RCNP-GANIL-Saclay-Huzhou Collaboration on Reaction Theory of Synthesis of SHE

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As is well known, there is no reliable theory for prediction of residue cross section for synthesis of Super-Heavy Elements (SHE). The reason is that we do not yet understand fusion mechanism in massive heavy-ion systems. The aim of the present collaboration is exactly construction of a theory, which enables us to quantitatively predict cross sections of SHE for given incident channels.

In order to accelerate the collaboration, Y. Abe visited Saclay and GANIL for two weeks in May, and in the summer we worked together a few weeks at RCNP.

We have two sub-subjects, that are firstly related to the *formation probability* of the compound nuclei and secondly to the *survival probability* against fission and charged particle emissions. The latter is known to be well described by the statistical theory of decay. Based on standard theory, we have developed the computer code KEWPIE suitable for decay of SHE in a transparent way [1], which is already used by several groups. We are improving the code by reducing ambiguities in the input parameters and by estimating uncertainties in the theoretical calculations [2].

For the former, the fusion probability is known to be strongly diminished by several orders of magnitude in collisions of heavy ions leading to SHE, which is experimentally known since many years ago, but physical mechanism was not understood, until the present collaborations proposed the diffusion mechanism. Without the correct theory of the hindrance, one cannot predict SHE production cross section [3].

We have presented an analytical formula for the hindrance of fusion for the inverted parabolic barrier under dissipation for the first time [4] which was employed by Swiatecki et al for predictions of cold fusion cross sections. But, they still had to introduce one free parameter (shift of the injection point outward) to reproduce absolute values of the known cross sections. This indicates that the formula explains the qualitative features of the hindrance, but is not accurate enough to quantitatively describe the hindered formation probabilities.

Therefore, we have started to investigate dynamics from di-nucleus configuration to mono-nucleus one and have shown that the neck degree of freedom is very fast to be in equilibrium, much faster than the characteristic evolution time of other degrees (radial and mass-asymmetry) of di-nucleus system [5]. Then, a question is how the fast degree affects the slow degrees, especially the radial degree, which governs the formation process of the compound nuclei. We have found that the coupling between them gives rise to an additional hindrance in accord with Swiatecki's parameter [6]. As this effect significantly affects the fusion probability, it has to be clearly studied. In the summer, we have investigated a possible framework to study dynamics in systems with slow and fast degrees, based on a general theory of non-equilibrium statistical mechanics. The framework shall give comprehensive understanding as well as a systematic approximation scheme.

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