# 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 $\beta$ 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 $\alpha$ 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 $\alpha$-decay chains were reported yielding $E_\alpha$ = 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 $\alpha$-decay chains of $^{199}$Fr and $^{198}$Fr, respectively. These isotopes have similar half-lives and overlapping $\alpha$-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 $\alpha$-decay energies from 7470 to 7930 keV for $^{198}$Fr (see Fig. 1).

In $^{195}$At, the $\alpha$-decay daughter of $^{199}$Fr, two $\alpha$-decaying states with different spins and parities are known. We observed the decay of both of these states correlated to the $\alpha$ decay of $^{199}$Fr. We present two scenarios for this observation. The first possibility is that in $^{199}$Fr exists one $\alpha$-decaying state with $E_\alpha$ = 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 $\alpha$ decay and with 12(5)-% probability by an E3 IT transition to $^{195g}$At. The second possibility is the presence of two $\alpha$-decaying states in $^{199}$Fr with similar decay properties: the decay with $E_\alpha$ = 7676(6) keV, $T_{1/2} = 6.2^{+1.1}_{-0.8}$ ms populating $^{195m}$At and the decay with $E_\alpha$ = 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.

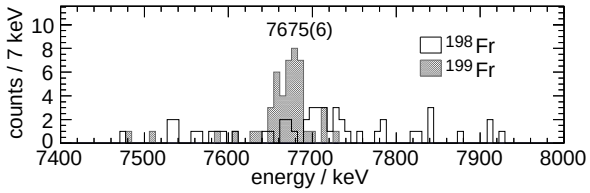


Figure 1: The $\alpha$-decay energy spectra of $^{199}$Fr (shaded region) and $^{198}$Fr (black solid line). The isotopes were distinguished using the different beam energies for their production: $(262 - 272)$ MeV for $^{199}$Fr and $(282 - 300)$ MeV for $^{198}$Fr.

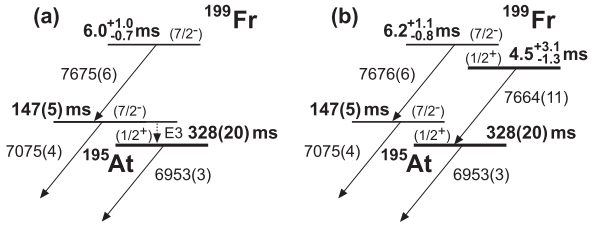


Figure 2: Proposed $\alpha$-decay schemes for $^{199}$Fr. The values for $^{195}$At are from [3]. Alpha-decay energies are in keV.

For the $\alpha$ decay of $^{198}$Fr we identified two components: a shorter-lived one with $T_{1/2}$ = 1.1(7) ms and $\alpha$-decay energy from 7580 to 7930 keV and a longer-lived one with $T_{1/2}$ = 15(3) ms and $\alpha$-decay energy from 7470 to 7920 keV. The existence of two $\alpha$-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-$\alpha$ decay chain attributed to the decay of the new isotope $^{197}$Fr. The identification was based on the correlations of the parent $\alpha$ decay with the known decays of daughter nuclei $^{193}$At and $^{189}$Bi.

## References

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