Heavy-ion fusion mechanism and synthesis of the superheavy elements

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As is welknown, predictions of the superheavy elements are based on a possible existence of the next double-closed shell nucleus next to 208Pb. Thus, they are unstable as a charged liquid drop due to large atomic numbers, i.e., too large charges which make the fissility parameter to be equal to or more than 1. According to the compound nucleus theory of reaction by N. Bohr, residue cross sections are given by a product of fusion and survival probabilities.

The former is given by the ratio of the decay widths of neutron emission and fission in the statistical theory of decay. Naturally, fission width of the compound nuclei (CN) formed by the fusion reaction is very small due to the fact that CN is excited and thus the shell is destroyed which guaranttees the stability.

The latter is also extremely small due to the fissility being equal to 1, which indicates that the saddle point is around the spherical shape, although the contact configuration of the projectile and target nuclei in the incident channel has a very large deformation as a compound system. This means that the system has to overcome the saddle(in general, conditional saddle)point after overcoming the Coulomb barrier. As is welknown, heavy-ion interactions are strongly dissipative, so there is no enough kinetic energy left for the overcoming the saddle, irrespectively of the incident energy. But the dissipation of energy is always accompanied with the fluctuation, which means that there is a small probabilities that the system has an enough kinetic energy. That is, fusion is given by the fluctuation of the energy or by the diffusion. In detail, the fusion probability is given by a product of probability passing over the Coulomb barrier and of that over the saddle point. This is proposed by the present author et al. and is called by a two-step model for fusion.

In actual predictions of the fusion and the residue cross sections, a Langevin equation is solved for passing over the saddle in two-dimensional model space with the distance and the mass-asymmetry, while the classical Surface Friction model is employed for passing over the Coulomb barrier. The model is found to well reproduce the fusion excitation function measured at Dubna for 58Fe+208Pb system without any adjustment. The 1n residue cross sections measured at GSI as well as those for xn channels at Dubna are also reproduced well by the only one assumption of the reduction factor for the shell correction energies predicted by the structure calculations.

References

[1] Y. Abe et al., Talk given at Frontiers in the Physics of Nucleus, Peterhof, Russia, June 28- July 01, 2005; Physics of Atomic Nuclei, Vol.69, No.7(2006),pp.1101-1109.