Fusion fission dynamics in Super Heavy Element synthesis

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Search for new elements is one of the major research activity in physics and chemistry over several decades. Elements up to atomic number Z = 118 have been discovered by fusion of two nuclei. However attempts to synthesis elements beyond Z = 118 were unsuccessful till date [1]. This demands the necessity of detailed study of reaction dynamics. There are several entrance channel factors on which Super Heavy Elements (SHE, elements having $Z \geq 104$) yield depends. Elements up to Z = 118 have been synthesized successfully where either doubly magic ^{48}Ca or ^{208}Pb have been extensively used due to the low excitaion energy reached in these reactions. But for the formation of elements beyond Og (Z =118), ^{48}Ca beam can no longer be used as in that case the other reaction partner required would be highly radioactive and are not available in required quantities.

For the formation of SHE nuclei, two colliding partners have to come in contact with each other to undergo fusion, but fast non-equilibrium deep-inelastic (DIC) and quasifission (QF) processes can cause the system to re-separate quickly. The whole process from capture to survive against fission leading to SHE formation can be written as the product of three terms, summed over all angular momenta (Jħ)

$$\sigma_{SHE}\,(E) = \sum \sigma_c(E, J)P_{CN}(E, J)W_{sur}(E^*, J)$$

Here σ_c is the capture (contact) cross section at a center of mass energy E. P_{CN} is the probability of surviving fast re-separation, resulting in fusion—the formation of a compact compound nucleus (CN). W_{sur} is the probability that after fusion the compound nucleus survives fission decay. Among these factors P_{CN} strongly depends on entrance channel dynamics and is least understood theoretically.

Current theoretical descriptions of the cold fusion reactions (reaction with ^{208}Pb) assume that the two fusing nuclei follow a thermal diffusion-like process to evolve into a compound nucleus, which is the basis for super heavy element production [2]. If true, the fusion suppression would be highest at the lowest excitation energies, as there, least amount of energy is available for this diffusion process. However, experimental data shows the suppression become smaller with the decreasing energy, indicating that cold fusion is not driven by a thermal diffusion process [3].

Experimental determination of P_{CN} is also challenging in the “SHE region” primarily due to uncertainty in identification and hence extraction of negligibly small CN fission (CNF which gives CN formation cross section) among all the fission like events (QF + CNF) due to unknown mass split in SHE fission. Theoretical calculations predicted both near-symmetric [4] as well as super-asymmetric [5] fission modes in SHE nuclei. Moreover CN fission cross section may be orders of magnitude lower than the cross section of total fission-like events [3]. Situation gets worser as the charged product of the reaction partners increases [6].

To understand the reaction dynamics and determine the P_{CN} from the experimental data a series of measurements have been performed at the Australian National University both in cold (using ^{208}Pb target) and hot fusion reactions (using ^{48}Ca + actinide target). In this talk two measurements will be presented (i) ^{48}Ca, ^{50}Ti, ^{54}Cr + ^{208}Pb reactions leading to heavy nuclei ^{256}No and SHE nuclei ^{258}Rf and ^{262}Sg. (ii) ^{48}Ca, ^{50}Ti, ^{54}Cr + actinide targets which would form different isotopes of Fl (Z = 114).

References

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