Decay of ^{200,201}Fr*

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In the region of neutron-deficient nuclei above lead several interesting nuclear-structure phenomena can be observed, e.g., coexistence of states with different shapes within one nucleus, or β-delayed fission. This motivated us to investigate the neutron-deficient isotopes ^{200,201}Fr.

The studied nuclei were produced at the velocity filter SHIP (GSI, Darmstadt) in fusion-evaporation reactions ^{56}Fe + ^{147,149}Sm at several beam energies from 236 to 275 MeV. Evaporation residues (ERs) were separated from other particles and transported into a focal-plane detector system. ERs were implanted into a 16-strip position-sensitive silicon detector (PSSD) recording also their α decays. Escaping α particles were recorded by a system of six silicon detectors placed upstream the beam covering 80 % of 2π. A germanium clover detector placed closely behind the PSSD registered γ and X-rays.

We measured E_α = 7470(5) keV and $T_{1/2}$ = 46(4) ms for ^{200}Fr confirming known α-decay data for this isotope. For its daughter isotope, ^{196}At, we observed a new weak α line at 6732(8) keV with a relative intensity of 4(2) % besides the main 7045(5)-keV α line. The determined energy of the level in ^{192}Bi populated by the 6732(8)-keV decay is 320(10) keV. Within a 5-μs coincidence time with implanted ERs followed by α decays of ^{200}Fr we observed weak γ lines at 75.5 and 77.1 keV and K$_\alpha$(Fr) X-rays. They indicate a short-lived γ-decaying state in ^{200}Fr with $T_{1/2} = 0.6^{+0.5}_{-0.2}\,\mu$s. One β-delayed fission (βDF) event attributed to ^{200}Fr was observed. Deduced probability of βDF for the daughter isotope ^{200}Rn is more than 1.4 % .

We identified a short-lived γ-decaying activity with $T_{1/2} = 0.7^{+0.5}_{-0.2}\,\mu$s also in ^{201}Fr based on the registration of γ and K$_\alpha$ X-rays. From the analysis of K-shell internal conversion coefficients (α_{K}) [1] and estimated single-particle half-lives ($T_{1/2,SP}$) according to Weisskopf [2] we suppose that observed γ and X-rays arise from an internal transition of $M2$ multipolarity. We tentatively assigned the spin and parity of 13/2$^+$ to the observed isomeric state in ^{201}Fr. The lower energy limit for this level was determined to be higher than the K-shell atomic-electron binding energy of francium (101.13 keV) because of the detection of K X-rays. The upper energy limit was roughly estimated to be 300 keV from the comparison of experimental and expected α_{K} and $T_{1/2,SP}$ for $M2$ transitions.

For most of the neutron-deficient francium ($Z = 87$) and astatine ($Z = 85$) isotopes a 9/2$^-$ state related to a spherical shape was identified to be a ground state. In astatine isotopes, the 7/2$^-$, 1/2$^+$, and 13/2$^+$ levels, related to oblate shapes, were observed with energies decreasing at decreasing N (see Fig 1). Starting with ^{195}At ($N = 110$), the 1/2$^+$ level becomes the ground state in astatine isotopes [3]. The energy interval of the tentative 13/2$^+$ level in ^{201}Fr estimated from our data follows the trend of decreasing energies at decreasing N of this level in francium isotopes. A similar trend was also observed for the 1/2$^+$ level. In the lightest francium isotopes we can expect a change of spin of the ground state, but it was not definitely identified so far. All of the 13/2$^+$, 7/2$^-$, 1/2$^+$ levels were reported to be detected in ^{199}Fr within 300 keV [4]. However, in recent measurements at SHIP we only observed the 7/2$^-$ level, and tentatively also the 1/2$^+$ level [5]. Higher statistics are needed to disentangle the level structure in this isotope.

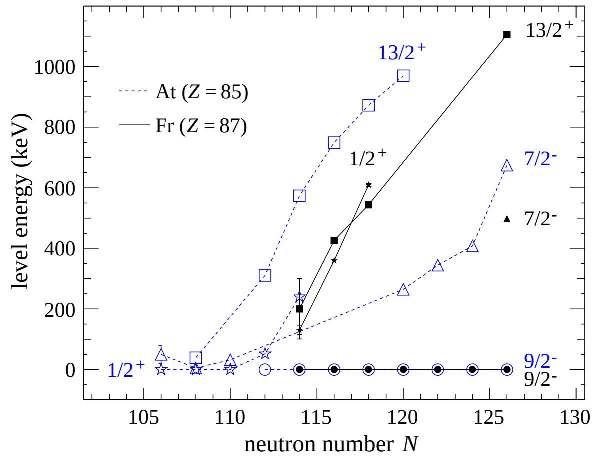

Figure 1: (Color online) Energy level systematics for odd-A astatine (dashed lines and open symbols) and francium (solid lines and full symbols) isotopes.

References

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