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Short note

Identification of the $13/2^+$ isomer in ^{199}At

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Abstract. The $13/2^+$ isomeric state in the ^{199}At nucleus has been identified at an excitation energy of 573 keV and its half-life measured to be 580(130) ns using the recoil-decay tagging technique.

PACS. 21.10.Tg Lifetimes – 23.20.Lv Gamma transitions and level energies – 27.80.+w $190 \leq A \leq 219$

The reasons for the recent growth of interest in studies of neutron deficient nuclei at and above the $Z = 82$ proton number is manifold. Of these, the two main reasons are: i) theoretical predictions of the ground-state deformation in those light nuclei and ii) the presently available experimental facilities and techniques that make feasible spectroscopic experiments in that region of the nuclear chart where fission processes dominate over fusion-evaporation reactions.

A search for signs of ground-state deformation in the neutron deficient astatine nuclei was initiated by our studies of the ^{199}At nucleus some time ago. That nucleus was predicted [1] as a transitional one between a spherical ^{201}At and a deformed ^{197}At. A recent coincidence experiment using the GAREL+ setup, where the Recoil Filter Detector (RFD) [2] was used, furnished a preliminary level scheme of that nucleus. The data has been presented in ref. [3].

An attempt given there to interpret the observed levels as the lowest excitations in ^{199}At was based only on the systematics of At nuclei with $A \geq 201$ and a comparison with the known level scheme of the odd-neighbour ^{201}At where the two lowest excitations are the $13/2^-$ state at 635 keV and an isomeric $13/2^+$ state at 749 keV with a half-life of 15.9 ns [4]. A similarity of the observed level pattern in ^{199}At to that in ^{201}At seemed to justify the afore mentioned interpretation of ^{199}At.

A new experiment and further detailed studies that revealed some additional γ-transitions and gave γ-ray angular distribution data have cast doubt on that interpretation. Moreover, the recent studies of ^{197}At [5] which identified an isomeric state at 311 keV with a lifetime $\tau = 8\,\mu$s have favoured the existence of an isomeric state in ^{199}At. Such an isomeric state has been suggested in our recent contribution to the Sevilla conference [6]. We anticipated its energy as 466 keV and a lifetime of about 1 μs. The use of the RFD that can work only with a thin target (below 1 mg/cm^2) made the observation of such a long lifetime impossible.

Thus, an experimental identification of the $13/2^+$ isomer in ^{199}At and its decay has become an important pending question. The lack of that information has prevented any further conclusions on the structure of ^{199}At, as well as any speculations on the onset of collectivity in this nucleus.

The present work was aimed at identifying, locating, and measuring the long-lived isomeric state in ^{199}At. An experiment was performed at the Accelerator Laboratory of the University of Jyväskylä using the recoil-decay tagging (RDT) technique [7,8] with the RITU gas-filled recoil separator [9]. The ^{199}At nuclei were produced in the fusion-evaporation reaction where a ^{146}Nd target of 500 μg/cm^2 was bombarded with ^{56}Fe projectiles of 250 MeV. The fusion-evaporation residues were separated from fission products and beam projectiles in the RITU separator and then implanted in a Si strip detector at its focal plane.

The silicon detector measured the position, energy and time of detection for each recoil and its subsequent α-decay. A Multi-Wire Proportional Counter (MWPC) placed upstream of the Si detector was used to veto low-energy scattered beam events, which contaminate the alpha-particle spectrum; and also to provide better dis-

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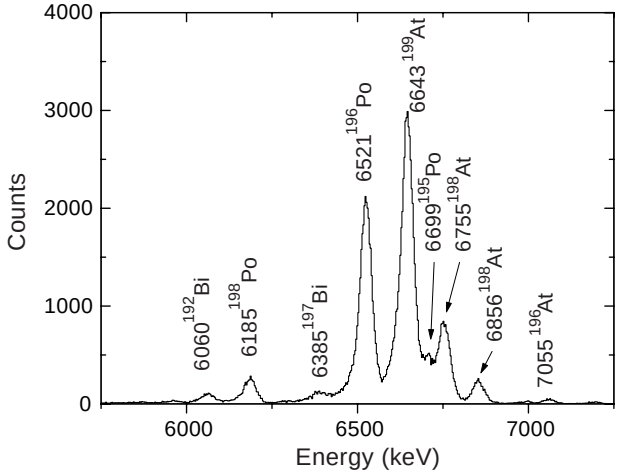

Fig. 1. The α-particle singles spectrum from the 250 MeV ^{56}Fe + ^{146}Nd reaction measured by the silicon strip detector of the recoil separator RITU.

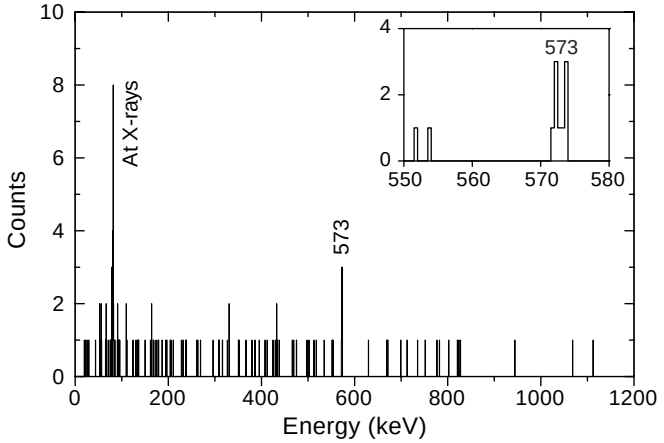

Fig. 2. Spectrum of γ-rays measured at the focal plane of the separator RITU in coincidence with recoils correlated with the alpha decay of $9/2^-$ state in ^{199}At. The inset shows the 573 keV line alone.

Table 1. Properties of the $13/2^+$ isomers in ^{195}Bi [11], ^{197}At [5] and ^{201}At [4] are compared with the 573 keV isomeric state in ^{199}At identified in this experiment.

Nucleus	E_x (keV)	τ (ns)	E_γ (keV)	$B(M2)$ (W.U.)
^{195}Bi	888	46(3)	888	0.048(8)
^{197}At	311	8000(2000)	311	0.021(6)
^{199}At	573	837(190)	573	0.020(6)
^{201}At	749	23(2)	749	0.17(3)
			114	

crimination of fusion-evaporation residues. Figure 1 shows the α-particle singles spectrum observed in our experiment.

The γ-radiation was measured in one Compton-suppressed NORDBALL-type Ge detector placed beyond the focal plane of the RITU. Exploiting the RDT-method and the well-known α-decay of the ^{199}At ground-state ($T_{1/2}$ = 7.2 s) [10], we have identified the isomeric state in this nucleus. This state is depopulated by a single γ-transition of 573 keV as shown in fig. 2.

A half-life of 580(130) ns was extracted for this state from the measured recoil-X-ray and recoil-gamma time distributions.

Table 1 compiles characteristics of the $13/2^+$ isomers in the neighbouring nuclei and compares the $B(M2)$ transition probabilities obtained for isomeric to ground-state $13/2^+ \rightarrow 9/2^-$ γ-decays.

The excitation energy of the isomeric state in ^{199}At fits very well with the systematics of the $13/2^+$ states in the odd astatine isotopes. It shows a smooth decrease in energy when going towards lighter At nuclei.

The present identification of the isomer in ^{199}At at 573 keV differs slightly from our anticipation of its position at 466 keV [6]. That estimate, however, was based on systematics of the odd At nuclei exclusively and some weak arguments of the intensity balance and a coincidence relations. The fact that the isomer decays by the single 573 keV γ-transition indicates that this level is the first excited state in ^{199}At and the $13/2^-$ excitation should lie higher in energy as anticipated in ref. [6]. However, the energies of levels suggested in that reference have to be revised. A detailed discussion on the decay scheme and structural properties of ^{199}At will be given in a forthcoming publication.

In conclusion, there is as yet no evidence in ^{199}At for the ground-state deformation and a further search for the collective properties in lighter At isotopes is still called for.

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