Problems of Dynamical Calculation for Synthesis of Superheavy Elements

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Recently the study on synthesis of superheavy elements becomes to be more exciting and heating. Synthesizing of new heavy elements are reported continuously from Dubna, Riken and GSI. However, the theoretical calculation has many unsolved problems and includes unknown parameters. Nevertheless, lately a number of theoretical papers have appeared in which predictions are made in terms of rather simplified models. Such simplified calculations show a good agreement with experimental data of the evaporation residue cross section of superheavy elements. Here, we list up the problems of dynamical calculation and discuss on the ambiguity of this model.

We divide the whole dynamical process into three stages; the (I) stage is approaching phase, then the (II) stage is the process from the contact point of two colliding nuclei to the formation of compound nucleus. The (III) stage is decay process of compound nuclei which are described by statistical model. In the (II) stage, we employ the fluctuation-dissipation model. We use the Langevin equation. We adopt a three-dimensional nuclear deformation space which are treated as follows: z (distance between two potential centers), δ (deformation of fragments) and α (mass asymmetry of the colliding partner). The problems on each stages are as follows:

(I)-stage: Two different models exist,

- Empirical coupled channel model *ECC* (can be applied sub-barrier energy region) (by V.I. Zagrebaev)
- Gross-Kalinowski model (classical model)

When we discuss on the cold fusion reaction, the enhancement of fusion in sub-barrier region is very important. We should use ECC for cold fusion reaction.

(II)-stage: Langevin calculation on the potential energy surface

- Potential energy surface, which one we use?
  - LDM (*can not reproduce the mass distribution of fission fragment at all*)
  - LDM+shell(T=0)
  - LDM+shell(T_{local})

When we use LDM+shell(T=0), fusion probability is smaller than that in LDM case by two order of magnitude (^{48}Ca+^{244}Pu at E=35 MeV))*

- Description of nuclear shape
  - 2dim-calculation (z, α) (*can not reproduce the mass distribution of fission fragment at all*)
  - 3dim-calculation (z, δ, α) (*fusion probability is smaller than 2-dim calculation by 2-order of magnitude*)
- ε-parameter:

We use ε=1.0 in LDM+shell(T=0), because at touching pointing the case of both colliding partner is spherical shape, the potential energy agrees with Bass model. The deference of potential energy at contact point between ε=1.0 (LDM+shell(T=0)) and ε=0.8 (LDM only) is about 16 MeV, so the difference of fusion probability is 2 -order of magnitude)

(III)-stage in Statistical model, we have many unknown parameters.

In the dynamical calculation, we have such uncertainty at each stages. However, the evaporation residue cross section can be reproduced as the experimental data by fitting the unknown parameters in statistical model. At present, it is meaningless to discuss the absolute value of evaporation residue cross section, only.

First of all we should focus on the dynamics in (II) stage. We have a lot of available experimental data to investigate the fusion-fission process, which are mass and TKE distribution of fission fragments, and neutron multiplicity. Such experimental data can not be reproduced by 2-dim calculation and using LDM potential energy surface at all. When we discuss the fusion probability, we have to treat correctly fusion-fission process, because fusion probability comes from the process which is competition between fusion and quasi-fission process. In our presentation, we will present the results which we try to reproduce the experimental data of mass distribution of fission fragments, and neutron multiplicity, and discuss on the fusion-fission process, precisely.