mass number and ν_T is the number of fission neutrons