Nuclear Fission Dynamics and Fission Time Measurement

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Introduction

Nuclear fission is a dynamical process that needs time to occur. Nuclear dissipation is well known to slow down the fission process [1] and is responsible for reductions of the statistical fission widths for the particle evaporation. Understanding of superheavy elements (SHEs) has become one of the long-standing questions in nuclear physics. The search for SHE started in the late 1960s. Initially in the process of fission and evaporation during a transient time, the statistical fission width progressively increases up to a stationary value. During this time, the particle evaporation is strongly favored. The alpha decay and also the spontaneous fission becomes an essential factor which determines the stability of superheavy elements (SHEs). Since the alpha decay, spontaneous fission, ternary fission and cluster radioactivity are essential to determine the decay of the compound nucleus during fission process.

The very large Coulomb energies involved make super-heavy elements (SHEs) extremely unstable against fission [1]. The liquid drop model predicts vanishing fission barriers for SHEs with atomic number beyond Z ∼ 104, but shell effects contribute to increase these barriers and very stable nuclei are thus expected in the neighborhood of closed-shell structures for spherical nuclei. However, the heaviest SHEs can only be formed with sizeable cross-sections by fusion reactions of heavy nuclei leading to compound nuclei at rather high excitation energies and the shell effects progressively vanish with temperature. Thus, the instability against fission becomes very high and the cross-sections for particle evaporation without fission are experimentally almost unreachable.

Simulation framework

By measuring the spontaneous fission of technique of Ge (74) + W, U (238) + Ge and the Th (232) + He & Ni (58) + W reaction at 6.6 MeV/nucleon in LISE ++ simulation software [2]. Spontaneous fission was described early within the geometrical framework of the charged liquid drop model [3]. The first semiempirical formula for calculating the spontaneous fission half-lives was proposed by Swiatecki in 1955 [3]. We use the spontaneous fission model NPA759(05)64 to determine the reaction time measurement for very long fission time longer than 10E-18 seconds, a signature of compound nucleus formation with $102 < Z < 125$.

Result and Discussions

In reactions between two heavy nuclei, the formation of SHEs compounds nuclei followed by spontaneous fission is a sign of longer fission time which has been achieved by the simulation LISE ++ [2]. Even though all these models IJPE21(12)1250013 & all the formulas from NPA759(0564) can reproduce the experimental spontaneous fission half-lives and model-to-model variations in predicting the fission half-lives of superheavy region is the evident from our study.

We have systematically calculated the spontaneous fission half-lives by using one of the generalized NPA759(05)64 formula 2-A [2] in LISE ++ and summarize the results in Fig.1 (Simulates the spontaneous fission half-life in log scale with atomic mass) of Ge (74) + W, U (238) + Ge and the Th (232) + He & Ni (58) + W in MATLAB and all these reactions give satisfactory results of fission half-life for heavy and super heavy compound nucleus ranging from Z = 102 to Z =125.

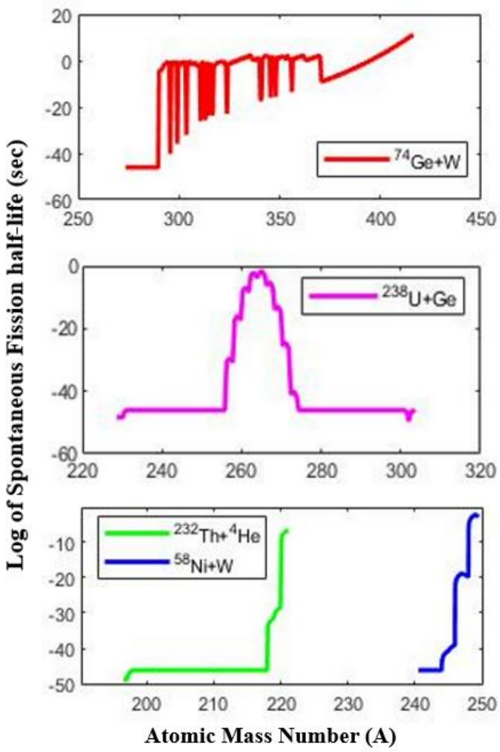

Fig. 1 Simulated Spontaneous Fission half-lives in log scale

Conclusion

The longer fission time results observed in Fig.1 are obtained using LISE ++ provides us with the quite direct evidence for the formation of compound nucleus of all possible isotopes with Z from 102 to 125 in Ge (74) + W, U (238) + Ge and the Th (232) + He & Ni (58) + W at 6.6 MeV/nucleon reactions. The agreement between the experimental results [3] and our simulated results of spontaneous fission half-lives is very satisfactory. From these results we can conclude that the very long fission times (half-lives) can only show up if the fission barriers of all the isotopes involved in spontaneous fission are high enough to allow small percentage of long fission time before fission.

References

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