PHYSICAL REVIEW C **101**, 024611 (2020)

Evaporation residue measurements of compound nuclei in the $A \approx 200$ region

P. Jisha,[1,*] A. M. Vinodkumar,[1] B. R. S. Babu,[1] S. Nath,[2] N. Madhavan,[2] J. Gehlot,[2] A. Jhingan,[2] T. Banerjee,[2,†] Ish Mukul,[2,‡] R. Dubey,[2,§] N. Saneesh,[2] K. M. Varier,[3] E. Prasad,[4] A. Shamlath,[4] P. V. Laveen,[4] and M. Shareef[4]
[1]*Department of Physics, Calicut University, Calicut 673 635, India*
[2]*Nuclear Physics Group, Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India*
[3]*Department of Physics, University College, Palayam, Thiruvananthapuram 695034, Kerala, India*
[4]*Department of Physics, School of Physical Sciences, Central University of Kerala, Kasaragod 671316, India*

(Received 12 November 2019; accepted 24 January 2020; published 27 February 2020)

Background: The onset of a noncompound nuclear fission (NCNF) process such as quasifission was already predicted for heavy symmetric systems with the charge product greater than 1400. However, quasifission is observed indeed in very asymmetric reactions forming ^{216}Ra with much lower charge product($\approx$700). A comprehensive idea about the dependence of quasifission on entrance channel mass asymmetry with smaller charge product is still missing. A clear understanding is vital in the production of superheavy elements.
Purpose: To investigate limiting value of mass asymmetry near the Businaro-Gallone point where the fusion probability starts to deviate from unity.
Method: Evaporation residue (ER) cross sections were measured for $^{16,18}\mathrm{O} + {}^{181}\mathrm{Ta}$ reactions at $E_{\mathrm{lab}} = 68$–110 MeV using a recoil mass spectrometer and compared with coupled-channel and statistical model calculations.
Results: Below the Coulomb barrier region, coupled channel calculations reproduced the excitation functions of both $^{16,18}\mathrm{O} + {}^{181}\mathrm{Ta}$ reactions. Further, statistical model calculations with the same fission barrier scaling factor $k_f = 0.95$ reproduced the experimental ER cross-section energies above the Coulomb barrier.
Conclusions: We do not observe any significant signature of fusion suppression in ER excitation functions of $^{18}\mathrm{O} + {}^{181}\mathrm{Ta}$ reaction, in comparison with that of $^{16}\mathrm{O} + {}^{181}\mathrm{Ta}$. This may be attributed to the high resemblance in mass asymmetry and other structural properties of these systems. A fission barrier scaling factor, $k_f = 0.95$ used in the statistical model calculations for both systems, explains the experimental ER and fission cross sections, indicating the absence of any NCNF.

DOI: 10.1103/PhysRevC.101.024611

I. INTRODUCTION

Measurement of evaporation residue (ER) cross sections is one of the principal methods to investigate the fusion suppression observed in heavy systems. Prior understanding of the causes of the fusion hindrance from heavy-ion reactions is crucial in superheavy element (SHE) production [1,2]. The ER measurements in the $A \approx 200$ region may allow us to find the triggering point of noncompound nuclear fission (NCNF) reactions and further help in explaining the reasons for fusion hindrances [3–6].

Fusion reactions near and below the Coulomb barrier region are extensively studied and interpreted in terms of coupling of relative motions of colliding nuclei with various internal degrees of freedom, such as static deformation, collective surface vibrations, transfer channels, etc. [7]. However, the barrier penetration model properly coupled with these degrees of freedom is inadequate to explain the fusion hindrance above the barrier energies with massive partners [8–10]. In heavy-ion collisions, at higher energies, even after capture there exists a probability for projectile-target system to reseparate before complete equilibration (quasifission [11,12], fast fission, etc.) and thereby to reduce the compound nucleus formation probability (P_{CN}). The corresponding ER cross sections at higher energies is weakly sensitive to nuclear potentials [6,13], and usually calculated with standard statistical model (SSM) parameters such as ratio of the level densities in fission and evaporation channels (a_f/a_n), fission barrier scaling factor (k_f), and ground state shell correction (δW_{gs} [14]). Usually, SSM calculations are carried out with a set of parameters [10,15]. Most of them being default parameters, a deviation of P_{CN} from unity indicates the presence of fusion suppression for systems forming the same compound nucleus (CN). In SSM calculations, fission and ER excitation functions of systems forming the same compound nuclei are reproduced with the same parameters of the nuclear potential k_f and with different P_{CN} [6,16]. However, there is no clear understanding of the factors affecting the P_{CN} [17]. Different models assume various factors such as mass asymmetry, or elongation, or both, in a time-independent or dynamical approach to approximate the value of P_{CN} [18,19]. Also, their predictions differ by orders of magnitude [20,21].

---

[*] jisha_dop@uoc.ac.in

[†] Flerov Laboratory of Nuclear Reactions (FLNR), Joint Institute for Nuclear Research (JINR), Dubna 141980, Russia.

[‡] Present address: TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 2A3.

[§] Present address: iThemba LABS, National Research Foundation, PO Box 722, 7129 Somerset West, South Africa.