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Short note

The α-decay energies and halflives of ^{195g,m}At and ^{199}Fr

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Abstract. The α-decay energy and halflife of ^{195m}At were determined to be 6960±20 keV and 385^{+69}_{-51} ms respectively, on the basis of genetic correlations in the ^{169}Tm(^{36}Ar, α6n)^{195}At reaction, while those of ^{195g}At measured simultaneously were 7105±30 keV and 146^{+21}_{-17} ms respectively, reconfirming the previously reported values. A new isotope ^{199}Fr was also produced and identified in the same way in the ^{169}Tm(^{36}Ar, 6n)^{199}Fr reaction, yielding E_α = 7655±40 keV and $T_{1/2} = 12^{+10}_{-4}$ ms.

PACS. 23.60.+e nbsp;decay – 25.70.Gh Compound nucleus – 27.80.+w $190 \leq A \leq 219$

The α-decay of ^{195}At was first studied by Treytl and Valli [1] and later by Leino [2]. Although possible assignment of the ground-state α-decay was reported in [2], it has not been adopted in recent compilations [3] presumably due to the poor statistics and complicated nature of the observed decays. Moreover, concerning the α-decay from a possible isomer in ^{195}At expected from the systematic trend of the neighbouring nuclei, only brief report was given in [4], in which no experimental details were described. We have therefore re-investigated ^{195}At and identified successfully α-decays from both the ground- (g) and isomeric- (m) states produced in the ^{169}Tm(^{36}Ar, α6n) reaction. In addition, the first evidence for the α-decay of ^{199}Fr produced in the ^{169}Tm(^{36}Ar, 6n) reaction has been found.

The experiment was carried out at the RIKEN Accelerator Research Facility (RARF). In order to use a high intensity beam from the RIKEN ring cyclotron, we employed a rotating target system. Metallic ^{169}Tm targets of about 0.44 mg/cm^2 thickness evaporated onto 13 μm thick Al foils were fixed on a rotating disk, which was 150 mm in diameter and rotated at 600 rpm. In the present setup each piece of the target effectively covered 30°, and there was 30° dead space between two neighbouring targets. A pulsed ^{36}Ar beam with 8.3 ms duty-on and 8.3 ms duty-off periods was used. The bombarding energy and beam intensity were monitored by measuring elastically-scattered ^{36}Ar with a small Si-detector placed at 46.1° with respect to the beam direction. The beam intensity was 1×10^{12} s^{-1} on the average, while the beam energy of 273.6 MeV from the cyclotron was degraded through Al foils of proper thickness down to 215±5 MeV at the target position.

Reaction products recoiling out of the target were separated from the primary beam with the gas-filled recoil separator GARIS [5], and were detected with a 300 μm thick, 64 mm wide and 64 mm high two-dimensional position sensitive detector (PSD) [6] placed at its focal plane. The energy resolution of the PSD was 60 keV at 5.5 MeV, while its position resolutions were 0.18 mm and 0.5 mm in horizontal and vertical directions respectively, for signals with energy higher than 5 MeV. A Si detector of almost the same size placed 0.5 cm behind the PSD was used as a veto counter, which turned out quite effective to reduce backgrounds such as light particles coming into the PSD. A micro-channel-plate (MCP) assembly [6] was also placed 70 cm upstream of the PSD. The data were taken continuously by tagging beam-on or beam-off signals.

In the present analysis, all the PSD signals in coincidence with MCP signals were regarded as evaporation residues (ER), while those without MCP signals were treated as possible α-decay events. Three successive events consisting of ER, first α-decay (α1), and second α-decay (α2) in this time sequence were searched on condition that they occured at the same position on the PSD within proper spread at adequate time intervals, Δt_1 and Δt_2, which are those between the first two and second two

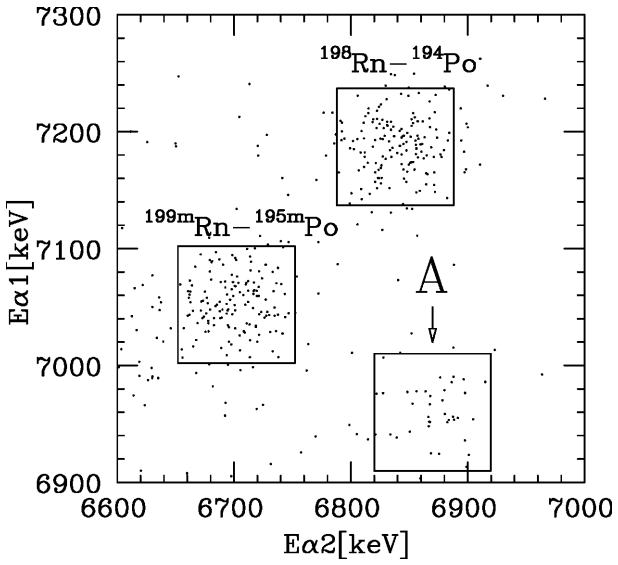

Fig. 1. The $E_{\alpha 1}$ and $E_{\alpha 2}$ from the ER-α1-α2 correlations with $\Delta t_1 \leq 1.0$ s and $\Delta t_2 \leq 0.5$ s. Group A: ^{195m}At-^{191m}Bi

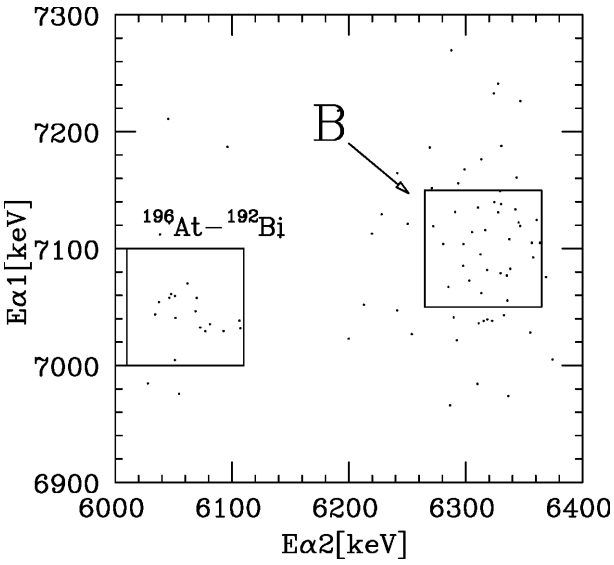

Fig. 2. The $E_{\alpha 1}$ and $E_{\alpha 2}$ from the ER-α1-α2 correlations with $\Delta t_1 \leq 0.15$ s and $\Delta t_2 \leq 15$ s. Group B: ^{195g}At-^{191g}Bi

events respectively. The present assignment is based on the agreement of the α2-decay properties (E_α and $T_{1/2}$) with those known in the literature [3,7,8].

Figure 1 shows the first and second α-decay energies obtained from the ER-α1-α2 correlations with $\Delta t_1 \leq 1.0$ s and $\Delta t_2 \leq 0.5$ s. On this condition the unknown correlations (group A) were observed together with the known ^{198}Rn-^{194}Po and ^{199m}Rn-^{195m}Po correlations. Since the observed E_α and $T_{1/2}$ of the α2 events in the group A are respectively 6869±20 keV and 156^{+27}_{-20} ms, being in excellent agreement with those of the known α-decay from a $(1/2^+)$ isomer at 242 keV in ^{191}Bi as shown in Table 1, the corresponding α1 events are assigned to originate from the nucleus ^{195}At mainly produced in the ^{169}Tm(^{36}Ar, α6n) reaction. Moreover, the present halflife of the α1 event (385^{+69}_{-51} ms) is reasonably consistent with the value of 225 ms calculated from the semi-empirical formula of [9] which is valid for the s-wave transition, indicating that the α1 decay occurs from a $(1/2^+)$ isomeric state in ^{195}At. As shown in Table 1, the α-decay energy determined in this work agrees with that reported by Leino et al. [4], while the present value of the halflife is considerably shorter than that given in [4]. The expected number of accidental correlations in the group A was about 0.2.

Figure 2 shows the $E_{\alpha 1}$-$E_{\alpha 2}$ map obtained from the ER-α1-α2 correlations with $\Delta t_1 \leq 0.15$ s and $\Delta t_2 \leq 15$ s. In this case, we have adopted those α2 events that were detected only during the beam-off period in order to decrease accidental correlations. The values of E_α and $T_{1/2}$ of the α2 events in the group B turned out to be 6323±20 keV and $13.0^{+2.1}_{-1.5}$ s respectively, being in good agreement with those of the known ^{191g}Bi decay as seen in Table 1. We therefore assigned the corresponding α1 events to the decay of ^{195g}At, of which the E_α and $T_{1/2}$ values were determined to be 7105±30 keV and 146^{+21}_{-17} ms. The halflife is consistent with the value of 68 ms calculated from the

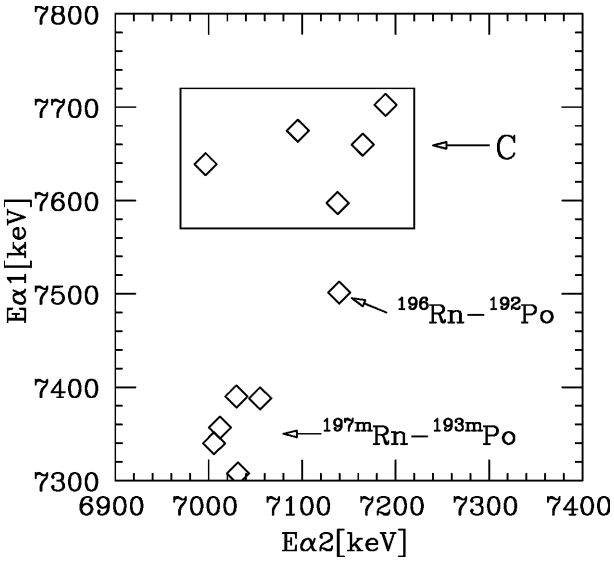

Fig. 3. The $E_{\alpha 1}$ and $E_{\alpha 2}$ from the ER-α1-α2 correlations with $\Delta t_1 \leq 0.2$ s and $\Delta t_2 \leq 1$ s. Group C: ^{199}Fr-^{195g}At

formula of [9]. The expected number of accidental correlations in the group B was about 1.6.

The present data of the ^{195g}At α-decay agree with those of [2], in which E_α = 7120±20 keV and $T_{1/2}$ = 150±30 ms have been reported. However, another ^{195}At decay component of E_α = 7190±30 keV and $T_{1/2}$ = 140±50 ms reported in [2] has not been confirmed in this work, although its presence cannot be excluded completely because of a somewhat broader correlation pattern of the group B in Fig. 2. Based on the present results, the excitation energy of ^{195m}At mentioned before is estimated to be 94±40 keV.

Figure 3 shows the $E_{\alpha 1}$-$E_{\alpha 2}$ map for the ER-α1-α2 correlations with $\Delta t_1 \leq 0.2$ s and $\Delta t_2 \leq 1$ s. On this con-

Table 1. The α-decay energies (E_α) and halflives ($T_{1/2}$) obtained in present work. All the $T_{1/2}$ were determined by the method of [10]

	Present		Literature	
Nuclide	E_α (keV)	$T_{1/2}$ (ms)	E_α (keV)	$T_{1/2}$ (ms)
^{195m}At	6960±20	385^{+69}_{-51}	6950±30 [4]	630^{+320}_{-160} [4]
^{191m}Bi	6869±20	156^{+27}_{-20}	6876±5 [3]	150±15 [7]
^{195g}At	7105±30	146^{+21}_{-17}	7120±20 [2]	150±30 [2]
^{191g}Bi	6323±20	$13.0^{+2.1}_{-1.5}$ s	6311±5 [3]	12±1 s [3,8]
^{199}Fr	7655±40	12^{+10}_{-4}	–	–

dition the unknown correlations (group C) were observed together with the known ^{197m}Rn-^{193m}Po and ^{196}Rn-^{192}Po correlations. Since the measured E_α (7117±70 keV) and $T_{1/2}$ (98^{+80}_{-31} ms) of the $\alpha 2$ events in the group C agree with those of the ^{195g}At α-decays obtained in this work, the $\alpha 1$ events are assigned to the ^{199}Fr α-decays. It should be noted here that although the point at $E_{\alpha 2} \approx 7000$ keV in the group C deviates in $\alpha 2$ energy somewhat largely from the other points, we tentatively attribute this point to the same origin, because the decay properties of $\alpha 1$ and $\alpha 2$ in the group C do not change significantly even if it is excluded. The E_α and $T_{1/2}$ of ^{199}Fr are 7655±40 keV and 12^{+10}_{-4} ms, respectively. The expected number of accidental correlations in the group C was about 0.1.

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