Cross-section measurement of complete and incomplete fusion reactions

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The incomplete fusion (ICF) reaction is a very promising tool for the spectroscopic studies of nuclei close to the β-stability line. The theoretical understanding indicates the good cross-section of ICF at the beam energy much higher than the Coulomb barrier energy [1]. The aim of our present study was to find the absolute cross-section of the ICF residues just above the Coulomb barrier energies and to understand theoretically the ICF reaction mechanism.

We performed two experiments to measure the cross-sections of the residues formed through the complete fusion (CF) and the incomplete fusion (ICF) reactions, $^{10, 11}$B + $^{122, 124}$Sn. The irradiations were done using the Pelletron accelerator at Tata Institute of Fundamental Research. The cross-section measurements were performed offline by determining the intensities of the decaying γ-transitions. All the residues with lifetimes more than 3 min were studied. These were ^{128}I (24.9 min), ^{126}I (12.9 d), ^{128}Cs (3.6 min), ^{123}I (13.2 hr), ^{124}I (4.1 d), ^{127}Cs (6.3 hr), ^{122}Sb (2.7 d), ^{129}Cs (32.1 hr), ^{130}Cs (29.2 min), ^{126}Sb (19.2 min).

The preliminary experimental results were presented in an earlier DAE symposium [2]. Here we present our data analysis for the reaction ^{10}B + ^{124}Sn at the beam energy of 64 MeV, as an example. Although there were many residues formed in this reaction, we discuss the determination of the absolute cross-sections of ^{128}Cs and ^{128}I, both decaying to ^{128}Xe via EC decay ($T_{1/2}$ = 3.62 m) and β^- decay ($T_{1/2}$ = 24.9 m), respectively (shown in the inset of Fig.1). The total area of the gamma peak of energy 443 keV ($2^+ \rightarrow 0^+$) belonging to ^{128}Xe consisted of two parts, for the decay of ^{128}I and ^{128}Cs. Denoting σ_1 and σ_2 as the values of cross-section for ^{128}Cs and ^{128}I, respectively,

Area = P1×σ_1 + P2×σ_2,

$$\mathrm{P1} = \frac{N_T}{\lambda_1} a_{\gamma_1} \varepsilon_\gamma I (1 - e^{-\lambda_1 T})(e^{-\lambda_1 t_1} - e^{-\lambda_1 t_2})$$

$$\mathrm{P2} = \frac{N_T}{\lambda_2} a_{\gamma_2} \varepsilon_\gamma I (1 - e^{-\lambda_2 T})(e^{-\lambda_2 t_1} - e^{-\lambda_2 t_2})$$

Here,

N_T ≡ Number of the target nuclei per unit volume,

ε_γ ≡ Efficiency of the detector at 443 keV,

I ≡ Beam current,

T ≡ Irradiation time,

t_1 ≡ Start time of data acquisition,

t_2 ≡ Stop time of data acquisition,

λ_1 ≡ Decay time constant for ^{128}Cs,

λ_2 ≡ Decay time constant for ^{128}I,

a_{γ_1} ≡ Gamma-ray branching intensity via EC,

a_{γ_2} ≡ Gamma-ray branching intensity via β^-.

In Fig.1, we plot the ratio Area/P2 against the ratio P1/P2. The data points correspond to different values of t_1 and t_2. From the straight line fit to the data points we obtained the cross-section values σ_1 = 213 ± 3 mb for ^{128}Cs and σ_2 = 9.4 ± 0.8 mb for ^{128}I.

In Fig. 2, the absolute cross-section values are plotted at different beam energies. Since ^{128}Cs is formed via complete fusion reaction, the experimental results are compared with the theoretical calculation using the computer code PACE. There is a large disagreement which we are currently investigating.

References

[1] G. D. Dracoulis *et al.*, J. Phys. G : Nucl. Part. Phys. 23, 1191 (1997).
[2] S. R. Meher *et al.*, Proceedings of the DAE Symposium, 47B, 282 (1004).

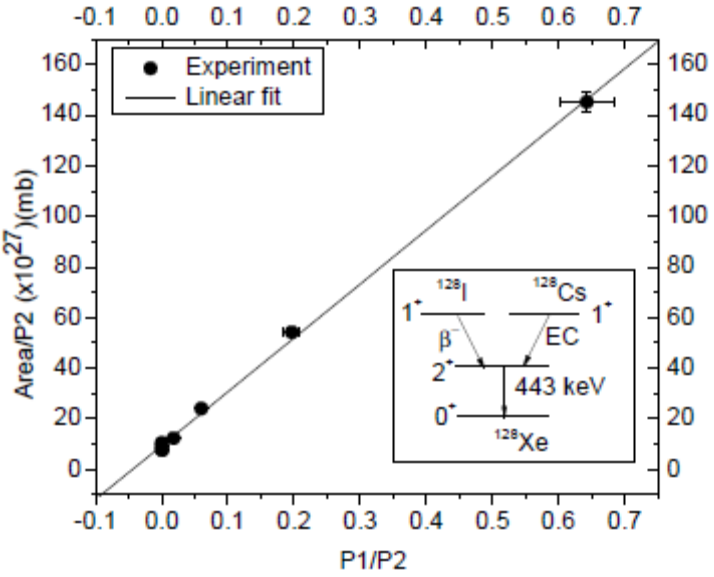

Fig. 1 Linear Plot of Area/P2 vs P1/P2, slope gives cross section of ^{128}Cs (σ_1) and intercept that of ^{128}I (σ_2)

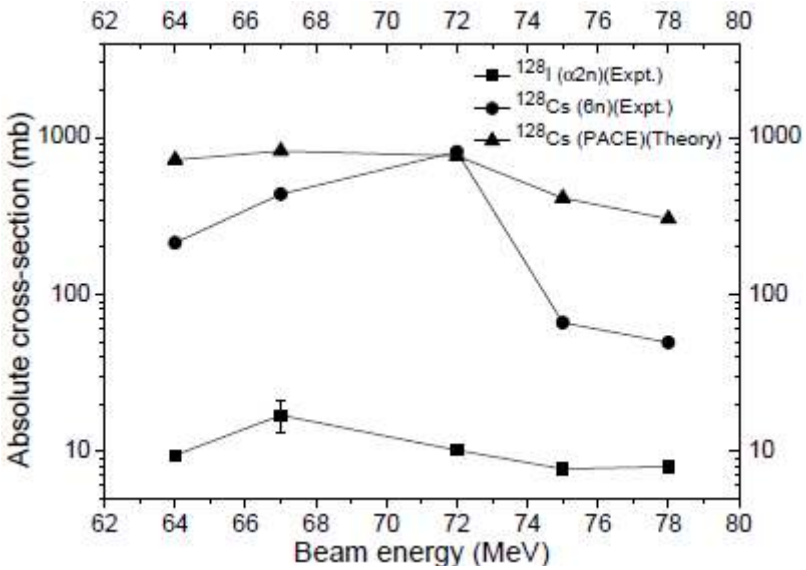

Fig. 2 Excitation function of ^{128}Cs and ^{128}I, former is compared with PACE calculation