

$^{231}\text{Pa}(\text{p,t}), ^{231}\text{Pa}(\text{P,t}\gamma)$ 1994Le22,1998Le15

Type	Author	History	Citation	Literature Cutoff Date
Full Evaluation	F. G. Kondev, J. K. Tuli and E. Browne		NDS 208,397 (2026)	23-Oct-2025

$J^\pi(^{231}\text{Pa})=3/2^-, \pi 1/2[530]$.

$^{231}\text{Pa}(\text{p,t})$:

1994Le22: 22 MeV protons from the Munich tandem accelerator bombarding ^{231}Pa target of $100 \mu\text{g}/\text{cm}^2$, evaporated on a $12 \mu\text{g}/\text{cm}^2$ carbon backing. The emitted tritons were analysed with the Q3D magnetic spectrometer and detected in a position-sensitive light-ion detector. Measured: $\sigma(\text{E},\theta)$. Determined: E, L, J^π and configurations. Other (the same collaboration): 1991Gr13.

1982Ah08: 16.5 MeV proton beam from the Argonne tandem accelerators. The emitted tritons were analysed with the Engle split-pole magnetic spectrograph. Measured: E(t).

$^{231}\text{Pa}(\text{p,t}\gamma)$:

1998Le15: 24 MeV protons from the Munich tandem accelerator bombarding $105 \mu\text{g}/\text{cm}^2$ -thick ^{231}Pa target. Detectors: a planar Ge and two telescopes each consisting of two PIN diodes and CsI(Tl) crystal. Measured: $\text{E}\gamma$, t- γ coincidences.

 ^{229}Pa Levels

E(level) [†]	J^π [‡]	$T_{1/2}$	L	$\sigma_{\text{int}} [\mu\text{b}]$ ^b	Comments
0.0	$5/2^+$	1.54 d 5			$J^\pi, T_{1/2}$: From Adopted Levels. configuration: $\pi 5/2[642]$ Nilsson assignment from Adopted levels. Other: $\pi 3/2[651]$ in 1998Le15.
12.211 [#] 25	$3/2^-$		0	401 22	E(level): From Adopted Levels. Others: 11.6 keV 3 from (p,t) in 1998Le15, 19 keV 9 from (p,t) in 1994Le22 and 128 keV 15 from 1982Ah08, identified as the strongest peak in the observed (p,t) spectrum. configuration: $\pi 1/2[530]$ Nilsson assignment (1998Le15).
27.3 [@] 4	$1/2^-$		2	≤ 1.4	E(level): Other: 24 keV 2 from 140 keV 2 + 12.211 keV 25 – 128 keV in 1982Ah08 (recalibrated by the evaluators). J^π : Other: similarity with the $\pi 1/2[530]$ band in ^{231}Pa .
68.3 [#] 3	$7/2^-$		2	46 2	E(level): Other: 71 keV 3 from 187 keV 3 + 11.6 keV 3 – 128 keV in 1982Ah08 (recalibrated by the evaluators). J^π : Other: similarity with the $\pi 1/2[530]$ band in ^{231}Pa .
99.9 [@] 3	$5/2^-$		2	13.0 7	E(level): Other: 101 keV 3 from 217 keV 3 + 11.6 keV 3 – 128 keV in 1982Ah08 (recalibrated by the evaluators). J^π : Other: similarity with the $\pi 1/2[530]$ band in ^{231}Pa .
137.3 4	$(5/2^-)$		2	0.5 1	configuration: Probably a mixture of $\pi 5/2[512]$ and $\pi 5/2[523]$ Nilsson orbitals.
178.3 [#] 3	$11/2^-$		4	9.9 5	
220.5 [@] 4	$9/2^-$		4	5.4 3	
252.5 ^{&} 5	$1/2^+$		1	0.5 1	
284.7 ^{&} 3	$5/2^+$		3	1.6 2	
303.6 ^a 3	$3/2^+$		3	0.9 1	
338.5 [#] 3	$15/2^-$		6	4.5 3	
377.3 ^{&} 3	$9/2^+$		3	1.0 1	
389.5 [@] 6	$13/2^-$		6	1.1 1	
521.5 ^{&} 5	$13/2^+$		5	0.4 1	
546.1 [#] 7	$19/2^-$		8	0.30 4	
595.3 [@] 9	$17/2^-$		8	0.12 2	
689.9 ^a 6	$15/2^+$		7	0.23 3	
715.0 7	$3/2^-, (17/2^+)$		0+(7)	1.5 2	
739.3 9	$(1/2^-)$		(2)	1.4 2	

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$^{231}\text{Pa}(\text{p,t}), ^{231}\text{Pa}(\text{P,t}\gamma)$ **1994Le22,1998Le15** (continued) ^{229}Pa Levels (continued)

E(level) [†]	J^π [‡]	L	$\sigma_{\text{int}} [\mu\text{b}]^b$	E(level) [†]	J^π [‡]	L	$\sigma_{\text{int}} [\mu\text{b}]^b$
768.0 6	(7/2 ⁻)	2	1.0 1	1241.4 11		(4)	3.9 3
789.0 7			0.8 2	1264.9 11		(2)	6.4 4
792.9 [#] 8	(23/2 ⁻)	(10)	<0.3	1299.1 12		(4)	2.6 3
812.7 6	(5/2 ⁻)	2	0.8 1	1314.4 12		(4)	2.7 5
842.7 6	3/2 ⁻	0	20.0 11	1371.2 10	3/2 ⁻	0	6.1 4
858.8 9	(1/2 ⁻)	2	0.9 1	1413.1 11	3/2 ⁻	0	2.5 3
877.2 7	(7/2 ⁻)	2	3.7 3	1439.2 11	(3/2 ⁻)	(0)	4.8 3
903.4 8	(5/2 ⁻)	(2)	0.20 3	1469.4 12	(3/2 ⁻)	(0)	2.8 3
942.7 10	(11/2 ⁻)	4	2.0 2	1491.5 12			<0.9
978.6 10	3/2 ⁻	0	30 2	1522.4 13	3/2 ⁻	0	20.7 14
991.8 9	3/2 ⁻	0	17.5 10	1535.9 13	3/2 ⁻	0	84 5
1006.5 9	3/2 ⁻	0	24.6 13	1552.2 14	1/2 ⁻	2	5.3 6
1024.8 15		(2)	2.6 3	1582.0 13	7/2 ⁻	2	13.6 10
1034.2 10		2	8.7 5	1604.9 13	5/2 ⁻ , 1/2 ⁺	2+1	16.7 11
1069.1 10		2	5.9 4	1629.0 13	5/2 ⁺	3	4.8 4
1076.1 13		2	2.0 2	1648.6 13	3/2 ⁺	3	5.9 5
1085.6 10		2	6.6 5	1665.2 13			3.5 3
1117.0 10	(3/2 ⁻)	(0)	5.4 4	1678.9 14	(11/2 ⁻)	4	3.5 3
1133.5 11		(2)	2.6 2	1698.4 14	(9/2 ⁺)	(3)	3.6 4
1146.5 12		(2)	2.8 3	1721.1 14	(9/2 ⁻)	(4)	5.2 4
1161.9 11		2	6.8 5	1743.5 14			2.6 3
1173.2 10		2	13.6 8	1754.3 14			3.1 3
1186.1 12		(2)	1.8 2	1768.9 14			11.7 8
1196.7 12		(2)	5.3 4	1785.4 14			10.3 7
1212.0 11		2	14.0 10	1844.8 15			10.6 9
1220.7 11		2	9.0 8				

[†] From **1994Le22**, relative to the excitation energy of 12.211 keV 25 for the $J^\pi=3/2^-$ level of the $\pi 1/2[530]$ band, unless otherwise stated.

[‡] From **1994Le22**, based on L, $\sigma(\text{p,t})$, and band assignment, unless otherwise stated.

[#] Band(A): $K^\pi=1/2^-$, $\pi 1/2[530]$ band ($s=-1/2$).

@ Band(B): $K^\pi=1/2^-$, $\pi 1/2[530]$ band ($s=+1/2$).

& Band(C): $K^\pi=1/2^+$, mixed $\pi 1/2[400]$ and $\pi 1/2[660]$ band ($s=-1/2$).

^a Band(D): $K^\pi=1/2^+$, mixed $\pi 1/2[400]$ and $\pi 1/2[660]$ band ($s=+1/2$).

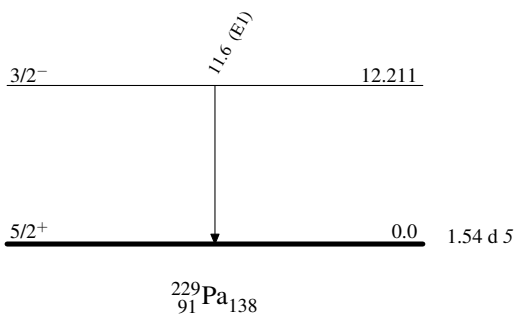
^b Integrated cross sections between 5° and 45°. Additional 20% systematics uncertainty needs to be added for absolute values.

 $\gamma(^{229}\text{Pa})$

E_γ	$E_i(\text{level})$	J_i^π	E_f	J_f^π	Mult.	Comments
11.6 3	12.211	3/2 ⁻	0.0	5/2 ⁺	(E1)	E_γ , Mult.: From 1998Le15 . Note, that $E_\gamma=12.211$ keV 25 from level energy difference – see Adopted Levels and gammas for detail.

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Level Scheme



$^{231}\text{Pa}(\text{p,t}), ^{231}\text{Pa}(\text{P,t}\gamma)$ 1994Le22,1998Le15

Band(A): $K^\pi=1/2^-$,
 $\pi 1/2[530]$ band ($s=-1/2$)

(23/2⁻) 792.9

Band(D): $K^\pi=1/2^+$,
mixed $\pi 1/2[400]$ and
 $\pi 1/2[660]$ band ($s=+1/2$)

15/2⁺ 689.9

Band(B): $K^\pi=1/2^-$,
 $\pi 1/2[530]$ band ($s=+1/2$)

17/2⁻ 595.3

Band(C): $K^\pi=1/2^+$,
mixed $\pi 1/2[400]$ and
 $\pi 1/2[660]$ band ($s=-1/2$)

19/2⁻ 546.1

13/2⁺ 521.5

13/2⁻ 389.5

9/2⁺ 377.3

15/2⁻ 338.5

3/2⁺ 303.6

5/2⁺ 284.7

1/2⁺ 252.5

9/2⁻ 220.5

11/2⁻ 178.3

5/2⁻ 99.9

7/2⁻ 68.3

1/2⁻ 27.3

3/2⁻ 12.211

$^{229}_{91}\text{Pa}_{138}$