²²¹Ra α decay 1997Li12,2015Ah04

History

Туре	Author	Citation	Literature Cutoff Date	
Full Evaluation	E. A. Mccutchan, J. Lee, N. Jovancevic	NDS 147, 382 (2018)	1-Dec-2017	

Parent: ²²¹Ra: E=0.0; $J^{\pi}=5/2^+$; $T_{1/2}=28 \text{ s } 2$; $Q(\alpha)=6880.4 \ 20$; % α decay=100.0

- 2015Ah04: Parent ²²⁵Th was produced by α decay of ²²⁹U produced via ²²⁹Th(⁴He,4n) and ²³⁰Th(³He,4n) reactions. The Th targets in milligrams were bombarded with microamp current of ⁴He and ³He beams provided by Argonne 152-cm cyclotron. The uranium activity produced in the reactions was chemically separated, followed by mass separation using the Argonne electromagnetic isotope separator. The experiment used both the mass separated as well as non-mass separated sources, the latter for higher statistics, since the activity of mass separated sources was much reduced in the separation process. Gamma rays were measured with a LEPs and a coaxial Ge(Li) detector. Measured E γ , I γ .
- 1997Li12: 10 g of a Th-Ce alloy were bombarded by a 280-MeV 2 μ A beam of ³He at the Orsay Synchrocyclotron. The target constituted the anode of an ion-source arc chamber and was continuously fluorinated by introducing CF₄ vapor. Using the ISOCELE separator and the selective fluorination method, ²²¹Ra was separated as RaF⁺. The resolution of the α detector was 21 keV. Measured E α , E γ , $\alpha\gamma$ -coin. Deduced levels, J, π , configuration.
- 1989Ac01: The ²²⁵Th α -radioactivity was produced by bombarding a ²²⁶Ra target with 52 MeV α -particles from the Bonn cyclotron. γ -rays and conversion-electrons were measured in coincidence with α -particles, with the beam pulsed on/off with a period of approximately 10 min. Deduced levels, ICC, I γ , γ -multipolarity.
- 1961Ru06: Using a 180° double-focusing alpha-particle spectrograph and scintillation spectrometers, the alpha and gamma radiations of ²²⁹U series were investigated. The light-uranium isotopes were produced by bombardment of ²³²Th with the internal helium ion beam of the 184-inch synchrocyclotron. Measured $E\alpha$, $I\alpha$, $E\gamma$, $I\gamma$, $\alpha\gamma$ -coin. Deduced levels.

(α)(γ) coincidences were taken by 1961Ru06, 1989Ac01, 1995Ch74 and 1997Li12, and (α)(ce) coincidences by 1989Ac01.
 The main decay scheme was first constructed by 1961Ru06, and confirmed by 1989Ac01 and 1997Li12. Additional transitions were observed and placed by 1997Li12 in the decay scheme with additional levels. The decay scheme is presented here as built by 1997Li12.

 α : Additional information 1.

²¹⁷Rn Levels

E(level) [†]	J#‡	T _{1/2}	Comments
0.0	9/2+	0.54 ms 5	T _{1/2} : from 1961Ru06.
88.89 4	$(11/2^+)$	≤1.5 [#] ns	
93.00 4	$(7/2^+)$	4.0 ns 4	$T_{1/2}$: from (α)(93 L x-ray)(t) (1989Ac01). Intensity imbalance at this level, which might be explained by the unobserved 4.11 γ .
149.14 <i>3</i>	5/2+	≤1.5 [#] ns	
174.29 6 184? [@]	(7/2,9/2,11/2)+	$\leq 1.5^{\#}$ ns	
234.7 <i>3</i> 295? [@] 374.90 <i>19</i>	(3/2 ⁺)		
382.15 <i>13</i> 474.5 <i>4</i> 500? [@] 569.64 <i>16</i> 600? [@] 618.8 <i>3</i>	(5/2+,7/2,9/2+)		

[†] From a least-squares fit to $E\gamma$, by evaluators, except where noted.

[‡] From the Adopted Levels.

[#] From prompt $(\alpha)(ce)(t)$ data (1989Ac01).

[@] Deduced by evaluators using $Q\alpha$ =6880.4 20 (2017Wa10) and measured E α .

²²¹Ra α decay **1997Li12,2015Ah04** (continued)

α radiations

$E\alpha^{\dagger}$	E(level)	$I\alpha^{\ddagger@}$	HF [#]	Comments
6147	618.8	≈0.05	≈28	
6170	600?			E α : from 1961Ru06. From the level energy of 600 keV, given in 1961Ru06, and the author's E_{α} (to g.s.)=6761 yield E_{α} =6172. This alpha was not confirmed by others; therefore, is considered questionable. I α : 0.3 2 (1961Ru06).
6195	569.64	0.2	12	
6260	500?			Iα: 0.7 3 (1961Ru06). Eα: from 1961Ru06. From the level energy of 500 keV, given 1961Ru06, and the author's E_{α} (to g.s.)=6761, E=6270 is calculated. This tentatively assigned alpha was not confirmed by others; therefore, is considered questionable.
6287	474.5	≈0.05	≈119	
6382	382.15	0.4	36	
6390	374.90	≈0.1	≈156	E_{α} =6410, I_{α} =0.3 2 (1961Ru06) is assumed to be the 6390 α observed by 1997Li12. This alpha was tentatively assigned by 1961Ru06 to this decay.
6463	295?	≈0.05	≈664	Other: E_{α} =6470, I_{α} =0.4 3 (1961Ru06). This alpha was tentatively assigned by 1961Ru06 and 1997Li12.
6526	234.7	0.3	193	
6581	184?			E α : from 1961Ru06 using the level energy given as 184 keV by 1961Ru06. This level energy and author's E_{α} (to g.s.) of 6761 give E_{α} =6573.
				I α : 3 <i>I</i> was measured by 1961Ru06. If this alpha indeed belongs to ²²¹ Ra decay, the intensities of other alpha transitions will have to be decreased by a factor of 0.97, so that the sum of all I _{α} 's will be 100%.
6579	174.29	5.6 24	18 8	Other: $E_{\alpha} = 6591$, $I_{\alpha} = 8 l$ (1961Ru06).
6607	149.14	38 4	3.3 5	Other: E_{α} =6613, I_{α} =34 2 (1961Ru06).
6662	93.00	23 <i>3</i>	9.1 14	Other: E_{α} = 6668, I_{α} = 20 2 (1961Ru06).
6667	88.89	<1.5	>134	$E\alpha$: deduced by evaluators, from level energy of 89-keV in 1997Li12 who indicate an upper limit for the alpha branch to the level.
6754	0.0	32 2	14.9 15	Other: $E_{\alpha} = 6761 5$, $I_{\alpha} = 30 2$ (1961Ru06).

[†] Except where noted, measurements of 1997Li12 are given. Calibration energies were not given; therefore, no adjustment for E_{α} 's has been made. If the energies were calibrated at $E_{\alpha}(g.s.)=6754$, as measured by 1961Ru06, then they should be increased by 7 keV due to increase in calibration energies used by 1961Ru06. No uncertainties were given by 1997Li12. Resolution was 21 keV. Other measurements: 1951Me10, 1961Ru06. The energies of 1961Ru06 are quoted with an increased value by 7 keV from their original energies, as recommended by 1991Ry01.

[‡] Alpha intensity per 100 alpha decays, measured by 1997Li12, See also a comment for 6581α . Uncertainties are assigned by the evaluators (no uncertainties were given in 1997Li02). Other measurement: 1961Ru06.

$r_0(^{217}Rn)=1.550$ 8, average of $r_0(^{216}Rn)=1.556$ 6 and $r_0(^{218}Rn)=1.5446$ 19 (1998Ak04), is used in calculations.

[@] Absolute intensity per 100 decays.

$\gamma(^{217}\mathrm{Rn})$

I γ normalization: relative photon intensities, normalized at 149.2 γ to 100, and intensities per 100 α decays were listed by 1997Li12 with I(149.2 γ)=12.5% given. The method of obtaining absolute intensities was not discussed by the authors. Uncertainty assumed by evaluators taking similar uncertainty which was obtained in 1961Ru06. Earlier measurement: I(149 γ)=13% 2, obtained by 1961Ru06 by (α)(γ) coincidences.

 $I(K\alpha x ray+K\beta x ray)(Rn)/I(149.2\gamma)=62 8/100 (1997Li12).$

			221 Ra α	decay	1997Li12	,2015Ah04 ((continued))
γ ⁽²¹⁷ Rn) (continued)								
E_{γ}^{\dagger}	Ι _γ ‡@	E _i (level)	J_i^π	\mathbf{E}_{f}	J_f^{π}	Mult. [#]	α	Comments
(4.12 8)		93.00	(7/2 ⁺)	88.89	(11/2+)			Transition was not observed. Its existence was deduced by 1997Li12 from observation of the 88.9γ in coincidence with the 6662α to the 93-keV level.
56.19 6	2.5 5	149.14	5/2+	93.00	(7/2+)	(M1)	13.71	$\begin{array}{l} \alpha(L)=10.43 \ 15; \ \alpha(M)=2.48 \ 4; \\ \alpha(N)=0.646 \ 10; \ \alpha(O)=0.1414 \ 21; \\ \alpha(P)=0.0206 \ 3 \end{array}$ $E_{\gamma}: \ weighted \ average \ of \ 56.16 \ 5 \\ (1997Li12) \ and \ 56.3 \ 1 \ (2015Ah04). \\ Other: \ 56.2 \ 2 \ (1989Ac01). \end{array}$ $I_{\gamma}: \ from \ 1997Li12. \ Others: \ 13.7 \ 17 \\ (2015Ah04), \ 3.1 \ 4 \ (1989Ac01). \\ Mult.: \ deduced \ from \ intensity \ balance. \end{array}$
(81.3)		174.29	(7/2,9/2,11/2)+	93.00	(7/2+)			This transition was not observed. It would be obscured by the K-x rays. It is tentatively proposed by 1997Li12.
85.4 3	0.15 5	174.29	$(7/2,9/2,11/2)^+$	88.89	$(11/2^+)$			
86.0 5 88.90 5	0.04 2 7.5 10	88.89	$(3/2^+)$ $(11/2^+)$	0.0	5/2* 9/2+	(M1)	3.59	α (L)=2.73 4; α (M)=0.649 10; α (N)=0.1693 24; α (O)=0.0370 6; α (P)=0.00541 8
93.02 5	33 3	93.00	(7/2+)	0.0	9/2+	E2(+M1)	11.33	Mult.: deduced from intensity balance. E_{γ} : Others: 93.1 2 (1989Ac01), 89 2 (1961Ru06). I_{γ} : Others: 24 3 (1989Ac01), 115 16 (1961Ru06, presumably includes the Rn K-x rays and the 88.9 γ). Mult.: (L1+L2)/L3=2.2 2 (1989Ac01; not corrected for possible ceK(174 γ)contribution on L1 line). Consistent with E2 but there might be very small contribution of M1. α : From BrIcc code assuming E2 because the contribution of M1 is very small
140.3 <i>3</i>	0.04 2	374.90		234.7	$(3/2^+)$			-
149.13 <i>3</i>	0.05 2	149.14	5/2+	0.0	9/2+	E2	1.577	$\begin{aligned} &\alpha(\text{K})=0.284 \ 4; \ \alpha(\text{L})=0.955 \ 14; \\ &\alpha(\text{M})=0.257 \ 4; \ \alpha(\text{N})=0.0668 \ 10; \\ &\alpha(\text{O})=0.01354 \ 19 \\ &\alpha(\text{P})=0.001527 \ 22 \\ & \text{E}_{\gamma}: \ \text{weighted average of } 149.2 \ 1 \\ &(1997\text{Li}12) \ \text{and } 149.12 \ 3 \\ &(2015\text{Ah}04). \ \text{Others: } 149.0 \ 1 \\ &(1989\text{Ac}01), \ 152 \ 2 \ (1961\text{Ru}06). \\ & \text{Mult: } (\text{L}1+\text{L}2)/\text{L}3=1.72 \ 9 \\ &(1989\text{Ac}01), \ \alpha(\text{L}1+\text{L}2)\text{exp}=0.46 \ 12, \\ &\alpha(\text{L}3)\text{exp}=0.34 \ 9 \ (2015\text{Ah}04). \end{aligned}$
174.29 8	16.8 <i>17</i>	174.29	(7/2,9/2,11/2)+	0.0	9/2+	(M1)	2.71	$\begin{array}{l} \alpha(\mathrm{K}) = 2.19 \ 3; \ \alpha(\mathrm{L}) = 0.396 \ 6; \\ \alpha(\mathrm{M}) = 0.0940 \ 14; \ \alpha(\mathrm{N}) = 0.0245 \ 4; \\ \alpha(\mathrm{O}) = 0.00536 \ 8 \\ \alpha(\mathrm{P}) = 0.000782 \ 11 \\ \mathrm{E}_{\gamma}: \ \text{weighted average of } 174.3 \ 1 \\ (1997 \mathrm{Li12}) \ \text{and} \ 174.28 \ 8 \end{array}$

Continued on next page (footnotes at end of table)

221 Ra α decay 1997Li12,2015Ah04 (continued) $\gamma(^{217}\text{Rn})$ (continued) Ι_γ‡@ E_{γ}^{\dagger} E_i (level) \mathbf{J}_i^{π} \mathbf{E}_{f} \mathbf{J}_{f}^{π} Comments (2015Ah04) Others: 174.1 2 (1989Ac01), 176 2 (1961Ru06). I_{γ} : weighted average of 17 2 (1997Li12) and 16.6 17 (2015Ah04). Others: 18 2 (1989Ac01), 15 4 (1961Ru06). Mult.: deduced from intensity balance. 207.9 2 0.6 2 382.15 $(5/2^+, 7/2, 9/2^+)$ 174.29 (7/2,9/2,11/2)+ 225.7 2 0.2 1 374.90 149.14 5/2+ $\begin{array}{c}(5/2^+,7/2,9/2^+)\\(5/2^+,7/2,9/2^+)\\(5/2^+,7/2,9/2^+)\end{array}$ 149.14 5/2+ 0.2 1 382.15 232.9 3 289.1 3 0.7 2 382.15 93.00 (7/2+) 382.15 382.2 3 0.3 1 0.0 9/2+ 174.29 (7/2,9/2,11/2)+ 395.2 3 0.3 1 569.64 420.6 2 0.7 2 569.64 149.14 5/2+ 444.3 5 0.2 1 618.8 174.29 (7/2,9/2,11/2)+ 149.14 5/2+ 469.7 5 0.15 6 618.8 474.5 4 0.35 12 474.5 $0.0 \quad 9/2^+$ 476.5 4 0.40 15 569.64 93.00 (7/2+) 0.15 5 93.00 (7/2+) 525.8 4 618.8

[†] From 1997Li12, except where noted. Other measurements: 1961Ru06, 1989Ac01, 2015Ah04. Of the four additional questionable γ 's reported by 1961Ru06, the gammas seen by 1961Ru06 at 219 keV *10* with I=0.1%, at 293 keV with I=0.6%, and at 415 *10* keV with I=0.5%, may be associated with the 207.9 γ , 289.1 γ , and 420.6 γ , respectively. The 320-keV gamma, however, was not confirmed by 1989Ac01 or 1997Li12, therefore, is not given here.

[‡] Relative photon intensities from 1997Li12 normalized at 149.2 γ to 100, except where noted. The intensities measured by 2015Ah04, 1989Ac01 and 1961Ru06 are re-normalized by the evaluators to I(149.2 γ)=100.

[#] From the Adopted Gammas. For cases where the multipolarity arises from this dataset, supporting evidence is included in the comments.

[@] For absolute intensity per 100 decays, multiply by 0.125 20.

 $x \gamma$ ray not placed in level scheme.

²²¹Ra α decay 1997Li12,2015Ah04

