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Fusion and quasifission studies in reactions forming Rn via evaporation residue measurements

A. Shamlath,[1] E. Prasad,[1,*] N. Madhavan,[2] P. V. Laveen,[1] J. Gehlot,[2] A. K. Nasirov,[3,†] G. Giardina,[4] G. Mandaglio,[5,‡] S. Nath,[2] Tathagata Banerjee,[2] A. M. Vinodkumar,[6] M. Shareef,[1] A. Jhingan,[2] T. Varughese,[2] DVGRKS Kumar,[7] P. Sandya Devi,[7] Khushboo,[8] P. Jisha,[6] Neeraj Kumar,[8] M. M. Hosamani,[9] and S. Kailas[10]

[1]*Department of Physics, School of Physical Sciences, Central University of Kerala, Kasaragod 671314, India*
[2]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India*
[3]*BLTP, Joint Institute for Nuclear Research, Joliot-Curie 6, Dubna 141980, Russia*
[4]*Dipartimento MIFT dell' Università di Messina, Salita Sperone 31, 98166 Messina, Italy*
[5]*Dipartimento ChiBioFarAm dell' Università di Messina, Salita Sperone 31, 98166 Messina, Italy*
[6]*Department of Physics, University of Calicut, Calicut 673635, India*
[7]*Department of Nuclear Physics, Andhra University, Visakhapatnam 530003, India*
[8]*Department of Physics and Astrophysics, University of Delhi, New Delhi 110007, India*
[9]*Department of Physics, Karnatak University, Dharwad 580003, India*
[10]*UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, Mumbai 400098, India*

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Background: Formation of the compound nucleus (CN) is highly suppressed by quasifission in heavy-ion collisions involving massive nuclei. Though considerable progress has been made in the understanding of fusion-fission and quasifission, the exact dependence of fusion probability on various entrance channel variables is not completely clear, which is very important for the synthesis of new heavy and superheavy elements.
Purpose: To study the interplay between fusion and quasifission in reactions forming CN in the boundary region where the fusion probability starts to deviate from unity.
Methods: Fusion evaporation residue cross sections were measured for the $^{28,30}Si + ^{180}Hf$ reactions using the Hybrid Recoil Mass Analyser at IUAC, New Delhi. Experimental data were compared with data from other reactions forming the same CN or isotopes of the CN. Theoretical calculations were performed using the dinuclear system and statistical models.
Results: Reduced evaporation residue cross sections were observed for the reactions studied compared with the asymmetric reaction forming the same CN, indicating fusion suppression in more symmetric systems. The observations are consistent with fission fragment measurements performed in the same or similar systems. Larger ER cross sections are observed with increase in mass in the isotopic chain of the CN.
Conclusions: Fusion probability varies significantly with the entrance channels in reactions forming the same CN. While complete fusion occurs for the $^{16}O + ^{194}Pt$ reaction, the fusion probability drops to approximately 60–70% for the $^{30}Si + ^{180}Hf$ and less than 20% for the $^{50}Ti + ^{160}Gd$ reactions, respectively, forming the same CN at similar excitation energies.

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I. INTRODUCTION

Remarkable progress has been achieved in recent years in the synthesis of new heavy and superheavy elements (SHE) [1–3] using heavy-ion fusion reactions. Elements up to $Z = 118$ have been successfully synthesized in the laboratory. The production cross sections of the superheavy evaporation residues (ER) in SHE synthesis are very low, often of the order of picobarns or less [1,3]. Conceptually, the process of formation of an ER in heavy-ion fusion reaction is considered to be a sequence of three stages—the capture of the projectile and target inside the potential pocket, formation of a completely equilibrated composite nucleus called CN, and CN survival against fission. It may be noted that the above factorization of ER formation as three steps is only a matter of convenience and they are not independent of each other in reality. However, these steps are distinct enough for a qualitative discussion. The time scales involved in these different stages are also different. Hence, the ER cross section may be treated as the product of capture cross section, CN formation probability, and the probability of survival against fission.

For fusion involving light, very asymmetric systems, overcoming the capture barrier automatically leads to the formation of the CN. For such systems, the contact configuration itself will be inside the unconditional saddle configuration [4,5]. Hence, the fusion probability P_{CN} is always unity for collisions involving such nuclei. For heavier systems, overcoming the capture barrier does not guarantee the formation of the CN as the contact configuration could be outside the unconditional saddle point and the system may reseparate before achieving

*Present address: Department of Nuclear Physics, Australian National University, Canberra ACT, Australia; prasad.e.nair@gmail.com.
†Present address: National University of Uzbekistan, 100174 Tashkent, Uzbekistan.
‡Present address: Istituto Nazionale di Fisica Nucleare, Sezione di Catania, Italy.

