Alpha Decay of $^{197-199}$Fr*

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In order to optimize and test theoretical nuclear-structure models, experimental data is needed for isotopes far from the line of β stability. Especially regions near closed shells provide a possibility to study unique phenomena. In this work we report on a study of nuclei in the vicinity of the $Z = 82$ shell closure.

We produced very neutron-deficient francium isotopes at the velocity filter SHIP (GSI, Darmstadt) using the fusion-evaporation reaction ^{60}Ni + ^{141}Pr $\rightarrow$ ^{201}Fr*. The irradiations were performed at several beam energies from 262 to 300 MeV. After separation from the primary beam, the evaporation residues were implanted into a position-sensitive silicon detector (PSSD) surrounded by six silicon detectors used to detect α particles escaped from the PSSD.

Prior to this work, the lightest identified francium isotopes were ^{199,198}Fr. The ^{199}Fr isotope was produced using the fusion-evaporation reaction ^{36}Ar + ^{169}Tm $\rightarrow$ ^{205}Fr* at the GARIS separator (RIKEN). Five α-decay chains were reported yielding E_α = 7655(40) keV and $T_{1/2} = 12^{+10}_{-4}$ ms [1]. The isotope ^{198}Fr was produced at the RITU separator (JYFL) [2], but no results were published so far.

In our study we detected $\sim$60 and $\sim$70 α-decay chains of ^{199}Fr and ^{198}Fr, respectively. These isotopes have similar half-lives and overlapping α-decay energies. However, a careful measurement of excitation functions for both isotopes enabled us the unambiguous distinction between them. We registered a single peak at 7675(6) keV for ^{199}Fr in contrast to the wide range of α-decay energies from 7470 to 7930 keV for ^{198}Fr (see Fig. 1).

In ^{195}At, the α-decay daughter of ^{199}Fr, two α-decaying states with different spins and parities are known. We observed the decay of both of these states correlated to the α decay of ^{199}Fr. We present two scenarios for this observation. The first possibility is that in ^{199}Fr exists one α-decaying state with E_α = 7675(6) keV, $T_{1/2} = 6.0^{+1.0}_{-0.7}$ ms populating ^{195m}At [see Fig. 2(a)]. This state decays with 88(5)-% probability by α decay and with 12(5)-% probability by an E3 IT transition to ^{195g}At. The second possibility is the presence of two α-decaying states in ^{199}Fr with similar decay properties: the decay with E_α = 7676(6) keV, $T_{1/2} = 6.2^{+1.1}_{-0.8}$ ms populating ^{195m}At and the decay with E_α = 7664(11) keV, $T_{1/2} = 4.5^{+3.1}_{-1.3}$ ms populating ^{195g}At [see Fig. 2(b)]. Within the limited statistics, we cannot favour either of the proposed decay patterns.

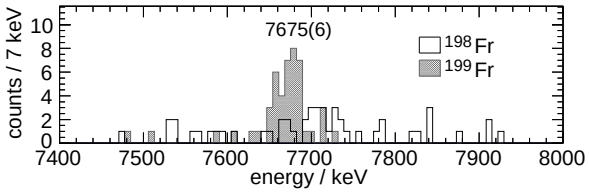

Figure 1: The α-decay energy spectra of ^{199}Fr (shaded region) and ^{198}Fr (black solid line). The isotopes were distinguished using the different beam energies for their production: $(262 - 272)$ MeV for ^{199}Fr and $(282 - 300)$ MeV for ^{198}Fr.

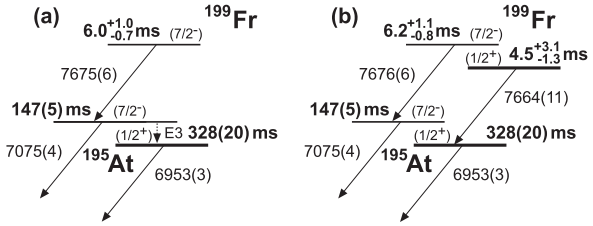

Figure 2: Proposed α-decay schemes for ^{199}Fr. The values for ^{195}At are from [3]. Alpha-decay energies are in keV.

For the α decay of ^{198}Fr we identified two components: a shorter-lived one with $T_{1/2}$ = 1.1(7) ms and α-decay energy from 7580 to 7930 keV and a longer-lived one with $T_{1/2}$ = 15(3) ms and α-decay energy from 7470 to 7920 keV. The existence of two α-decaying states in ^{198}Fr was confirmed by the correlated decay of ^{190}Bi; we observed decays of ^{190m1}Bi correlated with the 15(3)-ms state in ^{198}Fr and decays of ^{190m2}Bi correlated with the 1.1(7)-ms state in ^{198}Fr.

At the highest beam energy we detected one triple-α decay chain attributed to the decay of the new isotope ^{197}Fr. The identification was based on the correlations of the parent α decay with the known decays of daughter nuclei ^{193}At and ^{189}Bi.

References

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