Isomers and Enhanced Stability of Superheavy Nuclei

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Following the early discovery of two-quasiparticle, high-K isomers in ^{250}Fm (Z =100) and ^{254}No (Z = 102) by Ghiorso et al. [1], a number of spectroscopic studies were carried out in the Fermium region, which have different sensitivities both in terms of decay branches (e.g. α decay, γ decay, fission, etc.) and lifetime ranges. There has been continuing activity in addressing the complex question of whether such high-K states would be expected to be shorter- or longer-lived, given changes in the fission barriers, α decay and fission probabilities, and the effects of nuclear structure (such as K hindrance). One-dimensional barrier calculations that allow one to visualize a double-well structure are only part of the necessary considerations, since dynamics exploring a more complicated three-dimensional deformation space ultimately control fission probabilities. Theoretical studies predicting spontaneous-fission probabilities for the high-K, two-quasiparticle states in ^{250}Fm and ^{254}No using one-dimensional approach and the WKB approximation concluded that the rate of spontaneous fission could be orders of magnitude slower than that of the ground states, due to higher and wider fission barriers [2]. However, more extensive calculations [3] that examined a number of two-quasiparticle configurations in different nuclei indicated that, in general, the results depend sensitively on Z, with some examples (Z>104) having faster fission and, depending on other decay branches, shorter lifetimes than the ground states. By incorporating a dynamical treatment of pairing, the spontaneous fission of high-K states was also found to depend critically on dynamically induced superfluidity in the tunneling process [4]. Recently, the possibility that K isomers could be more stable (have longer lifetimes) in super-heavy elements has been pointed out again qualitatively in terms of the shape of the fission barriers when using configuration constraints in calculations of the potential energies and fission barriers, but without inclusion of dynamical effects or the calculation of lifetimes [5]. Theoretical predictions of spontaneous-fission probabilities (and lifetimes) for high-K, multi-quasiparticle states in super-heavy nuclei are still challenging, which is partially due to the paucity of experimental data.

In this talk a review of recent advances in studying properties of K-isomers in the fermium region will be made and new data on the ^{254}Rf nucleus, produced using the ^{50}Ti+^{206}Pb reaction and studied by means of the Fragment Mass Analyzer at ANL and the Berkeley Gas Separator at LBNL will be presented. Using a novel approach involving a pulse-shape analysis in conjunction with a digital data acquisition system, we developed sensitivity for identification of short-lived (up to 10 μs) states and discovered a ~4.7 μs isomer that depopulates via γ–ray emissions towards intermediate structures, and subsequently to the ^{254}Rf ground state ($T_{1/2}$~23 μs). A second γ–ray decaying isomer was also discovered and placed above the 4 μs one. Remarkably, it was found to be much longer-lived ($T_{1/2}$~250 μs) than the ground state, thus providing unambiguous evidence that high-K, multi-quasiparticle states may play an important role in enhancing the stability of super-heavy nuclei.

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