Effect of different entrance channels on neutron multiplicity measurement

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Introduction

Since the discovery of fission, there has been significant interest in studying heavy-ion-induced nuclear fusion-fission reactions and the impact of entrance channels [1-6]. Nuclear fission is a highly complex and dynamic process that remains incompletely understood due to the large-scale collective rearrangement of nucleons involved. Extensive theoretical research and experimentation have been conducted to gain a deeper understanding of the fission process, particularly from the saddle point to the scission of fission fragments. When a projectile is captured by the target nucleus, the formation of the compound nucleus takes place in an excitation state. Various probes have been employed to study nuclear fission, including the mass and total kinetic energy distribution of fission fragments, angular distribution, neutron multiplicity, giant dipole resonance (GDR) γ-ray multiplicity, and light-charged particle multiplicities. Among these methods, neutron multiplicity is particularly widely used in the study of nuclear fusion-fission dynamics as neutrons do not face any coulomb barrier by their neighboring nucleons. Many experimental and theoretical studies have been carried out for neutron multiplicity measurement in the past which shows that different entrance channel parameters such as excitation energy of compound nucleus, entrance channel mass asymmetry, N/Z ratio of compound nucleus, charge symmetry, shell effect, etc. influence the neutron multiplicity. Neutron multiplicity increases as we increase the excitation energy as well as the N/Z ratio of the compound nucleus. It has been observed that for the symmetric reaction the value of neutron multiplicity is larger as compared to the asymmetric reaction [7-9].

In the present work, we have investigated the effect of even-even and even-odd projectile target combinations on neutron multiplicity measurement for ^{210,211,212}Rn compound nuclei. For this study, we have taken the neutron multiplicity data of ^{210,212}Rn from the literature and calculated the neutron multiplicity for ^{211}Rn using systematic and VECSTAT for the reaction $^{14}N + ^{197}Au \rightarrow ^{211}Rn$.

Theoretical Study

We have done a comparative study of the impact of even-even and even-odd projectile target combinations on neutron multiplicity. For this purpose, we have selected the neutron multiplicity data taken from two different experiments populating the ^{198}Pb and ^{197}Tl [10,11] for the same energy range for the mass region of approximately 200.

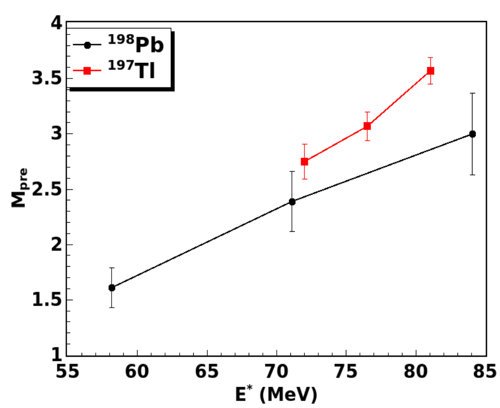

Fig. 1 Comparison of neutron multiplicities of ^{198}Pb and ^{197}Tl.

Motivated by this finding we want to study the effect of even-even and even-odd projectile

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target combinations on neutron multiplicity measurement. For this purpose, we have chosen even-odd projectile target combinations as-

$$^{14}N + ^{197}Au \rightarrow ^{211}Rn$$

We compared this reaction with already published data of ^{210}Rn and ^{212}Rn [12]. The theoretical calculation of neutron multiplicity for ^{211}Rn is done employing the nuclear code VECSTAT and systematics. In figure 2 we have presented the neutron multiplicities for the $^{210,211,212}Rn$ compound nucleus.

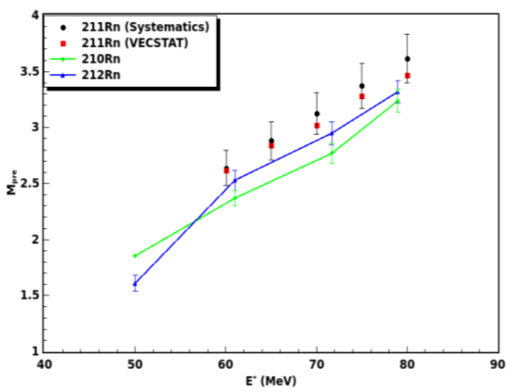

Fig. 2 Neutron multiplicity data for $^{210,211,212}Rn$.

Systematics

The pre-scission neutron multiplicity (M_{pre}) is derived from the systematic approach [13].

$$\widetilde{E^*} = E^* + \delta W$$

Where, first term is the liquid-drop excitation energy, E^* is the excitation energy, and δW is the shell correction which is a function of Z and A. The M_{pre} is described by the following expression:

$$M_{pre} = -10.64+0.0979A-0.0154\widetilde{E^*}-0.000234A^2 +0.000305A\widetilde{E^*}$$

Table 1: Calculated neutron multiplicity of $^{14}N + ^{197}Au \rightarrow ^{211}Rn$ using VECSTAT and Systematics

E_{lab} (MeV)	E^* (MeV)	M_{pre} VECSTAT	M_{pre} by Kozulin Systematics
85.20	60.03	2.617	2.6366
90.55	65.02	2.841	2.8814
95.90	70.02	3.023	3.1261
101.25	75.01	3.284	3.3709
106.60	80.01	3.467	3.6157

Conclusion

Our study reveals that entrance channels significantly influence fission reaction dynamics. We observed that neutron multiplicity increases with the excitation energy of the compound nucleus. As shown in Figures 1 and 2, neutron multiplicity is higher for odd-mass compound nuclei formed by even-odd or odd-even combinations of projectile and target, compared to even-mass compound nuclei. This highlights the importance of experimentally investigating the effects of odd-even and even-even projectile-target combinations.

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