Fission fragment mass distributions at high excitation energies for $^{16,18}O+^{194,198}Pt$ Systems

Rohit Sandal[1]*, B.R. Behera[1], Varinderjit Singh[1], A. Kumar[1], G. Singh[1], K.P. Singh[1], S. Mandal[2], S. Kalkal[2], D. Siwal[2], M. Saxena[2], S. Goyal[2], E. Prasad[3], P. Sugathan[4], A. Jhingan[4], K.S. Golda[4], R.P. Singh[4], R.K. Bhowmik[4], M.B. Chatterjee[4], K. Mahata[5], S. Santra[5], A. Saxena[5]

[1]*Department of Physics, Panjab University, Chandigarh -160014, INDIA.*
[2]*Department of Physics and Astrophysics, University of Delhi – 110007, INDIA.*
[3]*Department of physics, University of Calicut, INDIA*
[4]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA.*
[5]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai, - 400085, INDIA.*
** email: rohit1sept@yahoo.co.in*

Introduction

Fission fragments mass distributions in a fusion-fission reaction is a sensitive probe to understand the reaction mechanism and the dynamics involved in the fission process. In general, in fusion-fission reaction, the width of the fragment mass distributions depends on the temperature available at the scission point, fissility of the compound nucleus and the average angular momentum $<l^2>$[1,7]. Broader mass distribution is observed for systems involving heavy projectiles ($A_P \geq 20$), product of the charges $Z_t*Z_P \geq 1600$ and high bombarding energy [2]. Such observations are explained by quasi-fission phenomena which takes place for a composite system in which the unconditional saddle point (fission barrier) shape is more compact than the entrance channel contact configuration. Recently fission fragment anisotropy data obtained for lighter projectile ($A_p \leq 20$) induced reaction on actinide targets could not be explained by statistical transition state model. Hinde et al, have provided an explanation based on orientation dependent quasi-fission model involving deformed targets [3]. They have also proposed a wider mass distribution for such process. In another recent study Berrimann et al. [4], observed quasi-fission process even for systems $^{19}F+^{197}Au$ ($Z_t*Z_p<1600$). It is interesting to extend the study of mass distributions for less fissile target projectile combinations (having larger fission barrier) to understand the saddle to scission dynamics in the fission process. We have carried out measurements of the mass distribution in the above barrier energies for $^{16,18}O+^{194,198}Pt$ systems. The experimental results along with the existing data in the literature [5,6] for $^{12}C+^{183}W$, $^{12}C+^{198}Pt$, $^{12}C+^{197}Au$, $^{16}O+^{198}Pt$, $^{16}O+^{197}Au$ and $^{16}O+^{181}Ta$ are analyzed in a similar way. All the above systems are less fissile (fissility range 0.74 to 0.79), Z_t*Z_p values less than 700 and large mass asymmetry (α) in the entrance channel (α range 0.830 to 0.933). All the targets involved in the present analysis are also deformed.

Experimental Arrangement

The experiments were carried out at IUAC (New Delhi), using pulsed beams of ^{16}O (E_{Lab}=118, 110, 109.1 and 101.7 MeV) and ^{18}O (E_{Lab}=120, 115, 112.5 and 108 MeV) from the 15UD Pelletron plus first module of super-conducting linear accelerator (LINAC). The targets ^{194}Pt and ^{198}Pt were of thickness 530μg/cm^2 and 1.45 mg/cm^2 respectively. Fission fragments were detected by a pair of large area Multi-wire proportional counter (MWPC) (5”x3”) kept at fission fragment folding angle at a distance of 24 cm from target position. Two silicon surface barrier detectors were placed at ±16° out of plane for normalization purpose. The trigger of data acquisition was generated by logical OR of cathode signal of two MWPC further ANDed with RF of the beam pulse. The masses of the fission fragments were determined from the angles (θ, Φ) and TOF information obtained from the experiment using the following expression.

$$m_1=[(t_1-t_2)+\delta t_o+m_{CN}(d_1/d_2)] / (d_1/p_1+d_2/p_2)$$

Where, t_1, t_2 are the flight times of the fragments FF_1 and FF_2, over flight paths d_1 and d_2 respectively. These flight paths (d_1 and d_2) were determined from the distances from target to fragments in detectors, MWPC1 and MWPC2. The momentum of the fragments are p_1 and p_2 in the laboratory frame. δt_0 is the machine delay between the two anode pulses. The mass resolution determined from the elastic data in the forward MWPC comes out to be about 6 mass units.

Results and discussion

The mass distributions at all energies are found to be symmetric and can be fitted with a single Gaussian (as shown by solid line in Fig. 1), with peak close to the half of the combined target-projectile mass.

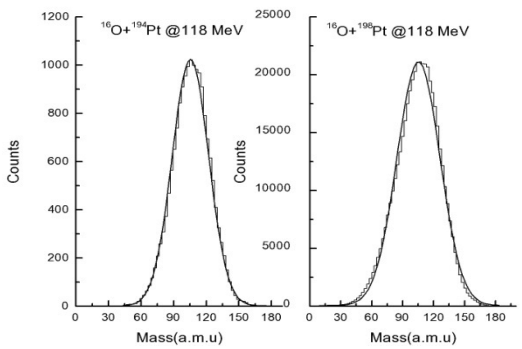

Fig.1 Mass distribution results for $^{16}O+^{194}Pt$ and $^{16}O+^{198}Pt$ systems.

The variation of width of the mass distributions for the measured four reactions (along with various measurements from the literature [5,6]) with excitation energies is shown in Fig-2. The variance of mass distribution was observed to be 14 to 16 mass units for $^{16}O+^{194}Pt$ systems. This observation is consistent with the systematics reported by Sawant et al. [7]. However, the corresponding measured mass distribution for targets involving ^{198}Pt is 4 to 5 mass units higher compared to targets involving ^{194}Pt. This discrepancy is perhaps due the large uncertainty in the time of flight for the thick ^{198}Pt target (1.45 mg/cm^2) used in the experiment. The mass width for $^{18}O+^{194}Pt$ is less compared to $^{16}O+^{194}Pt$ at same excitation energy. It may be due to the larger fissility involved in the $^{16}O+^{194}Pt$. A statistical model estimate for the variance of mass distribution at the scission point was performed starting from the energy and temperature available at the scission point and assuming decay from a fully equilibrated system. A linear dependence of temperature was assumed.

The solid line in the Fig 2.corresponds to the mass distribution obtained from scission

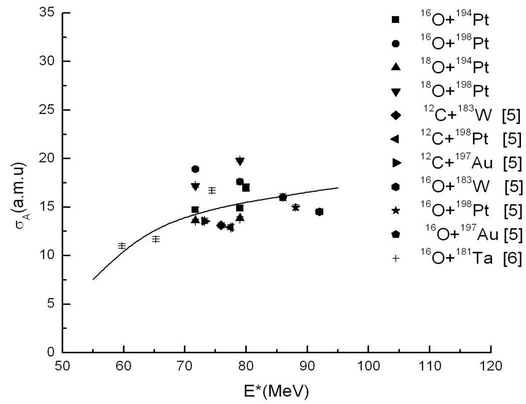

Fig 2. The standard deviation of the mass distribution for fission fragments is shown as a function of excitation energy. Solid line is the the scission point model estimate for $^{16}O+^{194}Pt$ system (see text).

point model for the system $^{16}O+^{194}Pt$. In the scission point model variance of mass distribution is directly proportional to the scission temperature. Our measured mass width for $^{16,18}O+^{194,198}Pt$ system and the results of the analyzed data from the literature are consistent with the estimates from the scission point model. We feel the absence of quasi-fission processes in the systems studied by us is due to relatively large above barrier energies involved (according to Hinde et al. [3] the quasi-fission effect is very pronounced at sub-barrier energies and progressively less important at above–barrier energies) and also they have relatively smaller Z_t*Z_p values (<700) (compared to the Z_t*Z_p values(>1600) for the cases where quasi-fission was reported [2]).

References

[1] R.K. Choudhury et al, Phys. Rev C 60 054609 (1999).

[2] B. B. Back et al, Phys. Rev. C53, 1734 (1996).

[3] D. J. Hinde et al, Phys. Rev. Lett. 74, 1295(1995)

[4] A. C. Berriman et al, Nature (London) 413, 144 (2001).

[5] M. G. Itkis et al, Yad. Fiz, 52, 23, (1990)

[6] B.R. Behera, Ph.D. Thesis, 2002,Utkal university (Unpublished).

[7] Y.S. Sawant et al, Phys. Rev C70 051602(R) (2004).