ER excitation function from fusion of ^{19}F with ^{184}W

S. Nath[1,2,*] J. Gehlot[1], E. Prasad[3], Gayatri Mohanto[1], Sunil Kalkal[4], Jhilam Sadhukhan[5], P.D. Shidling[6], K.S. Golda[1], A. Jhingan[1], P.V. Madhusudhana Rao[2], N. Madhavan[1], S. Muralithar[1], A.K. Sinha[7], and Santanu Pal[5]
[1] *Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India*
[2] *Department of Nuclear Physics, Andhra University, Visakhapatnam 503003, India*
[3] *Department of Physics, Calicut University, Calicut 673635, India*
[4] *Department of Physics and Astrophysics, Delhi University, Delhi 110007, India*
[5] *Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata 700064, India*
[6] *KVI, Zernikelaan 25, NL 9747 AA, Groningen, The Netherlands and*
[7] *UGC-DAE CSR, Kolkata Centre, 3/LB-8, Bidhan Nagar, Kolkata 700098, India*

Shells in nuclei play a central role in determining their shapes, sizes and stability. The predicted existence of superheavy elements (SHE) rely solely upon the stabilizing effects of nuclear shells against spontaneous fission. It is of interest to investigate whether shell closure favours the survival of evaporation residues (ERs) against fission. Since the formation cross sections of nuclei in the SHE region is prohibitively small (< 1 pb), it is practically impossible to study the reaction mechanism in this mass region within the prevailing limit of experimental sensitivity. However, one can study the reaction mechanism near the heaviest doubly magic spherical nucleus available in nature, *viz.* $^{208}_{82}Pb_{126}$.

D. Vermeulen *et al.* [1] carried out the first comprehensive study of the stabilizing effect of $N = 126$ spherical shell against fission competition. The results, however, revealed surprisingly low stabilizing influence on the ER survival probability. It has also been speculated earlier [2] that the $Z = 82$ shell closure might enhance the survival probability of the resulting compound nucleus (CN), from fusion between two heavy ions, in the form of ERs against fission.

We have measured ER excitation function for the system $^{19}F +^{184} W$ leading to the formation of $^{203}Bi^*$, which has one extra proton beyond $Z = 82$ shell closure. The experiment was performed at the 15UD Pelletron accelerator facility of IUAC. Pulsed ^{19}F beam with 4 μs pulse separation was incident onto a 210 $\mu g/cm^2$ ^{184}W target with 110 $\mu g/cm^2$ carbon backing. ER measurements were performed at beam energies (E_{lab}) in the range of 79 - 130 MeV. ERs were separated from intense primary beam background by the Heavy Ion Reaction Analyzer (HIRA) [3] and transported to its focal plane. HIRA was operated at 0° w.r.t. the beam with full acceptance (10 msr). Two silicon detectors were installed inside the sliding-seal scattering chamber at ±24° to measure Rutherford scattered beam particles. A 35 $\mu g/cm^2$ carbon foil was placed 10 cm downstream from the target to reset the charge state of ERs. At the focal plane of HIRA, a two-dimensional position-sensitive silicon detector with active area of 50 mm × 50 mm was used to detect ERs. Time of flight (TOF) of the slowly moving ERs over the flight path of HIRA (8.82 m) was recorded. The ERs were unambiguously identified in the two-dimensional plot of energy vs TOF.

For measuring transmission efficiency of ERs through HIRA (ϵ_{HIRA}), an HPGe detector was mounted at the target chamber. Characteristic γ-rays from ERs were recorded in singles and in coincidence with ERs at $E_{lab} =$ 99.2 MeV. At all other energies and for different xn-evaporation channels, we calculated ϵ_{HIRA} by the semimicroscopic Monte Carlo code TERS [4, 5].

The total evaporation residue cross section

*Electronic address: subir@iuac.res.in

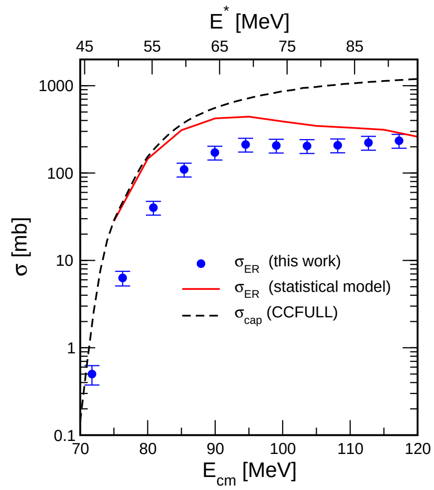

FIG. 1: Measured ER excitation function for the reaction $^{19}F+^{184}W$. Total ER cross sections, predicted by standard statistical model calculation and capture cross sections calculated by CCFULL [7] are also shown.

was calculated by the following relation

$$\sigma_{ER} = \frac{Y_{ER}}{Y_{norm}} (\frac{d\sigma}{d\Omega})_{Ruth} \Omega_{norm} \frac{1}{\epsilon_{HIRA}} \quad (1)$$

where Y_{ER} is the number of ERs detected at the focal plane of HIRA, Y_{norm} is the number of scattered beam particles detected by any of the normalization detectors, $(\frac{d\sigma}{d\Omega})_{Ruth}$ is the differential Rutherford scattering cross section in the laboratory system and Ω_{norm} is the solid angle subtended by any of the normalization detectors.

Here we must mention that the presence of longer half-lives ($\sim$20 ns or more) isomeric states in ERs might affect the transmission of ERs through HIRA. However, the actual uncertainty in ER transmission will depend on several factors *viz.* γ-ray energy, multipolarity and the branching to the isomer. Careful scrutiny of these factors rules out significant addition of uncertainty in ϵ_{HIRA} due to the presence of isomers [6].

The measured excitation function and the result of statistical model calculation are shown in Fig. 1. The spin distribution of the CN is determined from the capture cross-section (σ_{cap}) which is obtained from CCFULL [7]. Fission, light particle (n, p and α) evaporation and GDR γ-emission are considered as the decay channels of the CN in the statistical model calculation. The fission width given by the transition-state model [8] is used in the calculation while the particle and GDR-γ partial decay widths are obtained from the standard Weisskopf formula [9]. No dissipative fission dynamics are considered here. The calculated σ_{ER} are found to be several times larger than the experimental values around and above the Coulomb barrier ($\sim$77.8 MeV). One would expect σ_{ER} to constitute a major fraction of σ_{cap} in the above energy range for the ^{203}Bi nucleus ($B_f = 11.3$ MeV for $l = 0$). The results thus indicate an inconsistency between the magnitudes of σ_{cap} used in the calculation and the measured σ_{ER}. Reduction in σ_{ER} might be attributed either to fusion inhibition in the entrance channel or to lowering of B_f in the exit channel. We are in the process of comparing measured σ_{ER} with the same from several other neighbouring systems with similar entrance channel mass asymmetry to understand our observation.

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