Rapid Communications

Search for stabilizing effects of the $Z = 82$ shell closure against fission

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Background: Presence of closed proton and/or neutron shells causes deviation from macroscopic properties of nuclei, which are understood in terms of the liquid-drop model. Efforts to synthesize artificial elements are driven by the prediction of the existence of closed shells beyond the heaviest doubly magic nucleus found in nature. It is important to investigate experimentally the stabilizing effects of shell closure, if any, against fission.
Purpose: This Rapid Communication aims to investigate probable effects of proton shell ($Z = 82$) closure in the compound nucleus in enhancing survival probability of the evaporation residues formed in heavy ion-induced fusion-fission reactions.
Method: Evaporation residue cross sections have been measured for the reactions ^{19}F + ^{180}Hf, ^{19}F + ^{181}Ta, and ^{19}F + ^{182}W from $\simeq$9% below to $\simeq$42% above the Coulomb barrier; leading to the formation of compound nuclei with the same number of neutrons ($N = 118$) but different numbers of protons across $Z = 82$ employing the Heavy Ion Reaction Analyzer. Measured excitation functions have been compared with a statistical model calculation in which the reduced dissipation coefficient is the only adjustable parameter.
Results: Evaporation residue cross section, normalized by the capture cross section, is found to decrease gradually with increasing fissility of the compound nucleus. Measured evaporation residue cross sections require inclusion of nuclear viscosity in the model calculations. Reduced dissipation coefficient in the range of 1–3 $\times\ 10^{21}$ s^{-1} reproduces the data quite well.
Conclusions: Since entrance channel properties of the reactions and structural properties of the heavier reaction partners are very similar, the degree of presence of noncompound nuclear fission, if any, is not expected to be significantly different in the three cases. No abrupt enhancement of evaporation residue cross sections has been observed in the reaction forming a compound nucleus with $Z = 82$. Thus, this Rapid Communication does not find enhanced stabilizing effects of the $Z = 82$ shell closure against fission in the compound nucleus. One may attempt to measure cross sections of individual exit channels for further confirmation of our observation.

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I. Introduction. Bohr and Wheeler [1] modeled the atomic nucleus as a homogeneously charged liquid drop. Many macroscopic properties of nuclei, most notably the phenomenon of fission [2] in which a heavy nucleus splits itself into lighter fragments, could be understood in terms of the liquid-drop model (LDM). However, limitations of this model to explain microscopic features, e.g., enhanced stability of a few nuclei, led to the development of the nuclear shell model by Mayer and others [3]. Since then, effects of shells on nuclear reaction dynamics has been a topic of great interest. Most significantly, superheavy nuclei, beyond the heaviest nucleus available in nature, have been hypothesized to exist solely because of shell stabilization effects. Sustained efforts in the field of heavy element research since the first prediction [4] of a doubly shell-closed nucleus beyond $^{208}_{82}$Pb$_{126}$, culminated recently into completion of the seventh period of the periodic table of elements [5]. Although the trans-lead doubly shell-closed nucleus is yet to be synthesized in a laboratory, the cardinal role of shell stabilization in enhancing the lifetime of superheavy nuclei has been firmly established [6].

Formation cross sections of superheavy evaporation residues (ERs) being vanishingly small, it is rather

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