Nuclear Data Sheets for A = 209*

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(Received September 24, 2013; Revised March 31, 2015)

Abstract: The experimental data are evaluated for known nuclides of mass number A=209 (Au,Hg,Tl,Pb,Bi,Po,At,Rn,Fr,Ra,Ac,Th). Detailed evaluated level properties and related nuclear structure information are presented, with the best values recommended for level energies, half-lives, γ -ray energies and intensities, decay data (energies, intensities and placement of radiations), and other spectroscopic data. This work supersedes the earlier full evaluation of A=209 by M.J. Martin (1991Ma16).

Cutoff Date: Literature available in NSR database up to September 30, 2013 has been included.

General Policies and Organization of Material: see <http://www.nndc.bnl.gov/nds/NDSPolicies.pdf>.

Acknowledgments: The authors express their gratitude to Dr. J.K. Tuli, Mrs. J. Totans and Mrs. M. Blennau from the National Nuclear Data Center for their assistance during the evaluation process and the preparation of the manuscript. The authors are thankful to the reviewer, Dr. M.J. Martin, for his critical reading of the manuscript and many useful comments, and suggestions. The authors are also grateful to Dr. Gopal Mukherjee, Kolkata for his help with the evaluation of the ^{209}Bi data.

* This work is supported by the Office of Nuclear Physics, Office of Science, U.S. Department of Energy under contract DE-AC02-06CH11357.

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Skeleton Scheme for A=209

Skeleton Scheme for A=209 (continued)

Ground-State and Isomeric-Level Properties

Nuclide	Level	J^π	$T_{1/2}$	Decay Modes
^{209}Au	0.0	(3/2+)	>300 ns	$\% \beta^-=100$
^{209}Hg	0.0	(9/2+)	36 s +7-4	$\% \beta^-=100$
^{209}Tl	0.0	1/2+	2.162 min 7	$\% \beta^-=100$
^{209}Pb	0.0	9/2+	3.234 h 7	$\% \beta^-=100$
^{209}Bi	0.0	9/2-	2.01×10^{19} y 8	$\% \alpha=100$
^{209}Po	0.0	1/2-	125.2 y 33	$\% \alpha=99.546 \ 7$; $\% \epsilon + \% \beta^+=0.454 \ 7$
^{209}At	0.0	9/2-	5.42 h 5	$\% \alpha=4.1 \ 5$; $\% \epsilon + \% \beta^+=95.9 \ 5$
^{209}Rn	0.0	5/2-	28.8 min 10	$\% \alpha=17 \ 2$; $\% \epsilon + \% \beta^+=83 \ 2$
^{209}Fr	0.0	9/2-	50.5 s 7	$\% \alpha=89 \ 3$; $\% \epsilon + \% \beta^+=11 \ 3$
^{209}Ra	0.0	5/2-	4.8 s 2	$\% \alpha=100$
^{209}Ac	0.0	(9/2-)	0.87 s +12-9	$\% \alpha=100$
^{209}Th	0.0+x	(13/2+)	2.5 ms +17-7	$\% \alpha=100$
^{213}Bi	0.0	9/2-	45.61 min 6	$\% \alpha=2.140 \ 10$; ...
^{213}Po	0.0	9/2+	3.72 μ s 2	$\% \alpha=100$
^{213}At	0.0	9/2-	125 ns 6	$\% \alpha=100$
^{213}Rn	0.0	(9/2+)	19.5 ms 1	$\% \alpha=100$
^{213}Fr	0.0	9/2-	34.6 s 3	$\% \alpha=99.45 \ 3$; ...
^{213}Ra	0.0	1/2-	2.73 min 5	$\% \alpha=80 \ 5$; ...
	1770	(17/2-)	2.15 ms 7	$\% \alpha=0.6 \ 4$; ...
	1770	(17/2-)	2.18 ms 4	$\% \alpha=0.6 \ 4$; ...
^{213}Ac	0.0	9/2-	738 ms 16	$\% \alpha=100$
^{213}Th	0.0	(5/2-)	144 ms 21	$\% \alpha=100$
^{213}Pa	0.0	(9/2-)	5.3 ms +40-16	$\% \alpha=100$
^{223}Ra	0.0	3/2+	11.43 d 5	$\%^{14}\text{C}=7.7 \times 10^{-8} \ 13$; ...

Adopted Levels

$Q(\beta^-)=6180$ SY; $S(n)=4440$ SY; $S(p)=8770$ CA; $Q(\alpha)=1860$ CA 2012Wa38,1997Mo25.
 $\Delta Q=-430$ keV, $\Delta S(n)=500$ keV (syst,2012Wa38).
 $S(p)$ and $Q(\alpha)$ are from calculations in 1997Mo25.

 ^{209}Au Levels

E(level)	$J\pi$	$T_{1/2}$	Comments
0.0	(3/2+)	>300 ns	$\% \beta^- = 100$. $\% \beta^- n = 90.8$ predicted in 1997Mo25. $J\pi$: from systematics in neighboring odd mass Au isotopes ($J\pi=3/2+$ in ^{205}Au , ^{203}Au , ^{201}Au , and ^{199}Au); $J\pi=1/2+$ is predicted in 1997Mo25. $T_{1/2}$: lower limit estimated from the time-of-flight between the production target and the focal plane in 2006Ca30. The actual lifetime is expected to be much longer. For example, $T_{1/2}=1$ s is estimated from systematics of $\log(T_{1/2})$ versus $\log(Q_{\beta^5})$ data from neighboring ^{199}Au , ^{201}Au , ^{203}Au and ^{205}Au isotopes. $T_{1/2}=88$ s is predicted in 1997Mo25. configuration= $\pi(d_{3/2})^{-1}$. The assignment is tentative.

Adopted Levels

$Q(\beta^-)=4990$ SY; $S(n)=3450$ SY; $S(p)=9830$ SY; $Q(\alpha)=1900$ SY 2012Wa38.
 $\Delta Q(\beta^-)=150$ keV, $\Delta S(n)=150$ keV, $\Delta S(p)=330$ keV, $\Delta Q(\alpha)=330$ keV (syst,2012Wa38).

 ^{209}Hg Levels

E(level)	$J\pi$	$T_{1/2}$	Comments
0.0	(9/2+)	36 s +7-4	$\% \beta^- = 100$. $J\pi$: from systematics in neighboring N=129 isotones ($J\pi=9/2+$ in ^{211}Pb , ^{213}Po and ^{215}Rn); $J\pi=9/2+$ is predicted in 1997Mo25. $T_{1/2}$: weighted average of 35 s +9-6 from $\beta-324.0\gamma(t)$, 35 s +13-8 from $\beta-208.2\gamma(t)$, 42 s +24-11 from $\beta-738.8\gamma(t)$ and 36 s +16-8 from $\beta-1424.2\gamma(t)$ (1998Zh22,1998Zh19). configuration= $\nu(g_{9/2})^{+1}$. The assignment is tentative.

Adopted Levels, Gammas

Q(β⁻)=3976 8; S(n)=4960 8; S(p)=7660 30; Q(α)=2710 SY 2012Wa38.
Δ(Q_α)=200 keV (syst,2012Wa38).

²⁰⁹Tl Levels

Cross Reference (XREF) Flags

A ²⁰⁹Hg β⁻ Decay
B ²¹³Bi α Decay
C ⁹Be(²³⁸U,Xγ)
D ²¹⁰Pb(t,α)

E(level) [†]	Jπ	XREF	T _{1/2}	Comments
0.0	1/2+	ABCD	2.162 min 7	%β ⁻ =100. Jπ: L(t,α)=(0); analogy to the g.s. of ²⁰⁷ Tl (Jπ=1/2+). T _{1/2} : weighted average of 2.20 min 7 from 1950Ha64, 2.161 min 7 from 1993El08 (the value repeated by the same authors in 1994Ar23 and 1998Ar03), and 2.25 min 14 from 1998Zh22. configuration: π(s _{1/2}) ⁻¹ . XREF: D(325). Jπ: 323.70γ M1+E2 to 1/2+, L(t,α)=(2); analogy to E=350 keV 6 level in ²⁰⁷ Tl (²⁰⁸ Pb(t,α)). configuration: π(d _{3/2}) ⁻¹ . XREF: D(739). XREF: D(947).
323.81 5	3/2+	ABCD		
738.4 4		A D		
946.6 8		A D		
984.3	(7/2+) [‡]	C		
984.3+x	(9/2+) [‡]	C		
1121.1+x	(13/2+) [‡]	C		
1121.1+z	(17/2+) [‡]	C	95 ns 11	E(level): decays via an unobserved γ-ray transition to the 984.3-keV level. E(level): decays via an unobserved γ-ray transition to the 1121.1+x-keV. T _{1/2} : from 661.2γ(t), 323.1γ(t) and 136.8γ(t) (2009Al29). configuration: π(s _{1/2}) ⁻¹ ⊗v(g _{9/2}) ⁺² . The assignment is tentative.
1230 10		D		
1369 10	(11/2-)	D		Jπ: L(t,α)=(5); analogy to E=1341 keV 6 level in ²⁰⁷ Tl (²⁰⁸ Pb(t,α)). configuration: π(h _{11/2}) ⁻¹ . The assignment is tentative. XREF: D(1748).
1748.2 6	(5/2+)	A D		Jπ: L(t,α)=(2); analogy to E=1674 keV 6 level in ²⁰⁷ Tl(t,α) (²⁰⁸ Pb(t,α)). configuration: π(d _{5/2}) ⁻¹ . The assignment is tentative.

[†] From a least-squares fit to E_γ.

[‡] From ⁹Be(²³⁸U,Xγ) (2009Al29), based on comparison of the observed levels with shell-model predictions.

γ(²⁰⁹Tl)

E(level)	E _γ [†]	I _γ [†]	Mult.	δ	α	Comments
323.81	323.70 2	100	M1+E2	1.30 +23-19	0.174 18	E _γ ,I _γ : from ²¹³ Bi α decay. Mult.,δ: from α(K)exp=0.131 15 in ²¹³ Bi α decay (2000Gr35).
738.4	738.4 [‡] 4	100 [‡]				
946.6	208.2 [‡] 6	100 [‡]				
984.3	661.2	100				
984.3+x	x [§]					
1121.1+x	136.8	100	E2		1.652	Mult.: α(exp)=1.5 4 (2009Al29) from intensity balances in ⁹ Be(²³⁸ U,Xγ).
1121.1+z	y [§]					
1748.2	1424.2 4	100				

[†] From ⁹Be(²³⁸U,Xγ) (2009Al29), unless otherwise stated.

[‡] From ²⁰⁹Hg β⁻ decay.

[§] Not observed directly, but required by the coincidence relationships. A low-energy transition (les than 85.6 keV, which is the binding energy of the K-shell electrons) is expected to depopulate this state, as indicated by the low intensity of the observed K_α x-rays in ⁹Be(²³⁸U,Xγ) (2009Al29).

²⁰⁹Hg β⁻ Decay 1998Zh22

Parent ²⁰⁹Hg: E=0.0; Jπ=(9/2+); T_{1/2}=36 s +7-4; Q(g.s.)=4990 syst; %β⁻ decay=100.

²⁰⁹Hg-J,T_{1/2}: From Adopted Levels of ²⁰⁹Hg.

²⁰⁹Hg-Q(β⁻): From 2012Wa38, ΔQ(β⁻)=150.

1998Zh22 (also 1998Zh19): ²⁰⁹Hg produced in Pb(¹⁸O,X) at 600 MeV at the HIRFL facility in China. γ-rays were detected by a large BGO detector (FWHM=1.9 keV at Eγ=1.33 MeV) and the β-particles were detected by a 25 mm-diameter plastic scintillators of the 4πΔE_β-type. Measured Eγ, Iγ, βγ-coin. Deduced levels.

1998Zh22 constructed the level scheme for ²⁰⁹Tl from the γ-transitions based on the only fact that the timings of these transitions are all similar to that of the 324γ in ²⁰⁹Tl. This makes these transitions except 324γ questionable considering the possibility of wrong assignments. Also, if the parent has Jπ=(9/2+), it should decay predominantly to the Jπ=(9/2+) and (7/2+) levels at E=1000 keV and E=1100 keV in ²⁰⁹Tl, respectively, which will most probably feed the low-lying states, supporting the argument above. However, there could be another possibility, which can not be excluded, that these transitions could be from decays of a low-spin isomer in ²⁰⁹Hg instead of the Jπ=(9/2+) ground state.

The decay scheme is incomplete, thus absolute γ- and β-ray emission probabilities, and log ft values were not deduced.

²⁰⁹Tl Levels

E(level) [†]	Jπ [‡]
0.0	1/2+
324.0 4	3/2+
738.4 4	
946.6 8	
1748.2 6	(5/2+)

[†] From a least-squares fit to Eγ.

[‡] From Adopted Levels.

γ(²⁰⁹Tl)

Eγ [†]	E(level)	Iγ [†]	Mult.	δ	α	Comments
208.2 6	946.6	51 16				
324.0 4	324.0	100	M1+E2	1.30 +23-19	0.174 18	Mult.,δ: from Adopted Gammas.
738.4 4	738.4	56 20				
1424.2 4	1748.2	111 39				

[†] From 1998Zh22.

Decay Scheme

213Bi α Decay 2013Ma13

Parent ²¹³Bi: E=0.0; Jπ=9/2-; T_{1/2}=45.61 min 6; Q(g.s.)=5988 4; %α decay=2.140 10.

²¹³Bi-J: From Adopted Levels of ²¹³Bi.

²¹³Bi-T_{1/2}: Weighted average of 45.59 min 6 (1973Po16) and 45.62 min 6 (2013Ma13,2013Su13). Others: 47 min 1 (1950Ha52), 46 min 1 (1964Gr11) and 46 min (1947En03).

²¹³Bi-Q(α): From Eα=5875 4, weighted average of 5860 30 (1947En03), 5870 6 (1967Dz02), 5869 10 (1964Gr11) and 5878 4 (2013Ma13). Q(g.s.)=5982 6 from 2012Wa38.

²¹³Bi-%α decay: From a high-resolution α spectroscopy in 2013Ma13. Others: %α=2.20 3 (1997Ch53), 2.09 3 (1998Ar03), 2.022 26 (1986He06) and 2.16 11 (1964Gr11).

2013Ma13: ²¹³Bi activities were produced from an open ²²⁵Ac source. α-particles were detected with a high-resolution ion-implanted planar silicon detector (PIPS). Measured Eα, Iα, α(t). Deduced levels, T_{1/2}, α-branching ratios.

2000Gr35: Measured Eγ, Iγ, I(x-ray), γγ-coin, xy-coin. Deduced levels, conversion coefficients.

1997Ch53: ²¹³Bi activities were produced from a ²²⁵Ac source. Measured Eα, Iα.

1989Ko26: ²¹³Bi activities were produced from a 20 μg ²²⁹Th sample. γ-rays were detected by a 17% efficient HPGe coaxial detector (FWHM=1.9 keV at 1.33 MeV) and a 2 cm³ LEPS (FWHM=190 eV at the Fe K_α x-line and a 8% efficient Ge(Li) detector for γγ-coincidence measurements. Measured Eγ, Iγ, γγ-coin. Deduced levels.

1981Di14: ²¹³Bi activities were produced from a ²²⁹Th sample. Measured γ-rays using a 90 cm³ Ge(Li) detector (FWHM=3.75 keV at E=2614 keV) and a 200 cm³ high-resolution intrinsic Ge detector (FWHM=0.6 keV for E<200 keV).

1977Vy02: ²¹³Bi activities were produced from a ²²¹Rn sample. Measured Eγ, Iγ using Ge(Li) detectors.

Others: 2002Mo46, 1998MaZO, 1998Ar03, 1994Ar23, 1992Li26, 1986He06, 1972Dz14, 1969ArZV, 1968GuZW, 1967VrZZ, 1964Gr11.

209Tl Levels

E(level) ^{†‡}	Jπ [§]
0.0	1/2+
323.70 2	3/2+

[†] from a least-squares fit to Eγ.

[‡] 1989Ko26 proposed a level at 868.3-keV based on the observation of 544.9 keV 3 and 868.0 keV 2 γ-rays. However, the later work of 1998Ar03 showed that 868γ belongs to the β⁻ branch of ²¹³Bi, rather than to its α branch. The 544.9γ includes a contribution from the double-escape peak of the 1567γ in ²⁰⁹Tl β⁻ decay and without the parallel 868γ to define the level energy, the placement of the residual component of the 544.9γ to ²¹³Bi α decay cannot be established.

[§] From Adopted Levels.

α radiations

Eα	E(level)	Iα [‡]	HF [†]	Comments
5558 4	323.70	8.45 11	90 9	Eα: weighted average of 5560 keV 4 (2013Ma13) and 5549 keV 10 (1964Gr11). Iα: from 2013Ma13. Others: 6.8 1 (1997Ch53), 7.4 14 (1964Gr11).
5875 4	0.0	91.55 11	264 26	Eα: weighted average of 5860 keV 30 (1947En03), 5870 keV 6 (1967Dz02), 5869 keV 10 (1964Gr11) and 5878 keV 4 (2013Ma13). Iα: from 2013Ma13. Others: 93.2 14 (1997Ch53), 92.6 14 (1964Gr11).

[†] r₀(²⁰⁹Tl)=1.51 3, average of 1.5396 1 for ²¹⁰Pb (deduced from HF(7686.82α)=1) and 1.48 5 for ²⁰⁸Hg, estimated from r₀(²⁰⁶Hg)=1.45 4 and the systematics of 1998Ak04.

[‡] For α intensity per 100 decays, multiply by 0.02140 10.

γ(²⁰⁹Tl)

Eγ	E(level)	Iγ [†]	Mult.	δ	α	Comments
323.70 2	323.70	0.167 3	M1+E2	1.30 +23-19	0.174 18	Eγ: weighted average of 323.81 keV 5 (1977Vy02), 323.7 keV 2 (1981Di14), 323.71 keV 3 (1989Ko26), 323.69 keV 5 (1998Ar03), 323.69 keV 1 (1994Ar23) and 323.80 keV 4 (2000Gr35). Other measurement: 1964Gr11. Iγ: from Iγ(323γ)/Iγ(440γ in ²¹³ Po)=0.00639 12 (weighted average of 0.0062 3 (2000Gr35), 0.0057 5 (1998Ar03), 0.0057 4 (1994Ar23), 0.0062 6 (1989Ko26) and 0.00660 15 (1981Di14)) and %Iγ(440γ)=26.10 17 (weighted average of 26.1 3 (1986He06) and 26.1 2 (2002Mo46). The latter value supersedes that of 25.4 3 (2000Gr35), which is from the same laboratory). The value of

Continued on next page (footnotes at end of table)

²¹³Bi α Decay 2013Ma13 (continued)

$\gamma(^{209}\text{Tl})$ (continued)

E_γ	$I_\gamma^\dagger$	Comments
^x 544.9 [‡] 3	0.0167 24	<p>$I_\gamma(323\gamma)/I_\gamma(440\gamma)$ in ²¹³Po=0.0112 8 (1977Vy02) is excluded from the average, since it is much higher than others and is also superseded by 2000Gr35.</p> <p>Other: %I_γ=0.154 3 from %I_α=8.45 11, %α=2.140 10 and α.</p> <p>Mult.,δ: from $\alpha(K)\text{exp}$=0.131 15 (2000Gr35). Other (from the same group): $\alpha(K)\text{exp}$=0.40 9 (1998MaZO).</p> <p>E_γ: from 1989Ko26.</p> <p>I_γ: from $I_\gamma(544.9\gamma)/I_\gamma(323.7\gamma)$=0.100 14 (1989Ko26) and $I_\gamma(323.7\gamma)$= 0.167 3, as deduced in the present work.</p>

[†] For absolute intensity per 100 decays, multiply by 1.000 5.

[‡] Placement of transition in the level scheme is uncertain.

^x γ ray not placed in level scheme.

Decay Scheme

⁹Be(²³⁸U,X γ) 2009Al29

2009Al29: E=1 GeV/nucleon ²³⁸U beam was produced by the SIS-18 accelerator at GSI, Darmstadt. A target of 2.5 g/cm² ⁹Be on a 223 mg/cm² Nb. The nuclides were selected by the Fragments Separator (FRS) and implanted into a stopper with an area of 15 cm by 5 cm and a thickness of 2 mm, consisting of 6 double-sided silicon detectors; x- and γ -rays were detected by the RISING array of 15 Euroball cluster Ge detectors. Measured β -delayed E_γ , I_γ , $\gamma\gamma(t)$ coin, $\gamma(t)$, (fragments) $\gamma(t)$, (fragment) $\beta\gamma(t)$ coin. Comparison with shell-model calculations. Other (from the same collaboration): 2009Al15.

²⁰⁹Tl Levels

$E(\text{level})^\dagger$	$J\pi$	$T_{1/2}$	Comments
0.0	1/2+ [‡]		
324	3/2+ [‡]		
985	(7/2+) [§]		
985+x	(9/2+) [§]		
1123+x	(13/2+) [§]		
1123+z	(17/2+) [§]	95 ns 11	<p>$E(\text{level})$: from expected (unobserved) γ-ray transition to $E=1123+x$-keV level with $z=x+y$.</p> <p>$T_{1/2}$: from 661.2$\gamma(t)$, 323.1$\gamma(t)$ and 136.8$\gamma(t)$ in 2009Al29.</p> <p>configuration: $\pi(s_{1/2})^{-1}\otimes\nu(g_{9/2})^{+2}$.</p>

[†] From 2009Al29.

[‡] From Adopted Levels.

[§] From 2009Al29, based on comparison of the observed levels with shell-model predictions (2009Al29).

⁹Be(²³⁸U,X γ) 2009Al29 (continued)

 $\gamma(^{209}\text{Tl})$

E $\gamma^{\dagger}$	E(level)	I $\gamma^{\dagger}$	Mult.	Comments
x $\ddagger$	985+x			
y $\ddagger$	1123+z		[E2]	
136.8	1123+x	41 10	E2	Mult.: $\alpha(\text{exp})=1.5\ 4$ from intensity balances in 2009Al29.
323.1	324	100 15		
661.2	985	96 19		

$\dagger$ From 2009Al29.

$\ddagger$ Not observed directly, but required by the coincidence relationships. A low-energy transition (less than 85.6 keV, which is the binding energy of the K-shell electrons) is expected to depopulate this state, as indicated by the low intensity of the observed K $_{\alpha}$ x-rays in 2009Al29.

²¹⁰Pb(t, α) 1976El07

1976El07: E=20 MeV triton beam was produced from the Los Alamos three-stage tandem accelerator. A target of 240 $\mu\text{g}/\text{cm}^2$ ²¹⁰Pb metal on a 50 $\mu\text{g}/\text{cm}^2$ carbon backing was used. Reaction products were momentum analyzed with a broad-range magnetic spectrometer and recorded on photographic plates, $\theta=42^\circ$, FWHM=40 keV (estimated by the evaluators from the authors' spectrum). Measured $\sigma(E_{\alpha},\theta)$. Deduced levels.
Target J $\pi(^{210}\text{Pb g.s.})=0+$.

²⁰⁹Tl Levels

E(level)	J π	L †	Comments
0.0	1/2+	(0)	configuration: $\pi(s_{1/2})^{-1}$.
325 10	3/2+	(2)	configuration: $\pi(d_{3/2})^{-1}$.
739 10			
947 10			
1230 10			
1369 10	(11/2-)	(5)	configuration: $\pi(h_{11/2})^{-1}$.
1748 10	(5/2+)	(2)	configuration: $\pi(d_{5/2})^{-1}$.

$\dagger$ Not measured directly in 1976El07, but inferred from L(t, α) for analogous levels (g.s., 350 keV 6, 1341 keV 6 and 1674 keV 6) in ²⁰⁷Tl (1970Ba07).

Adopted Levels, Gammas

Q(β^-)=644.0 11; S(n)=3937.4 13; S(p)=8153.9 22; Q(α)=2248 4 2012Wa38.

209Pb Levels

Single-particle states

Each of the seven single-particle neutron states predicted, on the basis of the shell-model, for $126 < N \leq 184$, has been seen in single-particle stripping reactions on ^{208}Pb . Except for the $1j_{15/2}$ state, these states have spectroscopic factors close to unity (see $^{208}\text{Pb}(\text{d,p})$, (pol d,p), (t,d), and (α , ^3He)). The $1j_{15/2}$ state is expected to mix with $J=15/2^-$ states resulting from the $2g_{9/2}$ state coupled to negative-parity ^{208}Pb core excitations. From (α , ^3He), three $L=7$ states at 3052, 3558, and 3716 could account for $\approx 12\%$ of the $1j_{15/2}$ strength, leaving $\approx 30\%$ still unaccounted for (1975Ti02). However, based on (d,p) data, 1974Ko20 suggest that these $L=7$ states may, in fact, account for all the missing $1j_{15/2}$ strength.

1976Ha56 show, on the basis of $^{210}\text{Bi}(9^-)(\text{t},\alpha)$ σ data, that the $J=15/2^-$ states at 1423 and 3052 exhaust nearly all of the configuration= $v(2g_{9/2})^{+1} \otimes 3^-$ strength in the ratio $S(3052)/S(1423)=2.4$.

The 1423 E3-transition from the 1423 level is enhanced by 25 over the Weisskopf single-particle estimate. As pointed out by 1969El02, this enhancement can be explained on the basis of the particle-vibration calculation of 1969Ha13. The 644 M2 transition from the 1423 level is retarded by a factor 6.2. The introduction of particle-vibration coupling reduces this retardation to ≈ 4 (1969El02).

Two-particle, one-hole neutron states

The reactions $^{207}\text{Pb}(\text{t,p})$ and $^{210}\text{Pb}(\text{p,d})$ preferentially excite two-particle one-hole states in ^{209}Pb with

Configuration= $v(3p_{1/2})^{-1} \otimes (v(\text{nlj})v(\text{n'l'j'}))^{+2}$ and configuration= $v(\text{nlj})^{-1} \otimes v(2g_{9/2})^{+2}_{0+}$, respectively

(1971Ig01, 1971Fl06). The neutrons nlj , n'l'j' in the first reaction are in the shell $N > 126$, while in the second reaction the neutron hole is in the shell $N \leq 126$. From the $^{207}\text{Pb}(\text{t,p})$ data, 1971Fl06 show that the levels for which L and σ values have been obtained contain all the two-particle strength observed for the lowest $J=L=0, 2, 4, 6$, and 8 states in ^{210}Pb . Also, the centroids of these ^{209}Pb states, for a given L value, have nearly the same spacing as the states with corresponding L values in ^{210}Pb .

From the $^{210}\text{Pb}(\text{p,d})$ data, 1971Ig01 show that, for the group of states with given $L(n)$ and J containing the major fraction of the hole spectroscopic strength, the centroid spacing (relative to the 2152 level) and sum strength for each group agree closely with the energies and strengths for the neutron-hole excitations in ^{207}Pb . These authors assign configurations of the type configuration= $v(\text{nlj})^{-1} \otimes v(2g_{9/2})^{+2}_{0+}$ to each state for which $L(n)$ was determined. The evaluator presents here the configurations only for the strongest states.

Cross Reference (XREF) Flags

A ^{209}Tl β^- Decay	J $^{208}\text{Pb}(\alpha, ^3\text{He})$	$^{208}\text{Pb}(^{17}\text{O}, ^{16}\text{O})$
B ^{213}Po α Decay	K $^{208}\text{Pb}(^7\text{Li}, ^6\text{Li}\gamma)$	$^{208}\text{Pb}(^{20}\text{Ne}, ^{19}\text{Ne})$
C $^{207}\text{Pb}(\text{t,p})$, (pol t,p)	L $^{208}\text{Pb}(^7\text{Li}, ^6\text{Li})$	$^{208}\text{Pb}(^{58}\text{Ni}, ^{57}\text{Ni})$
D $^{208}\text{Pb}(\text{n}, \gamma)$: E=thermal	M $^{208}\text{Pb}(^9\text{Be}, ^8\text{Be})$	$^{209}\text{Bi}(\pi^-, \gamma)$
E $^{208}\text{Pb}(\text{n}, \gamma)$: E=0.8–20 MeV	N $^{208}\text{Pb}(^{11}\text{B}, ^{10}\text{B})$	$^{209}\text{Bi}(\text{n,p})$
F $^{208}\text{Pb}(\text{n}, \text{X})$: Resonances	O Others:	$^{210}\text{Pb}(\text{p,d})$
G $^{208}\text{Pb}(\text{d,p})$, (pol d,p)	$^{208}\text{Pb}(^{12}\text{C}, ^{11}\text{C})$	$^{210}\text{Bi}(\text{t}, \alpha)$: Target=9- Isomer
H $^{208}\text{Pb}(\text{d,p}\gamma)$	$^{208}\text{Pb}(^{16}\text{O}, ^{15}\text{O})$	^{223}Ra ^{14}C Decay
I $^{208}\text{Pb}(\text{t,d})$	$^{208}\text{Pb}(^{17}\text{O}, ^{16}\text{O}\gamma)$	

E(level) [†]	J π ^b	XREF	T _{1/2}	Comments
0.0	9/2+	ABCD FGHIJKLMNO	3.234 h 7	<p>%β^-=100.</p> <p>Jπ: L(pol d,p)=4 and L+1/2 transfer from analyzing power fits.</p> <p>T_{1/2}: weighted average of 3.232 h 5 (2013Su13) and 3.253 h 14 (1972Be44). Others: 2.75 h 5 (1940Kr08), 3.3 h 1 (1942Ma03), 3.32 h 3 (1941Fa04), 3.31 h 3 (1959Po64), 3.31 h 3 (1971Pe03).</p> <p>$\mu=-1.4735$ 16 (1986An06, 2011StZZ).</p> <p>Q=-0.27 17 (1986An06, 2011StZZ).</p> <p>μ, Q: from atomic beam with laser fluorescence spectroscopy in 1986An06 with $\mu/\mu(^{207}\text{Pb})=-2.4866$ 27 and $\mu(^{207}\text{Pb})=+0.59258$ 1 Other: $\mu=-1.438$ 29 assuming $\mu(^{207}\text{Pb})=+0.5783$ and Q=-0.16 10 (1983Th03).</p> <p>configuration=$v(2g_{9/2})^{+1}$.</p> <p>Optical isotope shifts and hyperfine structure measured by LASER resonance fluorescence from atomic beams (1983Th03).</p> <p>$\delta\langle r^2 \rangle = 0.091$ 5 (1983Th03).</p>

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Adopted Levels, Gammas (continued)

209Pb Levels (continued)

E(level) [†]	J _π ^b	XREF	T _{1/2}	Comments
778.87 5	11/2+	BC GHIJKLMNO	8.2 ps 9	XREF: O(800). J _π : L(pol d,p)=6 and L-1/2 transfer from analyzing power fits. T _{1/2} : from recoil distance method in (¹⁷ O, ¹⁶ Oγ) (1973Ha39). configuration=v(l _{i11/2}) ⁺¹ .
1423 ^f 1	15/2-	C GHIJ MN _o	1.36 ns 30	J _π : L(pol d,p)=7 and L+1/2 transfer from analyzing power fits. T _{1/2} : from p(644γ)(t) in (d,pγ) (1967El05). configuration=v(l _{j15/2}) ⁺¹ .
1567.08 3	5/2+	A CD GHI KL MN _o	0.33 ps 9	J _π : L(pol d,p)=2 and L+1/2 transfer from analyzing power fits, 1567.087γ E2 to 9/2+. T _{1/2} : from (⁷ Li, ⁶ Liγ) (1972Ha59) by DSAM. configuration=v(3d _{5/2}) ⁺¹ .
2032.21 4	1/2+	A CD GHI M O	160 ps 6	XREF: O(2050). J _π : L(pol d,p)=L(t,d)=0. T _{1/2} : weighted average of 161 ps 8 from (117γ)(467γ)(ΔT) (1965Sa08) in ²⁰⁹ Tl β ⁻ decay and 160 ps 6 from p(465γ)(t) (1978Ju02) in (d,pγ). configuration=v(4s _{1/2}) ⁺¹ .
2149.42 4	1/2-	A CD G I O	3.96 ns 4	J _π : L(t,p)=0, L(d,p)=L(p,d)=1, 117.212γ E1 to 1/2+. T _{1/2} : from β(582γ)(t) in ²⁰⁹ Tl β ⁻ decay (1980Da15). configuration=v(3p _{1/2}) ⁻¹ .
2315.90 16	3/2- ^c	A D GH O		J _π : L(d,p)=(p,d)=1, 748.3γ to 5/2+, 2315.8γ to 9/2+.
2424? 5		A GH O		
2461.0 3	(5/2)-	A GH O		J _π : L(p,d)=3, possible feeding in ²⁰⁹ Tl β ⁻ decay from J _π =1/2+.
2491 1	7/2+	C GHI lMNO		J _π : L(d,p)=L(t,d)=4, L(t,p)=3. dominant configuration=v(2g _{7/2}) ⁺¹ .
2524.92 21	(1/2, 3/2)	A		J _π : direct feeding in ²⁰⁹ Tl β ⁻ decay from J _π =1/2+.
2537.5 4	3/2+	CD GHI lM O		J _π : L(d,p)=L(t,d)=2, L(t,p)=1. configuration=v(3d _{3/2}) ⁺¹ .
2563& 5	5/2-, 7/2-			J _π : L(p,d)=3.
2588 2	(11/2-)	C GHI O		J _π : L(d,p)=4,5. DWBA fit to σ(θ) suggests configuration=dominant v(2h _{11/2}) ⁺¹ .
2736 5	5/2-	C GH O		J _π : L(p,d)=3, L(t,p)=2. configuration=dominant v(2f _{5/2}) ⁻¹ .
2869 5	5/2-	C G O		J _π : L(p,d)=3, L(t,p)=2. E(level): weighted average of 2868 5 from (t,p), 2866 5 from (d,p), 2873 5 from (p,d).
2905.27 25	3/2-	A C O		J _π : L(p,d)=1, L(t,p)=2.
2994 5	3/2-, 5/2-	C I O		E(level): weighted average of 2992 5 from (t,p), 2996 5 from (t,d). J _π : L(t,p)=2.
3027 5	9/2-	C G o		E(level): weighted average of 3026 5 from (d,p) and 3028 5 from (t,p). J _π : L(d,p)=4,5, L(t,p)=4.
3031& 5	1/2-, 3/2-			J _π : L(p,d)=1.
3047 ^f 5	(15/2)-	GHIJ O		J _π : L(d,p)=7. No decay to 11/2+. Possible l _{j15/2} component.
3069.94 16	3/2- ^c	A G O		J _π : L(d,p)=L(p,d)=1. S in (p,d). configuration=dominant v(3p _{3/2}) ⁻¹ .
3072 [§] 5	11/2-, 13/2-	C		J _π : L(t,p)=6.
3100 [§] 5	(15/2-, 17/2-)	C		J _π : L(t,p)=(8).
3205 5	7/2-	C G		E(level): weighted average of 3206 5 from (t,p), 3203 5 from (d,p). J _π : L(d,p)=2,3, L(t,p)=4.
3302 5	11/2-	C GHI		J _π : L(d,p)=4,5, L(t,p)=6.
3361.2 15	(5/2-)	GHI		XREF: I(3373). J _π : γ transitions to 3/2+, 7/2+, no feedings to 1/2+ or 9/2+ levels. Note that L(n)=4,5 from (d,p), with suggested configuration=v(2h _{11/2}) ⁺¹ , is not consistent with the γ-decay mode from (d,pγ).

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Adopted Levels, Gammas (continued)

209Pb Levels (continued)

E(level) [†]	J ^π ^b	XREF		Comments
3361.5 3	(1/2, 3/2)	A		J ^π : 1329.3γ to 1/2+, direct feeding in ²⁰⁹ Tl β ⁻ decay from J ^π =(1/2+).
3389.09 16	(1/2, 3/2)	A C	G	J ^π : direct feeding in ²⁰⁹ Tl β ⁻ decay from J ^π =(1/2+), 1239.66γ to 1/2-.
3414@ 5			G	
3423 5	15/2-, 17/2-	C	GH	J ^π : L(t,p)=8.
3477§ 5		C		
3494 5	(7/2)- ^c		G O	E(level): weighted average of 3499 5 from (p,d) and 3490 5 from (d,p). J ^π : L(p,d)=3, L(d,p)=2,3, S from (p,d) and (d,p).
3524& 5	(3/2)- ^c		O	J ^π : L(p,d)=(1).
3530 ^a 5			O	
3557 5	(15/2)-	C G J		E(level): weighted average of 3556 5 from (d,p) and 3559 5 from (t,p). 3550 14 from (α, ³ He). J ^π : L(d,p)=7, L(t,p)=(8).
3562 5	(3/2)- ^c		O	E(level): from (p,d). J ^π : L(p,d)=(1).
3615@ 5			G	
3637& 5	(3/2)- ^c		O	J ^π : L(p,d)=(1).
3650‡ 7	(5/2-)	C GH		E(level): from Eγ. 3656 5 from (d,p) and 3659 5 from (t,p). J ^π : L(d,p)=2,3, L(t,p)=(2).
3657‡ ^e 5			O	
3659‡& 5	13/2+		O	configuration=dominant v(1i _{13/2}) ⁻¹ . J ^π : L(p,d)=6, S in (p,d).
3681 5	(1/2-, 3/2-)		GH	XREF: H(3676). E(level): from (d,p). J ^π : L(d,p)=(1). Possible 1644γ to 1/2+.
3708§ 5	(5/2+, 7/2+)	C		J ^π : L(t,p)=(3).
3716 5	13/2-, 15/2-		G J	E(level): from (d,p). 3715 14 from (α, ³ He). J ^π : L(d,p)=7.
3743§ 5	(7/2-, 9/2-)	C		J ^π : L(t,p)=(4).
3751& 5	9/2-, 11/2, 13/2+		O	J ^π : L(p,d)=5,6.
3802 ^e 5		I	O	E(level): weighted average of 3800 10 from (t,d), 3802 5 from (t,α): Target=9- Isomer.
3813 5	9/2-, 11/2, 13/2+	C	O	E(level): weighted average of 3814 5 from (t,p), 3811 5 from (p,d). J ^π : L(p,d)=5,6.
3831& 5	(3/2)- ^c		O	J ^π : L(p,d)=(1).
3839 ^a ^e 5			O	
3854§ 8		C		
3897 5	(7/2)- ^c	C	GH O	XREF: G(3904). J ^π : L(p,d)=3, 3897γ to 9/2+.
3936 2	(1/2-, 3/2-)		gH	J ^π : proposed by 1975Du08 based on the argument that only the configuration=d _{5/2} ⊗3- or i _{11/2} ⊗5- are consistent with the observed γ decay.
3940 4	13/2+ ^d		gH J O	J ^π : L(p,d)=6, γ transitions to 9/2+, 15/2-. L(α, ³ He)=6,7,8 for E=3934.
3947 5		C	G	E(level): weighted average of 3946 8 from (t,p), 3947 5 from (d,p).
3958 ^a ^e 5			O	
3977 3	(11/2-, 13/2+)		GH	E(level): from (d,pγ), 3985 5 from (d,p). J ^π : suggested by 2554γ to 15/2-, 3198γ to 11/2+ and 3977γ to 9/2+, but in disagreement with L(d,p)=(2,3).
3984.4 13		c F		E(level): from (n,X), 3989 8 from (t,p).
3991 ^e 5	11/2+, 13/2+	c i	o	J ^π : L(p,d)=6. E(level): weighted average of 3987 5 from (t,α), 3995 5 from (p,d), 3989 8 from (t,p), 3998 10 from (t,d).
4005 4			Hi o	J ^π : γ to 15/2- suggests J≥11/2.
4008.3 [#] 13	3/2-		FG	XREF: G(4008).
4015.3 [#] 13	3/2-		F	
4016 6	(7/2-)	C	GH	J ^π : L(d,p)=(2,3), L(t,p)=(4), but in disagreement with L(d,pγ)≥4.
4023.5 [#] 14	1/2-		F O	XREF: O(4024). J ^π : Other: L(p,d)=(1).
4032 ^a 5			O	
4054.1 [#] 13	3/2-		F	
4066.9 [#] 13	3/2+, 5/2+		F	J ^π : L(n)=2 from (n,X).
4075 5	(3/2+, 5/2, 7/2-)	C G I		E(level): weighted average of 4074 8 from (t,p), 4075 5 from (d,p), 4075 10 from (t,d). J ^π : L(d,p)=(2,3).

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Adopted Levels, Gammas (continued)

²⁰⁹Pb Levels (continued)

E(level) [†]	J ^π ^b	XREF	Comments
4080 ^a 5			O
4089.3 13	1/2-, 3/2-	F	O XREF: O(4084). J ^π : L(n)=1 from (n,X); L(p,d)=(1).
4097 5	(5/2+)	C G I	E(level): weighted average of 4099 8 from (t,p), 4096 5 from (d,p), 4094 10 from (t,d). J ^π : L(d,p)=(2,3), L(t,p)=(3).
4100.1 [#] 13	1/2-, 3/2-	F	J ^π : L(n)=1 from (n,X).
4104.6 [#] 13	3/2+, 5/2+	F	J ^π : L(n)=2 from (n,X).
4105.1 [#] 13	3/2-	F	
4106.0 [#] 13	3/2+, 5/2+	F	J ^π : L(n)=2 from (n,X).
4112 5	(3/2+, 5/2, 7/2-)	G I	J ^π : L(d,p)=(2,3).
4119& 5	1/2-, 3/2-		J ^π : L(p,d)=1.
4138 5	(5/2, 7/2-)	C GHI	O XREF: H(4129). E(level): weighted average of 4140 8 from (t,p), 4137 5 from (d,p), 4146 10 from (t,d), 4145 5 from (p,d), 4129 5 from (d,pγ). J ^π : L(d,p)=(2,3), 4138γ to 9/2+, in disagreement with L(d,pγ)≥5.
4164 ^{ae} 5			O
4168 5	(11/2-)	C G	O E(level): weighted average of 4169 8 from (t,p), 4166 5 from (d,p), 4174 10 from (p,d). J ^π : L(d,p)=(5), L(t,p)=(6).
4206.2 [#] 13	3/2+	F	
4211 14		J	E(level): from (α, ³ He) only. J ^π : L(α, ³ He)=6,7, or 8.
4212 5	(7/2)- ^c	G	O E(level): weighted average of 4211 7 from (d,p), 4212 5 from (p,d). J ^π : L(p,d)=3.
4214.1 [#] 13	1/2-	F	
4222 5	(7/2)- ^c	g	O XREF: g(4239). E(level): from (p,d). J ^π : L(p,d)=3.
4248 5		g	O XREF: g(4239). E(level): from (t,α): Target=9- Isomer.
4260.1 [#] 13	3/2-	F	
4265 ^a 10			O
4267 5	(7/2)- ^c	C	O E(level): weighted average of 4260 8 from (t,p), 4270 5 from (p,d). J ^π : L(p,d)=3.
4281 8		C I	
4289.8 [#] 13		F	
4289.8 [#] 13	3/2+	F	
4295 [@] 5	(1/2, 3/2-)	G	J ^π : L(d,p)=(0,1).
4312 5	5/2-, 7/2-	C I	O E(level): weighted average of 4315 8 from (t,p), 4322 10 from (t,d), 4309 5 from (p,d). J ^π : L(p,d)=3.
4342.6 [#] 13	3/2-	F	
4347 5		G	O E(level): weighted average of 4348 5 from (d,p), 4345 8 from (p,d), 4345 10 from (t,α).
4353.8 13	3/2-	C F	O XREF: C(4363)O(4358). J ^π : L(t,p)=(2).
4373.6 [#] 13		F	
4385 ^e 5	(13/2-)	C G	O E(level): weighted average of 4384 8 from (t,p), 4380 5 from (d,p), 4390 5 from (t,α). J ^π : L(t,p)=(6). Excitation in (t,α), if the same level as seen in (t,p), makes 13/2- much more likely than 11/2-.
4395& 5	5/2-, 7/2-		O J ^π : L(p,d)=3.
4413 [§] 8		C	
4424.1 [#] 13	1/2-	Fg	XREF: g(4430).
4440.7 [#] 13	3/2-	Fg	XREF: g(4430).
4441.0 [#] 13	1/2+	F	
4451 [§] 8	(11/2-, 13/2-)	C	J ^π : L(t,p)=(6).
4462.0 [#] 13	5/2+	F	
4466 ^a 5			O
4466 7	1/2-, 3/2-	G	O E(level): weighted average of 4464 7 from (d,p), 4472 12 from (p,d). J ^π : L(p,d)=1.
4498.6 [#] 13	1/2-	F	

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Adopted Levels, Gammas (continued)

²⁰⁹Pb Levels (continued)

E(level) [†]	Jπ ^b	XREF	Comments
4502.3 [#] 13	5/2-, 7/2-	F	Jπ: L(n)=3 from (n,X).
4505.5 [#] 13	3/2+, 5/2+	F	Jπ: L(n)=2 from (n,X).
4506 8		C G	E(level): weighted average of 4502 10 from (d,p), 4508 8 from (t,p).
4518.2 [#] 13		F	
4532.1 [#] 13	5/2-, 7/2-	F	Jπ: L(n)=3 from (n,X).
4535 8		C G	O E(level): weighted average of 4539 8 from (t,p), 4530 10 from (d,p), 4529 12 from (p,d), 4538 10 from (t,α).
4543.6 [#] 13	5/2-, 7/2-	F	Jπ: L(n)=3 from (n,X).
4547.5 [#] 13	5/2-, 7/2-	F	Jπ: L(n)=3 from (n,X).
4550.4 [#] 13		F	
4560 5	5/2-, 7/2-	G	O E(level): weighted average of 4552 10 from (d,p), 4562 5 from (p,d). Jπ: L(p,d)=3.
4566 ^a 10			O
4569.3 [#] 13	5/2-	F	
4570.5 [#] 13	7/2	F	
4581 5	(7/2)-	C G	O E(level): weighted average of 4578 8 from (t,p), 4575 10 from (d,p), 4584 5 from (p,d). Jπ: L(p,d)=3, L(t,p)=(4).
4598 ^a 10			O
4617 10		G	O E(level): weighted average of 4612 10 from (d,p), 4621 10 from (p,d).
4620.8 13	5/2-	F	
4627.3 [#] 13	5/2-, 7/2-	F	Jπ: L(n)=3 from (n,X).
4629 8	(11/2-, 13/2-)	C G	E(level): weighted average of 4629 8 from (t,p), 4629 10 from (d,p). Jπ: L(t,p)=(6).
4633.6 [#] 13	5/2+	F	
4655.0 [#] 13	5/2+	F	
4655.6 [#] 13	3/2-	F	
4656.9 [#] 13	5/2-, 7/2-	F	Jπ: L(n)=3 from (n,X).
4660 6		C G	E(level): weighted average of 4560 8 from (t,p), 4661 10 from (d,p).
4673.0 [#] 13	5/2-	FG	O XREF: G(4671)O(4676). Jπ: Other: L(p,d)=3.
4688 5	5/2-, 7/2-	C	O E(level): weighted average of 4686 8 from (t,p), 4690 5 from (p,d). Jπ: L(p,d)=3.
4698.0 [#] 13	3/2-	F	
4698.6 [#] 13	7/2-	F	
4701 ^a 10			O
4719.7 [#] 13	5/2-	C FG	O XREF: C(4715)G(4706)O(4715). Jπ: Other: L(p,d)=3.
4729 8		C G	E(level): weighted average of 4731 8 from (t,p), 4726 10 from (d,p).
4745 8		C G	E(level): weighted average of 4743 8 from (t,p), 4747 10 from (d,p).
4747.6 [#] 13	7/2-	F	
4747.9 [#] 13	1/2-	F	
4749.2 [#] 13	5/2+	F	
4757.5 [#] 13	5/2-	F	
4758 8		C G	E(level): weighted average of 4754 8 from (t,p), 4764 10 from (d,p).
4765.5 [#] 13	5/2-, 7/2-	F	Jπ: L(n)=3 from (n,X).
4767 ^{ae} 10			O
4780 8	5/2-, 7/2-	C	O E(level): weighted average of 4778 8 from (t,p), 4781 8 from (p,d). Jπ: L(p,d)=3.
4783.8 [#] 13	3/2+	F	Jπ: L(n)=3 from (n,X).
4794.3 [#] 13	5/2-	F	
4799 [@] 10		G	
4811.0 [#] 13	3/2-	F	
4816 7	1/2-, 3/2-	C	O E(level): weighted average of 4813 8 from (t,p), 4819 7 from (p,d). Jπ: L(p,d)=1.
4818.0 [#] 13	1/2-	F	
4821.4 [#] 13	1/2+	F	
4837 ^{ae} 10			O
4839 5	(1/2-, 3/2-)	C	O E(level): weighted average of 4843 8 from (t,p), 4837 5 from (p,d). Jπ: L(p,d)=(1).
4843.6 [#] 13	1/2-	F	
4844.6 [#] 13	7/2-	F	
4852 ^a 10			O

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)
²⁰⁹Pb Levels (continued)

E(level) [†]	J _π ^b	XREF			Comments
4853.5 [#] 13	5/2-		F		
4860.0 [#] 13	1/2-		F		
4869 8		C	G	O	E(level): weighted average of 4877 8 from (t,p), 4864 10 from (d,p), 4865 8 from (p,d).
4877.3 [#] 13	3/2+		F		
4880.1 [#] 13	1/2-		F		
4880.8 [#] 13	3/2-		F		
4882.5 [#] 13	5/2+		F		
4897 9		C	G		E(level): weighted average of 4904 8 from (t,p) and 4885 10 from (d,p).
4907.0 [#] 13	3/2-		F		
4916.9 [#] 13	3/2-		F		
4923 5			G	O	E(level): weighted average of 4920 10 from (d,p), 4924 5 from (p,d).
4930.3 [#] 13	1/2+		F		
4937? ^a 10				O	
4938 8	1/2-, 3/2-	C	G	O	E(level): weighted average of 4931 8 from (t,p), 4940 10 from (d,p), 4944 9 from (p,d). J _π : L(p,d)=1.
4965 10		C	G	O	XREF: O(4967). E(level): weighted average of 4966 10 from (t,p), 4962 10 from (d,p), 4967 10 from (t,α).
4985 ^e 10			G	o	XREF: o(4900). E(level): weighted average of 4986 10 from (d,p), 4984 10 from (t,α).
4997 10		C		o	XREF: o(4900)o(5000). E(level): from (t,p).
5026 10		C	G	O	E(level): weighted average of 5026 10 from (t,p), 5028 10 from (d,p), 5022 15 from (t,α).
5059 7		C	G		E(level): weighted average of 5057 10 from (t,p), 5061 10 from (d,p).
5081 10	(1/2-, 3/2-)	C	G	O	E(level): weighted average of 5083 10 from (t,p), 5085 10 from (d,p), 5074 10 from (p,d). J _π : L(p,d)=(1).
5100 10		C	G	O	E(level): weighted average of 5107 10 from (t,p), 5102 10 from (d,p), 5094 8 from (p,d).
5115 ^a 10				O	
5135 10		C	I	O	E(level): weighted average of 5134 10 from (t,p), 5134 10 from (t,d), 5136 10 from (p,d).
5159 10		C	G I	O	E(level): weighted average of 5161 10 from (t,p), 5153 10 from (d,p), 5160 10 from (t,d) and (p,d).
5172 ^e 10			G	O	E(level): weighted average of 5170 10 from (d,p), 5174 10 from (t,α).
5202 ^{ae} 15				O	
5216 10	1/2-, 3/2-	C		O	E(level): weighted average of 5211 10 from (t,p), 5222 12 from (p,d). J _π : L(p,d)=1.
5241 [§] 10		C			
5290 ^{ae} 15				O	
5326 10		C		O	E(level): weighted average of 5326 10 from (t,p), 5328 15 from (t,α).
5359 ^{&} 10				O	
5400 [§] 10		C			
5423 [§] 10		C			
5476 [§] 10		C			
5513 [§] 10		C			
5577 [§] 10		C			
5600 [§] 10		C			
5637 10		C		O	XREF: O(5620). E(level): from (t,p).
5684 [§] 10		C			
5759 [§] 10		C			
5834 [§] 10		C			
5861 [§] 10		C			
5931 [§] 10		C			
5985 [§] 10		C			
6050 [§] 10		C			
6082 [§] 10		C			
6138 [§] 10		C			
6198 [§] 10		C			

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Adopted Levels, Gammas (continued)

209Pb Levels (continued)

E(level) [†]	XREF	Comments
6248 [§] 10	C	
6390 [§] 10	C	
6437 10	C	O XREF: O(6470).
		E(level): from (t,p).
7.9×10 ³ 4	O	E(level): from (π ⁻ ,γ) (1974Ba44).
		Γ=2 MeV from ²⁰⁹ Bi(n,p) (1984Br03).
		analog of possible giant quadrupole resonance expected at ≈26.5 MeV in ²⁰⁹ Bi (1984Br03).
13700 500	E	O XREF: O(13000)O(15000).
		E(level): from (n,γ): E=0.8–20 MeV (1972Be46).
		Giant dipole resonance, Γ=2–4 MeV from ²⁰⁹ Bi(n,p) (1984Br03).

[†] From a least-squares fit to γ-ray energies, unless otherwise noted.

[‡] 1977Ha07 report a level at 3657 5 from ²¹⁰Bi(9-)(t,α), which based just on energy could correspond to either (or both) the (5/2-) 3656 or 13/2+ 3659. As pointed out by the authors, the 5/2- level could only be reached through 1i_{13/2} proton pickup whose component in the ²¹⁰Bi(9-) target is very small. The 13/2+ level could be reached by 1h_{11/2} proton pickup.

[§] From (t,p), (pol t,p).

From (n,X): Resonances.

@ From (d,p), (pol d,p).

& From (p,d).

a From (t,α): Target=9- Isomer.

b Assignments given without arguments are from 1986Ho19 in (n,X), based on R-matrix fits to experimental differential cross section data, unless otherwise noted. See (n,X) for details.

c From 1971Ig01, based on L(n) in (p,d) and the following assumptions: 1) for L(n)=1, the 2152 level exhausts all the 3p1/2 neutron strength, 2) for L(n)=3, the 2463, 2741 and 2873 levels exhaust all the 2f5/2 neutron strength.

d A level at 3947 5 with L(n)=(2,3) is reported in (d,p). This L(n) value is not consistent with the J value for either member of the 3936, 3940 doublet seen in (d,pγ).

e On the basis of σ in (t,α), 1977Ha07 suggest that this level has a configuration containing a large component of ²¹⁰Bi(9-) coupled to a proton hole.

f On the basis of σ in (t,α), 1977Ha07 suggest that the configuration=v(2g_{9/2})⁺¹⊗3⁻ (J=15/2-) strength is contained mainly in the 1423 and 3052 levels.

γ(²⁰⁹Pb)

E(level)	Eγ [†]	Iγ [†]	Mult. [§]	α	Comments
778.87	778.87 5	100	[M1]	0.0339	Eγ: from ²¹³ Po α decay.
					B(M1)(W.u.)=0.0055 6.
1423	644 [‡] 2	11 [‡] 1	[M2]	0.1488 25	B(M2)(W.u.)=0.57 14.
	1423 [‡] 1	100 [‡] 2	[E3]	0.00716	B(E3)(W.u.)=26 6.
1567.08	1567.08 2	100	E2	0.00294	B(E2)(W.u.)=2.5 7.
					Mult.: α(K)exp=0.0024 9 (2000Gr35) from ²⁰⁹ Tl β ⁻ decay is consistent with E2 and possibly with E1, but T _{1/2} (γ to 9/2+) consistent with E2 not E1.
2032.21	465.128 24	100	E2	0.0350	B(E2)(W.u.)=2.13 8.
					Mult.: α(K)exp=0.027 4 (2000Gr35) from ²⁰⁹ Tl β ⁻ decay.
2149.42	117.21 5	100 3	E1	0.295	Mult.: α(K)exp=0.25 2 (2000Gr35) from ²⁰⁹ Tl β ⁻ decay.
					B(E1)(W.u.)=2.32×10 ⁻⁵ 11.
	582.4 2	0.39 5	[M2]	0.200	B(M2)(W.u.)=0.0100 14.
	2149.0# 10	<8.4×10 ⁻⁴	[M4]	0.01529	B(M4)(W.u.)<7.
2315.90	284.04 23	100 50	[E1]	0.0335	
	748.3 3	57 21	[E1]	0.00428	
	2315.9 3	21 2	[E3]	0.00292	
2461.0	311.5 3		[E2]	0.1034	Eγ: observed in ²⁰⁹ Tl β ⁻ decay only.
	898 [‡] 6	25 [‡] 25	[E1]	0.00304 6	Eγ: not observed in ²⁰⁹ Tl β ⁻ decay.
	2465 [‡] 4	100 [‡] 50	[M2]	0.00473	Eγ: not observed in ²⁰⁹ Tl β ⁻ decay.
2491	1712 [‡] 2	3.1 [‡] 5	[E2]	0.00256	
	2491 [‡] 1	100 [‡] 1	[M1]	0.00252	
2524.92	375.5 2	100	[E1]	0.01773	
2537.5	970.5 5	100	[M1]	0.0192	Eγ: from (n,γ) thermal; Other: 970 1 from (d,pγ).
2588	2588 [‡] 2	100 [‡]			
2736	1169 [‡] 5	100 [‡]	[E1]	0.00190	
2905.27	755.6 3	19 3	[M1]	0.0366	

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Adopted Levels, Gammas (continued) $\gamma(^{209}\text{Pb})$ (continued)

E(level)	$E_{\gamma}^{\dagger}$	$I_{\gamma}^{\dagger}$	Mult. [§]	α	Comments
2905.27	873.5 4	100 14	[E1]	0.00320	
3047	1624 $\frac{1}{2}$ 5	100 $\frac{1}{2}$			
3069.94	920.53 17	100	[M1]	0.0220	
3302	3302 $\frac{1}{2}$ 5	100 $\frac{1}{2}$			
3361.2	824 $\frac{1}{2}$ 2	100 $\frac{1}{2}$ 18			
	870 $\frac{1}{2}$ 2	55 $\frac{1}{2}$ 9			
	1794 $\frac{1}{2}$ 5	27 $\frac{1}{2}$ 9			
3361.5	1329.3 3	100			
3389.09	1239.66 15	100			
3423	2000 $\frac{1}{2}$ 5	100 $\frac{1}{2}$			
3650	3650 $\frac{1}{2}$ 7	100 $\frac{1}{2}$			
3897	3897 $\frac{1}{2}$ 5	100 $\frac{1}{2}$			
3936	1399 $\frac{1}{2}$ 3	18 $\frac{1}{2}$ 12			
	1904 $\frac{1}{2}$ 2	100 $\frac{1}{2}$ 12			
3940	2517 $\frac{1}{2}$ 4	67 $\frac{1}{2}$ 17			
	3940 $\frac{1}{2}$ 5	100 $\frac{1}{2}$ 17			
3977	2554 $\frac{1}{2}$ 4	55 $\frac{1}{2}$ 18			
	3198 $\frac{1}{2}$ 5	27 $\frac{1}{2}$ 18			
	3977 $\frac{1}{2}$ 5	100 $\frac{1}{2}$ 18			
4005	2582 $\frac{1}{2}$ 4	100 $\frac{1}{2}$			
4016	4016 $\frac{1}{2}$ 6	100 $\frac{1}{2}$			
4138	4138 5				

E γ : from level energy difference, 4129 5 from (d,p γ).[†] From ²⁰⁹Tl β -decay, unless otherwise noted.[‡] From (d,p γ).[§] Based on conversion coefficients deduced from relative intensities of K x-rays or K-conversion lines and γ -rays in ²⁰⁹Tl β -decay (2000Gr35).

Placement of transition in the level scheme is uncertain.

209Tl β^- Decay 2000Gr35,1998Ar03,1989Ko26Parent ²⁰⁹Tl: E=0.0; J π =1/2⁺; T_{1/2}=2.162 min 7; Q(g.s.)=3976 8; % β^- decay=100.²⁰⁹Tl-J, T_{1/2}: From Adopted Levels of ²⁰⁹Tl.²⁰⁹Tl-Q(β^-): From 2012Wa38.

2000Gr35: ²⁰⁹Tl source was prepared from the decay of ²²⁵Ac at JINR. γ -rays were detected with a 200 cm³ HPGe detector (FWHM=3.5 keV at E γ =1.33 MeV), a 60 cm³ Ge(Li) detector (FWHM=1.9 keV) and a 2 cm³ HPGe detector (FWHM=1.0 keV); β -rays were detected with a Si(Li) detector (FWHM=2.1 keV for the ²⁰⁷Bi K1063 line). Measured E γ , I γ , $\gamma\gamma$ -coin, I β . Deduced levels, γ -branchings, β -branchings, log ft.

1998Ar03, 1994Ar23 and 1993El08: ²⁰⁹Tl activities were produced from α decays of ²¹³Bi sources. γ -rays were detected with spectrometers of a n-type HPGe detector of 17% relative efficiency and a 30% p-type coaxial HPGe, FWHM=1.90 keV at 1.33 MeV. Measured E γ , I γ , γ (t), $\gamma\gamma$ -coin. Deduced levels, J π , log ft.

1989Ko26: ²⁰⁹Tl was prepared from a ²²⁹Th sample following α decays of ²¹³Bi at the C.E.N. at Fontenay aux Roses. γ -rays were detected with γ -spectrometers of a HPGe detector (17%, FWHM=1.9 keV), a low-energy photon spectrometer (LEPS, FWHM=190 eV at the Fe K α x-line, and a 8% Ge(Li) detector. Measured E γ , I γ , $\gamma\gamma$ -coin. Deduced levels.

1981Di14: ²⁰⁹Tl was produced at ORNL. γ -rays were detected with a 90 cm³ Ge(Li) detector and a 200 cm³ HPGe detector. Measured E γ , I γ . Deduced levels, γ -branchings.

1980Da15: ²⁰⁹Tl activities were produced from the ²²⁵Ac source. γ -rays were detected with a Ge(Li) detector.

Measured E γ , I γ , γ (t). Deduced the decay-branching to the E=2032 level and T_{1/2} of the E=2150 level.

1977Vy02: ²⁰⁹Tl was produced at JINR. γ -rays were detected with four Ge(Li) detectors and β -rays were detected with a Si(Li) detector. Measured E γ , I γ . Deduced levels, branching ratios.

1965Sa08: ²²⁵Ac sample. γ -rays were detected with scintillators. Measured E γ , $\gamma\gamma$ (t). Deduced levels, T_{1/2} from delayed coincidence.

1956St79: ²²⁵Ac sample. β particles and γ -rays were detected by scintillation detectors. Measured E γ , $\beta\gamma$ (t). Deduced levels, T_{1/2}.

1999GrZT: Measured E γ , I γ . Deduced levels, branching ratios.

2003ChZV: Measured E γ , I γ with HPGe detectors. Deduced levels, branching ratios.

Others: 1950Ha64, 1952Wa24, 1955Ma61, 1955St04, 1972Dz14, 1986He06, 1998MaZO, 2006Va23.

209Tl β⁻ Decay 2000Gr35,1998Ar03,1989Ko26 (continued)**209Pb Levels**

E(level) [†]	Jπ [‡]	T _{1/2}	Comments
0.0	9/2+		
1567.08 3	5/2+	<45 ps	T _{1/2} : from (450γ)(1566γ)(Δt) (1965Sa08). Other: 1956St79 (<1500 ps).
2032.21 4	1/2+	161 ps 8	T _{1/2} : from (117γ)(467γ)(ΔT) (1965Sa08).
2149.42 4	1/2-	3.96 ns 4	T _{1/2} : from β(582γ)(t) (1980Da15). Other: 3.1 ns 2 (1965Sa08), 3.1 ns 10 (1956St79).
2315.90 16	3/2-		
2460.9 3	(5/2)-		
2524.92 21	(1/2, 3/2)		
2905.27 25	3/2-		
3069.92 16	3/2-		
3361.5 3	(1/2, 3/2)		
3389.09 16	(1/2, 3/2)		

[†] From a least-squares fit to γ-ray energies.[‡] From Adopted Levels.**β⁻ radiations**

Eβ ⁻	E(level)	Iβ ^{-†}	Log ft	Comments
(587 8)	3389.09	0.439 17	5.77 3	
(615 8)	3361.5	0.10 3	6.48 14	
(906 8)	3069.92	0.644 23	6.255 21	
(1071 8)	2905.27	0.70 9	6.48 6	
(1451 8)	2524.92	0.070 15	7.95 10	
(1515 8)	2460.9	0.031 16	9.20 ^{1u} 23	
(1660 8)	2315.90	0.25 8	7.62 14	
(1827 8)	2149.42	97 4	5.186 20	Eβ ⁻ : E=1800 200 from 1955Ma61. Others: 1952Wa24, 1950Ha64.
(1944 8)	2032.21	<0.1	>8.3	Iβ ⁻ : from βγ(t) (1980Da15). The limit is quoted at the 99% confidence level.

[†] From an intensity balance at each level, except for the branch to the 2149 level, which is constrained by the condition ΣIβ=100.**γ(209Pb)**Kα₁ x ray=11.0 11, Kα₂ x ray=6.5 7 (1972Dz14), relative to Iγ(465)=100.

Iγ normalization: From I(γ+ce)(1567.087γ)+I(γ+ce)(2315.8γ)=100, assuming no direct feeding to the ground state.

Eγ [#]	E(level)	Iγ ^{@b}	Mult.&	α	Comments
117.21 5	2149.42	76 3	E1	0.295	%Iγ=76 3, using the calculated normalization. Eγ: weighted average of 117.211 21 (1977Vy02), 117.25 5 (1981Di14), 117.21 1 (1989Ko26), 117.24 5 (1998Ar03) and 117.18 10 (2000Gr35). Iγ: weighted average of 73 4 (1998Ar03) and 78 4 (2000Gr35) Others: 90.3 22 (1977Vy02), 85 3 (1981Di14) and 85 4 (1989Ko26),. Mult.: α(K)exp=0.25 2 (2000Gr35).
284.04 [‡] 23	2315.90	0.14 [‡] 7	[E1]	0.0335	%Iγ=0.14 7, using the calculated normalization.
311.5 [‡] 3	2460.9	0.028 [‡] 14	[E2]	0.1034	%Iγ=0.028 14, using the calculated normalization.
375.5 [‡] 2	2524.92	0.070 [‡] 15			%Iγ=0.070 15, using the calculated normalization.
465.14 1	2032.21	95.7 10	E2	0.0350	%Iγ=95.4 10, using the calculated normalization. Eγ: weighted average of 465.065 25 (1977Vy02), 465.1 2 (1981Di14), 465.4 1 (1986He06), 465.14 1 (1989Ko26), 465.10 5 (1998Ar03) and 465.21 4 (2000Gr35). Iγ: weighted average of 98.5 20 (1981Di14), 94.5 13 (1986He06), 97 4 (1989Ko26), 95 5 (1998Ar03), 97 5 (2000Gr35) and 95 3 (2003ChZV). The value from 1986He06 is deduced from I(465γ)=2.022 26 per 100 ²¹³ Bi decays in 1986He06 and %α(²¹³ Bi)=2.140 10 in 2013Ma13. Others: 108 3 deduced by the evaluators from data in 1977Vy02. Mult.: α(K)exp=0.027 4 (1998MaZO,2000Gr35).
*469.7 [‡] 3		0.03 [‡] 2			%Iγ=0.030 20, using the calculated normalization. Iγ: 0.12 3 from 2000Gr35.

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²⁰⁹Tl β⁻ Decay 2000Gr35,1998Ar03,1989Ko26 (continued)

γ(²⁰⁹Pb) (continued)

Eγ [#]	E(level)	Iγ ^{@b}	Mult.&	α	Comments
582.4 2	2149.42	0.31 3	[M2]	0.200	%Iγ=0.31 3, using the calculated normalization. Eγ: from 2000Gr35. Iγ: weighted average of 0.28 4 from 2000Gr35 and 0.32 4 from 2003ChZV.
748.3 3	2315.90	0.080 21	[E1]	0.00428	%Iγ=0.080 21, using the calculated normalization. Eγ: weighted average of 748.0 3 (1998Ar03) and 748.5 3 (2000Gr35). Iγ: weighted average of 0.09 3 (1998Ar03) and 0.07 3 (2000Gr35).
755.6†§ 3	2905.27	0.11† 2	[M1]	0.0366	%Iγ=0.110 20, using the calculated normalization.
*860.5†§c 3		0.26† 4			%Iγ=0.26 4, using the calculated normalization.
873.5†§ 4	2905.27	0.59† 8	[E1]	0.00320	%Iγ=0.59 8, using the calculated normalization.
*890.0†§c 4		0.12† 3			%Iγ=0.12 3, using the calculated normalization.
*902.8†§c 4		0.10† 2			%Iγ=0.100 20, using the calculated normalization.
920.53 17	3069.92	0.632 22	[M1]	0.0220	%Iγ=0.630 22, using the calculated normalization. Eγ: weighted average of 920.2 3 (1989Ko26), 920.34 9 (1998Ar03), and 920.8 1 (2000Gr35). Iγ: weighted average of 0.63 6 (1989Ko26), 0.70 7 (1998Ar03), 0.63 5 (2000Gr35) and 0.62 3 (2003ChZV). Note, Iγ=0.127 7 in 2003ChZV is a typo and should read as 0.0127 7.
1239.73 15	3389.09	0.440 17			%Iγ=0.439 17, using the calculated normalization. Eγ: weighted average of 1239.5 5 (1989Ko26), 1239.76 15 (1998Ar03), and 1239.7 2 (2000Gr35). Placement of this γ-ray is based on a 117γ-1239γ coincidence observed in 1998Ar03. 2000Gr35 placed this γ-ray as a transition from a level at 2806 to 1567, based on the observed 1239γ-1567γ coincidence. 1999GrZT assigned this γ-ray from 3271 keV to 2032 keV. Iγ: weighted average of 0.42 4 (1989Ko26), 0.31 12 (1998Ar03), 0.42 7 (2000Gr35) and 0.45 2 (2003ChZV).
1329.3 3	3361.5	0.10 3			%Iγ=0.10 3, using the calculated normalization. Eγ: weighted average of 1329.3 3 (1998Ar03) and 1329.3 3 (2000Gr35). Iγ: from 2000Gr35. Others: 0.26 5 (1998Ar03) and 0.14 (2003ChZV). Note, that 0.026 5 in the table of 1998Ar03 is a typo.
1567.08 2	1567.08	100	E2	0.00294	%Iγ=99.663 7, using the calculated normalization. Eγ: weighted average of 1566.95 6 (1977Vy02), 1566.9 2 (1981Di14), 1567.11 2 (1989Ko26), 1566.96 5 (1998Ar03) and 1566.9 3 (2000Gr35). Mult.: α(K)exp=0.0024 9 (2000Gr35).
*1661.1† 5		0.10† 2			%Iγ=0.100 20, using the calculated normalization.
*1673.2† 4		0.48† 4			%Iγ=0.48 4, using the calculated normalization.
*1781.7† 5		0.04† 2			%Iγ=0.040 20, using the calculated normalization.
*2032.1† 5		<0.001†			%Iγ=0.0005 5, using the calculated normalization. Iγ: <0.02 from 2003ChZV.
2149.0†c 10	2149.42	0.015† 5	[M4]	0.01529	%Iγ=0.015 5, using the calculated normalization. Iγ: Others: <0.00064 in 2003ChZV, <0.013 from 2006Va23.
2315.9 3	2315.90	0.0285 24	[E3]	0.00292	%Iγ=0.0284 24, using the calculated normalization. Eγ: from 2000Gr35. Iγ: weighted average of 0.03 1 (2000Gr35) and 0.0284 25 (2003ChZV). Other: 0.027 12 (2006Va23).

† From 2000Gr35.

‡ From 1998Ar03.

§ The authors of 2000Gr35 state that these transitions may belong to the decay of ²¹³Bi nucleus rather than ²⁰⁹Tl.

2000Gr35 supersedes 1999GrZT. 1998Ar03 supersedes 1993E108 and 1994Ar23.

@ Normalized to Iγ(1567)=100.

& From Adopted Gammas.

b For absolute intensity per 100 decays, multiply by 0.99663 7.

c Placement of transition in the level scheme is uncertain.

x γ ray not placed in level scheme.

²⁰⁹Tl β⁻ Decay 2000Gr35,1998Ar03,1989Ko26 (continued)

²¹³Po α Decay 1998Ar03,1989Ko26,1982Bo04

Parent ²¹³Po: E=0.0; Jπ=9/2+; T_{1/2}=3.72 μs 2; Q(g.s.)=8536.1 26; %α decay=100.

²¹³Po-Q(α): From 2012Wa38.

²¹³Po-J,T_{1/2}: From Adopted Levels of ²¹³Po.

1998Ar03: ²¹³Po particles were from β-decays of the ²¹³Bi from the ²²⁹Th parent source. γ-rays were detected by a HPGe detector of 17% efficiency (FWHM=1.9 keV at 1.33 MeV) and a coaxial HPGe detector of 30% efficiency (FWHM=1.9 keV). Measured E_γ, I_γ, γγ-coin. Deduced levels, α-branchings.

1989Ko26: ²¹³Po particles were from β-decays of the ²¹³Bi source from the C.E.N. at Fontenay aux Roses. γ-rays were detected with a 17% efficiency HPGe coaxial detector (FWHM=1.9 keV at 1.33 MeV), a 2 cm³ low-energy photon spectrometer (LEPS) (FWHM=190 eV at the Fe K_α x-line) and an Ge(Li) detector. Measured E_γ, I_γ, γγ-coin. Deduced levels, branchings.

1982Bo04: source activity was produced from the LBL Bevatron. Decay α-particles were detected with gold-plated silicon surface-barrier detectors. Measured E_α, I_α. Deduced levels.

Others: 2009In01, 2000Gr35, 1998Wa25, 1997Ch53, 1997Wa27, 1986He06, 1977Vy02, 1964Va20, 1963Uh01, 1961Ru06, 1960Vo05, 1955St04, 1951Me10, 1950Ha52, 1948Cr12, 1969LeZW.

²⁰⁹Pb Levels

E(level)	Jπ [†]
0.0	9/2+
778.8 3	11/2+

[†] From Adopted Levels.

α radiations

Eα	E(level)	Iα [‡]	HF [†]	Comments
7614 10	778.8	0.0045 4	236 22	Eα: from 1964Va20. Iα: from I _γ . Iα=0.003 1 is reported by 1964Va20, and 0.006 2 by 1969LeZW.
8376 3	0.0	100	1.47 5	Eα: weighted average from 8376 3 (1982Bo04), 8377 5 (1964Va20), 8368 10 (1960Vo05). 8375.9 25 is recommended by 1991Ry01.

[†] r₀(²⁰⁹Pb)=1.530 9, unweighted average of r₀(²⁰⁸Pb)=1.5212 4 and r₀(²¹⁰Pb)=1.5394 6, deduced from HF=1.

[‡] Absolute intensity per 100 decays.

²¹³Po α Decay 1998Ar03,1989Ko26,1982Bo04 (continued)

 $\gamma(^{209}\text{Pb})$

E γ	E(level)	I $\gamma^\dagger$	Mult.	α	Comments
778.87 5	778.8	0.0044 4	[M1]	0.0339	E γ : from 1998Ar03. Other: 778.8 keV 3 (1989Ko26). I γ : from I γ (778.87 in ²⁰⁹ Pb)/I γ (440 γ ²¹³ Po)=0.000165 15 from the ²¹³ Bi decay chain (1998Ar03), with the adopted I γ (440 γ)=25.94 15 per 100 ²¹³ Bi decays, % β^- (²¹³ Bi)=97.860 10 (2013Ma13) and % α (²¹³ Po)=100.

 $\dagger$ Absolute intensity per 100 decays.

Decay Scheme

Intensity: I(γ +ce) per
100 parent decays

9/2+ 0.0 3.72 μ s
²¹³Po₈₄129 $\downarrow$ % α =100
 $Q_\alpha=8536.1^{26}$

²⁰⁷Pb(t,p),(pol t,p) 1971F106,1986Da15,1968Bj03

Target ²⁰⁷Pb J π (g.s.)=1/2-.

1971F106: E=20 MeV triton beam was produced from the Los Alamos accelerator. Data were obtained by two instruments.

One was a ΔE -E counter telescope (FWHM=32 keV) and the other one is a magnetic spectrograph (FWHM=18 keV).

Measured $\sigma(\theta)$. Deduced levels, J π , L, spectroscopic factors from DWBA analysis. Data supersede authors' earlier data in 1969F101, 1970F106.

1986Da15: E=17 MeV polarized triton beam was produced from the tandem accelerator at the Los Alamos National Laboratory. A 0.97 mg/cm² enriched ²⁰⁷Pb target was used. Reaction products were momentum analyzed with a magnetic Q3D spectrometer, FWHM=19 keV. Measured $\sigma(\theta)$. Deduced levels, J π , spectroscopic factors from DWBA analysis.

1968Bj03: E=13 MeV triton beam was produced from the Aldermaston tandem accelerator. Target was 95.12% enriched ²⁰⁷Pb. Reaction products were momentum analyzed with a multi-angle spectrograph and detected in nuclear emulsions (FWHM=20 keV). Measured $\sigma(\theta)$. Deduced levels, J π , L.

Other: 1962Er01 (E=7.5 MeV).

²⁰⁹Pb Levels

E(level) †	L ‡	E(level) †	L ‡	E(level) †	L ‡
0.0	5 $\S$	3072 5	6	3946 8	
779 5	5 $\S$	3100 5	(8)	3989 8	
1425 5	8 $\S$	3206 5	4	4022 8	(4)
1568 5	3 $\S$	3308 5	6	4074 8	
2034 5	1 $\S$	3384 5		4099 8	(3)
2153 5	0	3432 5	8	4140 8	
2496 5	3 $\S$	3477 5		4169 8	(6)
2542 5	1 $\S$	3559 5	8	4260 8	
2591 5		3659 5	(2)	4277 8	
2738 5	2	3708 5	(3)	4315 8	
2868 5	2	3743 5	(4)	4363 8	(2)
2903 5	2	3814 5		4384 8	(6)
2992 5	2	3854 8		4413 8	
3028 5	4	3902 8		4451 8	(6)

Continued on next page (footnotes at end of table)

²⁰⁷Pb(t,p),(pol t,p) 1971F106,1986Da15,1968Bj03 (continued)

²⁰⁹Pb Levels (continued)

<u>E(level)[†]</u>	<u>L[‡]</u>	<u>E(level)[†]</u>	<u>E(level)[†]</u>
4508 8		4966 10	5600 10
4539 8		4997 10	5637 10
4578 8	(4)	5026 10	5684 10
4629 8	(6)	5057 10	5759 10
4660 8		5083 10	5834 10
4686 8		5107 10	5861 10
4715 8		5134 10	5931 10
4731 8		5161 10	5985 10
4743 8		5211 10	6050 10
4754 8		5241 10	6082 10
4778 8		5326 10	6138 10
4813 8		5400 10	6198 10
4843 8		5423 10	6248 10
4877 8		5476 10	6390 10
4904 8		5513 10	6437 10
4931 8		5577 10	

[†] Values for levels below E=4660 are from weighted average of 1971F106 and 1968Bj03. Others are from 1971F106.

[‡] From 1971F106, except where noted otherwise, based on DWBA fits and comparison with ²⁰⁸Pb(t,p) states of known spin in ²¹⁰Pb.

§ From 1986Da15 based on DWBA fits.

²⁰⁸Pb(n,γ): E=thermal 2002B108

S(n)=3937.4 13 from 2012Wa38.

2002B108: cold neutrons were produced from the Research Reactor NBSR at the National Institute for Standards and Technology (NIST Center for Neutron Research. A target of 2.318 g lead sample was used. γ-rays were detected by the NIST Prompt Gamma Activation Analysis (PGAA). Spectrometer. Measured E_γ, I_γ. Deduced levels.

Other: 1973Al06.

Measured thermal-neutron capture cross section=230 μb 12 (2002B108).

²⁰⁹Pb Levels

<u>E(level)[†]</u>	<u>Jπ[‡]</u>
0.0	9/2+
1567.1 3	5/2+
2032.4 4	1/2+
2149.7 7	1/2-
2316.5 9	3/2-
2537.7 5	3/2+
3938.0 5	1/2+

[†] From a least-squares fit to γ-ray energies.

[‡] From Adopted Levels.

γ(²⁰⁹Pb)

<u>Eγ[†]</u>	<u>E(level)</u>	<u>Iγ[‡]</u>
465.3 3	2032.4	175 12
970.5 5	2537.7	23 7
1400.3 3	3938.0	25 5
1567.1 3	1567.1	230 12
1621.5 7	3938.0	28 9
1788.3 4	3938.0	51 9
1905.7 4	3938.0	78 10

[†] Transitions from levels at E=2150 and 2317 were unobserved because of the large background at low γ-ray energies.

[‡] Values are for γ-ray cross sections in units of μb by normalizing the observed γ yields to that of the 1262-keV γ-ray from the ¹²C(n,γ)¹³C reaction.

208Pb(n,X): Resonances 1986Ho19

S(n)=3937.4 13 (2012Wa38).

1986Ho19: E=50-1005 keV neutron beams were produced from the Oak Ridge Electron Linear Accelerator (ORELA). Target was 45.71 g/cm² 208Pb (72.4% enriched). Measured $\sigma(E_n)$. Deduced levels, $J\pi$, L, widths from R-Matrix analysis.

Other: 1967Gi13 (E=70, 77 keV), 1961Ne16 (E<55 keV), 1973Mu14 (E=80-1900 keV).

The neutron resonances are given explicitly here since several of the charged particle reactions report peaks above the neutron separation energy. S(n)=3937.4 13, and the resonance energies are given in lab coordinates.

209Pb Levels

E(level)	$J\pi^\dagger$	$L^\dagger$	Γ_n (eV)	E(level)	$J\pi^\dagger$	$L^\dagger$	Γ_n (eV)
S(n)+47.26 2		(2)	0.02 1	S(n)+636.1 2	7/2-	3	293 5
S(n)+71.21 2	3/2-	1	101 5	S(n)+686.8 2	5/2-	3	191 9
S(n)+78.25 2	3/2-	1	958 10	S(n)+693.2 2	(5/2)-	3	74 5
S(n)+86.56 3	1/2-	1	75.4 30	S(n)+699.5 2	5/2+	2	304 4
S(n)+117.22 4	3/2-	1	317 6	S(n)+721.0 2	5/2+	2	3938 43
S(n)+130.17 4	(5/2)+	2	9.7 9	S(n)+721.7 2	3/2-	1	564 15
S(n)+153.25 5	(3/2)-	1	10.5 10	S(n)+723.0 2	(7/2-)	3	165 6
S(n)+163.50 5	(3/2)-	1	8.2 10	S(n)+739.1 2	5/2-	3	193 5
S(n)+168.00 5	(5/2)+	2	7.6 8	S(n)+764.3 3	3/2-	1	2643 30
S(n)+168.53 5	3/2-	1	28.4 14	S(n)+764.9 3	7/2-	3	369 7
S(n)+169.38 5	(3/2)+	2	21.9 16	S(n)+786.1 3	5/2-	3	116 5
S(n)+270.10 8	3/2+	2	120 4	S(n)+814.1 3	7/2-	3	114 5
S(n)+277.99 9	1/2-	1	315 9	S(n)+814.4 3	1/2-	1	375 19
S(n)+324.23 10	3/2-	1	135 3	S(n)+815.7 3	5/2+	2	8916 90
S(n)+354.0 1	(5/2-)		23 2	S(n)+824.0 3	5/2-	3	221 7
S(n)+354.1 1	3/2+	2	4989 16	S(n)+832.1 3	(7/2)-	3	80 4
S(n)+407.1 1	3/2-	1	222 4	S(n)+850.5 3	3/2+	2	4074 50
S(n)+418.5 2	3/2-	1	76 2	S(n)+861.0 3	5/2-	3	810 12
S(n)+438.3 2	(5/2-)		10.5 12	S(n)+877.8 3	3/2-	1	484 15
S(n)+489.0 2	1/2-	1	2992 35	S(n)+884.8 3	1/2-	1	4779 83
S(n)+505.7 2	3/2-	1	194 6	S(n)+888.2 3	1/2+	0	5490 75
S(n)+506.0 2	1/2+	0	53590 250	S(n)+910.6 3	1/2-	1	422 23
S(n)+527.1 2	5/2+	2	4625 50	S(n)+911.6 3	7/2-	3	276 9
S(n)+563.9 2	1/2-	1	531 15	S(n)+920.5 3	5/2-	3	330 10
S(n)+567.6 2	(7/2)-	3	16.2 18	S(n)+927.0 3	1/2-	1	192 14
S(n)+570.8 2	(3/2)+	2	9.9 11	S(n)+944.4 3	3/2+	2	3213 43
S(n)+583.6 2	(5/2-)		34 3	S(n)+947.2 3	1/2-	1	1336 63
S(n)+597.6 2	(5/2)-	3	74 4	S(n)+947.9 3	3/2-	1	1490 50
S(n)+609.1 2	(5/2)-	3	119 5	S(n)+949.6 3	5/2+	2	391 13
S(n)+613.0 2	(7/2)-	3	140 3	S(n)+974.3 3	3/2-	1	1647 52
S(n)+615.9 2	(5/2+)		30 2	S(n)+984.2 3	3/2-	1	2384 55
S(n)+634.9 2	5/2-	3	623 9	S(n)+997.7 3	1/2+	0	3889 60

[†] From R-matrix fits to experimental cross sections in 1986Ho19. $J\pi$ given in parentheses are assumed by authors for the extraction of neutron widths.

208Pb(n, γ): E=0.8-20 MeV 1972Be46,1981Dr08,1982Jo01

S(n)=3937.4 13 (2012Wa38).

1972Be46: E=6.2-14.7 MeV neutrons were produced by ³H(p,n) with proton beams from the Los Alamos Van de Graaff accelerator. γ -rays were detected with a NaI(Tl) detector. Measured $\sigma(E\gamma)$. Deduced giant resonance structure.

1981Dr08: E=10-20 MeV neutrons at the Los Alamos tandem. NaI detector. Measured $\sigma(E\gamma)$, asymmetry. Deduced E2 giant isovector resonance.

1982Jo01: E=0.8-7.7 MeV neutrons at the tandem accelerators at Bruyeres-le-Chatel and Uppsala. NaI(Tl) detector. Measured $\sigma(E\gamma)$.

1982Ki05: E=7-13 MeV. Measure $\sigma(E\gamma,\gamma)$. Deduced dipole EWSR in GDR region.

Others: 2010Se03, 2008Re07, 2004Ra29, 2003Be49, 1971Be38, 1971Dr07, 1967Cs01.

1972Be46 studied $\sigma(E)$ for transitions to bound single-particle states of ²⁰⁹Pb (unresolved). Energy of giant dipole state found to be 13.6 MeV 5 (from decay to 2g_{9/2}), 13.7 MeV 5 (from decay to 1i_{11/2}), 13.8 MeV 5 (from decay to 1j_{15/2}+3d_{5/2}), and 13.7 MeV 5 (from decay to 2g_{7/2}+3d_{3/2})

1981Dr08 measured fore-aft asymmetry (ratio of difference to sum of yields at 55° and 125°). From a comparison of this asymmetry with theory, they suggest that the E2 giant isoscalar resonance is centered within 1 MeV of 23.5 MeV.

Continued on next page

²⁰⁸Pb(n,γ): E=0.8-20 MeV 1972Be46,1981Dr08,1982Jo01 (continued)

1982Jo01 looked for an asymmetry in the yield around 90° as evidence for possible excitation of isoscalar E2 and M1 giant resonances. No asymmetry was seen.
1982Ki05 measured γ(θ) for the transitions to the g.s. and first excited states. These exhaust 0.39% and 0.13%, respectively, of the classical dipole sum rule between E(exc)=10.9 and 16.9 MeV.

²⁰⁹Pb Levels

E(level)	Comments
13.7×10 ³ 5	E(level): from 1972Be46.

²⁰⁸Pb(d,p),(pol d,p) 1974Ko20,1973Vi06,1978Ba13

Target ²⁰⁸Pb Jπ(g.s.)=0+.
1974Ko20: E=20 MeV deuteron beam was produced from the Yale tandem accelerator. Targets were 100 μg/cm² 99.9% enriched ²⁰⁸Pb evaporated on carbon foils. Reaction products were momentum analyzed with the Yale multigap spectrograph (FWHM=10-15 keV). Measured σ(θ). Deduced levels, Jπ, L, spectroscopic factors from DWBA analysis.
1973Vi06: E(pol d)=12.3 MeV beam was produced from the University of Wisconsin tandem. A 15 mg/cm² lead target was used. Reaction products were momentum analyzed with a magnetic spectrograph, FWHM=70 keV. Measured σ(θ), analyzing powers. Deduced levels, Jπ, spectroscopic factors from DWBA analysis.
1978Ba13: E(pol d)=12.3 MeV deuteron beam was produced from the University of Birmingham Radial Ridge Cyclotron. A 8 mg/cm² 99.1% enriched ²⁰⁸Pb target was used. Protons were detected in six telescopes of a surface barrier silicon detector (ΔE) and a Li-drifted detector (E). Measured σ(θ), analyzing powers. Deduced levels, Jπ, L from DWBA analysis.
1967Do02: E=8 MeV beam was from the Heidelberg tandem. Measure σ(θ).
Deduced levels, spectroscopic factors from DWBA analysis.
1967Mu16: E=14.8, 20.1, 24.8 MeV beams were produced from the Michigan 83-inch cyclotron. Reaction products were momentum analyzed with a magnetic spectrograph. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis. 20.1-MeV data presented here.
1968Cr04: E=8 MeV beam was produced from the ANU tandem. Reaction products were momentum analyzed with a Buechner broad-range spectrograph. Measured σ(θ). Deduced levels, L, spectroscopic factors from DWBA analysis.
1969El02: E=12 MeV beam was produced from the Niels Bohr Institute tandem. Protons were detected with a Si(Li) counter, FWHM<50 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.
1969Je01: E=8-18.7 MeV beams were produced from the Oxford tandem. Reaction products were momentum analyzed with the Oxford multichannel spectrograph. Measured σ(θ). Deduced levels, Jπ, L, spectroscopic factors from DWBA analysis. 18.7-MeV data presented here.
1969Va02: E=8.7-15.8 MeV beams were produced from the 110 cm cyclotron of the CSIR. Protons were detected with a ΔE-E telescope of a silicon surface barrier detector and a Li-drifted detector. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis. Average of spectroscopic data presented here.
1973Ca04: E(pol d)=12.3, 15 MeV beams were produced from the Los Alamos tandem. Protons were detected with a ΔE-E telescope of a surface barrier silicon detector and a Li-drifted detector, FWHM=26 keV. Measured σ(θ), analyzing powers. Deduced levels, Jπ, spectroscopic factors from DWBA analysis.
1977St33: E=7-11 MeV beams were produced from the FN tandem at Universitat zu Koln. Protons were detected with four silicon surface barrier detectors, FWHM=15 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.
1980St18: E(pol d)=7, 8, 9 MeV. Measured σ(θ), analyzing powers. Deduced levels, Jπ. ²H deduced asymptotic d- to s-state amplitude ratio.
1984Go10: E(pol d)= 9 MeV. Measured σ(θ), analyzing powers.
1985MuZX: E(pol d)=12.3, 15 MeV. Measured σ(θ), analyzing powers.
1977Kn05: E(pol d)=5.5 MeV. Measured σ(θ), analyzing powers.
1970De21: E(pol d)=12.3 MeV. Measured σ(θ), analyzing powers.
1970Ki09: E(pol d)=11-30 MeV. Measured σ(θ), analyzing powers.
1990Ro02: E(pol d)=6, 7 MeV. Measured σ(θ), analyzing powers.
1998Hi05: E(pol d)=22.0 MeV. Measured σ(θ), analyzing powers.
2001Li41: E=8 MeV. Measured σ(θ).
Others: 1962Er01, 1962Mu05, 1967Mu16, 1968Be07, 1970HeZI, 1973LuZN, 1977JaZP, 1977Ma04, 2005Ya02, 2010Pa39.
1978Ba13 measured tensor analyzing powers for the g.s., 1565, and 2033 levels. They confirm the J dependence of these analyzing powers. See also 1985MuZX.

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208Pb(d,p),(pol d,p) 1974Ko20,1973Vi06,1978Ba13 (continued)

Summary of strengths: 1969Je01 and 1969Va02 give more than one set of C²S values corresponding to different choices of optical-model parameters. For each of these authors, the compilers have chosen the set such that the C²S values are from a zero-range, local DWBA calculation with neutron parameters radius=1.20–1.25 fm, diffuseness=0.60–0.65, spin-orbit coupling=25–32, and deuteron well depth and radius ≈100 MeV and ≈1.15 fm, respectively. This choice of parameters is consistent with that used by the other authors and puts all the C²S values on roughly the same footing. 1977St33 extract asymptotic normalization factors for the levels given in the table below. The authors point out that these factors are less sensitive than are the C²S to the choice of optical model parameters for the bound neutron.

	C ² S						
	g . s . 2g _{9/2}	779 1i _{11/2}	1424 1j _{15/2}	1565 3d _{5/2}	2033 4s _{1/2}	2492 2g _{7/2}	2537 3d _{3/2}
1967Do02	0.88	1.52	1.38	1.06	0.97	1.04	0.99
1967Mu16&	0.77	0.78	0.79	1.05	0.90	1.08	1.07
1968Cr04	0.99			1.10	1.05	0.96	1.00
1969El02	0.78	0.96	0.53	0.88	0.88	0.78	0.88
1969Je01#	0.66	0.75	0.71	0.62	0.70	0.81	0.88
1969Va02	1.08			1.13	1.00	1.22†	
1973Ca04	0.91	1.2	0.66	0.89	0.91	1.1	0.97
1974Ko20	0.83	0.86	0.58	0.98	0.98	1.05	1.07
1987Ro20@	0.8	0.9	0.53	0.85	0.8	0.9	0.74

& for E_t=20.3 MeV. See 1977Ma04 for a reanalysis of the data of these authors

See 1977Ma04 for a reanalysis of the 24.8-MeV data of these authors

@ Reanalysis of data of 1974Ko20 using a formalism that includes breakup of the deuteron

† Value for unresolved 2492+2537 levels

209Pb Levels

E(level)†	Jπ‡	L§	C ² S#	Comments
0.0	9/2+	4	0.83	C ² S: for configuration=v(2g _{9/2}) ⁺¹ .
779 5	11/2+	6	0.86	C ² S: for configuration=v(1i _{11/2}) ⁺¹ .
1424 5	15/2-	7	0.58	C ² S: for configuration=v(1j _{15/2}) ⁺¹ .
1565 5	5/2+	2	0.98	C ² S: for configuration=v(3d _{5/2}) ⁺¹ .
2033 5	1/2+	0	0.98	C ² S: for configuration=v(4s _{1/2}) ⁺¹ .
2152 5		1		C ² S: 0.0067 if configuration=v(3p _{1/2}) ⁻¹ , 0.0036 if v(4p _{1/2}) ⁺¹ .
2319 5		1		E(level): 2310 keV 5 (1969Je01). C ² S: 0.0074 if configuration=v(3p _{3/2}) ⁻¹ , 0.0045 if v(4p _{3/2}) ⁺¹ .
2424? 5				
2461 5	(2,3)			C ² S: 0.0012 if configuration=v(2f _{5/2}) ⁻¹ , 0.0013 if v(3f _{5/2}) ⁺¹ .
2492 5	4	1.05		C ² S: for configuration=v(2g _{7/2}) ⁺¹ .
2537 5	2	1.09		C ² S: for configuration=v(3d _{3/2}) ⁺¹ .
2592 5	4,5	0.0185@		Jπ: magnitude of σ(θ) is reproduced by a distorted wave calculation for configuration h _{11/2} , but the shape is not well reproduced (1969Ha13 as reported by 1969El02).
2738 5	2,3			C ² S: 0.0027 if configuration=v(2f _{5/2}) ⁻¹ , 0.0005 if v(3f _{5/2}) ⁺¹ .
2866 5	(2,3)			C ² S: 0.0010 if configuration=v(2f _{5/2}) ⁻¹ , 0.0002 if v(3f _{5/2}) ⁺¹ .
3026 5	4,5	0.0090&		
3052 5	7	0.070 ^a		
3075 5	1			C ² S: 0.0021 if configuration=v(3p _{3/2}) ⁻¹ , 0.0012 if v(4p _{3/2}) ⁺¹ .
3203 5	2,3			C ² S: 0.0012 if configuration=v(2f _{7/2}) ⁻¹ , 0.0007 if v(3f _{7/2}) ⁺¹ .
3309 5	4,5	0.0050@		
3365 5	4,5	0.0087@		
3389 5				
3414 5				
3430 5				
3490 5	2,3			C ² S: 0.0017 if configuration=v(2f _{7/2}) ⁻¹ , 0.0010 if v(3f _{7/2}) ⁺¹ .
3556 5	7	0.032 ^a		E(level): 1969Je01 report a level at 3567 keV 10.
3615 5				
3656 5	2,3			C ² S: 0.0070 if configuration=v(2f _{5/2}) ⁻¹ , 0.0044 if v(3f _{5/2}) ⁺¹ .
3681 5	(1)			C ² S: 0.0048 if configuration=v(3p _{1/2}) ⁻¹ , 0.0029 if v(4p _{1/2}) ⁺¹ .
3716 5	7	0.032 ^a		
3904 5	(2,3)	0.0113 ^b		E(level): 3917 keV 20 from 1969Je01.
3947 5				E(level): 3955 keV 20 (1969Je01). L,C ² S: fit by authors to L=3 with S=0.0161 for configuration=v(3f _{7/2}) ⁺¹ ; however, this peak is a doublet in (d,pγ).
3985 5	(2,3)	0.0178 ^b		

Continued on next page (footnotes at end of table)

²⁰⁸Pb(d,p),(pol d,p) 1974Ko20,1973Vi06,1978Ba13 (continued)

²⁰⁹Pb Levels (continued)

E(level) [†]	L [‡]	C ² S [#]	Comments
4008 5	(2,3)	0.0070 ^b	E(level): 4000 keV 20 (1969Je01).
4022 5	(2,3)	0.0038 ^b	
4075 5	(2,3)	0.0030 ^b	
4096 5	(2,3)	0.012	C ² S: if configuration= $\nu(3d_{5/2})^{+1}$.
4112 5	(2,3)	0.0125 ^b	E(level): 4123 keV 20 (1969Je01).
4137 5	(2,3)	0.0078 ^b	E(level): 4145 keV 20 (1969Je01).
4166 5	(5)	0.0023 [@]	E(level): 4175 keV 20 (1969Je01).
4211 7			E(level): 4216 keV 5 (1969E102).
4239? 10			
4295 5	(0,1)	0.093	E(level): 4298 keV 5 (1969E102), 4304 keV 20 (1969Je01). C ² S: configuration= $\nu(4p_{3/2})^{+1}$.
4348 5			
4380 5			
4430 9			E(level): 4415 keV 20 (1969Je01).
4464 7	(0,1)	0.109	C ² S: configuration= $\nu(4s_{1/2})^{+1}$.
4502 10			
4530 10			
4552 10			
4575 10			
4612 10			
4629 10			
4661 10			
4676 10			
4706 10			
4726 10			
4747 10			
4764 10			
4799 10			
4864 10			
4885 10			
4920 10			
4940 10			
4962 10			
4986 10			
5028 10			
5061 10			
5085 10			
5102 10			
5153 10			
5170 10			

[†] From 1974Ko20, unless otherwise noted.

[‡] From L+1/2 or L-1/2 transfers from analyzing power fits to measured cross sections (1973Vi06, 1978Ba13).

[§] From 1974Ko20, based on DWBA analysis. Except for the single-particle states, L(n)=2 cannot be distinguished from L(n)=3, nor can L(n)=4 be distinguished from L(n)=5. For some levels the L(n) ambiguities can be removed by comparison with L(t,p) or L(n) in (p,d). 1974Ko20 point out that, for the two-particle one-hole states below ≈4 MeV, only negative-parity states are expected (except for the configuration= $\nu(1i_{13/2})^{-1}$ state) so that L(n)=odd.

[#] From 1974Ko20, $S=(1/(2J+1))(\sigma(\theta)^{\text{exp}}/\sigma(\theta)^{\text{DWBA}})/n$, calculated using local zero-range DWBA with normalization factor 1.5 and neutron parameters radius=1.23 fm, diffuseness=0.65 fm, and spin-orbit coupling strength=25. The neutron well depth was chosen based on the separation-energy approximation. The authors also quote strengths based on a deuteron breakup potential.

[@] If configuration= $\nu(2h_{11/2})^{+1}$.

[&] If configuration= $\nu(1h_{9/2})^{-1}$.

^a If configuration= $\nu(1j_{15/2})^{+1}$.

^b If configuration= $\nu(3f_{7/2})^{+1}$.

208Pb(d,pγ) 1975Du08,1967E105,1978Ju02

1975Du08: E=11 MeV deuteron beam was produced from the Heidelberg EN tandem accelerator. A 200 μg/cm² thick self-supporting ²⁰⁸Pb target was used. Charged particles were detected with three silicon surface barrier detectors, FWHM=14 keV (singles), 120 keV (pγ-coin), and γ-rays were detected by a Ge(Li) detector FWHM=4 keV at Eγ=4 MeV. Measured σ(E_p), Eγ, Iγ. Deduced levels, γ-branching ratios, transition probabilities.

1967E105 and 1969E102: E=12 MeV deuteron beam was produced from the Niels Bohr Institute tandem accelerator. A 40 μg/cm² thick self-supporting target of ²⁰⁸Pb (99.3% enriched) was used. Protons were detected with a Si(Li) detector (FWHM=50 keV) and γ-rays were detected with a Ge(Li) detector and a NaI(Tl) detector. Measured Eγ, pγ-coin, pγ(t). Deduced levels, T_{1/2}.

1978Ju02: E=10 MeV. Measured particle spectrum, pγ(t). Deduced levels, T_{1/2}.

209Pb Levels

E(level) [†]	T _{1/2} [‡]	L [§]	Comments
0.0			
779 1	<1.0 ns		
1423 1	1.36 ns 30		T _{1/2} : from p(644γ)(t) (1967E105).
1567 1	<0.5 ns		
2032 1	160 ps 6		T _{1/2} : from p(465γ)(t) (1978Ju02).
2319 3			
2465 4			
2491 1			
2537 1			
2588 2			
2736 5			
3047 5			
3302 5			
3361 2			
3423 5			
3650 7			
3676? 5			
3897 5			
3936 2			
3940 4			
3977 3		≥4	
4005 5		≥4	
4016 6		≥4	
4129 5		≥5	

[†] From a least-squares fit to γ-ray energies.

[‡] From pγ(t) (1967E105), except for the 2032 level which is from pγ(t) of 1978Ju02.

[§] Lower limits are given for unbound states by 1975Du08 based on competition between γ-ray decay and neutron emission.

γ(209Pb)

E(level)	Eγ [†]	Iγ [‡]	Comments
779	779 1		
1423	644 2	10 1	
	1423 1	90 2	
1567	1567 1		
2032	465 1		
2319	287 2		
2465	898 [§] 6	20 20	
	2465 4	80 40	
2491	1712 2	3.0 5	
	2491 1	97 1	γ-branching: possible 924γ to 1567 level not observed, I(924γ):I(2491γ)<1:99 (1975Du08).
2537	970 1		γ-branching: possible 505γ to 2032 level not observed, I(505γ):I(970γ)<1:99 (1975Du08).
2588	2588 2		
2736	1169 5		
3047	1624 5		
3302	3302 5		
3361	824 2	55 10	
	870 2	30 5	
	1794 5	15 5	
3423	2000 5		

Continued on next page (footnotes at end of table)

²⁰⁸Pb(d,pγ) 1975Du08,1967El05,1978Ju02 (continued)

γ(²⁰⁹Pb) (continued)

E(level)	Eγ [†]	Iγ [‡]	E(level)	Eγ [†]	Iγ [‡]	E(level)	Eγ [†]
3650	3650 7		3940	2517 4	40 10	4005	2582 4
3676?	1644 § 4			3940 5	60 10	4016	4016 6
3897	3897 5		3977	2554 4	30 10	4129	4129 5
3936	1399 3	15 10		3198 5	15 10		
	1904 2	85 10		3977 5	55 10		

[†] From 1975Du08.

[‡] Quoted uncertainties in 1975Du08 include contributions from p-γ correlations.

§ Placement of transition in the level scheme is uncertain.

²⁰⁸Pb(t,d) 1969Ig02

Target ²⁰⁸Pb Jπ(g.s.)=0+.

1969Ig02: E=20 MeV triton beam was produced from the Los Alamos three-stage Van de Graaff accelerator. A 200 μg/cm² enriched ²⁰⁸Pb target on a 40 μg/cm² carbon backing was used. Reaction products were detected with a counter telescope of a silicon surface barrier ΔE detector and a lithium-drifted E detector, FWHM=37 keV (for cross sections) and with a Elbek type magnetic spectrograph, FWHM=14 keV. Measured σ(θ). Deduced level, L, spectroscopic factors from DWBA analysis.

Other: 1976Fr22.

²⁰⁹Pb Levels

E(level)	L [‡]	S [†]	Comments
0.0	4	0.93	S: for configuration=v(2g _{9/2}) ⁺¹ .
781 5	6	1.05	S: for configuration=v(1i _{11/2}) ⁺¹ .
1428 5	7	0.60	S: for configuration=v(1j _{15/2}) ⁺¹ .
1573 5	2	1.02	S: for configuration=v(3d _{5/2}) ⁺¹ .
2039 5	0	1.00	S: for configuration=v(4s _{1/2}) ⁺¹ .
2153 5			
2496 5	4	1.05	S: for configuration=v(2g _{7/2}) ⁺¹ .
2542 5	2	0.96	S: for configuration=v(3d _{3/2}) ⁺¹ .
2592 5			σ(θ) is isotropic. Both the magnitude and the shape of σ(θ) are well reproduced for configuration=π(2h _{11/2}) ⁺¹ (1969Ha13).
2996 5			
3049 5			
3305 10			
3373 10			
3800 10			
3998 10			
4075 10			
4094 10			
4146 10			
4283 10			
4322 10			
5136 10			
5160 10			

[†] Calculated using local zero-range DWBA with normalization factor N=4.15 and neutron parameters radius=1.25 fm, diffuseness=0.65 fm, and spin-orbit coupling strength=25. Neutron well depth chosen based on separation-energy approximation. The above normalization factor was chosen so that the average spectroscopic value for the single-particle states, excluding the 1j_{15/2} state, is unity. σ(θ) is well fit by a distorted-wave calculation for the indicated single-particle state.

dσ/dΩ(exp)=N×(2J+1)×S×dσ/dΩ(DWBA) (1969Ig02).

[‡] From DWBA fits to measured σ(θ) (1969Ig02).

²⁰⁸Pb(α ,³He) 1975Ti02,1986Ma49,1981Pe10

Target ²⁰⁸Pb target J π =0+.

1975Ti02: E=58 MeV α beam was produced from the University of Michigan 83-inch cyclotron. A 98% enriched self-supporting 1.5 mg/cm² ²⁰⁸Pb target was used. Reaction products were detected by an array of position-sensitive detectors on the focal plane of a magnetic spectrograph, FWHM=50 keV (estimated by evaluator). Measured $\sigma(\theta)$. Deduced levels, spectroscopic factors from DWBA analysis.

1986Ma49: E=183 MeV α beam was produced from the K220 Orsay synchrocyclotron. A 10 mg/cm² 99.9% enriched ²⁰⁸Pb target was used. Reaction products were detected by two multiwire proportional chambers at the focal plane of a large magnetic spectrometer, FWHM=200 keV. Measured $\sigma(\theta)$. Deduced levels, strength functions.

1981Pe10: E=61.5 and 81.5 MeV beams were produced from the University of Maryland Isochronous Cyclotron. Target was 1 mg/cm² 99% enriched ²⁰⁸Pb evaporated onto a 10 μ g/cm² carbon backing. Reaction products were detected by two telescopes of a silicon ΔE detector and a Si(Li) E detector, FWHM<100 keV for E=61 MeV, 150 keV for E=81 MeV. Measured $\sigma(\theta)$. Deduced levels, spectroscopic factors from DWBA analysis.

Others: 1999Ah01, 1984Ga37.

²⁰⁹Pb Levels

E(level) [†]	L [‡]	S [#]
0.0		0.94 ^{&}
781 8		1.05 ^a
1426 8		0.57 ^b
2520 [@]		0.93 ^c
3050 14		0.062 ^b
3550 14		0.032 ^b
3715 14		0.028 ^b
3934 14	6, 7, 8 [§]	
4211 14	6, 7, 8 [§]	

[†] From 1975Ti02. In addition to the resolved peaks in the range 0 to 4.2 MeV, 1986Ma49 also study the region from 4.5 to 15 MeV, in which region the spectrum is dominated by a wide bump at about 10.7 MeV. On the basis of $\sigma(\theta)$ and C²S for several energy slices in this region, the authors suggest that the enhanced cross section is due to neutron stripping to high-spin states with neutron number n>185, namely, 2h_{11/2}, 1j_{13/2}, and 1k_{17/2}.

[‡] Values reported in (α ,³He) by 1986Ma49 and 1975Ti02 (for the first three states) agree with the (d,p) values, but the shapes for adjacent L values are not sufficiently different to yield unique L assignments.

[§] Fit consistent with L=8 (possible 1k_{17/2}) as suggested by core-particle model, however, fit is equally good for L=7 (possible 1j_{15/2}) and for L=6 (although not considered by authors), so a unique L value cannot be assigned. L=6 is assigned to a level at 3937 5 in (p,d).

[#] From 1975Ti02 (except 2520 level) calculated using local zero-range DWBA with normalization factor=50 and neutron parameters radius=1.275 fm, diffuseness=0.65 fm, and spin-orbit coupling strength=25. Neutron well depth chosen based on separation energy approximation. 1986Ma49 report values in good agreement with those of 1975Ti02 except for S(g.s.)=0.69. 1981Pe10 report values for the first three states of 0.86, 0.69, and 0.98 at E=61, and somewhat lower values (8 to 16%) for E=81. The results of these authors for S(781 and 1426 levels) do not agree with those of the other authors in (α ,³He) or of other single particle transfer reactions.

[@] From 1986Ma49. Peak is masked by impurities in spectrum of 1975Ti02.

[&] For configuration=v(2g_{9/2})⁺¹.

^a For configuration=v(1i_{11/2})⁺¹.

^b For configuration=v(1j_{15/2})⁺¹.

^c For configuration=v(2g_{7/2})⁺¹, from 1986Ma49.

²⁰⁸Pb(⁷Li,⁶Li) γ 1972Ha59

1972Ha59: E=31.5 MeV ⁷Li beam was produced from the Chalk River MP tandem accelerator. A 10 mg/cm² thick target of ²⁰⁸Pb was used. γ -rays were detected in a 45 cm³ Ge(Li) counters and back-scattered particles were detected by a annular detector. Measured E γ , Doppler-shift attenuation. Deduced levels, transition probabilities, T_{1/2}.

²⁰⁹Pb Levels

E(level)	J π [†]	T _{1/2} [‡]
0.0	9/2+	
779	11/2+	>2 ps
1567	5/2+	0.33 ps 9

[†] From Adopted Levels.

[‡] From DSAM in 1972Ha59.

²⁰⁸Pb(⁷Li,⁶Li)^γ ¹⁹⁷²Ha59 (continued)

γ(²⁰⁹Pb)

<u>Eγ</u>	<u>E(level)</u>
779	779
1567	1567

²⁰⁸Pb(⁷Li,⁶Li) ¹⁹⁹⁴Ru07

Target ²⁰⁸Pb Jπ(g.s.)=0+.

¹⁹⁹⁴Ru07: E=33 MeV polarized ⁷Li beam was produced from the SERC Nuclear Structure Facility at Daresbury. A 150 μg/cm² self-supporting ²⁰⁸Pb target was used. Scattered particles were detected with six 50×50 mm² position sensitive ΔE-E telescopes. Measured σ(θ), analyzing power T₂₀(θ). Deduced levels, Jπ, L from CCBA, CRC analysis.

Other: 1993Yo01.

²⁰⁹Pb Levels

<u>E(level)[†]</u>	<u>Jπ</u>	<u>L</u>
0.0	9/2+ [§]	4
779	11/2+ [#]	6
1567	5/2+ [§]	2
2491 [‡]		
2537 [‡]		

[†] Rounded-off values from Adopted Levels.

[‡] Unresolved doublet.

[§] L+1/2 transfer from analyzing power fits.

[#] L-1/2 transfer from analyzing power fits.

²⁰⁸Pb(⁹Be,⁸Be) ¹⁹⁷⁷St20

¹⁹⁷⁷St20: E=50 MeV ⁹Be beam was produced from the Lawrence Berkeley Laboratory 88-inch cyclotron. ⁸Be particles were identified by detecting their decay α-particles using phosphorus-diffused silicon twin transmission detectors and a surface-barrier silicon PSD, FWHM=450 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

²⁰⁹Pb Levels

<u>E(level)[†]</u>	<u>S[‡]</u>
0.0	1
779	1.50
1423 [@]	1.19 [§]
1567	1.19 [§]
2032 ^a	0.88
2491 ^{&}	1.06 [#]
2538	1.06 [#]

[†] Rounded-off values from Adopted Levels.

[‡] Relative values normalized to S(g.s.)=1. Authors also give absolute values (S(g.s.)=0.16) extracted using S(⁹Be)=0.58, a theoretical value. The configurations are taken as known.

[§] 1.19 for the 1423+1567 keV levels.

[#] 1.06 for the 2491+2538 keV levels.

[@] Not resolved from strong 1567 keV level.

[&] Not resolved from strong 2538 keV level.

^a Not resolved from strong 1567 and 2538 keV levels.

²⁰⁸Pb(¹¹B, ¹⁰B) 1974Fo22

Target ²⁰⁸Pb J π (g.s.)=0+.

1974Fo22: E=72.2 MeV ¹¹B beam was produced from the Oak Ridge isochronous cyclotron. Target was 100 μ g/cm² ²⁰⁸Pb evaporated onto a 40 μ g/cm² carbon foil. Reaction products were momentum analyzed with an Elbek spectrograph and detected by an proportional counter, FWHM=185-250 keV. Measured $\sigma(\theta)$. Deduced levels, spectroscopic factors from DWBA analysis.

Others: 2003Sa54, 1973An14.

E; From 1974Fo22.

²⁰⁹Pb Levels

E(level)	S [†]	Comments
0.0	1.38	S: if configuration= $v(2g_{9/2})^{+1}$.
780	1.56	S: if configuration= $v(1i_{11/2})^{+1}$.
1420 [‡]		
1570 [‡]		
2490	1.56	S: If configuration= $v(2g_{7/2})^{+1}$. $\leq 10\%$ of this strength is estimated by the authors as being due to the unresolved $v(3d_{3/2})$ level at 2540 keV.

[†] Calculated using finite-range DWBA with neutron parameters deduced from sub-Coulomb stripping measurements. S(¹¹B=¹⁰B+n) is taken to be 1.09. Some contribution to the strengths for the $v(1i_{11/2})$ and $v(g_{7/2})$ levels could be coming from excited ¹⁰B states at 717 and 1740 keV (1974Fo22).

[‡] Unresolved in $\sigma(\theta)$.

²⁰⁸Pb(¹²C, ¹¹C) 1988Me04

1988Me04: E=480 MeV ¹²C beam was produced from the GANIL cyclotron. A 99% enriched ²⁰⁸Pb target was used. Reaction products were momentum analyzed with the magnetic spectrometer SPEG and detected in gas counters, FWHM=200 keV. Measured $\sigma(\theta)$. Deduced levels, spectroscopic factors from DWBA analysis.

²⁰⁹Pb Levels

E(level) [†]	S [‡]	Comments
0.0	0.80	S: for configuration= $v(2g_{9/2})^{+1}$.
779	0.50	S: for configuration= $v(1i_{11/2})^{+1}$.
1423	0.62	S: for configuration= $v(1j_{15/2})^{+1}$, contribution from the unresolved 1567 keV $v(3d_{5/2})^{+1}$ state is negligible.
2491	0.92	S: for configuration= $v(2g_{7/2})^{+1}$, contribution from the unresolved 2537 keV $v(3d_{3/2})^{+1}$ state is negligible.
3020	0.085	S: for configuration= $v(1j_{15/2})^{+1}$.
3600	0.065	S: for configuration= $v(1j_{15/2})^{+1}$ as suggested by 1986Ma49 in (α , ³ He). Peak is probable doublet consisting of 3550-keV and 3715-keV levels reported in (α , ³ He).
4060	0.13	S: for configuration= $v(1k_{17/2})^{+1}$, as suggested by 1986Ma49 in (α , ³ He). Peak is probable doublet consisting of 3934-keV and 4211-keV levels reported in (α , ³ He).
4990		
5620		
6470		

[†] Values below 2000 are rounded-off values from Adopted Levels. In addition to the resolved peaks listed here, broad structures are observed around an excitation energy of 10 MeV (1988Me04).

[‡] Spectroscopic factors are normalized to the theoretical value of 0.62 for the 1426 level (1973Ri13). Excitation of the 1567 $v(3d_{5/2})^{+1}$ level, which would be unresolved from the 1426 level, is expected to be negligible. The configurations of the g.s. and first three excited states are taken by the authors of 1988Me04 as known (see Adopted Levels).

²⁰⁸Pb(¹⁶O, ¹⁵O) ¹⁹⁷⁵Be40

¹⁹⁷⁵Be40: E=139 MeV ¹⁶O beam was produced from the Lawrence Berkeley Laboratory 88-inch cyclotron. Targets were 100–150 μg/cm² enriched ²⁰⁸Pb on carbon backings. Reaction products were momentum analyzed with an energy-loss magnetic spectrometer, FWHM=180–240 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

Others:

¹⁹⁷⁸O102: E=312.6 MeV beam was produced from the Berkeley 88-inch cyclotron. Thick targets of 1–3 mg/cm² ²⁰⁸Pb were used. Reaction products were momentum analyzed with a quadrupole–sextupole–dipole (QSD) magnetic spectrometer, FWHM=300 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

¹⁹⁸⁷Me05: E=793 MeV beam was produced from the GANIL facility. A 300 μg/cm² ²⁰⁸Pb on a 30 μg/cm² carbon backing was used. Reaction products were momentum analyzed with the magnetic spectrometer, FWHM=215 keV (see also ¹⁹⁸⁶Be41). Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

¹⁹⁷⁵Be40 deduce rms radius difference <n>–<p> =0.1 fm *I*.

²⁰⁹Pb Levels

E(level) [†]	S [‡]	Comments
0.0	0.89	S: for configuration=v(2g _{9/2}) ⁺¹ .
800 50	0.83	S: for configuration=v(1i _{11/2}) ⁺¹ .
1450 50	0.75	S: for configuration=v(1j _{15/2}) ⁺¹ . Value given is corrected for a small contribution (theory value of 0.91 assumed) from unresolved v(3d _{5/2}) ⁺¹ level at 1567 keV.
2050 50	≤9.8 §	S: for configuration=v(4s _{1/2}) ⁺¹ .
2490 50	1.7 §	S: for configuration=v(2g _{7/2}) ⁺¹ . Value given is corrected for a small contribution (theory value of 0.90 assumed) from unresolved v(3d _{3/2}) ⁺¹ level at 2538 keV.
3050 50	0.07 §	S: for configuration=v(1j _{15/2}) ⁺¹ .
≈3800	0.25 §	S: if levels in the broad peak 3500–4100 keV are v(1j _{15/2}) ⁺¹ .
5000 50		
5880 50		
6320 50		

[†] From ¹⁹⁷⁵Be40.

[‡] From 139–MeV data of ¹⁹⁷⁵Be40 (finite-range DWBA) as recalculated by ¹⁹⁷⁸O102. The values are normalized to S(g.s.)=0.89, the theoretical value from ¹⁹⁷³Ri13. See ¹⁹⁷⁸O102 and ¹⁹⁸⁷Me05 for values of s deduced from data taken at higher bombarding energies. ¹⁹⁷⁵Be40 state that strength ≤0.1 for any high-spin J=L+1/2 single-particle fragments in the energy range 5–10 MeV.

§ Approximate value since fit to data is poor.

²⁰⁸Pb(¹⁷O, ¹⁶Oγ) ¹⁹⁷³Ha39

¹⁹⁷³Ha39: E=77 MeV ¹⁷O beam was produced from the Chalk River MP Tandem accelerator. A target of 0.8 mg/cm² ²⁰⁸Pb on 0.13 mg/cm² thick Al foil. γ-rays were detected in two 40 cm³ Ge(Li) detectors. Measure Eγ, recoil distance.

Deduced levels, T_{1/2}.

²⁰⁹Pb Levels

E(level)	Jπ [†]	T _{1/2} [‡]
0.0	9/2+	
778	11/2+	8.2 ps 9

[†] From Adopted Levels.

[‡] From ¹⁹⁷³Ha39 using the recoil distance method.

γ(²⁰⁹Pb)

Eγ	E(level)
778	778

²⁰⁸Pb(¹⁷O,¹⁶O) 1987Fe04

Target ²⁰⁸Pb J π (g.s.)=0+.

1987Fe04: E=376 MEV ¹⁷O beam was produced from the coupled tandem cyclotron accelerators at the Holifield Heavy Ion Research Facility (HHIRF). A self-supporting enriched target of ²⁰⁸Pb was used. Reaction products were momentum analyzed by a broad-range spectrograph, FWHM=250 keV. Measured $\sigma(\theta)$. Deduced levels, J π , spectroscopic factors from DWBA analysis.

Others: 1987Li04, 1979Fr07, 1982Ku14.

²⁰⁹Pb Levels

E(level) [†]	J π [‡]	S $\S$	Comments
0.0	9/2+	0.89	S: if configuration= $v(2g_{9/2})^{+1}$.
780	11/2+	0.62	S: if configuration= $v(1i_{11/2})^{+1}$.
1510			E(level): unresolved doublet of 1420 and 1560. single-particle orbital $1j_{15/2}+3d_{5/2}$ (1979Fr07).
2030			E(level): from 1979Fr07, single-particle orbital $4s_{1/2}$.
2490	7/2+	0.81	E(level): 2510 ($2g_{7/2}+3d_{3/2}$) from 1979Fr07.
			S: if configuration= $v(2g_{7/2})^{+1}$.
3070			
4000			

[†] From 1987Fe04, unless otherwise noted. The $v(4s_{1/2})$ state at 2033 was not observed by 1987Fe04.

[‡] From comparisons of experimental cross-section data with the DWBA predictions (1987Fe04).

[§] Values are relative spectroscopic factors normalized to the theoretical value of 0.89 for the ground state (1967Do02). See 1987Fe04 for additional values, deduced with other potentials, and for absolute values.

²⁰⁸Pb(²⁰Ne,¹⁹Ne) 1990Fo04

E=500, 600 MeV ²⁰Ne beam was produced from the K500 superconducting cyclotron at Michigan State University. A 99.9% enriched 3.0 $\mu\text{g}/\text{cm}^2$ thick ²⁰⁸Pb target was used. Reaction products were momentum analyzed with the S320 broad range magnetic spectrograph, FWHM=1-2 MeV. Measured $\sigma(\text{fragment E}, \theta)$. Deduced structure characteristics from DWBA analysis.

The spectra consist of broad peaks at ≈ 1.5 MeV and ≈ 10 MeV. On the basis of DWBA calculations, the authors suggest that the main components in the peak at 1.5 MeV are the 11/2+ state at 779, the 15/2- state at 1423, and possibly the 9/2+ ground state. The authors suggest that the peak at 10 MeV is due mainly to neutron transfer to high-spin orbitals such as $1k_{17/2}$.

²⁰⁸Pb(⁵⁸Ni,⁵⁷Ni) 1987Be03

E=598, 1011 MeV ⁵⁸Ni beams were produced from the coupled tandem plus cyclotron at the Holifield Heavy Ion Research Facility (HHIRF). Target was 50 $\mu\text{g}/\text{cm}^2$ ²⁰⁸Pb evaporated onto 15 $\mu\text{g}/\text{cm}^2$ carbon backings. Reaction products were momentum analyzed with the HHIRF broad-range magnetic spectrograph, FWHM=600 keV. Measured $\sigma(\theta)$. DWBA analysis.

The spectrum is complex and is analyzed using a complete set of bound and unbound orbitals. Included are the bound orbitals $2g_{9/2}$, $1i_{11/2}$, $1j_{15/2}$, $3d_{5/2}$, $2g_{7/2}$, and the unbound orbitals $3f$, $1j_{13/2}$, $2h$, and $1k_{17/2}$. The energy spectrum up to 10-15 MeV of excitation, and angular distributions for several selected excitation-energy intervals, are reasonably well described by this approach. The authors suggest that the spectrum is dominated by the transfer of neutrons from the valence shell of ⁵⁸Ni to bound and unbound shells in ²⁰⁹Pb.

²⁰⁹Bi(π^- , γ) 1974Ba44

1974Ba44: E=190 MeV/c pion beam was produced from the Lawrence Berkeley Laboratory 184-inch cyclotron. Target was a metallic Bi plate. γ -rays were detected in a 180° pair-spectrometer. Measured photon spectrum. Deduced levels, γ -width.

Total radiative branching=0.98% 10. Radiative branching to levels in region 0-4 MeV=0.0036% 18 (1974Ba44).

²⁰⁹Pb Levels

E(level)	Comments
0.0	

Continued on next page

²⁰⁹Bi(π^-,γ) 1974Ba44 (continued)

²⁰⁹Pb Levels (continued)

E(level)	Comments
7.9×10 ³ 4	E(level): if π^- capture is in 4f orbital. E=8.5 MeV 4 if π^- capture is in 5g orbital. 1974Ba44 suggests this level is analog of possible giant quadrupole resonance expected at ≈26.5 MeV in ²⁰⁹ Bi. Radiative branching to 7900 level=0.047% 7.
13×10 ³ 2	Radiative branching to 13000 level=0.096% 16.

²⁰⁹Bi(n,p) 1984Br03

1984Br03: E=60 MeV neutron beam was produced by the ⁷Li(p,n) reaction at the University of California, Davis.
Protons were detected by ΔE -E telescopes of large-area plastic ΔE and NaI E detectors, FWHM=500 keV at E_p=50 MeV.
Measured $\sigma(\theta)$. Deduced analog isovector resonances.
Others:
1990Fr05: E=300–580 MeV. Measured $\sigma(\theta)$.
1990Ry01: E=14.3 MeV. Measured $\sigma(\theta)$.

²⁰⁹Pb Levels

E(level)	L	Comments
≈8000		$\Gamma=2$ MeV. Authors of 1984Br03 suggest this may be the analog of possible giant isovector quadrupole resonance at ≈26 MeV in ²⁰⁹ Bi or possibly a 2 $\hbar\omega$ -type transition.
≈15000	0	$\Gamma=2$ to 4 MeV. Authors of 1984Br03 suggest this may be the analog of possible giant isovector monopole resonance predicted at ≈30 MeV in ²⁰⁹ Bi and assign L=0.

²¹⁰Pb(p,d) 1971Ig01

Target ²¹⁰Pb J π (g.s.)=0+.
1971Ig01 (also 1969Fl01): E=20.6 MeV proton beam was produced from the Los Alamos Scientific Laboratory tandem Van de Graaff facility. Target was 240 $\mu\text{g}/\text{cm}^2$ enriched ²¹⁰Pb. Reaction products were momentum analyzed with an Elbek-type magnetic spectrograph (FWHM=14 keV) and detected in a CsI(Tl) scintillator. Measure $\sigma(\theta)$. Deduced levels, J π , L, spectroscopic factors from DWBA analysis.

²⁰⁹Pb Levels

E(level) [†]	L [‡]	S [§]	Comments
0.0		1.34	S: for configuration= $v(2g_{9/2})^{+1}$.
782 5		0.39	S: for configuration= $v(1i_{11/2})^{+1}$.
1426 5		0.42	S: for configuration= $v(1j_{15/2})^{+1}$.
1571 5		0.02	S: for configuration= $v(3d_{5/2})^{+1}$.
2035 5		0.003	S: for configuration= $v(4s_{1/2})^{+1}$.
2152 5	1	2.15	
2320 5	1	0.50	
2463 5	3	0.61	
2499 5		0.04	S: for configuration= $v(2g_{7/2})^{+1}$.
2547 5		0.007	S: for configuration= $v(3d_{3/2})^{+1}$.
2563 5	3	0.02	
2584 5			
2741 5	3	4.76	
2873 5	3	1.02	
2906 5	1	0.20	
3031 5	1	0.01	
3077 5	1	2.62	L: authors' parentheses around this L value in their Table vi is apparently a misprint. See authors' Fig. 6 and the text (1971Ig01).
3499 5	3	0.16	
3524 5	(1)	0.03	

Continued on next page (footnotes at end of table)

$^{210}\text{Pb}(\text{p,d})$ 1971Ig01 (continued) **^{209}Pb Levels (continued)**

E(level) [†]	L [‡]	S [§]	Comments
3562 5	(1)	0.02	
3637 5	(1)	0.11	
3659 5	6	11.8	
3751 5	5, 6	0.14	S: for L=6.
3811 5	5, 6	0.32	S: for L=6.
3831 5	(1)	0.04	
3906 6	3	0.11	
3937 5	6	0.92	
3995 5	6	0.41	
4024 5	(1)	0.03	
4084 11	(1)	0.06	
4119 5	1	0.16	
4145 5			
4174 10			
4212 5	3	0.91	
4222 5	3	2.08	
4270 5	3	1.44	
4309 5	3	0.91	
4345 8			
4358 5			
4395 5	3	0.06	
4472 12	1	0.09	
4529 12			
4562 5	3	0.32	
4584 5	3	0.14	
4621 10			
4671 5	3	0.09	
4690 5	3	0.25	
4715 10	3	0.17	
4781 8	3	0.11	
4819 7	1	0.12	
4837 5	(1)	0.12	
4865 8			
4924 5			
4944 9	1	0.06	
5074 10	(1)	0.23	
5094 8			
5136 10			
5160 10			
5222 12	1	0.11	
5359 10			

[†] From 1971Ig01.[‡] Values for strong levels at 2741, 3077, 3659, and 4222 determined from DWBA fits (1971Ig01). Shape of $\sigma(\theta)$ for these levels used to assign other L values.[§] Values for the single-particle states (5 lowest levels plus 2499 and 2547 levels) have been calculated using local zero-range DWBA with normalization factor 2.29 and neutron parameters radius=1.19 fm, diffuseness=0.75 fm, and spin-orbit coupling strength=20.5. Neutron well depth chosen based on separation energy approximation. Values for the other levels have been obtained under the assumption that the 2152 level has the same spectroscopic factor as the ^{207}Pb g.s.. 1971Ig01 makes the following further assumptions: 1) the 2152 level contains all the $p_{1/2}$ strength; 2) the three lowest L=3 levels have $J=5/2$, the 2873 level has $J=5/2$ or $7/2$, and the other L=3 levels have $J=7/2$; 3) the L=6 levels have $J=13/2$ (1971Ig01).

210Bi(t,α): Target=9- Isomer 1977Ha07

Target ²¹⁰Bi isomer Jπ=9-.

1977Ha07: E=20 MeV triton beam was produced from the Los Alamos three-stage Van de Graaff accelerator. Target was 8 μg/cm² ^{208m}Bi on a carbon backing. Reaction products were momentum analyzed with a Q3D magnetic spectrograph and detected in a helical cathode proportional counter, FWHM=15 keV. Measured σ(θ). Deduced levels, Jπ, spectroscopic factors from DWBA analysis.

Sum ²¹⁰Bi(9-)(t,α) strength/sum ²⁰⁸Pb(t,α) strength=0.85-0.9, (excluding ²⁰⁹Pb g.s. and 11/2+ single-particle states from sum). The authors of 1977Ha07 suggest that the (t,α) on ²¹⁰Bi(9-) proceeds mainly by pickup of the 3s_{1/2}, 2d_{3/2}, 1h_{11/2}, and 2d_{5/2} proton-hole states. The ²¹⁰Bi(9-) target is composed mainly of a g_{9/2} neutron and an h_{9/2} proton coupled to the ²⁰⁸Pb core.

209Pb Levels

E(level)	S	E(level)	E(level)
0.0	≈ 1 [#]	4164 [§] 5	4852 10
780 5	≈ 0.033 [@]	4248 5	4937?† 10
1420 [‡] 5		4265 10	4967?† 10
3059 [‡] 5		4345 10	4984 [§] 10
3530 5		4390 [§] 5	5022?† 15
3657 [§] 5		4466 5	5115 10
3802 [§] 5		4538 10	5174 [§] 10
3839 5		4566 10	5202 [§] 15
3958 5		4598 10	5290 [§] 15
3987 [§] 5		4701 10	5328 15
4032 5		4767 [§] 10	
4080 5		4837 [§] 10	

† Observed only at three angles (1977Ha07).

‡ σ(3059)/σ(1420)=2.4. 1977Ha07 suggests that this ratio can be taken as a rough estimate of the relative ²⁰⁸Pb 3- core admixtures in these two 15/2- levels. By assuming 2d_{3/2} proton pickup the authors obtain S(3059)/S(1420)=1.5-2.0. The sum of the cross sections to these two levels is roughly equal to that for excitation of the ²⁰⁸Pb 3- level in ²⁰⁹Bi(t,α). The authors suggest that this indicates that the configuration=v(2g_{9/2})⁺¹⊗3- strength is primarily contained in the 1420 and 3059 levels.

§ Maximum cross section is larger than 150 μb/sr suggesting that the level has a configuration containing a large component of ²¹⁰Bi(9-) coupled to a proton hole (1977Ha07).

From σ=σ[²⁰⁹Bi(t,α) to ²⁰⁸Pb g.s.].

@ Relative to S(g.s.)=1.

223Ra 14C Decay 1989Br34,1995Ho11,1990Hu07

Parent ²²³Ra: E=0.0; Jπ=3/2+; T_{1/2}=11.43 d 5; Q(g.s.)=31829 3; %¹⁴C decay=7.7×10⁻⁸ 13.

²²³Ra-J,T_{1/2}: From Adopted Levels of ²²³Ra.

²²³Ra-Q(g.s.): deduced from masses in 2012Wa38 (evaluators).

²²³Ra-%¹⁴C decay: Unweighted average of 8.9×10⁻⁸ % 4 (1995Ho11) and 6.4×10⁻⁸ % 4 (1989Br34).

1989Br34: ²²³Ra activity from a thin and intense ²²⁷Th source. Measured ¹⁴C energies and intensities. Charged particles were detected by a semiconductor, FWHM=110 keV for ¹⁴C, FWHM=16-17 keV for α particles. The energy scale was calibrated with a ¹⁴C beam scattered on a gold target and measured at θ=30°, which has the same energy as that of the ¹⁴C emitted by ²²³Ra.

1995Ho11: ²²³Ra source was produced from the ISOLDE mass-separator. Charged particles were detected by a Si detector. Measured σ. Deduced levels.

1990Hu07 and 1990Hu02 have interpreted ¹⁴C emission in terms of a cluster formation mechanism, and calculated hindrance factors for the ¹⁴C groups that populate the g.s. and some low-lying excited levels in ²⁰⁹Pb. The low hindrance factors of 3.9 and 4.6 for the ¹⁴C groups that populate the 779- (configuration=v(1i_{11/2})⁺¹) and 1423-keV (configuration=v(1j_{15/2})⁺¹) levels in ²⁰⁹Pb, respectively, are consistent with the assignment of 3/2+(-0.1,0.6) (3/2[631], 3/2[761]) to ²²³Ra g.s.. The Nilsson orbitals involved in this single-particle configuration also originate from the 1i_{11/2} and 1j_{15/2} spherical shells.

Others: 1992Ar02, 1991Ho15, 1990We01, 1985Al28, 1985Ku24, 1985Pr01, 1984Al34, 1984Ga38, 1984Ro30.

209Pb Levels

E(level) [†]	Jπ [‡]	Comments
0.0	9/2+	E(¹⁴ C)=29.8 MeV 2 (1985Ku24), I(¹⁴ C)=15 3 (1989Br34), HF(¹⁴ C)=583 (1990Hu07). Other: I(¹⁴ C)=18 (1995Ho11).
779	11/2+	E(level): from 1989Br34. I(¹⁴ C)=81 6 (1989Br34), HF(¹⁴ C)=3.9 (1990Hu07). Other: I(¹⁴ C)=82 (1995Ho11).

Continued on next page (footnotes at end of table)

^{223}Ra ^{14}C Decay $^{1989}\text{Br}34,^{1995}\text{Ho}11,^{1990}\text{Hu}07$ (continued)

^{209}Pb Levels (continued)

E(level) [†]	J π [‡]	Comments
1423	15 / 2-	I(^{14}C)=4.0 (1989Br34), HF(^{14}C)=4.6 (1990Hu07).
1567	5 / 2+	
2032	1 / 2+	

[†] Rounded-off values from Adopted Levels.

[‡] From Adopted Levels.

Adopted Levels, Gammas

$Q(\beta^-) = -1892.6$ 16; $S(n) = 7459.8$ 19; $S(p) = 3799.0$ 8; $Q(\alpha) = 3137.3$ 8 2012Wa38.

209Bi Levels**Single-particle states**

Each of the six single-particle proton states predicted, on the basis of the shell-model, for $82 < N \leq 126$, has been observed in single-particle proton stripping reactions on ^{208}Pb . Except for the $1i_{13/2}$ and $3p_{1/2}$ members, these states appear to contain most of the single-particle strength. The missing $3p_{1/2}$ strength may be concentrated in one of the components of a doublet at 4421+4447 (1970El13; see also 1968Ba34 and 1968El01). The $1i_{13/2}$ state at 1608, the only single-particle in the $82 < N \leq 126$ shell with positive parity, is expected to have its strength fragmented because of coupling with the positive-parity, particle-vibration states. This state is excited in inelastic scattering with $\sigma = 20\%$ that of the $13/2^+$ member of the assumed configuration $= \pi(1h_{9/2})^{+1} \otimes 3^-$ multiplet (1971Un01). Also, the $13/2^+$ member of the multiplet is excited in single-particle transfer (on ^{208}Pb) with strength $\approx 10\%$ that of the $13/2^+$ single-particle level (1967Li09, 1968El01). See 1974Sc20 for a discussion of core-polarization effects in the structure of the single-proton states as deduced from (p,p') inelastic scattering. These authors deduce 8% for the admixture of the configuration $= \pi(1h_{9/2})^{+1} \otimes 3^-$ in the $1i_{13/2}$ state.

Particle-vibration coupled states (^{208}Pb 3-)

The group of seven states with $E(\text{level}) = 2492-2741$ appear to be well described as a multiplet formed by coupling a $1h_{9/2}$ single-particle proton state (^{209}Bi g.s.) with the 3- collective excitation at 2614 in ^{208}Pb . The strongest evidence for this configuration assignment is the excellent agreement between the $B(E3)$ and $(\beta_3)^2$ values for the combined seven states (0.54 7 from Coulomb excitation and 0.11 from (p,p')) and those for the 3- state in ^{208}Pb (0.58 4 and 0.110) as well as the agreement between the energy of the septuplet centroid (2620 with spins as adopted) and that for the 3- state (2614). The spins of the individual levels in the septuplet have been assigned partly from (p,p') σ data on the basis of the $(2J+1)$ -rule (1966Ha35), and partly from $\gamma(0)$ data in (t,2n γ). The doublet at 2600 was unresolved in (p,p') and assigned as $11/2+13/2$. The doublet was subsequently resolved and the J-assignments of 1966Ha35 confirmed by the Coulomb-excitation data of 1969He07 and 1970Br12 and the (t,2n γ) data of 1983Ma15. See these authors, especially 1970Br12 and 1983Ma15, for a detailed discussion of the spin assignments for the septuplet. From (p,p') data, 1974Cl07 show that the $3/2^+$ state at 2492 contains only 64% 7 of the expected strength for the $3/2^+$ -member of the multiplet. They suggest that the 2957 level contains an additional 17% 6 of the configuration $= \pi(1h_{9/2})^{+1} \otimes 3^-$ strength. See also "particle-vibration coupled states (^{210}Po 0+, 4+)" below.

Particle-vibration coupled states (^{208}Pb 4-, 5-)

The coupling of the $1h_{9/2}$ ^{209}Bi g.s. to the core states in ^{208}Pb at 3198 ($J\pi=5^-$) and 3475 ($J\pi=4^-$) would result in a decuplet and a nonet of states, respectively. As pointed out by 1974Cl06, these core states are dominated by configuration $= v(2g_{9/2}^{13}p_{1/2}^{-1})^2$ so that the nineteen states of the decuplet and nonet should be dominated by the configuration $= \pi(1h_{9/2})^{+1} \otimes v(2g_{9/2}^{13}p_{1/2}^{-1})^2$. 1974Cl06 suggest that an alternate representation of these 19 states is in terms of the coupling of a $3p_{1/2}$ neutron hole to the 10 states with $J=0-$ to $9-$ in ^{210}Bi identified as members of the configuration $= \pi(1h_{9/2}) \otimes v(2g_{9/2})$ multiplet. (see also 1980Cl05 who, on the basis of the (d,t) reaction on a $9-^{210}\text{Bi}$ target, suggest that the levels seen in that reaction have a dominant configuration $= 9- \otimes v(nlj)^{-1}$ structure). Insofar as this alternate representation is correct, the 19 states should be populated in $^{209}\text{Bi}(p,p')$ at proton energies corresponding to excitation of isobaric analogs in ^{210}Po . Of the 10 ^{210}Bi core states mentioned above, a group of 8 states with energies in the range 2766-3170 in (p,p') (two states assumed doublets) has been interpreted as the decuplet with configuration $= \pi(1h_{9/2})^{+1} \otimes 5^-$ (1974Cl06, 1974Cl07). These states account for 88% 6 of the ^{208}Pb $L=5$ strength (1974Cl07). The centroid of the decuplet is at 3090 (with spins as adopted). 1974Cl07 observe that the 2987 $19/2^+$ level contains only 59% 7 of the strength expected for the configuration $= \pi(1h_{9/2})^{+1} \otimes 5^-$ $19/2^+$ member of the decuplet, which implies strong fragmentation of this configuration. They suggest that the 3957 level contains most of the missing strength. The spin assignments for the assumed members of the decuplet (except for the $19/2^+$ level) from 1974Cl06 and 1974Cl07 are based on the strength in $^{209}\text{Bi}(p,p')$ via direct scattering and in $^{209}\text{Bi}(p,p')$ via analog resonances. The spin of $19/2^+$ for the 2987 level suggested by these authors is confirmed by the γ -branching observed by 1978Be17 in $^{208}\text{Pb}(^7\text{Li}, \alpha 2n\gamma)$ but is in disagreement with that based solely on the $(2J+1)$ -rule in (p,p') (see 1975Wa03). For other differences between assignments based on the $(2J+1)$ -rule and those of 1974Cl06 and 1974Cl07, see 1975Wa03. Confirming arguments for J are based on $\gamma(0)$ in (t,2n γ). A group of 9 states with energies in the range 2919 to 3503 have been interpreted by 1974Cl06 as the above mentioned multiplet with configuration $= \pi(1h_{9/2})^{+1} \otimes 4^-$. The spin assignments for the assumed members of this multiplet from 1974Cl06 are based on the strength of resonances in $^{209}\text{Bi}(p,p')$ excitation functions at energies corresponding to isobaric analogs of states with known spin in ^{210}Bi along with the assumption that the 19 states of the decuplet and nonet exhaust all the spins possible from the two-particle, one-hole configurations involving the $1h_{9/2}$ proton and $1g_{9/2}$ neutron single-particle and $3p_{1/2}$ neutron single-hole states. See 1974Cl06 for detailed assignments. Confirming arguments for J are based on $\gamma(0)$ in (t,2n γ). See 1983Ma15 for a calculation of the energies and wave functions for all nineteen states. The calculation is based on the configuration $= \pi(1h_{9/2})^{+1} \otimes v(1g_{9/2}^{13}p_{1/2}^{-1})^2$ representation.

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Adopted Levels, Gammas (continued)**209Bi Levels (continued)**Particle-vibration coupled states (²¹⁰Po 0+, 4+)

On the basis of a comparison of experimental energies and spectroscopic factors with values predicted by a core-coupling calculation, 1972Ba81 in (t,α) propose configurations of the type configuration=(0+⊗π(nlj)⁻¹)+(3-⊗π(nlj)) for several of the states seen in (t,α), as indicated below. The authors also propose configuration=(0+⊗π(nlj)⁻¹)+(4+⊗π(nlj)⁻¹) for states at 4000 15 and 4120 15. It is not clear whether these correspond to states seen at these energies in other reactions, or whether they are separate states.

For a discussion of particle-vibration coupling involving ²⁰⁸Pb core states other than those discussed above, see 1974Cl06, 1974Cl07, 1975Wa03, and 1983Ma15.

Cross Reference (XREF) Flags

A ²⁰⁹ Pb β ⁻ Decay	M ²⁰⁸ Pb(³ He,dγ)	²⁰⁹ Bi(e,e'): Giant Resonance
B ²⁰⁹ Po ε Decay	N ²⁰⁸ Pb(α,t)	²⁰⁹ Bi(e,n): Giant Resonance
C ²¹³ At α Decay	O Others:	²⁰⁹ Bi(n,n'γ)
D ²⁰⁷ Pb(α,d)	²⁰⁸ Pb(⁷ Li,α2nγ)	²⁰⁹ Bi(p,p')
E ²⁰⁸ Pb(p,γ)	²⁰⁸ Pb(⁷ Li, ⁶ He),(pol ⁷ Li, ⁶ He)	²⁰⁹ Bi(p,p'): Giant Resonance
F ²⁰⁸ Pb(p,γ): Giant Resonance	²⁰⁸ Pb(¹¹ B, ¹⁰ Be)	²⁰⁹ Bi(d,d')
G ²⁰⁸ Pb(p,γ): IAR	²⁰⁸ Pb(¹² C, ¹¹ B)	²⁰⁹ Bi(α,α'): Giant Resonance
H ²⁰⁸ Pb(p,p'),(pol p,p'): IAR	²⁰⁸ Pb(¹⁶ O, ¹⁵ N)	²¹⁰ Bi(d,t): Target=9- Isomer
I ²⁰⁸ Pb(d,n)	²⁰⁸ Pb(³² S,Xγ)	²¹⁰ Po(t,α)
J ²⁰⁸ Pb(d,nγ)	²⁰⁹ Bi(γ,γ')	Coulomb Excitation
K ²⁰⁸ Pb(t,2nγ)	²⁰⁹ Bi(γ,n)	Inelastic Scattering
L ²⁰⁸ Pb(³ He,d)	²⁰⁹ Bi(γ,p),(e,p): IAR	Muonic Atom

E(level) [†]	Jπ	XREF	T _{1/2}	Comments
0.0	9/2-	ABCDEF IJKLMNO	2.01×10 ¹⁹ y 8	<p>%α=100. Jπ: atomic beam (1976Fu06), L(α,t)=L(³He,d)=5 from 0+. T_{1/2}: from α-decay in 2012Be06. 1.9E19 y 2 from 2003De11 deduced only from the partial width for the ground state decay. μ=+4.1103 5 (1953Ti01). Q=-0.55 1 (1983De07). Octupole moment=+0.5 (1976Fu06). μ: from 1996Ba94 re-evaluation with correction for diamagnetism of +4.1106 2 by NMR in 1953Ti01. Q: from atomic beam method in 1983De07. Others: -0.37 3 (muonic x-ray hyperfine structure, 1972Le07), -0.40 5 (1974Ho40), -0.39 3 (optical spectroscopy, 1967Di04, 1970Ge10), -0.50 8 (pionic x-ray hyperfine structure, 1978Be24), -0.5 2 (pionic x-ray hyperfine structure). configuration=π(1h_{9/2})⁺¹. π⁰ emission not found (1989St01). Isotope shift(²⁰⁷Bi-²⁰⁹Bi)=0.0999 cm⁻¹ 20 (1985Ba21). Charge density distribution measured (1973Si20,1978Eu01).</p>
896.28 5	7/2-	B DE IJKLMNO	8.2 ps 12	<p>Jπ: L(³He,d)=L(α,t)=3, 896.28γ M1+E2 to 9/2-. T_{1/2}: from B(E2)↑=0.00261 16 and the adopted mixing ratio of δ(896.28γ)=-0.62 6. B(E2)↑=0.00261 16, weighted average of 0.0018 6 (1969He07), 0.0024 2 (1972Ha59), and 0.00275 14 (1973Kr02). Other: B(E2)↑=0.00139 +16-23 (1970Br12), but the bombarding energy was such that the assumption of a pure Coulomb excitation may not be valid (1973Kr02). configuration=π(2f_{7/2})⁺¹.</p>

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Adopted Levels, Gammas (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
1608.57 5	13/2+	DE I KLMNO	0.23 ns 13	<p>Jπ: L(α,t)=L(³He,d)=6, 1608.53γ M2+E3 to 9/2-.</p> <p>T_{1/2}: from B(E3)$\uparrow$=0.026 3 and the adopted mixing ratio of δ(1608.53γ)=+0.33 10.</p> <p>B(E3)$\uparrow$=0.026 3, weighted average of B(E3)$\uparrow$=0.022 8 from Coulomb excitation (1969He07) and B(E3)$\uparrow$=0.027 3 from (p,p') (1974Sc20). Other B(E3)$\uparrow$=0.0124 32 (1970Br12), but see also the comment to the 896-keV level.</p> <p>Q=-0.37 3 (1972Le07).</p> <p>Q: from muonic x-ray hyperfine structure (1972Le07).</p> <p>configuration: probable a mixture of $\pi(1i_{13/2})^{+1}$ and $\pi(1h_{9/2})^{+1}\otimes 3^-$ (1974Cl07).</p> <p>Isomer shift measured in muonic atom: 3.7 +6-8 (1974Ba77), 3.5 6 (1972Le07), 3.8 3 (1984Ru08).</p>
2442.92 6	1/2+	JK M O	11.3 ns 4	<p>XREF: O(2430).</p> <p>Jπ: L(t,α)=(0), 1546γ E3 to 7/2-.</p> <p>T_{1/2}: from 1546.7γ(t) in (n,nγ) (1996De48).</p> <p>Other: 10 ns 2 from ce(K)(896γ)(t)(1978El07) in (d,nγ). T_{1/2}>2 ps from 1546(t) in (⁷Li,α2nγ), but note that the authors place the 1546γ from the 3154-keV doublet.</p> <p>configuration: probable a mixture of $\pi(3s_{1/2})^{-1}$ and $\pi(2f_{7/2})^{+1}\otimes 3^-$ (1972Ba81).</p>
2492.86 6	3/2+ [@]	K MNO	$\approx$ 31 ps	<p>XREF: O(2480)O(2480).</p> <p>Jπ: L(α,t)=2, L(p,p')=3. RUL rules out mult(49.94γ to 1/2+)=pure E2.</p> <p>T_{1/2}: from B(E3)$\uparrow$=0.021 3 in Coulomb excitation (1969He07) and the adopted branching for the 2492.86γ.</p> <p>B(E3)$\uparrow$=0.021 3, from 0.053 7 in Coulomb excitation (1969He07).</p> <p>configuration=$\pi(1h_{9/2})^{+1}\otimes 3^-+\pi(2d_{3/2})^{-1}$ (1972Ba81).</p>
2564.14 10	(9/2)+ [@]	K O	0.015 ps 3	<p>Jπ: L(p,p')=3, 2564γ E1+E3 to 9/2-.</p> <p>T_{1/2}: weighted average of 0.015 ps 3, from $\Gamma(\gamma_0)^2/\Gamma=0.030$ eV 5 in (γ,γ') (1969Me21) for J=9/2, and 0.014 ps 11, from DSAM in (⁷Li,α2nγ) (1972Ha59).</p> <p>B(E3)$\uparrow$=0.073 11, weighted average of B(E3)$\uparrow$=0.074 11 from Coulomb excitation (1969He07) and 0.072 14 in muonic atom (1972Le07).</p> <p>μ=3.5 7; Q=+0.11 5 (1972Le07).</p> <p>μ,Q: from muonic x-ray hyperfine structure in 1972Le07.</p> <p>configuration=$\pi(1h_{9/2})^{+1}\otimes 3^-$ (1974Cl07,1983Ma15).</p> <p>Isomer shift=6.2 5 (1974Ba77), 5.8 5 (1972Le07), 6.6 3 (1984Ru08) in Muonic atom dataset.</p>
2583.02 8	(7/2)+ [@]	K O	0.31 ps 10	<p>B(E3)$\uparrow$=0.052 8 (1969He07).</p> <p>Jπ: L(p,p')=L(e,e')=3, 1686.66γ E1+(M2) to 7/2-, 2583.07γ E1+E3 to 9/2-.</p> <p>T_{1/2}: from DSAM in (⁷Li,α2nγ) (1972Ha59).</p> <p>Other: 0.15 ps +14-7 from DSAM in Coulomb excitation (1970Br12).</p> <p>configuration=$\pi(1h_{9/2})^{+1}\otimes 3^-$ (1974Cl07,1983Ma15).</p> <p>β_3=0.122 6 from inelastic scattering (1967Al14).</p>

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Adopted Levels, Gammas (continued)
²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF		T _{1/2}	Comments
2599.91 9	11/2+ [@]	d	Kl no	36 fs 10	J π : L(α ,t)=6 for 2600 doublet, 2599.9 γ E1+E3 to 9/2-. T _{1/2} : from $\Gamma(\gamma_0)^2/\Gamma=0.0090$ eV 24 in (γ,γ') (1969Me21) for J=11/2 and the adopted branching ratio of $\Gamma(\gamma_0)/\Gamma=0.847$ 18. configuration= $\pi(1h_{9/2})^{+1}\otimes 3^-$ (1983Ma15). B(E3) $\uparrow=0.094$ 14 in Coulomb excitation (1969He07).
2600.92 5	13/2+ [@]	d	K no	0.44 ps 14	J π : L(α ,t)=6 for 2600 doublet, 992.35 γ M1(+E2) to 13/2+, 140.13 γ M1(+E2) from 15/2+. T _{1/2} : from DSAM in (⁷ Li, α 2n γ) (1972Ha59). Other: 0.24 ps +14-10 in Coulomb excitation (1969He07). configuration= $\pi(1h_{9/2})^{+1}\otimes 3^-$ (1983Ma15). B(E3) $\uparrow=0.108$ 15 from B(E3)=0.072 11 in Coulomb excitation (1969He07).
2617.34 6	5/2+ [@]		K O	7.2 ps 11	J π : L(p,p')=3, 124.48 γ M1(+E2) to 3/2+, and 1721.08 γ E1(+M2) to 7/2-. T _{1/2} : from adopted B(E3) $\uparrow=0.034$ 5, by assuming a pure E3 transition for 2617.35 γ . Other: >2 ps from DSAM in (⁷ Li, α 2n γ) (1972Ha59). B(E3) $\uparrow=0.034$ 5 from B(E3)=0.057 9 in Coulomb excitation (1969He07). configuration= $\pi(1h_{9/2})^{+1}\otimes 3^-$ (1974Cl07,1983Ma15).
2741.05 5	15/2+		K o	9.1 ps 12	J π : L(d,t)=1 from 9-, L(p,p')=3, 2741.03 γ E3 to 9/2-. T _{1/2} : from the adopted B(E3) $\uparrow=0.077$ 10 and branching ratios. Other: >2 ps from DSAM in (⁷ Li, α 2n γ) (1972Ha59). B(E3) $\uparrow=0.077$ 10 from B(E3)=0.048 6, weighted average of 0.048 7 in Coulomb excitation (1969He07) and 0.047 10 in Muonic atom (1972Le07). $\mu=6.2$ 12; Q=0.0 4 (1972Le07). μ ,Q: From muonic x-ray hyperfine structure in 1972Le07. configuration= $\pi(1h_{9/2})^{+1}\otimes 3^-$ (1974Cl07,1983Ma15). For isomer shift measurement see Muonic atom (1972Le07).
2766.66 6	3/2+ ^{&}		K M o		J π : L(p,p')=5, 323.74 γ M1 to 1/2+. Note, that L(p,p')=4 in 1975Wa03. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^-$ (1974Cl07,1983Ma15).
2826.1 4	5/2-	DE	I KL NO	6.9 fs 9	J π : L(³ He,d)=L(α ,t)=3, 2826.0 γ E2 to 9/2-. T _{1/2} : from $\Gamma(\gamma_0)^2/\Gamma=0.034$ eV 4 in (γ,γ') for J=5/2 and the adopted branching ratio of $\Gamma(\gamma_0)/\Gamma=0.718$ 16 Other: <14 fs from DSAM in (⁷ Li, α 2n γ) and 7.8 fs 27 from B(E2) $\uparrow=0.029$ 10 in Coulomb excitation (1970Br12). B(E2) $\uparrow=0.029$ 10 in Coulomb excitation (1970Br12). configuration: probable a mixture of $\pi(2f_{5/2})^{+1}$ and $\pi(1h_{9/2})^{+1}\otimes 2^+$ (1974Cl07).
2845.20 6	1/2+		K M O		J π : 402.27 γ (θ) is isotropic. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^-$ (1974Cl07,1983Ma15).
2916.62 7	(1/2)+	D	K M O		J π : 149.98 γ M1+E2 to 3/2+. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^-$ (1974Cl07,1983Ma15).

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Adopted Levels, Gammas (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
2955.93 7	(3/2)+	K M O		J π : L(p,p')=3, 677.8 γ from 1/2-. Spin was tentatively suggested by 1972Ba81, based on strength in (t, α) and possible L=2 with configuration= $\pi(2d_{3/2})^{-1}$. A $\pi(1h_{9/2})^{+1}\otimes 3^{-}$ component is suggested by 1974Cl07 on the basis of (p,p') data, and by 1983Ma15 on the basis of (t,2n γ) data. Gammas to 1/2+ and 5/2+ are observed in (t,2n γ). The 2955 γ to 9/2- is reported only in (n,n' γ). See comment on the 2955 γ . configuration= $\pi(2d_{3/2})^{-1}+\pi(1h_{9/2})^{+1}\otimes 3^{-}$ (1972Ba81).
2986.80 5	19/2+&	D K O	17.9 ns 5	XREF: D(2979). J π : L(d,t)=1 from 9-, L(p,p')=5 from 9/2-, 245.73 γ E2 to 15/2+. T _{1/2} : weighted average of 17.9 ns 5 from γ (t) in (n,n' γ) (1996De48), and 18 ns 1 from γ (t) in (⁷ Li, α 2n γ) (1972Ha59). μ =3.50 8 (1978Be17). μ : From g=0.368 8 in (⁷ Li, α 2n γ) by time dependent perturbed angular distribution (1978Be17). configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ (1974Cl07,1983Ma15).
3038.88 10	5/2+&	D K O		J π : L(p,p')=5, 2142.78 γ E1 to 7/2- and 272.2 γ (M1+E2) to 3/2+. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ (1974Cl07,1983Ma15).
3090.16 8	(7/2)+&	K O		J π : L(p,p')=5, 2194.1 γ to 7/2- and 3089.48 γ (E1+M2) to 9/2-. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ (1983Ma15).
3119.48 8	3/2-	E I KLMNO	0.021 ps 14	XREF: N(3139). J π : L(³ He,d)=1, 2223.23 γ E2 to 7/2-. T _{1/2} : from DSAM in (⁷ Li, α 2n γ) (1972Ha59). configuration= $\pi(3p_{3/2})^{+1}$.
3132.97 9	11/2+&	d K o		J π : 3132.96 γ E1 to 9/2- and 1524.1 γ to 13/2+. L(p,p')=5, but the peak is a probable doublet, based on σ and on the observation that the (p,p') excitation function appears to resonate at both the J π =5- and 7- isobaric analog resonances. J π =(13/2+) in (n,n' γ). configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ (1974Cl07,1983Ma15). β_5 =0.067 4 from inelastic scattering (1967Al14).
3135.77 7	(15/2)+&	d K o		J π : L(p,p')=5, 394.72 γ M1 to 15/2+ and 1527.13 γ M1 to 13/2+. See also the 3133 level. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ (1983Ma15).
3152.83 20	(9/2)+&	K O		J π : L(p,p')=5, 3152.80 γ E1 to 9/2-. configuration: probable a mixture of $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ and $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07).
3154.06 6	17/2+&	K o		J π : L(p,p')=5, 167.16 γ M1 to 19/2+ and 413.04 γ M1(+E2) to 15/2+, L(d,t)=1 from 9-. configuration: probable a mixture of $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ and $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07).

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Adopted Levels, Gammas (continued)
²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
3159.33 8	3/2(+)	K M o		J π : 314.2 γ (M1) to 1/2+. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1983Ma15).
3169.07 6	(13/2)+&	K o		J π : L(p,p')=5, 1560.49 γ M1 to 13/2+. J=(11/2+) from (n,n' γ) (1996De48). configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_5^{-}$ (1974Cl07,1983Ma15).
3197.60 9	(1/2+, 3/2+)	D K M O		J π : 352.3 γ (M1) to 1/2+ and 705.1 γ to 3/2+.
3211.85 6	(17/2)+&	K O		J π : L(p,p')=5, 225.05 γ (M1) to 19/2+, L(d,t)=1 from 9-.
3221.65 8	5/2+ ^a	K O		configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1983Ma15). Note, that $\pi(1h_{9/2})^{+1}\otimes 5_1^{-}$ is proposed in 1974Cl07.
3269.64 11	1/2+, 3/2+	K M O		J π : 455.02 (M1) to 3/2+ and $\gamma(0)$ is not consistent with a J to J transition;
3311.14 6	(7/2+, 9/2+)	K O		131.45 γ to 7/2+. configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07,1983Ma15).
3354.8 4	(5/2+) ^a	K o		J π : 424.49 γ (M1) to 1/2+.
3362.00 11	(5/2+, 7/2+, 9/2+)	K o		J π : L(p,p')=(3). 2414 γ to 7/2- and 3310 γ to 9/2-.
3378.16 9	(9/2+) ^a	K O		configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07).
3393.38 21	(15/2+) ^a	K o		J π : from 588 γ to 3/2+ in (t,2n γ), but $\gamma(0)$ is not consistent with a J to J transition.
3395.00 11	5/2-, 7/2, 9/2, 11/2-	d o		J π : 2465.7 γ D to 7/2-. Note, that J π =(3/2+) from (n,n' γ) (1996De48).
3406.21 9	13/2+ ^a	D KL NO		J π : 3378.11 γ (E1) to 9/2-.
3449.7 4	(7/2+) ^a	K M O		configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1983Ma15).
3464.12 10	11/2+ ^a	K o		J π : 1784.8 γ D to 13/2+. J=(17/2+) from (n,n' γ).
3467.67 7	19/2+ ^a	d K o		J π : 2498.7 γ to 7/2- and 3395.6 γ to 9/2-.
3486.93 7	(19/2+)	d K O		XREF: D(3400).
3489.88 20	(7/2, 9/2)	d K O		J π : L(α ,t)=6, 1797.64 γ M1 to 13/2+; $\gamma(0)$ is consistent with J to J transition. Note, that J=(11/2+) in (n,n' γ) (1996De48).
3502.23 12	(15/2+) ^a	d K o		configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07,1983Ma15).
3505.28 20	5/2-, 7/2-	No		J π : 2553.4 γ (E1) to 7/2-.
3541.60 21	(5/2-, 7/2, 9/2)	K O		configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07,1983Ma15).
3575.08 21	(5/2, 7/2+)	d K o		J π : L(d,t)=3 from 9- for E=3469, L(p,p')=5 for E=3466, 3464.09 γ E1 to 9/2-; $\gamma(0)$ is not consistent with J to J transition.
				Note, that J=(9/2)+ in (n,n' γ).
				configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07,1983Ma15).
				J π : L(d,t)=3 from 9- for E=3469, L(p,p')=5 for E=3466. 480.87 γ M1 to 19/2+, 313.70 γ to 17/2+.
				J π : 500.12 γ (M1) to 19/2+.
				probable configuration= $\pi(1h_{9/2})^{+1}\otimes v(1i_{11/2}^{+1}3p_{1/2}^{-1})$ (1983Ma15).
				J π : 2593.6 γ to 7/2-, 3490.1 γ to 9/2-.
				J π : 290.38 γ D to 17/2+.
				configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_4^{-}$ (1974Cl07,1983Ma15).
				J π : L(α ,t)=3 for E=3503 15.
				J π : 2545.3 γ to 7/2-, 3542.7 γ to 9/2-.
				J π : 808 γ to 3/2+ and 2678.8 γ to 7/2-.

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Adopted Levels, Gammas (continued)

209Bi Levels (continued)

E(level) [†]	J π	XREF			T _{1/2}	Comments
3579.00 11	(17/2+ to 21/2+)	d	K	o		J π : L(p,p')=5, 592.2 γ D to 19/2+. probable configuration= $\pi(1h_{9/2})$ $+1\otimes v(1i_{11/2}+13p_{1/2}^{-1})$ (1983Ma15).
3590.50 21			M			
3597.14 10	19/2+		K	O		J π : L(p,p')=5 and L(d,t)=1,3, 610.33 γ M1 to 19/2+; $\gamma(0)$ in (t,2n γ) is consistent with J to J transition. configuration= $\pi(1h_{9/2})+1\otimes 5_2^{-}$ or $\pi(1h_{9/2})+1\otimes 5_1^{-}$ (1974Cl07). J π : 2705 γ (E1) to 7/2-. probable configuration= $\pi(2f_{7/2})+1\otimes 3^{-}$ or $\pi(1h_{9/2})+1\otimes 5^{-}$ (1983Ma15). XREF: N(3650)O(?). J π : L(³ He,d)=L(α ,t)=1, analyzing power fits in (pol ⁷ Li, ⁶ He). configuration= $\pi(3p_{1/2})+1$. E(level): from (p,p'). J π : L(p,p')=5 from 9/2-. XREF: D(?).
3601.72 11	(5/2+, 7/2+, 9/2+)		K	O		J π : suggested by 1972Ba81 in (t, α) on the basis of energy and strength as the h _{11/2} hole state, 3692.14 γ to 9/2-. configuration= $\pi(1h_{11/2})^{-1}$ (1972Ba81). configuration: the authors of 1972Ba81 in (t, α) also propose a small component with configuration= $\pi(1h_{9/2})+1\otimes 3^{-}$. XREF: D(?).
3633.85 8	1/2-	dE	LMNO			E(level): two close levels at this energy are reported in (n,n' γ) (1996De48). However, no strong evidence supports two separate levels and the 664.8 γ and 3703 γ were placed from the same level in (t,2n γ) while assigned to the two separate levels in (n,n' γ). The evaluators treat them as the same level. J π : 664.8 γ D to 5/2+ and 3703.4 γ to 9/2-; $\pi=+$ from probable configuration= $\pi(2f_{7/2})+1\otimes 3^{-}$ or $\pi(1h_{9/2})+1\otimes 5^{-}$. See (n,n' γ) dataset for J π comments for the two separate levels at this level energy.
3684 3	17/2+, 19/2+, 21/2+	d		O		J π : from (t,2n γ). Note, that (5/2+) in (n,n' γ). E(level): from (p,p').
3692.14 20	(11/2-)	D	K	nO		J π : L(d,t)=1,3 from 9- for 3735+3766. If L=3 for the 3766 component, as suggested by the observed g.s. transition from that level, then L=1 and thus J=15/2 to 21/2 for the 3735 level.
3703.55 20	7/2(+)	D	K	no		J π : L(d,t)=1,3 from 9- for 3735+3766. J is limited to 11/2 if the 3767 γ in (n,n' γ) can be assigned as a transition to the ground state. J π : 2886.78 γ to 7/2-.
3717.64 10	(7/2+, 9/2+, 11/2+)		K	nO		J π : L(p,p')=(3), 2904.8 γ to 7/2- and 3800.7 γ to 9/2-.
3735 5	(15/2 to 21/2)+			O		J π : L(d,t)=3 from 9- for E=3818, 825.45 γ E2 to 19/2+. probable configuration= $\pi(1h_{9/2})+1\otimes v(2g_{9/2}+12f_{5/2}^{-1})$ (1983Ma15).
3752.2 ^{\$} 3				o		
3759.0 5			M			
3766.9 ^{\$} 3	(11/2)+			o		
3772.60 21			M			
3783.08 15	(5/2, 7/2, 9/2) [#]		K	M	O	
3800.85 17	(7/2+, 9/2+)	d	LM	o		
3808.29 21		d	LM	o		
3812.25 16	23/2+		K	o		

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Adopted Levels, Gammas (continued) ^{209}Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
3816.70 21		M		J π : 2920.4 γ to 7/2-.
3817.86 20	(11/2+, 13/2+)	D	l o	J π : 2209.3 γ to 13/2+ and 1253 γ to 9/2+. L(d,t)=3 from 9- for E=3818, if this corresponds in part to the 3817 level, would rule out J=9/2 and would require $\pi=+$.
3839 4	11/2+, 13/2+	NO		XREF: O(3870). E(level): from (p,p'). J π : L(α ,t)=6 for E=3835 15.
3849.94 20		K O		
3884.3 $\S$ 5		O		
3889.5 $\S$ 3		O		
3905.9 3		o		
3912 10	(15/2 to 21/2)+	o		E(level): from (d,t). J π : L(d,t)=1 from 9-.
3913.26 21	(1/2 to 7/2+)	M		J π : 1420.4 γ to 3/2+.
3921.22 10	(7/2+, 9/2+)	O		J π : 3024.5 γ to 7/2- and 3921.2 γ to 9/2-, L(p,p')=(3).
3936.74 $\S$ 10	(13/2-)	NO		J π : L(α ,t)>6. J is limited to 13/2 (and thus L=7) if the 3937 γ in (n,n' γ) can be assigned as a ground-state transition.
3950 5	(13/2+ to 17/2+)	l no		E(level): from (p,p'). J π : L(p,p')=(3) from 9/2-.
3962.27 22	(7/2, 9/2)	l o		J π : 3066.1 γ to 7/2-, 3962.1 γ to 9/2-.
3980.04 10	(11/2, 13/2)-	Kl o		J π : L(p,p')=2, 3980 γ to 9/2-. $g\Gamma^2_{\gamma 0}/\Gamma=0.82$ 8. configuration= $\pi(1h_{9/2})^{+1}\otimes 2^{+}$ (1974Cl07).
4000.71 15	9/2+, 11/2, 13/2-#	no		J π : 2391.8 γ to 13/2+ and 4001 γ to 9/2-.
4002 10	(15/2 to 23/2)+	o		E(level): from (d,t). J π : L(d,t)=1 from 9-.
4009.3 $\S$ 4		no		E(level): if the 4009 γ is incorrectly assigned as a transition to the ground state, then the only evidence for a level at this energy is a (p,p') level at 4013 5. This level might be the same as the (d,t) level at 4002 10.
4021 10		no		E(level): from (d,t). J π : L(α ,t)>6 for 4019 25.
4036.5 $\S$ 4		O		
4046.54 $\S$ 20		O		
4065 ^d 10		o		E(level): from (d,t).
4079 ^d 7		o		E(level): from (p,p').
4088.34 10	(5/2 to 13/2)-	l o		XREF: O(4092). J π : L(p,p')=2 from 9/2-. $g\Gamma^2_{\gamma 0}/\Gamma=0.28$ 3.
4091.4 4	(1/2-, 3/2-)	lM o		J π : 1648.5 γ to 1/2+, $\pi=-$ from probable configuration. configuration= $\pi(1h_{9/2})^{+1}\otimes 2^{+}$ or $\pi(2f_{5/2})^{+1}$ (1974Cl07).
4096.34 17	(9/2+, 11/2, 13/2-)	l o		XREF: O(4101). J π : 2488.2 γ to 13/2+ and 4096.1 γ to 9/2-.
4096.59 22	(1/2 to 7/2-)	lM o		J π : 977.1 γ to 3/2-.
4116 4	(+)	o		J π : L(p,p')=(7) from 9/2-.
4123 7		o		E(level): from (p,p').
4134.0 $\S$ 20		o		E(level): from (p,p').
4141.95 10	21/2(+)	D K o		J π : 544.85 γ and 654.98 γ D to J=19/2; π from probable configuration= $\pi(2f_{7/2})^{+1}\otimes 3^{-}$ or $\pi(1h_{9/2})^{+1}\otimes 5^{-}$ (1983Ma15).
4148.11 14	(9/2+, 11/2-)	l o		J π : 2539.6 γ to 13/2+ and 3251.6 γ to 7/2-. $g\Gamma^2_{\gamma 0}/\Gamma=0.07$ 2.

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Adopted Levels, Gammas (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
4158.79 19	—	1 O		XREF: O(4157). J π : L(p,p')=2, 3262.8 γ to 7/2- and 4158.7 γ to 9/2-.
4160.9 ^{\$} 7	(13/2-)	1 nO		g $\Gamma^2_{\gamma 0}/\Gamma=0.21$ 4. XREF: O(4162). J π : L(p,p')=(2), J π =13/2-, 15/2- for E=4174 25 from L(α ,t)=7. γ to 9/2- rules out the 15/2- alternative if the (α ,t) peak corresponds to the 4161 level. configuration= $\pi(1h_{9/2})^{+1}\otimes 2^{+}$ (1974Cl07). E(level): from (p,p'). J π : L(p,p')=(2); high spins are suggested in (α ,d).
4168 7	(11/2- to 15/2-)	d 1 nO		J π : 4176.1 γ to 9/2-, L(p,p')=3. g $\Gamma^2_{\gamma 0}/\Gamma=0.21$ 4. XREF: O(4210). J π : L(p,p')=2 (1974Cl07), L(p,p')=3 (1975Wa03). g $\Gamma^2_{\gamma 0}/\Gamma=0.25$ 3. configuration= $\pi(1h_{9/2})^{+1}\otimes 2^{+}$ (1974Cl07).
4176.14 10	(7/2, 9/2, 11/2)+	d 1 O		XREF: O(4220). E(level): from (d,t). J π : L(d,t)=1 from 9-.
4207.5 4		O		J π : L(α ,t)=7. J is limited to 13/2 if the 4233 γ in (n,n' γ) can be interpreted as a ground-state transition corresponding to the (α ,t) level; otherwise, J π =13/2-, 15/2- for E=4247 25.
4222.9 ^{\$} 7		1 no		
4225 10	(15/2 to 21/2)+	1 o		
4233.75 ^{\$} 20	(13/2)-	1 no		
4236.9 3		1M o		
4257 4	(15/2 to 21/2)+	O		E(level): from (p,p'). J π : L(d,t)=1 from 9-.
4262.95 20		O		
4286 3	15/2-, 17/2-, 19/2-	D O		XREF: D(4276)O(4270). E(level): from (p,p'). J π : L(p,p')=4 from 9/2-.
4297.73 17		O		XREF: O(4294). J π : L(p,p')=7.
4300.75 ^{\$} 10	(+)	O		E(level): from (p,p'). E(level): from (p,p').
4313? 7		O		
4326 3		D O		
4335.3 3		O		
4340.7 ^{\$} 5		o		
4349 7	(15/2 to 21/2)+	o		E(level): from (p,p'). J π : L(d,t)=1 from 9-.
4361.89 21	(11/2, 13/2, 15/2)-	O		J π : L(p,p')=4, 2753.3 γ to 13/2+.
4376.5 ^{\$} 6		O		
4381.31 21		O		
4388.15 19		d o		J π : 3491.9 γ to 7/2- and 4387.7 γ to 9/2-.
4397.85 ^{\$} 20		d o		
4409.05 ^{\$} 20		d o		J π : L(p,p')=8 from 9/2-.
4415.33 16	1/2-	E LMNo		XREF: L(4421)N(4459). J π : 1295.9 γ to 3/2- and 1922.4 γ to 3/2+, L(³ He,d)=(1), p _{1/2} state suggested in (p, γ) and in (³ He,d), L(α ,t)=1+3 for E=4459 25. configuration= $\pi(3p_{1/2})^{+1}$ (1970El13). E(level): from (d,t). J π : L(d,t)=1 from 9-.
4417 10	(15/2 to 21/2)+	O		
4426.7 3		M		
4441.7 ^{\$} 10	(7/2)-	1MnO		configuration= $\pi(2f_{7/2})^{+1}$ (1970El13). J π : L(p,p')=4, L(³ He,d)=(2,3), L(α ,t)=1+3 for E=4459 25. 4439.1 γ to 9/2-. Possible f _{7/2} state suggested in (³ He,d). XREF: O(4469). J π : 2862.5 γ to 13/2+ and 4470.5 γ to 9/2-.
4471.0 3	(9/2+, 11/2, 13/2-)	d O		

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Adopted Levels, Gammas (continued) ^{209}Bi Levels (continued)

E(level) [†]	J π	XREF		T _{1/2}	Comments
4478.2 3		d	M		
4484.79 11		d	O		
4506.85 20		d	O		
4515.23 10	(9/2+, 11/2, 13/2-)	d	o		J π : 2906.6 γ to 13/2+ and 4515.3 γ to 9/2-.
4516.5 3		d	M o		
4522 10		d	L		E(level): from ($^3\text{He},d$). L($^3\text{He},d$)=low suggests that this level is distinct from that at 4515 or at 4532.
4532 4	(13/2-, 15/2-)		NO		XREF: N(4543). E(level): from (p,p'). J π : L(p,p')=8, L(α,t)=(7) for E=4543 25.
4588.3 3			M O		XREF: O(4592).
4602.6 $\S$ 13	(5/2-, 7/2, 9/2+)	D	L O		J π : L($^3\text{He},d$)=low for 4600 10, assuming L<5. 4602.5 γ to 9/2-.
4613 5	5/2-, 7/2-		NO		E(level): from (p,p'). J π : L(α,t)=3 for E=4613 25.
4646.1 $\S$ 3			O		
4682.0 8			no		
4700 25			no		E(level): one or both of the transitions with energy 4691.5 3 and 4702.3 4 reported in (n,n' γ) could be ground-state transitions corresponding to the peak at 4700 seen in (α,t) and (p,p').
4739.62 21		d	M		
4750.79 17		d	O		
4755.76 20	(7/2, 9/2, 11/2) ^c	d	o		J π : 4755.7 γ (D) to 9/2-. g $\Gamma^2_{\gamma 0}/\Gamma$ =2.8 4.
4762.3 3			o		
4786.32 21			M o		
4789.8 4	(9/2+, 11/2, 13/2-)		no		J π : 3181.1 γ to 13/2+ and 4790 γ to 9/2-. L(α,t)=6 for E=4795 25. See also 4796.1 level.
4796.1 3	(7/2, 9/2, 11/2) ^c		no		J π : 4796.0 γ (D) to 9/2-, L(α,t)=6 for E=4795 25. See also 4789.8 level.
4830.3 3	(7/2, 9/2, 11/2) ^c		O		g $\Gamma^2_{\gamma 0}/\Gamma$ =2.9 5. J π : 4830.2 γ (D) to 9/2-.
4837.6 3			O		g $\Gamma^2_{\gamma 0}/\Gamma$ =1.4 2.
4853.46 $\S$ 20			O		
4879.47 19			o		
4886 25	13/2-, 15/2-		No		E(level): from (α,t). J π : L(α,t)=7.
4904.2 3		D	M		
4948.3 5			O		
4967.6 $\S$ 15			O		
4996.2 3	(13/2)-		NO		J π : L(α,t)=7, J is limited to 13/2 if the 4996 γ in (n,n' γ) can be interpreted as a ground-state transition corresponding to the (α,t) level; otherwise, J π =13/2-, 15/2- for E=4998 25.
5054.0 4			M o		
5056.7 $\S$ 6	(11/2)+		o		J π : L(d,t)=3 from 9-, J is then limited to 11/2 if the 5057 γ in (n,n' γ) can be interpreted as a ground-state transition corresponding to the (d,t) level; otherwise J π =11/2+ to 25/2+ for E=5058 10.
5087 25	5/2-, 7/2-		N		E(level): one or both of the transitions with energy 5074.9 and 5096.6 reported in (n,n' γ) could be ground-state transitions corresponding to the peak at 5087 seen in (α,t). J π : L(α,t)=3.

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Adopted Levels, Gammas (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
5131 6		O		E(level): from (p,p'). J π : L(p,p')=7.
5152.2 3		M		
5167.3 3	(9/2+, 11/2, 13/2-)	O		J π : 3558.5 γ to 13/2+ and 5167.6 γ to 13/2+.
5182.7 7	5/2-, 7/2-	NO		XREF: N(5173)O(?). J π : L(α ,t)=3 for E=5173 25. g $\Gamma^2_{\gamma 0}$ / Γ =0.9 3.
5190.7 4		M		
5235.1 3	(7/2, 9/2, 11/2) ^c	O		XREF: O(5241). J π : 5235.0 γ (D) to 9/2-.
5256 10	+	O		g $\Gamma^2_{\gamma 0}$ / Γ =1.4 3. E(level): from (d,t). J π : L(d,t)=3 from 9-.
5277 25	13/2-, 15/2-	i N		E(level): from (α ,t). J π : L(α ,t)=7.
5281.9 11	(7/2, 9/2, 11/2) ^c	i O		J π : 5281.8 γ (D) to 9/2-.
5292.7 4		i M		g $\Gamma^2_{\gamma 0}$ / Γ =5.5 11.
5293.4 6	(7/2, 9/2, 11/2) ^c	i 1 O		J π : 5293.3 γ (D) to 9/2-.
5312.6 13	(7/2, 9/2, 11/2) ^c	i 1 O		g $\Gamma^2_{\gamma 0}$ / Γ =2.2 6. J π : 5312.5 γ (D) to 9/2-.
5333 5		O		g $\Gamma^2_{\gamma 0}$ / Γ =3.0 9.
5354.0 4	(7/2, 9/2, 11/2) ^c	o		E(level): from (p,p'). J π : 5353.9 γ (D) to 9/2-.
5367 10	+	o		g $\Gamma^2_{\gamma 0}$ / Γ =3.0 9. E(level): one or both of the transitions with energy 5361.6 12 and 5371.9 7 reported in (n,n' γ) could be ground-state transitions corresponding to the peak at 5367 seen in (d,t). J π : L(d,t)=3 from 9-.
5369.8 4	(1/2, 3/2, 5/2+)	M		J π : 2926.9 γ to 1/2+.
5380 25	13/2-, 15/2-	N		E(level): several transitions in (n,n' γ) could correspond to ground-state transitions from the peak at 5380 25 reported in (α ,t). J π : L(α ,t)=7.
5404.5 [§] 6	(11/2)+	O		J π : L(d,t)=3 from 9-, J is limited to 11/2 if the 5404.5 γ in (n,n' γ) can be interpreted as a ground-state transition corresponding to the (d,t) level; otherwise J π =11/2+ to 25/2+ for E=5402 10.
5411.2 6		O		E(level): unresolved multiplet in (γ , γ') with g $\Gamma(\gamma_0)^2$ / Γ =3.3 8 (1980Ch22).
5424.62 24	(9/2+, 11/2)	O		J π : 3815.9 γ to 13/2+ and 5424.6 γ to 9/2-; excitation in (γ , γ'). g $\Gamma^2_{\gamma 0}$ / Γ =1.7 5.
5440.2 10	(7/2, 9/2, 11/2)	o		J π : 5440.1 γ to 9/2-; excitation in (γ , γ'). g $\Gamma^2_{\gamma 0}$ / Γ =1.6 5.
5464.6 8	11/2+	No	0.39 fs 11	J π : L(α ,t)=6 for E=5469 25, L(d,t)=3 for E=5464 10. 5464.5 γ to 9/2-.
5484.4 5	(7/2, 9/2, 11/2) ^c	O		T _{1/2} : deduced by evaluators from g $\Gamma(\gamma_0)^2$ / Γ =1.4 eV 4 in (γ , γ'). J π : 5484.3 γ (D) to 9/2-.
5498.0 10	(7/2, 9/2, 11/2) ^c	O		g $\Gamma^2_{\gamma 0}$ / Γ =4.0 8. J π : 5497.9 γ (D) to 9/2-.
5510.53 24	(9/2+, 11/2, 13/2-)	O		g $\Gamma^2_{\gamma 0}$ / Γ =4.8 9. E(level): unresolved multiplet in (γ , γ') with g $\Gamma(\gamma_0)^2$ / Γ =6.8 12.
5523.5 5		O		J π : 3902 γ to 13/2+ and 5510.4 γ to 9/2-.

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Adopted Levels, Gammas (continued)
²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
5538.4 7	(7/2, 9/2, 11/2)	O		E(level): unresolved multiplet in (γ, γ') with $g\Gamma(\gamma_0)^2/\Gamma=4.4$ 10. J π : 4641.8 γ to 7/2- and 5538.4 γ to 9/2-; excitation in (γ, γ').
5559.6 6	(7/2, 9/2, 11/2)	no		E(level): 5554 2 is reported in (γ, γ'). The evaluator assumes that this is the same level as that reported in (n,n' γ). J π : 4663 γ to 7/2- and 5559.8 γ to 9/2-; excitation in (γ, γ'). $g\Gamma_{\gamma_0}^2/\Gamma=2.6$ 8.
5563.4 6		M o		
5570.6 7	(11/2+)	no	0.32 fs 19	J π : 5570.5 γ to 9/2-, L(α, t)=6 for E=5580 25. T _{1/2} : deduced by evaluators from $g\Gamma(\gamma_0)^2/\Gamma=1.7$ eV 10 in (γ, γ').
5589.2 7	(11/2+)	nO	0.17 fs 5	J π : 5589.1 γ to 9/2-, L(α, t)=6 for E=5580 25. T _{1/2} : deduced by evaluators from $g\Gamma(\gamma_0)^2/\Gamma=3.2$ eV 9 in (γ, γ').
5609 5	11/2-	O	0.48 fs 10	J π : 5609 γ M1 to 9/2- and $\gamma(\theta)$, $\gamma(\text{pol})$ in (γ, γ'). T _{1/2} : deduced by evaluators from $\Gamma=0.95$ eV 20 in (γ, γ') (1974Te01).
5609.8 3		O		
5652.6 $\frac{5}{8}$ 8	(11/2)+	O		J π : L(d,t)=3 from 9-, J is limited to 11/2 if the 5652.5 γ in (n,n' γ) can be interpreted as a ground-state transition corresponding to the (d,t) level; otherwise, J π =11/2+ to 25/2+ for E=5657 10.
5662.1 20	(7/2, 9/2, 11/2)	O		J π : 5662 γ to 9/2-; excitation in (γ, γ'). $g\Gamma_{\gamma_0}^2/\Gamma=1.6$ 4.
5668.3 3		M		
5693 25	(3/2+, 5/2+)	N		E(level): from (α, t). J π : L(α, t)=(2).
5769 5		O		E(level): from (p,p').
5788.7 4		M		
5795 7		O		E(level): probable multiplet from (p,p').
5835 8		O		E(level): probable multiplet from (p,p').
5925.1 17	(11/2)+	O		J π : L(d,t)=3 from 9-. J is limited to 11/2 if the 5925.1 γ in (n,n' γ) can be interpreted as a ground-state transition corresponding to the (d,t) level; otherwise J π =11/2+ to 25/2+ for E=5924 10.
6301.1 4		M		
6382.0 6		M		
6392 8		O		
6556.1 10		O		
6712.2 4		M		
6900.5 7		M		
6911? 4	(7/2, 9/2, 11/2)	O		J π : 6911 γ to 9/2-; excitation in (γ, γ'). $g\Gamma_{\gamma_0}^2/\Gamma=2.4$ 5.
6944.8 21	(7/2, 9/2, 11/2)	O		XREF: O(?). J π : 6944.7 γ to 9/2-; excitation in (γ, γ'). $g\Gamma_{\gamma_0}^2/\Gamma=2.1$ 6.
6983 4	(7/2, 9/2, 11/2)	O		J π : 6983 γ to 9/2-; excitation in (γ, γ'). $g\Gamma_{\gamma_0}^2/\Gamma=2.6$ 5.
7106? 4	(7/2, 9/2, 11/2)	O		J π : 7106 γ to 9/2-; excitation in (γ, γ'). $g\Gamma_{\gamma_0}^2/\Gamma=1.0$ 3.
7168.1 10	9/2+	L O	0.56 fs 3	XREF: L(7153). J π : 7168 γ E1 to 9/2- and $\gamma(\theta)$, $\gamma(\text{pol})$ in (γ, γ'). T _{1/2} : deduced by evaluators from $\Gamma=0.82$ eV 4 in (γ, γ') (1972Wo21).
7171 4	(7/2, 9/2, 11/2)	O		J π : 7171 γ to 9/2-; excitation in (γ, γ'). $g\Gamma_{\gamma_0}^2/\Gamma=4.7$ 10.

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Adopted Levels, Gammas (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
7176.6 10	(7/2, 9/2, 11/2)	O		XREF: O(?). J π : 7176.5 γ to 9/2-; excitation in (γ, γ'). g $\Gamma^2_{\gamma 0}/\Gamma=24$ 5.
7202 5	11/2+, 13/2+	NO		XREF: N(7200). J π : L(α, t)=6; 7202 γ to 9/2-; excitation in (γ, γ'). g $\Gamma^2_{\gamma 0}/\Gamma=30$ 5.
7243.9 13	(7/2, 9/2, 11/2)	O		J π : 7243.8 γ to 9/2-; excitation in (γ, γ'). g $\Gamma^2_{\gamma 0}/\Gamma=3.7$ 8.
7264 4	(7/2, 9/2, 11/2)	O		g $\Gamma^2_{\gamma 0}/\Gamma=2.4$ 9. J π : 7264 γ to 9/2-; excitation in (γ, γ').
7279.1 10		O		
7279+x		O		E(level): x=200 eV. See (γ, γ').
7287 4	(7/2, 9/2, 11/2)	O		J π : 7287 γ to 9/2-; excitation in (γ, γ'). g $\Gamma^2_{\gamma 0}/\Gamma=2.6$ 7.
7360 4	(7/2, 9/2, 11/2)	O		J π : 7360 γ to 9/2-; excitation in (γ, γ'). g $\Gamma^2_{\gamma 0}/\Gamma=4.3$ 11.
7416.1 10	9/2-	O	1.9 fs +46-12	J π : from 7416 γ (θ) (D) to 9/2- and γ, γ (pol) in (γ, γ'). T _{1/2} : deduced by evaluators from $\Gamma=0.24$ eV +38-17 in (γ, γ').
7632.1 10	(9/2+)	O	<0.9 fs	J π : from L(γ, n)=0 to 5+ and 4+; 7632 γ (θ) (D) to 9/2-. T _{1/2} : deduced by evaluators from $\Gamma>0.5$ eV in (γ, γ').
8400		O		$\Gamma=4$ MeV.
8.7 $\times 10^3$ 5		N		E(level): from ($^7\text{Li}, ^6\text{He}$). E(level): from (α, t). J π : L(α, t)=(6+7).
9000		O		E(level): from (p, p') giant resonance. L=(2). %EWSR(E2)=9.
10.3 $\times 10^3$ 5		L		
10900 300		O		$\Gamma=2.7$ MeV 3. E(level), Γ : from (α, α') giant resonance. Others: E=10.9 MeV, $\Gamma=2.7$ MeV from (e, n) giant resonance; E=10.7 MeV, $\Gamma=2.2$ MeV from (p, p') giant resonance. %EWSR(E2)=50 30 from (e, n); 90-150 for L=2, or 50-150 for L=2 with 20-40% for L=4 from (α, α').
13450 10		O		$\Gamma=3.89$ MeV 3. E(level), Γ : from (e, n) giant resonance. Other: (γ, γ'), (α, α'): giant resonance. %EWSR=80-120 for L=0 and 30-50 for L=2 with the maximum contribution from L=4 giving %EWSR=15-30 ((α, α'): giant resonance).
18627 $\frac{1}{2}$ 4	9/2+b	GH	O	
19382 $\frac{1}{2}$ 26	(11/2+) ^b	GH	O	
20100 $\frac{1}{2}$ 150	(15/2+) ^b	H		
20186 $\frac{1}{2}$ 4	5/2+b	GH		
20671 $\frac{1}{2}$ 6	(1/2+) ^b	H		
21114 $\frac{1}{2}$ 16	7/2+b	GH		
21172 $\frac{1}{2}$ 18	3/2+b	H		
=22000		F	O	E(level): reported values are 20.2 MeV with $\Gamma=6$ MeV in (e, n), ≈ 20 MeV with $\Gamma=8$ MeV in (e, e'), and ≈ 23 MeV with $\Gamma=3.5$ MeV in (p, γ) giant resonance. %EWSR(E2)=200 90 determined in (e, n). E2 or E0 excitation suggested in (e, e'), but observation in (p, γ) rules out E0. Possible isovector E2 giant resonance.

[†] From a least-squares fit to γ -ray energies, unless otherwise noted.

Adopted Levels, Gammas (continued)

²⁰⁹Bi Levels (continued)

- ‡ IAR from ²⁰⁸Pb(p,p'),(pol p,p'). See the IAR source data sets for information on widths.
 § From E_γ to ground state in (n,n'γ). The placement of the authors is based on the agreement in energy with a previously-known level. Since only a single transition is observed, the existence of the (n,n'γ) level is not definitely established.
 # From 1996De48 in (n,n'γ), based on comparisons of the measured γ-yields with the theoretical predictions based on the statistical model of the compound nucleus.
 @ L(p,p')=3, σ(p,p'). See comment "particle-vibration coupled states (²⁰⁸Pb 3-)".
 & L(p,p')=5. See comment "particle-vibration coupled states (²⁰⁸Pb 4-, 5-)".
 a See comment "particle-vibration coupled states (²⁰⁸Pb 4-,5-).
 b from ²⁰⁸Pb(p,pol p), analog resonance to the levels in ²⁰⁹Pb.
 c Excitation in (γ,γ') is probably D (or D+Q). The measured values of gΓ(γ₀)²/Γ lead to B(E2)(W.u.)>10. Values this large are not expected for the probable configurations involved.
 d L(d,t)=1 from 9- for 4065+4084+4122 peak.

$\gamma(^{209}\text{Bi})$						Comments
E(level)	E _γ [†]	I _γ [†]	Mult. ^a	δ ^c	α	
896.28	896.28 [‡] 7	100 [‡]	M1+E2	-0.62 6	0.0208 8	Mult.,δ: from α(K)exp=0.0170 5 in ²⁰⁹ Po ε decay. Sign is from γ(θ) in Coulomb excitation. Other: δ=-0.95 25 from Coulomb excitation (1973Kr02).
1608.57	1608.53 [‡] 8	100 [‡]	M2+E3	+0.33 10	0.0127 5	B(M1)(W.u.)=0.0026 5; B(E2)(W.u.)=0.44 9. Mult.: A ₂ =+0.47 2 (1978Be17) in (⁷ Li,α2nγ) and A ₂ =+0.42 1 (1983Ma15) in (t,2nγ). δ: from γ(θ) in (⁷ Li,α2nγ) (1978Be17). B(M2)(W.u.)=0.32 18; B(E3)(W.u.)=7 6.
2442.92	1546.52 9	100	E3		0.00639	E _γ : weighted average of 1546.47 5 in (t,2nγ), 1546.7 1 in (n,n'γ) and 1546.2 5 in (d,nγ). Mult.: α(K)exp=0.0054 14 in (d,nγ) (1978E107), γ(θ) is isotropic from (t,2nγ) (1983Ma15). B(E3)(W.u.)=1.95 7.
2492.86	(49.94 7)	≈1.6	[M1]		14.51	E _γ ,I _γ : from (t,2nγ) (1983Ma15). Transition not seen directly. Energy from level energy difference and total intensity inferred from γγ to be ≈20% of the branching from the 2493 level. Mult.: from J _π difference and RUL. B(E2)(W.u.)(49.94γ) would be 710 if mult were pure E2. This is an unreasonably large value for this mass region. B(M1)(W.u.)=0.073.
2564.14	2492.86 [‡] 11 2564.12 [‡] 10	100 [‡] 100 [‡]	[E3] E1+E3	0.026 3	0.00275 1.43×10 ⁻³	B(E3)(W.u.)=20. Mult.: A ₂ =+0.25 3 (1983Ma15) in (t,2nγ). δ: From the Adopted half-life of 0.015 ps 3 and B(E3)=0.073 11. B(E1)(W.u.)=0.00076 16; B(E3)(W.u.)=29 9.
2583.02	1686.66 [‡] 10 2583.07 [‡] 10	100 [‡] 2 46 [‡] 2	E1 E1+E3		1.36×10 ⁻³ 1.48×10 ⁻³ 3	Mult.: from γ(θ) from (t,2nγ), A ₂ =+0.08 2 (1983Ma15). B(E1)(W.u.)=9.×10 ⁻⁵ 3. I _γ : In (n,n'γ), the 30 1 from 1984Pr08 appears to be an outlier and in weighted average, 46.8 18 from 2008Mi01 in (n,n'γ) is used.
2599.91	992.0 5	17.6 24	[M1]		0.0196	Mult.,δ: A ₂ =+0.20 5 (1983Ma15) in (t,2nγ). δ: From the Adopted half-life of 0.31 ps 10 and B(E3)=0.067 4, weighted average of 0.065 10 from Coulomb excitation (1969He07) and 0.067 4 (1968Zi02). Note, that B(E3)=0.67 4 is quoted in 1968Zi02, which is a typo. B(E1)(W.u.)=1.1×10 ⁻⁵ 4; B(E3)(W.u.)=22 10. E _γ ,I _γ : from Coulomb excitation (1969He07). B(M1)(W.u.)=0.09 3.

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Bi})$ (continued)

E(level)	$E_{\gamma}^{\dagger}$	$I_{\gamma}^{\dagger}$	Mult. ^a	δ^c	α	Comments
2599.91	2599.9 $\frac{1}{2}$ 1	100 $\frac{1}{2}$ 2	E1+E3	0.051 8	1.45 $\times 10^{-3}$	Mult.: (D) from $\gamma(0)$ in (t,2n γ). δ : from the adopted $T_{1/2}$ of 36 fs 10 and B(E3)=0.078 12 from Coulomb excitation (1969He07). B(E1)(W.u.)=0.00026 8; B(E3)(W.u.)=36 15.
2600.92	992.35 $\frac{1}{2}$ 2	100 $\frac{1}{2}$ 1	M1(+E2)	-0.04 4	0.0196	Mult.: $A_2=+0.27$ 4 in ($^7\text{Li},\alpha 2n\gamma$) (1978Be17), $A_2=+0.27$ 2 in (t,2n γ) (1983Ma15). δ : from 1978Be17 in ($^7\text{Li},\alpha 2n\gamma$) based on a comparison of the experimental B(E2) for each δ solution with the value from a weak-coupling calculation. B(M1)(W.u.)=(0.050 16); B(E2)(W.u.)=(0.03 +6-3).
	2600.6 5	1.3 5	(M2+E3)	>0.9	0.0031 6	I_{γ} ,Mult.: from a comparison of B(E3)(2601 level) in Coulomb excitation, and the adopted $T_{1/2}$ value, along with $I_{\gamma}(2601\gamma)/I_{\gamma}(992\gamma)<0.018$ from (t,2n γ) and $\Delta\pi=\text{yes}$ (from level scheme), one gets branching(2601 γ)=1.3% 5 and mult(2601 γ)=(M2+E3) with $\delta>0.9$. B(M2)(W.u.)<0.18?; B(E3)(W.u.)>3.7?
2617.34	124.48 $\frac{1}{2}$ 5	5.24 $\frac{1}{2}$ 21	M1(+E2)		5.45	Mult.: $A_2=-0.05$ 5 from (t,2n γ) (1983Ma15).
	1721.08 $\frac{1}{2}$ 13	100 $\frac{1}{2}$ 5	E1(+M2)		0.00145 11	Mult.: $A_2=-0.04$ 4 from (t,2n γ) (1983Ma15).
	2617.35 $\frac{1}{2}$ 10	50.2 $\frac{1}{2}$ 14	E3(+M2)		0.00354 97	Mult.: from Coulomb excitation.
2741.05	140.13 $\frac{1}{2}$ 1	14.47 $\frac{1}{2}$ 23	M1(+E2)	<0.3	3.80 11	Mult., δ : from $\alpha(\text{exp})=4.1$ 3 based on $I(\gamma+\text{ce})(140\gamma)/I_{\gamma}(1132+2741\gamma\text{'s})=0.356$ 22 in ($^7\text{Li},\alpha 2n\gamma$) (1978Be17) and relative I_{γ} data in (t,2n γ) (1983Ma15). B(M1)(W.u.)>0.042?; B(E2)(W.u.)<89?
	1132.46 $\frac{1}{2}$ & 4	67.7 $\frac{1}{2}$ 8	M1+E2	+0.14 4	0.01380 22	Mult.: $A_2=-0.12$ 1, $A_4=-0.02$ 3 (1978Be17) in ($^7\text{Li},\alpha 2n\gamma$). δ : from $\gamma(0)$ in ($^7\text{Li},\alpha 2n\gamma$) (1978Be17), +0.05 from (t,2n γ) (1983Ma15). B(M1)(W.u.)=0.00046 7; B(E2)(W.u.)=0.0025 15.
	2741.03 $\frac{1}{2}$ & 6	100 $\frac{1}{2}$ 1	E3		0.00243	Mult.: $A_2=+0.48$ 1 (1983Ma15) in (t,2n γ) and $A_2=+0.42$ 3 (1978Be17) in ($^7\text{Li},\alpha 2n\gamma$). B(E3)(W.u.)=18.6 25.
2766.66	149.3 $\frac{1}{2}$ 1	6.2 $\frac{1}{2}$ 3	[M1]		3.25	
	273.80 $\frac{1}{2}$ 3	31.8 $\frac{1}{2}$ 4	[M1]		0.596	
	323.74 $\frac{1}{2}$ 2	100 $\frac{1}{2}$ 2	M1		0.377	Mult.: $A_2=-0.08$ 4 (1983Ma15).
	2766.9 2	=8				E_{γ}, I_{γ} : Reported only in (n,n' γ). There is a peak at about this energy in the (t,2n γ) spectrum, and the evaluators estimate $I_{\gamma}/I_{\gamma}(324\gamma)=0.08$.
2826.1	1929.9 $\frac{1}{2}$ 5	39 3	[M1]		0.00397	I_{γ} : weighted average of 33 9 from (t,2n γ), and 48 4 (1984Pr08) and 37.1 19 (2008Mi01) from (n,n' γ). B(M1)(W.u.)=0.124 19.
	2826.0 $\frac{1}{2}$ 4	100 2	E2		1.67 $\times 10^{-3}$	Mult.: $A_2=+0.17$ 5 (1983Ma15) in (t,2n γ). B(E2)(W.u.)=4.4 6.
2845.20	78.60 $\frac{1}{2}$ 10	=15 $\frac{1}{2}$				
	402.27 $\frac{1}{2}$ 3	100 $\frac{1}{2}$ 2				
2916.62	149.98 $\frac{1}{2}$ 5	100 $\frac{1}{2}$	M1+E2		3.21	Mult.: $A_2=+0.04$ 8 (t,2n γ) (1983Ma15).
2955.93	110.67 $\frac{1}{2}$ 15	4.2 $\frac{1}{2}$ 4	[M1]		7.63	
	338.65 $\frac{1}{2}$ 10	15.7 $\frac{1}{2}$ 18	[M1]		0.334	
	463.04 $\frac{1}{2}$ 8	100 $\frac{1}{2}$ 3	[M1]		0.1438	
	513.0 $\frac{1}{2}$	<3.6 $\frac{1}{2}$	[M1]		0.1095	E_{γ}, I_{γ} : transition not observed. E_{γ} from energy level difference. Branching<3% is reported in (t,2n γ) (1983Ma15).

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Adopted Levels, Gammas (continued)

$\gamma(^{209}\text{Bi})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^a	α	Comments
2955.93	2954.7 ^d 4	<22	[E3]	0.00223	E γ ,I γ : reported only in (n,n' γ) although there is a possible indication of a peak at this energy in (t,2n γ). From the (t,2n γ) spectrum, the evaluator estimates I γ <22 relative to I γ (463 γ)=100 The energy expected from the level scheme is 2955.87 7.
2986.80	245.73 [§] 2	100 [§]	E2	0.224	Mult.: A ₂ =+0.26 3 in (⁷ Li, α 2n γ) (1978Be17), A ₂ =+0.31 5 in (t,2n γ) (1983Ma15), T _{1/2} rules out M2.
	385.9 ^d	<0.8	[M3]	2.14	B(E2)(W.u.)=0.387 12. E γ ,I γ : transition not observed. E γ from level energy difference. Branching limit reported in (⁷ Li, α 2n γ) (1978Be17).
3038.88	272.2 [§] 1	25.6 [§] 6	(M1+E2)	0.606	B(M3)(W.u.)=8. $\times$ 10 ³ 8.
	2142.78 18	100 9	E1	1.34 $\times$ 10 ⁻³	Mult.: A ₂ =-0.02 4 (1983Ma15). Mult.: A ₂ =-0.07 3 (1983Ma15) in (t,2n γ). I γ : from (t,2n γ).
3090.16	2194.1 2	18.6 13	[E1]	1.35 $\times$ 10 ⁻³	
	3089.96 12	100 2	(E1+M2)	0.00161 3	Mult.: A ₂ =+0.10 5 (1983Ma15).
3119.48	2223.23 10	100	E2	0.00195	Mult.: A ₂ =+0.09 5 (1983Ma15) in (t,2n γ). B(E2)(W.u.)=7 5.
3132.97	1524.2 [§] 3	28.3 [§] 25	[M1]	0.00666	
	3132.96 9	100 2	E1	1.61 $\times$ 10 ⁻³	Mult.: A ₂ =-0.24 4 (1983Ma15) in (t,2n γ).
3135.77	394.72 [§] 7	13.6 [§] 4	M1	0.220	Mult.: A ₂ =+0.12 8 (1983Ma15) in (t,2n γ). I γ : Other: 17.5 23 (2008Mi01) in (n,n' γ).
	1527.13 14	100 1	M1	0.00663	Mult.: A ₂ =-0.06 2 (1983Ma15) in (t,2n γ).
3152.83	3152.80 20	100	E1	1.61 $\times$ 10 ⁻³	Mult.: A ₂ =+0.26 6 (1983Ma15) in (t,2n γ).
3154.06	167.16 [§] 6	6.59 [§] 19	M1	2.36	Mult.: A ₂ =-0.25 10 (1983Ma15) in (t,2n γ).
	413.04 3	100 2	M1(+E2)	0.195	Mult.: A ₂ =-0.32 3 (1983Ma15) in (t,2n γ).
3159.33	242.73 5	82 16			E γ : weighted average of 242.73 5 in (t,2n γ) and 242.7 1 in (³ He,d γ). I γ : weighted average of 92 12 in (t,2n γ) and 55 20 in (³ He,d γ). Mult.: A ₂ =-0.15 10 (1983Ma15) in (t,2n γ). E γ : weighted average of 314.2 2 in (t,2n γ) and 314.2 2 in (³ He,d γ). I γ : weighted average of 100 13 in (t,2n γ) and 100 10 in (³ He,d γ). E γ : weighted average of 392.56 10 in (t,2n γ) and 39.5 2 in (³ He,d γ). I γ : weighted average of 72 5 in (t,2n γ) and 40 10 in (³ He,d γ). E γ ,I γ : from (³ He,d γ) only.
	314.2 2	100 10	(M1)	0.409	Mult.: A ₂ =-0.15 10 (1983Ma15) in (t,2n γ). E γ : weighted average of 314.2 2 in (t,2n γ) and 314.2 2 in (³ He,d γ). I γ : weighted average of 100 13 in (t,2n γ) and 100 10 in (³ He,d γ). E γ : weighted average of 392.56 10 in (t,2n γ) and 39.5 2 in (³ He,d γ). I γ : weighted average of 72 5 in (t,2n γ) and 40 10 in (³ He,d γ). E γ ,I γ : from (³ He,d γ) only.
	716.5 2	90 20			
3169.07	1560.49 4	100	M1	0.00630	Mult.: A ₂ =+0.18 5 (1983Ma15) in (t,2n γ).
3197.60	352.30 8	70 20	(M1)	0.300	E γ : from (t,2n γ). I γ : from (³ He,d γ). Mult.: A ₂ =+0.03 5 (1983Ma15) in (t,2n γ). E γ ,I γ : from (³ He,d γ) only.
	431.2 2	50 15			
	705.1 2	100 10			
3211.85	225.05 [§] 2	100 [§]	(M1)	1.026	E γ ,I γ : from (³ He,d γ) only. Mult.: A ₂ =-0.15 4 (1983Ma15) in (t,2n γ).
3221.65	131.45 [§] 8	17.1 [§] 9			
	265.74 [§] 8	49.3 [§] 27			
	455.02 [§] 10	100 [§] 4	(M1)	0.1506	Mult.: A ₂ =-0.12 10 (1983Ma15) in (t,2n γ).
3269.64	424.5 [§] 1	100 [§] 10	(M1)	0.181	E γ ,I γ : also placed from 3579 level. Component from 3269 established on the basis of $\gamma\gamma$. Mult.: A ₂ =+0.14 3 (1983Ma15) in (t,2n γ). E γ ,I γ : from (³ He,d γ) only.
	826.5 2	30 10			
3311.14	2414.84 4	100 3			
	3310.6 ^{#d} 1	47.6 [#] 16			I γ : from (n,n' γ). The 3310 γ is not reported in (t,2n γ); however, there is a peak at this energy in the (t,2n γ) spectrum in 1983Ma15, with I γ /I γ (2414 γ) estimated by evaluators as $\approx$ 0.5. The energy expected from the level scheme is 3311.15 6.
3354.8	588.1 [§] 4	100 [§]			Mult.: A ₂ =+0.05 8 (1983Ma15) in (t,2n γ).
3362.00	2465.70 10	100	D		Mult.: A ₂ =-0.01 10 (1983Ma15) in (t,2n γ).

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Adopted Levels, Gammas (continued)

$\gamma(^{209}\text{Bi})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^a	α	Comments
3378.16	2481.94 18	44 3			I γ : from (n,n' γ). I γ (2481 γ)/I γ (3378 γ)<0.11 is reported in (t,2n γ).
	3378.11 10	100 3	(E1)	1.68 $\times 10^{-3}$	Mult.: A ₂ =+0.10 5 (1983Ma15) in (t,2n γ).
3393.38	1784.8 $\S$ 2	100 $\S$	D		E γ : Other: 1785.9 1 from (n,n' γ) (1984Pr08). Mult.: A ₂ =-0.21 4 (1983Ma15) in (t,2n γ).
3395.00	2498.7 $\#$ 1	100 $\#$			E γ : observed only in 1996De48.
	3395.6 $\#$ d 5	25 $\#$			
3406.21	270.4 $\S$ 1	34.4 $\S$ 19			
	806.36 15	52 8			
	1797.64 12	100 3	M1	0.00458	Mult.: A ₂ =+0.23 4 (1983Ma15) in (t,2n γ).
3449.7	2553.4 4	100	D		E γ : weighted average of 2553.9 6 in (t,2n γ), 2552.8 2 in (³ He,d γ) and 2554.0 2 in (n,n' γ). Mult.: A ₂ =+0.10 17 (1983Ma15) in (t,2n γ).
3464.12	3464.09 10	100	E1	1.71 $\times 10^{-3}$	Mult.: A ₂ =-0.28 8 (1983Ma15) in (t,2n γ).
3467.67	313.70 $\S$ 16	27 $\S$ 3	M1	0.411	Mult.: from γ (θ) in (t,2n γ) (1983Ma15).
	480.87 $\S$ 5	100 $\S$ 2	M1	0.1300	Mult.: A ₂ =+0.43 4 (1983Ma15) in (t,2n γ).
3486.93	500.12 $\S$ 5	100 $\S$	(M1)	0.1172	Mult.: A ₂ =+0.42 4 (1983Ma15) in (t,2n γ).
3489.88	2593.6 2	100 4			
	3489.6 8	36.2 17			
3502.23	290.38 $\S$ 10	100	D		Mult.: A ₂ =-0.13 8 (1983Ma15) in (t,2n γ).
3505.28	921.9 $\#$ 8	100 $\#$ 25			
	2609.0 $\#$ 2	39 $\#$ 3			
3541.60	2645.3 $\#$ 2	100 $\#$ 5			I γ : reported only in (n,n' γ). Branching is too weak to be seen in the (t,2n γ) spectrum. The energy expected from the level scheme is 3541.61 18.
	3542.7 $\#$ d 4	19.2 $\#$ 18			
3575.08	808.0 $\#$ 10	100 $\#$ 40			
	2678.8 2	58 4			
3579.00	424.9				E γ ,I γ : also placed from the 3270 level. Total intensity of the doublet is 126 4 relative to I γ (592.2)=100 as upper limit. Component from 3579 is established on the basis of $\gamma\gamma$. The measured energy of the multiplet is 424.49 8. E γ is from the level energy difference. A comparison of this value with the measured energy suggests that the dominant component of the 424 multiplet is from a placement other than the 3579 level (evaluators). Mult.: A ₂ =-0.36 12 (1983Ma15) in (t,2n γ).
	592.2 $\S$ 1	100 $\S$ 6	D		
3590.50	745.3 $\#$ 2	100 $\#$			
3597.14	443.15 $\S$ 12	18.4 $\S$ 14			
	610.33 $\S$ 15	100 $\S$ 3	M1	0.0693	Mult.: A ₂ =+0.49 7 (1983Ma15) in (t,2n γ).
3601.72	2705.42 10	100 3	(E1)	1.47 $\times 10^{-3}$	Mult.: A ₂ =-0.29 8 (1983Ma15) in (t,2n γ).
	3601.7 $\#$ 6	6.2 $\#$ 12			I γ : reported only in (n,n' γ). Branching is too weak to be seen in the (t,2n γ) spectrum.
3633.85	514.37 $\#$ 2	100 $\#$ 30	[M1]	0.1087	
	677.8 $\#$ 2	20 $\#$ 6	[E1]	0.00538	
	788.8 $\#$ 2	3 $\#$ 1	[E1]	0.00403	
	867.2 $\#$ 2	20 $\#$ 6	[E1]	0.00338	
	1140.8 $\#$ 2	6 $\#$ 2	[E1]	0.00207	
	1191.0 $\#$ 2	4 $\#$ 1	[E1]	0.00193	
3692.14	3692.1 2	100			
3703.55	664.8 $\S$ 2	100 $\S$ 6	D		Mult.: A ₂ =-0.25 10 (1983Ma15) in (t,2n γ).
	2806.2 $\#$ 6	8 $\#$ 3			E γ ,I γ : reported only in (n,n' γ), intensity normalized to I γ (3703).
	3703.4 6	89 2			E γ : from (t,2n γ). E γ =3702.3 1 is reported in (n,n' γ), but this value is inconsistent with E(level) deduced from the 664.8 γ .
3717.64	3717.6 $\#$ 1	100 $\#$			
3752.2	2855.9 $\#$ 3	100 $\#$			
3759.0	2862.7 $\#$ 5	100 $\#$			
3766.9	3766.9 $\#$ 3	100 $\#$			
3772.60	2876.3 $\#$ 2	100 $\#$			

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Bi})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^a	α	Comments
3783.08	2886.78 14	100			E γ : weighted average of 2887.3 4 in (t,2n γ), 2886.3 3 in (³ He,d γ) and 2886.8 1 in (n,n' γ).
3800.85	2904.8 3	100 5			E γ : weighted average of 2904.5 2 in (n,n' γ) and 2905.1 2 in (³ He,d γ).
	3800.7# 2	70# 5			
3808.29	2199.7@ 2	100@			
3812.25	825.45\$ 15	100\$	E2	0.01024	Mult.: A ₂ =+0.36 7 (1983Ma15) in (t,2n γ).
3816.70	2920.4@ 2	100@			
3817.86	1253# 1	94# 31			
	2209.3# 2	100# 9			
3849.94	3849.9# 2	100#			
3884.3	3884.3# 5	100#			
3889.5	3889.5# 3	100#			
3905.9	3009.6# 3	100# 7			
	3905.9# 7	19# 4			
3913.26	1420.4@ 2	100@			
3921.22	3024.5# 5	25# 5			
	3921.2# 1	100# 5			
3936.74	3936.7# 1	100#			
3962.27	3066.1# 3	83# 6			
	3962.1# 3	100# 6			
3980.04	3980.0# 1	100#			
4000.71	2391.8# 2	100# 10			
	4001.0# 2	57# 5			
4009.3	4009.3# 4	100#			
4036.5	4036.5# 4	100#			
4046.54	4046.5# 2	100#			
4088.34	4088.3# 1	100#			
4091.4	1648.5@ 4	100@			
4096.34	2488.2# 3	53# 6			
	4096.1# 2	100# 3			
4096.59	977.1@ 2	100@			
4134.0	4134# 2	100#			
4141.95	544.85\$ 10	89\$ 3	D		Mult.: A ₂ =-0.23 7 (1983Ma15) in (t,2n γ).
	654.98\$ 10	100\$ 4	D		Mult.: A ₂ =-0.28 8 (1983Ma15) in (t,2n γ).
4148.11	2539.6# 2	100# 10			
	3251.6# 6	20# 5			
	4148.0# 2	75# 5			
4158.79	3262.8# 5	22# 4			
	4158.7# 2	100# 4			
4160.9	4160.9# 7	100#			
4176.14	4176.1# 1	100#			
4207.5	4207.5# 4	100#			
4222.9	4222.9# 7	100#			
4233.75	4233.7# 2	100#			
4236.9	3340.6@ 3	100@			
4262.95	4262.9# 2	100#			
4297.73	3401.6# 3	100# 9			
	4297.6# 2	80# 5			
4300.75	4300.7# 1	100#			
4335.3	2726.7# 3	100#			
4340.7	4340.7# 5	100#			
4361.89	2753.3# 2	100#			
4376.5	4376.5# 6	100#			
4381.31	3485.0# 2	100#			
4388.15	3491.9# 2	100# 8			
	4387.7# 5	22# 3			
4397.85	4397.8# 2	100#			
4409.05	4409.0# 2	100#			
4415.33	1295.9@ 2	100@ 30			
	1922.4@ 2	3@ 1			
4426.7	3530.4@ 3	100@			
4441.7	3542.6@ 3	@			

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Bi})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^a	α	Comments
4441.7	4439.1@ 3	@			E γ : Other: 4441.6 keV from ²⁰⁸ Pb(³ He,d γ).
4471.0	2862.5# 3	100# 6			
	4470.5# 6	19.4# 22			
4478.2	3581.9@ 3	100@			
4484.79	2876.2# 1	100#			
4506.85	4506.8# 2	100#			
4515.23	2906.6# 1	100# 3			
	4515.3# 2	20.0# 13			
4516.5	3620.2@ 3	100@			
4588.3	3692.1@ 3	@			
	4587.8@ 6	100@			
4602.6	4602.5# 13	100#			
4646.1	4646.0# 3	100#			
4682.0	3785.4# 16	100# 32			
	4682.0# 9	60# 12			
4739.62	3843.3@ 2	100@			
4750.79	3854.4# 2	100# 7			
	4750.9# 3	33.3# 20			
4755.76	4755.7# 2	100#	(D) ^b		
4762.3	3866.0# 3	100# 10			
	4762.2# 5	45# 5			
4786.32	3890.0@ 2	100@			
4789.8	3181.1# 5	100# 20			
	4790.0# 6	100# 8			
4796.1	4796.0# 3	100#	(D)		
4830.3	4830.2# 3	100#	(D) ^b		
4837.6	3941.4# 6	70# 11			
	4837.5# 3	100# 7			
4853.46	4853.4# 2	100#			
4879.47	3983.1# 2	100# 9			
	4879.6# 4	27# 3			
4904.2	4007.9@ 3	100@			
4948.3	4051.8# 5	100# 8			
	4948.6# 8	40# 5			
4967.6	4967.5# 15	100#			
4996.2	4996.1# 3	100#			
5054.0	4157.7@ 4	100@			
5056.7	5056.6# 6	100#			
5152.2	4255.9@ 3	100@			
5167.3	3558.5# 3	100# 8			
	5167.6# 5	25.6# 22			
5182.7	5182.6# 7	100#			
5190.7	4294.4@ 4	100@			
5235.1	5235.0# 3	100#	(D) ^b		
5281.9	5281.8# 11	100#	(D) ^b		
5292.7	2095.1@ 3	100@			
	2525.6@ 5	100@			
5293.4	5293.3# 6	100#	(D) ^b		
5312.6	5312.5# 13	100#	(D) ^b		
5354.0	5353.9# 4	100#	(D) ^b		
5369.8	2926.9@ 4	100@			
5404.5	5404.4# 6	100#			
5411.2	5411.1# 6	100#			
5424.62	3815.9# 4	100# 12			
	5424.6# 3	80# 4			
5440.2	5440.1# 10	100#			
5464.6	5464.5# 8	100#			
5484.4	5484.3# 5	100#	(D) ^b		
5498.0	5497.9# 10	100#	(D) ^b		
5510.53	3902.0# 4	100# 13			
	5510.4# 3	70# 4			
5523.5	4627.0# 5	100# 12			
	5523.9# 9	44# 8			

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Bi})$ (continued)

E(level)	$E\gamma^\dagger$	$I\gamma^\dagger$	Mult. ^a	α	Comments
5538.4	4641.8# 8	100# 18			
	5538.7# 10	59# 12			
5559.6	4663.0# 7	100# 8			
	5559.8# 8	62# 8			
5563.4	3070.5@ 6	100@			
5570.6	5570.5# 7	100#			
5589.2	5589.1# 7	100#			
5609	5609 $\frac{1}{2}$ & 5	100\$	M1	0.00252	Mult.: from $\gamma(0)$ and $\gamma(\text{pol})$ in (γ,γ') . B(M1)(W.u.)=0.26 6.
5609.8	4713.5# 3	100#			
5652.6	5652.5# 8	100#			
5662.1	5662 $\frac{1}{2}$ & 2	\$			
5668.3	4772.0@ 3	100@			
5788.7	4892.4@ 4	100@			
5925.1	5925.0# 17	100#			
6301.1	5404.7@ 4	100@			
6382.0	5485.6@ 6	100@			
6392	6392 $\frac{1}{2}$ & 8	100\$			
6556.1	6556 $\frac{1}{2}$ & 8	100\$			
6712.2	5815.8@ 4	100@			
6900.5	6004.1@ 7	100@			
6911?	6911 $\frac{1}{2}$ &d 4	100\$			
6944.8	6944.7# 21	100#			
6983	6983 $\frac{1}{2}$ & 4	100\$			
7106?	7106 $\frac{1}{2}$ &d 4	100\$			
7168.1	7168 $\frac{1}{2}$ & 8	100\$	E1		Mult.: from $\gamma(0)$ and $\gamma(\text{pol})$ in (γ,γ') , $\delta < 0.05$ if J(7168)=9/2 and -0.1 if J(7168)=11/2. B(E1)(W.u.)=0.00093 5.
7171	7171 $\frac{1}{2}$ & 4	100\$			
7176.6	7176.5# 10	100#			
7202	7202 $\frac{1}{2}$ &d 5	100\$			
7243.9	7243.8# 13	100#			
7264	7264 $\frac{1}{2}$ & 4	100\$			
7279.1	7279.0 $\frac{1}{2}$ & 8	100\$			
7279+x	6382 $\frac{1}{2}$ & 8	\$			
	7279 $\frac{1}{2}$ & 8	\$			
7287	7287 $\frac{1}{2}$ & 4	100\$			
7360	7360 $\frac{1}{2}$ & 4	100\$			
7416.1	7416 $\frac{1}{2}$ & 8	100\$	(D)		Mult.: $A_2=+0.20$ 3 (1969Ra09) in (γ,γ') .
7632.1	7632 $\frac{1}{2}$ & 8	100\$	(D)		Mult.: $A_2=+0.24$ 4 (1974Wo05) in (γ,γ') .

[†] Weighted averages of values from (t,2n γ) and (n,n' γ), unless otherwise noted. Energies without uncertainties are from level-energy differences.

[‡] Weighted average of values from (t,2n γ), (n,n' γ) and Coulomb excitation.

\$ From (t,2n γ).

From (n,n' γ).

@ From (³He,d γ).

& From (γ,γ') .

^a From $\gamma(0)$ in (t,2n γ) (1983Ma15), unless otherwise noted.

^b Excitation in (γ,γ') is probably D (or D+Q) based on the measured values of $g\Gamma(\gamma_0)^2/\Gamma$, which leads to unexpected large B(E2)(W.u.)>10 and rules out the possibilities of pure quadrupole transitions.

^c If no value given it was assumed $\delta=0.00$ for E2/M1, $\delta=1.00$ for E3/M2 and $\delta=0.10$ for the other multipolarities.

^d Placement of transition in the level scheme is uncertain.

209Pb β^- Decay 1972Be44

Parent ²⁰⁹Pb: E=0.0; J π =9/2+; T_{1/2}=3.234 h 7; Q(g.s.)=644.0 11; % β^- decay=100.

²⁰⁹Pb-Q(β^-): from 2012Wa38.

²⁰⁹Pb-J,T_{1/2}: from Adopted Levels of ²⁰⁹Pb.

1972Be44: Source prepared by a (d,p) reaction using the internal beam of the Karlsruhe isochronous cyclotron.

Measured T_{1/2}, E β using an iron-free intermediate image β -spectrometer. Deduced log *ft*, shape factor.

Others: 1986He06, 1981Di14, 1971Pe03, 1953Wa61.

No γ , K x-ray (<1%), no ce with E(ce)>30 keV ($\leq 2\%$) (1953Wa61).

209Bi Levels

E(level)	J π	Comments
0.0	9/2-	J π : From Adopted Levels.

 β^- radiations

E β^-	E(level)	I β^- [†]	Log <i>ft</i>	Comments
644.6 12	0.0	100	5.534 3	E β^- : from 1972Be44. Others: 634 4 (1971Pe03), 634 10 (1968Va17), 635 10 (1953Wa61). No deviation observed from allowed shape (1971Pe03,1972Be44).

[†] Absolute intensity per 100 decays.

209Po ϵ Decay 1996Sc24,1989Ma05,1966Ha29

Parent ²⁰⁹Po: E=0.0; J π =1/2-; T_{1/2}=125.2 y 33; Q(g.s.)=1892.6 16; % ϵ +% β^+ decay=0.454 7.

²⁰⁹Po-Q(ϵ): From 2012Wa38.

1996Sc24: x-rays and γ -rays were detected by germanium detectors. Measured E γ , E α , E(x-ray), I γ , I α , I(x-ray).

Deduced levels, K-shell to total electron capture ratio.

1989Ma05: ²⁰⁹Po was produced by ^{nat}Pb(α ,3n) with E α =45 MeV from VECC, BARC, India. γ -rays were measured by two hyperpure Ge detectors. Measured E γ , I γ , E(x-ray), I(x-ray), E(α), I(α). Deduced K-capture probability, levels, conversion coefficients, subshell branching ratio.

1966Ha29: ²⁰⁹Po was produced by ²⁰⁹Bi(p,xn). Measured E γ , E γ , I α , I γ , I(ce), $\alpha\gamma^-$, $\gamma\gamma^-$ and γ (ce)-coin. Deduced levels, J π , log *ft*.

Other: 1984Sh32.

209Bi Levels

E(level) [†]	J π [‡]
0.0	9/2-
896.28 7	7/2-

[†] From a least-squares fit to E γ .

[‡] From Adopted Levels.

 β^+, ϵ Data

E ϵ	E(level)	I ϵ [†]	Log <i>ft</i>	Comments
(996.3 16)	896.28	0.454 7	14.493 ^{2u} 14	I ϵ : from 1996Sc24. 0.48 4 from 1989Ma05.

[†] Absolute intensity per 100 decays.

 γ (²⁰⁹Bi)

E γ	E(level)	I γ [†]	Mult.	δ	α	Comments
896.28 7	896.28	100	M1+E2	-0.62 6	0.0208 8	E γ , Mult., δ : from Adopted Gammas. Other: E γ =896.6 keV 1 in 1989Ma05.

[†] For absolute intensity per 100 decays, multiply by 0.00445 7.

²⁰⁷Pb(α,d) 1971Le09 (continued)
²⁰⁹Bi Levels (continued)

E(level)	dσ/dΩ(θ _{lab} =40°) (μb/sr) [§]	Comments
2603 5	=6.1	configuration=π(1h _{9/2}) ⁺ 1⊗3 ⁻ .
2819 6	18	
2910 20	=4.8	
2979 5	26	
3040 20	=6.5	configuration=π(1h _{9/2}) ⁺ 1⊗5 ⁻ .
3143 10	56	
3197 10	19	
≈3400 [†]		
3476 10	79	configuration=π(1h _{9/2}) ⁺ 1⊗4 ⁻ for 3476+3496. dσ/dΩ(θ _{lab} =40°) (μb/sr): for 3476+3496.
3496 10		
3569 10	58	
3670 20		
3700?		
3802 10	≈312 [#]	
3822 10	≈312 [#]	
≈3950 [†]		
4133 [‡] 6	≈130	
4178 [‡] 10	≈145	
4276 10		
4320?		
4397 10		
4470 20		
4516 10		
4601 5		
4650 5		
4745 10		
≈4910 [†]		
≈5540 [†]		

[†] Unresolved group of levels.

[‡] Based on the large σ, the authors suggest high spin.

[§] Uncertainty=15%.

[#] Summed cross section for the unresolved 3802-keV and 3822-keV levels. The authors suggest high spin, based on large σ.

²⁰⁸Pb(p,γ) 2004Li58

2004Li58: E=11.3–14.8 MeV protons were produced from the Separated Sector Cyclotron at iThemba LABS. A 1 mg/cm² enriched ²⁰⁸Pb target on a thick carbon backing was used. Beam energies were measured by time-of-flight of protons and γ-rays were detected using AFRODITE Ge detector array of eight Ge clover detectors surrounded by BGO anti-Compton shields. Measured Eγ, Iγ, γγ, excitation functions. Deduced levels, Jπ. Proton captures into single-particle states in ²⁰⁹Bi.

Others:

2006Li17: E=14.8, 15.7, 16.9 MeV. Measured Eγ, Iγ, γγ. AFRODITE array at iThemba LABS. Deduced excitation functions.

Proton capture to continuum states in ²⁰⁹Bi.

2006Li05: E=11–17 MeV. Measured Eγ, Iγ. AFRODITE array.

1987Ra23: E=7–9 MeV. Measured absolute thick target γ yield.

²⁰⁹Bi Levels

E(level) [†]	Jπ [‡]
0.0	9/2-
896	7/2-
1609	13/2+
2826	5/2-
3120	3/2-
3633	1/2-
4418	1/2-

Footnotes continued on next page

²⁰⁸Pb(p,γ) 2004Li58 (continued)

²⁰⁹Bi Levels (continued)

[†] Round-off values from a least-squares fit to γ-ray energies by assuming ΔEγ=1 keV.

[‡] From comparisons of the experimental excitation functions with the theoretical predictions of the direct-semi-direct model (DSD) (2004Li58).

γ(²⁰⁹Bi)

Eγ [†]	E(level)
513	3633
896	896
1298	4418
1609	1609
1930	2826
2224	3120
2826	2826

[†] From 2004Li58, no uncertainties are given by the authors.

²⁰⁸Pb(p,γ): Giant Resonance 1974Sn01

E=17.5–25.0 MeV proton beam was produced from the three-stage FN accelerator at the University of Washington. Target was self-supporting 2.8 mg/cm² ²⁰⁸Pb. γ-rays were detected with a 10 inch by 10 inch. NaI detector. Measured γ(θ).

Deduced resonance.

Excitation function and asymmetry measured for unresolved γ's to g.s., 897, and 1608 levels.

²⁰⁹Bi Levels

E(level)	Comments
0.0	
≈23000	Γ=3.5 MeV. Based on a comparison with a collective E0 or E2 resonance observed at ≈22 MeV in ²⁰⁸ Pb(e,e'), the authors suggest that the observed resonance at 23 MeV is a collective E2 excitation. Observation in (p,γ) rules out E0.

²⁰⁸Pb(p,γ): IAR 1971Sn03

S(p)=3799.0 8 from 2012Wa38.

1971Sn03:E=8.8–18.0 proton beams were produced from the Stony Brook FN Tandem Van de Graaf accelerator. Target was 3.5 mg/cm² self-supporting ²⁰⁸Pb. γ-rays were detected in a large NaI spectrometer. Measured σ(Eγ). Authors obtained resonance energies and total widths but quote values only for the ²⁰⁹Pb ground-state analog. They claim good agreement with values of 1968Wh02 based on (p,p').

Other:

1968Cr05: proton beams were produced from the University of Washington High Voltage FN tandem accelerator. γ-rays were detected with a 20.7 cm³ coaxial Ge(Li) detector. Measured σ(Eγ,θ). Deduced levels.

²⁰⁹Bi Levels

Γ_γ(nlj) are radiative widths to proton states with configuration=nlj deduced in 1971Sn03 using Γ_p from 1968Wh02.

E(level) [†]	Jπ [‡]	Comments
S(p)+14899	9/2+	E(level): E(res)=14930 30 (1971Sn03). Γ=275 keV 20. Γ _γ (2f _{7/2})=110 eV, Γ _γ (1h _{9/2})<10 eV.
S(p)+15658	(11/2+)	Γ _γ (1h _{9/2})=190 eV.
S(p)+16466	5/2+	Γ _γ (2f _{7/2})=40 eV, Γ _γ (3p _{3/2})=95 eV.
S(p)+17398	7/2+	Γ _γ (1h _{9/2})=15 eV, Γ _γ (2f _{7/2})<10 eV.

[†] Resonance energies (given in the lab coordinate system), are from ²⁰⁸Pb(p,p')(pol p,p') IAR (1985Me01).

[‡] From Adopted Levels.

208Pb(p,p'),(pol p,p'): IAR 1985Me01,1968Wh02,1969Fi01

S(p)=3799.0 8 (2012Wa38).

1985Me01: (pol p,p') E=14.2–17.4 MeV polarized proton beams were produced from the Koln FN tandem Van de Graaff accelerator. Measured $\sigma(E_p, \theta)$. Deduced isobaric analog resonances (IAR), spectroscopic factors.

1968Wh02: (p,p') E=14–18 MeV proton beams were produced from the University of Washington three-stage FN tandem Van de Graaff. A 99% enriched ²⁰⁸Pb target was used. Scattered protons were detected by two Si(Li) detectors, FWHM=26 keV. Measured $\sigma(E_p)$. Deduced levels, widths, isobaric analog.

1969Fi01: (p,pol p) E=16–18 MeV. Scattered protons were detected by a surface barrier detector. Measured $\sigma(E, \theta)$. Deduced breakup Radius.

1971Da18: (p,p) E=8–18 MeV. Scattered protons were detected by lithium-drifted silicon detectors. Measured $\sigma(E_p, \theta)$. Deduced isobaric analog resonance parameters, spectroscopic factors.

Others:

(p,p'): 2011He08, 2010He08, 2008GoZT, 1996Ra07, 1969Ri10.

(p,p): 1966Ka02, 1969DoZZ, 1972Se10.

Spreading widths and isospin purity of the IAR are deduced by 1985Me01.

Coulomb energy difference=18793 11, a weighted average of values of 1968Wh02 (18787 11) and 1972Se10 (18811 19). The value quoted for 1968Wh02 is a weighted average deduced by evaluators based on E(res)–E(²⁰⁹Pb parent state)+S(n)(²⁰⁹Pb) with the resonance energies, E(res), in center-of-mass coordinates.

209Bi Levels

Level widths are weighted averages, as given by 1985Me01, of values of 1968Wh02 and 1985Me01. The elastic-scattering partial widths, Γ_p , are weighted averages, as given by 1985Me01, of data of 1968Za01 (as reanalyzed by 1968Wh02) and 1985Me01.

E(level) [†]	J $\pi^{\ddagger}$	S §	Comments
S(p)+14899 4	9/2+	0.98	$\Gamma=251$ keV 6; $\Gamma_p=21.9$ keV 6. J π : if L(n)=4 for the analog state in ²⁰⁹ Pb.
S(p)+15658 26	(11/2+)		$\Gamma=221$ keV 19; $\Gamma_p=1.7$ keV 4. J π : probable analog of the 1i _{11/2} neutron state in ²⁰⁹ Pb.
S(p)+16380	(15/2+)		$\Gamma=202$ keV 25; $\Gamma_p=0.85$ keV 80. J π : probable analog of the 1j _{15/2} neutron state in ²⁰⁹ Pb. E(level): the uncertainty is 150 keV. The proton partial Γ is from 1985Me01.
S(p)+16466 4	5/2+	0.86	$\Gamma=297$ keV 5; $\Gamma_p=46$ keV 6. J π : if L(n)=2 for the analog state in ²⁰⁹ Pb.
S(p)+16953 6	(1/2+)	0.90	$\Gamma=320$ keV 10; $\Gamma_p=52.0$ keV 15. J π : probable analog of the 4s _{1/2} neutron state in ²⁰⁹ Pb.
S(p)+17398 16	7/2+	0.84	$\Gamma=293$ keV 16; $\Gamma_p=43$ keV 4. J π : if L(n)=4 for the analog state in ²⁰⁹ Pb. Γ_p is from 1968Za01 as reanalyzed by 1968Wh02. The value from 1985Me01 is suspect since the authors' energy range covers only the lower part of the resonance.
S(p)+17457 18	3/2+	0.86	$\Gamma=278$ keV 19; $\Gamma_p=35$ keV 7. J π : if L(n)=2 for the analog state in ²⁰⁹ Pb. Γ_p is from 1968Za01 as reanalyzed by 1968Wh02. The value from 1985Me01 is suspect since the authors' energy range covers only the lower part of the resonance.

[†] Resonance energies (given in the lab coordinate system), are from 1985Me01. Values are systematically lower by 25 keV on the average compared with data of 1968Wh02 and 1983BaZL. Others: 1968Wh02, 1971Da18 (no uncertainties given), 1983BaZL.

[‡] From (p,pol p) data of 1969Fi01 (except for the ground-state value which is from 1967FiZY) based on known L(n) transfer to assumed parent analog. Additional tentative assignments are noted.

[§] From 1971Da18. Several sets of values, calculated with different models and parameters, are also given by 1985Me01.

208Pb(d,n) 1974Ad11

1974Ad11: E=12.5 MeV deuteron beam was produced from the tandem Van de Graaff accelerator at the Centre d'Etudes de Bruyeres-le-Chatel. Neutrons were detected by a multi-detector time-of-flight system. Measured $\sigma(E_n)$. Deduced levels.

209Bi Levels

E(level)
0.0
900

Continued on next page

²⁰⁸Pb(d,n) 1974Ad11 (continued)

²⁰⁹Bi Levels (continued)

E(level)

1620
2820
3120
4420
5300

²⁰⁸Pb(d,n γ) 1978El07

1978El07: E=6,8,10 MeV deuteron beams were produced from the University of Jyvaskyla 90-cm cyclotron. Targets were 99% enriched self-supporting metallic ²⁰⁸Pb foils with thickness of 500 $\mu\text{g}/\text{cm}^2$. Conversion electrons were detected with a magnetic lens plus Si(Li) spectrometer and γ -rays were detected with standard 40 cm^3 Ge(Li) detectors. Measured E γ , ce(t). Deduced levels, J π , T $_{1/2}$.

No delayed conversion electrons with energies in the range 50 to 300 keV were observed, and a γ spectrum, delayed by 10 to 25 ns with respect to the pulsed beam and in coincidence with γ -rays in the energy range 600 to 1700 keV, showed only the 894 and 1546 γ . The authors of 1978El07 therefore conclude that the observed 10 ns half-life is associated with the 2442 level. Assignment of the 1546 γ to Bi is based on a comparison of E(γ) and E(ce(K)) of the 1546 γ with that of the 1566 γ in ²⁰⁹Pb (from (d,p γ)).

²⁰⁹Bi Levels

E(level)	J $\pi^\dagger$	T $_{1/2}$	Comments
0.0	9/2-		
896.3	7/2-		
2442.5 5	1/2+	10 ns 2	T $_{1/2}$: from 896 γ ce(K)(t) (1978El07).

 $\dagger$ From Adopted Levels.

 $\gamma(^{209}\text{Bi})$

E γ	E(level)	Mult.	Comments
896.3	896.3		E γ : rounded-off value from Adopted Gammas.
1546.2 5	2442.5	E3	Mult.: M1 or E3 from $\alpha(\text{K})(\text{exp})=0.0054$ 14, deduced from I(ce(K))/I(γ) relative to the 1566 γ (in ²⁰⁹ Pb from (d,p γ)) and the 1608 γ , both known to be M2. M1 is ruled out by the long half-life.

²⁰⁸Pb(t,2n γ) 1983Ma15

1983Ma15: E=11-16 MeV triton beams were produced from the 3-state Van de Graaff facility of the Los Alamos National Laboratory. Targets were enriched metallic Pb (>98.5%). γ -rays were detected by a pure Ge low-energy photon (LEPS) detector (FWHM=0.5 keV at 100 keV), a pure Ge planar detector (FWHM=1 keV at 800 keV) and a 50 cm^3 coaxial Ge(Li) detector (FWHM=2.5 keV at 1.5 MeV). Measured E γ , I γ , $\gamma(\theta)$, $\gamma\gamma$ -coin, $\gamma\gamma$ -coin. Deduced levels, J π , branchings. Also see 1983Be28.

²⁰⁹Bi Levels

E(level) †	J $\pi^\dagger$	Comments
0.0	9/2-	configuration= $\pi(1h_{9/2})^{+1}$.
896.32 6	7/2-	configuration= $\pi(2f_{7/2})^{+1}$.
1608.54 6	13/2+	configuration= $\pi(1i_{13/2})^{+1}$.
2442.83 6	1/2+	J π : 1546 $\gamma(\theta)$ is isotropic.
		configuration= $\pi(3s_{1/2})^{-1}$.
2492.77 $\S$ 6	3/2+	
2564.32 $\S$ 20	9/2+	
2582.84 $\S$ 11	7/2+	

Continued on next page (footnotes at end of table)

$^{208}\text{Pb}(t,2n\gamma)$ 1983Ma15 (continued) **^{209}Bi Levels (continued)**

$E(\text{level})^\dagger$	$J\pi^\ddagger$	Comments
2599.78§ 14	11/2+	
2600.87§ 6	13/2+	
2617.25§ 7	5/2+	
2741.00§ 6	15/2+	
2766.57# 6	3/2+	
2826.18 15	5/2-	configuration= $\pi(2f_{5/2})^{+1}$.
2845.10# 7	1/2+	$J\pi$: 402 $\gamma(0)$ to 1/2+ is isotropic (1983Ma15).
2916.53@ 8	1/2+	
2955.85 8	3/2+	$J\pi$: γ -branching ratio to 3/2+ and 5/2+ members of the configuration= $\pi(1h_{9/2})^{+1}\otimes 3^-$ septuplet agrees with the calculated value for assignment as a 3/2+ component (fragmented) of the same multiplet (1983Ma15).
		configuration= $\pi(2d_{3/2})^{-1}+\pi(1h_{9/2})^{+1}\otimes 3^-$ (1983Ma15).
2986.73# 6	19/2+	
3038.79# 10	5/2+	
3090.24# 10	7/2+	
3119.56 12	3/2-	configuration= $\pi(3p_{3/2})^{+1}$.
3132.77# 17	11/2+	
3135.65# 7	15/2+	
3153.23# 20	9/2+	
3154.02# 6	17/2+	
3159.23@ 8	3/2+	
3169.02# 6	13/2+	
3197.40 11	(1/2+, 3/2+, 5/2+)	
3211.78@ 6	17/2+	
3221.63@ 9	5/2+	
3269.59 11	(1/2+, 3/2+, 5/2+)	
3311.19 7	(7/2+)	
3354.7 4	(3/2+)	
3362.0 4	(5/2+, 7/2+, 9/2+)	
3378.2@ 3	9/2+	
3393.34 21	(15/2+)	
3406.06@ 11	13/2+	
3450.2@ 6	7/2+	
3464.0@ 3	11/2+	
3467.61 8	19/2+	
3486.87 8	19/2+	probable configuration= $\pi(1h_{9/2})^{+1}\otimes v(1i_{11/2}^{+1}3p_{1/2}^{-1})$.
3490.2 3	(7/2+, 9/2+)	
3502.16@ 12	15/2+	
3541.6 3	(5/2+, 7/2+, 9/2+)	
3575.7 4		
3578.68 9	21/2+	probable configuration= $\pi(1h_{9/2})^{+1}\otimes v(1i_{11/2}^{+1}3p_{1/2}^{-1})$.
3597.09 10	19/2+	probable configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}2f_{5/2}^{-1})$.
3601.84 21	(9/2+)	
3693.0 5	(11/2-)	
3703.58 21	(7/2+)	
3719.0 20	(7/2+, 9/2+, 11/2+)	
3783.6 4	(5/2+, 7/2+, 9/2+)	
3812.18 16	23/2+	probable configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}2f_{5/2}^{-1})$.
3853.0 20	(7/2+, 9/2+, 11/2+)	
3979.5 6	(7/2+, 9/2+, 11/2+)	
4141.89 11	21/2+	

† From a least-squares fit to γ -ray energies.

‡ From 1983Ma15.

§ Member of the $\pi(1h_{9/2})^{+1}\otimes 3^-$.# configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_{5^-}$.@ configuration= $\pi(1h_{9/2})^{+1}\otimes v(2g_{9/2}^{+1}3p_{1/2}^{-1})_{4^-}$.

		²⁰⁸ Pb(t,2nγ)		1983Ma15 (continued)		
				<u>γ(²⁰⁹Bi)</u>		
Eγ	E(level)	Iγ [‡]	Mult. [†]	δ	α	Comments
(49.9)	2492.77	≈1.73	[M1]		14.46	Iγ: from 1983Ma15. Transition not seen directly. Energy from level energy difference and total intensity inferred from γγ to be ≈20% of the branching from the 2493 level.
78.60 10	2845.10	≈4				Iγ: seen only in the low-energy photon detector. Iγ is ≈15% of the 402γ (1983Ma15).
110.67 15	2955.85	0.70 7				A ₂ =+0.4 3.
124.48 5	2617.25	1.73 7	M1			Mult.: A ₂ =-0.05 5.
131.45 8	3221.63	1.28 7				A ₂ =+0.02 15.
140.13 1	2741.00	38.5 6	M1			Mult.: A ₂ =-0.19 4.
149.3 1	2766.57	3.8 2				A ₂ =-0.08 8.
149.98 5	2916.53	7.1 2				A ₂ =+0.04 8.
167.16 6	3154.02	3.4 1	M1			Mult.: A ₂ =-0.25 10.
225.05 2	3211.78	34.6 5				A ₂ =-0.15 4.
242.73 5	3159.23	5.6 [§] 7				
245.73 2	2986.73	266 5	E2			Mult.: A ₂ =+0.31 5.
265.74 8	3221.63	3.7 2				
270.4 1	3406.06	5.5 3				A ₂ =-0.07 7.
272.2 1	3038.79	8.7 2				A ₂ =-0.02 4.
273.80 3	2766.57	19.4 3				A ₂ =+0.02 4.
290.38 10	3502.16	5.7 3	M1			Mult.: A ₂ =-0.13 8.
313.70 16	3467.61	7.8 8	M1			
314.2 2	3159.23	6.1 8	M1			Mult.: A ₂ =-0.15 10.
323.74 2	2766.57	61 1	M1			Mult.: A ₂ =-0.08 4.
338.65 10	2955.85	2.6 3				A ₂ =-0.1 2.
352.30 8	3197.40	7.0 3				A ₂ =+0.03 5.
392.56 10	3159.23	4.4 3				A ₂ =+0.07 10.
394.72 7	3135.65	11.8 3	M1			Mult.: A ₂ =+0.12 8.
402.27 3	2845.10	26.8 4				
413.04 3	3154.02	51.6 8	M1+E2			Mult.: A ₂ =-0.32 3.
424.49 [#] 8	3269.59	13.2 [#] 4				A ₂ =+0.14 3.
	3578.68	13.2 [#] 4				
443.15 12	3597.09	4.1 3				A ₂ =-0.1 2.
455.02 10	3221.63	7.5 3				A ₂ =-0.12 10.
463.04 8	2955.85	16.6 4				A ₂ =0.00 5.
480.87 5	3467.61	28.6 6	M1			Mult.: A ₂ =+0.43 4.
500.12 5	3486.87	35.3 7	M1			Mult.: A ₂ =+0.42 4.
(513.0)	2955.85	<0.8				Eγ: not seen. Eγ is from the level energy difference. The authors quote an upper limit of 3% for the branching to the 2443 level (value given in text in 1983Ma15).
544.85 10	4141.89	15.9 5	M1			Mult.: A ₂ =-0.23 7.
588.1 4	3354.7	10.3 6				A ₂ =+0.05 8.
592.2 1	3578.68	10.5 6	M1			Mult.: A ₂ =-0.36 12.
610.33 15	3597.09	22.3 7	M1			Mult.: A ₂ =+0.49 7.
654.98 10	4141.89	17.8 7	M1			Mult.: A ₂ =-0.28 8.
664.8 2	3703.58	9.4 6	M1			Mult.: A ₂ =-0.25 10.
806.36 15	3406.06	7.8 [§] 9				
825.45 15	3812.18	13.8 7	E2			Mult.: A ₂ =+0.36 7.
896.30 7	896.32	1000 10	M1+E2			A ₂ =+0.04 2.
991.2	2599.78	<4				Eγ: from level energy difference.
						Iγ: transition not observed. Intensity is limit based on possible component in the 992.34 peak.
992.34 2	2600.87	225 3	M1+E2			Mult.: A ₂ =+0.27 1.
1132.45 2	2741.00	180 2	M1+E2	+0.05		Mult.,δ: A ₂ =-0.12 1.
1524.1 3	3132.77	10.2 [§] 9				A ₂ =-0.04 10.
1527.02 8	3135.65	87 1	M1			Mult.: A ₂ =-0.06 2.
1546.47 5	2442.83	196 2	E3			Mult.: γ(θ) to 1/2- is isotropic.
1560.48 2	3169.02	44 5	M1			Mult.: A ₂ =+0.18 5.
1608.48 8	1608.54	1000 6	M2+E3			A ₂ =+0.42 1.
1686.52 10	2582.84	46.8 8	E1+M2			Mult.: A ₂ =+0.08 2.
1720.95 10	2617.25	33 [§] 8				A ₂ =-0.04 4.
1784.8 2	3393.34	16.2 5	M1			Mult.: A ₂ =-0.21 4.
1797.4 2	3406.06	16.0 5	M1			Mult.: A ₂ =+0.23 4.
1929.7 2	2826.18	15 4				

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²⁰⁸Pb(t,2n γ) 1983Ma15 (continued)
 $\gamma(^{209}\text{Bi})$ (continued)

E γ	E(level)	I $\gamma^{\ddagger}$	Mult. [†]	Comments
2142.52 15	3038.79	34 3	E1	Mult.: A ₂ =-0.07 3.
2194.3 2	3090.24	5.9 [§] 6		A ₂ =+0.10 12.
2223.23 10	3119.56	65 2	E2	Mult.: A ₂ =+0.09 5.
2414.85 3	3311.19	16.9 6		A ₂ =+0.03 5.
2465.7 4	3362.0	13.0 7		A ₂ =-0.01 10.
2481.7 4	3378.2	<1.5		I γ : from branching relative to the 3378 γ as given in authors' Table II.
2492.72 10	2492.77	170 10		A ₂ =+0.04 2.
2553.9 6	3450.2			A ₂ =+0.10 17.
2564.3 2	2564.32	65 2	E1	Mult.: A ₂ =+0.25 3.
2582.7 4	2582.84	20.4 10	E1+M2	Mult.: A ₂ =+0.20 5.
2593.5 3	3490.2	12 3		
2599.9 2	2599.78	89 2	E1	Mult.: A ₂ =-0.11 4.
2600.8	2600.87	<11		E γ : from level energy difference. I γ : transition not observed. Intensity is limit based on possible component in the 2599.9 peak.
2617.25 15	2617.25	19 4		
2645.3 3	3541.6			A ₂ =+0.05 5.
2679.4 4	3575.7	29 5		
2705.5 2	3601.84	22 5	E1	Mult.: A ₂ =-0.29 8.
2740.99 7	2741.00	266 2	E3	Mult.: A ₂ =+0.48 1.
2826.3 2	2826.18	46 1	E2	Mult.: A ₂ =+0.17 5.
2887.3 4	3783.6	12.0 7		Mult.: A ₂ =+0.17 10.
3090.2 2	3090.24	33 1	E1+M2	Mult.: A ₂ =+0.10 5.
3132.8 2	3132.77	36 1	E1	Mult.: A ₂ =-0.24 4. E γ : the authors' value of 3132.85 2 is a misprint.
3153.2 2	3153.23	37 1	E1	Mult.: A ₂ =+0.26 6.
3378.3 4	3378.2	13.5 7	E1	Mult.: A ₂ =+0.10 5.
3464.0 3	3464.0	13.3 8	E1	Mult.: A ₂ =-0.28 8.
3491.0 5	3490.2	5 [§] 3		
3693.0 5	3693.0			
3703.4 6	3703.58	8.4 [§] 22		
3719 2	3719.0			
3853 2	3853.0			
3979.5 6	3979.5			A ₂ =-0.05 10.

[†] Tentative assignments from 1983Ma15 based on $\gamma(0)$ and spin-parity assignments, unless otherwise noted.

[‡] Relative thick target yields integrated over all angles from E=16-MeV spectrum (1983Ma15). Authors also give I γ at 13 MeV.

[§] Since I γ at 16 MeV is not given, the quoted value is from branching reported in the 13-MeV data.

[#] Multiply placed; undivided intensity given.

²⁰⁸Pb(³He,d) 1970El13,1980Gr09,1968Ba34

Target ²⁰⁸Pb J π (g.s.)=0+.

1970El13: E=18 MeV ³He beam was produced from the EN tandem Van de Graaff accelerator of the University of Pittsburgh. A 100 $\mu\text{g}/\text{cm}^2$ carbon-backed 99.5% enriched ²⁰⁸Pb target was used. Deuterons were momentum analyzed by an Enge split-pole magnetic spectrometer and detected in photographic plates, FWHM=16 keV. Measured $\sigma(E_d,0)$. Deduced levels.

1980Gr09: E=30 MeV ³He beam was produced from the Princeton Cyclotron. Target were 65-160 $\mu\text{g}/\text{cm}^2$ thick 99% enriched ²⁰⁸Pb on 5 and 10 $\mu\text{g}/\text{cm}^2$ carbon backings. Deuterons were momentum analyzed with the Princeton quadrupole-three dipole (Q-3D) magnetic spectrograph and detected by a single-wire charge-division position-sensitive proportional counter, FWHM=10-14 keV. Measured $\sigma(E_d,0)$. Deduced levels, J π , spectroscopic factors from DWBA analysis.

1968Ba34: E=44.2 MeV ³He beam was produced from the University of Michigan 83-inch sector-focused cyclotron. A 0.75 mg/cm^2 thick target of 99.3% enriched ²⁰⁸Pb was used. Deuterons were momentum analyzed by a magnetic spectrographs and detected in nuclear track plate, FWHM=50 keV. Measured $\sigma(E_d,0)$. Deduced levels, J π , spectroscopic factors from DWBA analysis.

1967Wi09: E=51.3 MeV ³He beam was produced from the Oak Ridge Isochronous Cyclotron. A target of 0.47 mg/cm^2 thick 95% enriched ²⁰⁸Pb foil was used. Deuterons were momentum analyzed with a broad range magnetic spectrograph, FWHM=60 keV. Measured $\sigma(E_d,0)$. Deduced levels, L, J π , spectroscopic factors from DWBA analysis.

1967Wo03: E=24 MeV ³He beam was produced from the Los Alamos tandem Van de Graaff accelerator. A target of 200 $\mu\text{g}/\text{cm}^2$ self-supporting ²⁰⁸Pb foil was used. Deuterons were momentum analyzed with an Elbek magnetic spectrograph, FWHM=25 keV. Measured $\sigma(E_d,0)$. Deduced levels, J π , spectroscopic factors from DWBA analysis.

Continued on next page (footnotes at end of table)

208Pb(3He,d) 1970El13,1980Gr09,1968Ba34 (continued)

1968El01: E=20.3 MeV ³He beam was produced from the tandem accelerator of the Niels Bohr Institute. Target was 300 μg/cm² self-supporting foil of ²⁰⁸Pb, 99.3% enriched. Deuterons were momentum analyzed with a broad-range magnetic spectrograph, FWHM=30 keV. Measured σ(E_d,θ). Deduced levels, Jπ, spectroscopic factors from DWBA analysis.

1984Ga37: E= 240 MeV α beam was produced from the Grenoble cyclotron. Deuterons were momentum analyzed with a QD spectrometer and detected by a gas delay-line counter, FWHM=50 keV. Measured σ(θ). Deduced levels, Γ, spectroscopic factors.

209Bi Levels

Spectroscopic factor C²S: N×g×C²S=σ(θ)^{exp}/σ(θ)^{DWBA}, where N is the normalization factor and g=(2J_f+1)/(2J_i+1) for (³He,d) reactions (1966Ba54). N=4.4 (1968Ba34), 4.42 (1967Wi09).

Summary of spectroscopic values. Parameters used by authors for extraction of spectroscopic values given below are very similar except for the spin-orbit strength (so). The second column of so=6 data of 1967Wi09 are from 1974Fo22 based on their reanalysis of data of 1967Wi09 to include non-locality and finite range corrections.

E(level)		configuration		C ² S			
				1967Wi09	1967Wo03	1968Ba34	1968El01 1980Gr09
				so=6	so=6	so=?	so=6 so=32 so=6
g.s.	1h _{9/2}	1.00	0.54	1.00#	0.95	1.17	1.00#
897	2f _{7/2}	1.12	0.65	0.88	1.18	0.78	1.38
1612	1i _{13/2}	0.94	0.52	0.92	0.88	0.56	0.85
2601	1i _{13/2}				-@	0.06	0.08
2824	2f _{5/2}	1.14	0.61	1.12	1.15	0.88	0.87
3116	3p _{3/2}	1.08	0.58		1.03	0.67	0.98
3637	3p _{1/2}	0.7-0.9		0.49†	0.63	0.49	0.54
4421+	if 3p _{1/2} &				0.46&		
4447	if 2f _{7/2} &					0.16&	

@ σ is ≈13% of the 1612 1i_{13/2} level

† Level misinterpreted by authors as 3p_{3/2} (see 1967Li09)

& 4421+4447 peak analyzed as single level. 1968Ba34 assumed 3p_{1/2} whereas 1968El01 assumed 2f_{7/2}. 1970El13 resolved the doublet and determined σ(4421)/σ(4447)=3. Based on a reanalysis of the data of 1968El01, 1970El13 suggest that the more intense 4421 level has the 3p_{1/2} strength and the weaker 4447 level the 2f_{7/2} strength

Spectroscopic values normalized to unity for the ground-state transition

E(level) [†]	L [§]	C ² S	E(level) [†]	L [§]	C ² S	E(level) [†]	L [§]	C ² S
0.0	5		3490 10			4421 10	(1)&	
899 1	3		3635 4	1		4447 10	(2,3)&	
1613 2	6		3810 22			4522 10	#	
2601 3	@		3970 22			4600 10	#	
2826 3	3		4095 10			5304 10		
3121 3	1		4160 22			7150 [‡] 150	6 [‡]	0.15 [‡]
3410 22			4240 22			10.3×10 ^{3‡} 5	(6+7) [‡]	≈1.0 [‡]

† Data with ΔE=10 keV are from 1970El13; data with ΔE=1-4 keV are from 1980Gr09; other data are from 1968Ba34, unless otherwise noted.

‡ From 1984Ga37. Γ(7.15E3)=1.5 MeV 3, Γ(10.3E3)=5.7 MeV 10.

§ From 1967Wi09 and 1968Ba34 based on DWBA analysis.

σ(θ) indicates low-L(n) transfer (1968Ba34).

@ σ(θ) indicates high-L(n) transfer (1968Ba34).

& From 1970El13 based on a reanalysis of data of 1968Ba34 for 4421+4447 doublet with relative strength 75%(4421) and 25%(4447) as found in the work of 1970El13.

²⁰⁸Pb(³He,dγ) 2000Ti04

2000Ti04: E=20.5 MeV ³He beam was produced from the Cologne FN tandem accelerator. γ-rays were detected by two unshielded EUROBALL CLUSTER detectors with a total photopeak efficiency of about 7% at 1332 keV. Measured Eγ, Iγ, γγ-coin. Deduced levels, γ-branchings.

²⁰⁹Bi Levels

E(level) [†]	E(level) [†]	E(level) [†]
0.0	3759.0 5	4739.6 2
896.3 1	3772.5 2	4786.3 3
1608.6 1	3782.6 2	4904.2 3
2442.9 1	3801.4 2	5054.0 4
2492.8 1	3808.2 2	5152.2 3
2766.6 1	3816.7 3	5190.7 4
2845.1 1	3913.2 2	5291.4 4
2917.6 1	4091.4 4	5292.5 3
2955.9 1	4096.6 2	5369.7 4
3119.5 1	4236.8 3	5563.3 6
3159.3 1	4415.4 [‡] 2	5668.3 3
3197.4 2	4426.7 3	5788.7 4
3269.6 2	4438.9 2	6301.0 4
3449.1 2	4478.2 3	6381.9 6
3590.5 2	4516.5 3	6712.1 4
3633.8 [‡] 2	4588.1 3	6900.4 7

[†] From a least-squares fit to γ-ray energies.

[‡] configuration=π(3p_{1/2})⁺¹.

γ(²⁰⁹Bi)

E(level)	Eγ [†]	Iγ [†]	E(level)	Eγ [†]	Iγ [†]	E(level)	Eγ [†]	Iγ [†]
3119.5	2223.2		3759.0	2862.7 5	100	4588.1	4587.8 6	
3159.3	242.7 1	55 20	3772.5	2876.3 2	100	4739.6	3843.3 2	100
	314.2 2	100 10	3782.6	2886.3 3	100	4786.3	3890.0 2	100
	392.5 2	40 10	3801.4	2905.1 2		4904.2	4007.9 3	100
	716.5 2	90 20		3801.0 5		5054.0	4157.7 4	100
3197.4	352.3 1	70 20	3808.2	2199.7 2	100	5152.2	4255.9 3	100
	431.2 2	50 15	3816.7	2920.4 2	100	5190.7	4294.4 4	100
	705.1 2	100 10	3913.2	1420.4 2	100	5291.4	2525.6 5	100
3269.6	424.5 1	100 10	4091.4	1648.5 4	100	5292.5	2095.1 3	100
	826.5 2	30 10	4096.6	977.1 2	100	5369.7	2926.9 4	100
3449.1	2552.8 2	100	4236.8	3340.6 3	100	5563.3	3070.5 6	100
3590.5	745.3 2	100	4415.4	1295.9 2	100 30	5668.3	4772.0 3	100
3633.8	436.3 2	2 1		1922.4 2	3 1	5788.7	4892.4 4	100
	514.37 2	100 30	4426.7	3530.4 3	100	6301.0	5404.7 4	100
	677.8 2	20 6	4438.9	3542.6 3		6381.9	5485.6 6	100
	788.8 2	3 1		4439.1 3		6712.1	5815.8 4	100
	867.2 2	20 6	4478.2	3581.9 3	100	6900.4	6004.1 7	100
	1140.8 2	6 2	4516.5	3620.2 3	100			
	1191.0 2	4 1	4588.1	3692.1 3				

[†] From 2000Ti04.

²⁰⁸Pb(α,t) 1985Ga01,1980Gr09,1984Ga37

Target ²⁰⁸Pb Jπ(g.s.)=0+.

1985Ga01: E=80 MeV α beam was produced from the K90 isochronous Institut de Physique Nucleaire (ISN) Grenoble cyclotron. Targets were 98% enriched ²⁰⁸Pb of 6 and 1 mg/cm² thick. Tritons were momentum analyzed by the quadrupole-dipole (QD) magnetic spectrometer and detected by a gas delay-line counter backed by two plastic scintillators, FWHM=60 keV. Measured σ(E_t,θ). Deduced levels, L, Jπ from DWBA analysis.

1980Gr09: E=40 MeV α beam was produced from the Princeton Cyclotron. Targets were 65-160 μg/cm² thick 99% enriched ²⁰⁸Pb on 5 and 10 μg/cm² carbon backings. Tritons were momentum analyzed with the Princeton quadrupole-three dipole (Q-3D) magnetic spectrograph and detected by a single-wire charge-division position-sensitive proportional counter, FWHM=10-14 keV. Measured σ(E_d,θ). Deduced levels, Jπ, spectroscopic factors from DWBA analysis.

1984Ga37: E= 80 MeV α beam was produced from the Grenoble cyclotron. Tritons were momentum analyzed with a QD spectrometer and detected by a gas delay-line counter, FWHM=50 keV. Measured σ(θ). Deduced levels, Γ, spectroscopic factors.

Others: 1967Li09, 1981Pe10 (studied the energy dependence of the spectroscopic factors at 39.8, 61.5, and 81.4 MeV), 1985IsZV, 1985OhZS, 1985OhZX, 1986IsZX. See also 1985Sa34 for a comparison of these excitation energies with a calculation based on the coupling of the proton states with eight collective surface vibrational states in ²⁰⁸Pb.

²⁰⁹Bi Levels

E(level) [†]	Jπ [#]	L [@]	C ² S ^{&}	Comments
0.0	9/2-	5	0.80	
899 [‡] 1	7/2-	3	0.76	C ² S: 0.89 normalized to unity for the ground-state (1980Gr09).
1608 [‡] 2	13/2+	6	0.74	C ² S: 1.05 normalized to unity for the ground-state (1980Gr09).
2499 7	3/2+	2	0.014	
2601 [‡] 3	13/2+	6	0.065	C ² S: 0.09 normalized to unity for the ground-state (1980Gr09).
2826 [‡] 3	5/2-	3	0.57	C ² S: 0.65 normalized to unity for the ground-state (1980Gr09).
3139 15	3/2-	1	0.44	
3410 15	13/2+	6	0.03	
3503 15	5/2-, 7/2-	3	0.04, 0.03	
3650 15	1/2-	1	0.20	
3707 15				
3835 15	13/2+	6	0.03	
3927 15		≥7		
4019 25		≥7		
4174 25	15/2-	7	0.045	
4247 25	15/2-	7	0.06	
4459 25	1/2- and 7/2-	1+3	0.10+0.10	
4543 25	15/2-	(7)	<0.02	
4613 25	5/2-, 7/2-	3	0.06, 0.05	
4700 25				
4795 25	11/2+, 13/2+	6	0.04	
4886 25	15/2-	7	0.02	
4998 25	15/2-	7	0.03	
5087 25	5/2-	3	0.07	
5173 25	5/2-	3	0.07	
5277 25	15/2-	7	0.04	
5380 25	15/2-	7	0.03	
5469 25	11/2+	6	0.06	
5580 25	11/2+	6	0.04	
5693 25	3/2+, 5/2+	(2)	0.15	
7.2×10 ³ § 2		6§	0.15§	
8.7×10 ³ § 5		(6+7)§	≈1.0§	

[†] From 1985Ga01, unless otherwise noted.

[‡] From 1980Gr09.

§ From 1984Ga37. Γ(7.2E2)=0.63 MeV 20, Γ(8.7E3)= 5.3 MeV 10.

From 1985Ga01, assumed by the authors for the extraction of C²S.

@ From comparison of experimental cross sections with DWBA predictions (1985Ga01).

& Spectroscopic factor C²S=(σ(θ)^{exp}/σ(θ)^{DWBA})/(N×g), where N=36 (1985Ga01) is the normalization factor and g=(2J_f+1)/(2J_i+1).

²⁰⁸Pb(⁷Li,α2nγ) ¹⁹⁷²Ha59,1978Be17

¹⁹⁷²Ha59: E=28-31.5 MeV ⁷Li beam was produced from the Chalk River MP tandem accelerator. Target was 10 mg/cm² thick ²⁰⁸Pb. γ-rays were detected in a 45 cm³ Ge(Li) counters and back-scattered particles were detected by an annular detector. Measured Eγ, αγ-coin, Doppler-shift attenuation. Deduced levels, transition probabilities, T_{1/2}. Data reported here were taken at 31.5 MeV.

¹⁹⁷⁸Be17: E=32-44 MeV ⁷Li beam was produced from the Chalk River MP tandem accelerator. γ-rays were detected by two Ge(Li) detectors. Measured Eγ, Iγ, γγ-coin, γ(t). Deduced levels, Jπ, branchings, mixing ratios, T_{1/2}. Data reported here were taken at 36 MeV.

²⁰⁹Bi Levels

E(level) [†]	Jπ [†]	T _{1/2} [‡]	Comments
0.0	9/2-		configuration=π(1h _{9/2}) ⁺¹ .
897	7/2-		configuration=π(2f _{7/2}) ⁺¹ .
1609	13/2+		configuration=π(1i _{13/2}) ⁺¹ .
2444	1/2+	>2 ps	Jπ: from Adopted Levels. T _{1/2} : from 1547γ(t) assigned to 3156 level by 1972Ha59. See comment on 1547γ.
2493	3/2+	>2 ps	
2563	9/2+	0.014 ps 11	
2584	7/2+	0.31 ps 10	
2600	13/2+	0.44 ps 14	
2617	5/2+	>2 ps	
2741	15/2+	>2 ps	T _{1/2} : other: 7 ps +4-2 from B(E3)↓(2741γ)=0.065 20 in 1978Be17.
2826	5/2-	<0.014 ps	configuration=π(2f _{5/2}) ⁺¹ .
2986	19/2+	18 ns 1	g=0.368 8. E(level),Jπ: from 1978Be17. T _{1/2} : weighted average of values from 245γ(t), 1133γ(t), 2741γ(t), 992γ(t) and 1608γ(t) (1978Be17). g: from γ(0,H,t) (1978Be17).
3120	3/2-	0.021 ps 14	configuration=π(3p _{3/2}) ⁺¹ .

[†] From 1972Ha59, unless otherwise noted.

[‡] From 1972Ha59 by Doppler-shift attenuation method (DSAM), unless otherwise noted.

γ(²⁰⁹Bi)

E(level)	Eγ [†]	Iγ [‡]	Mult.§	δ§	α	I(γ+ce)	Comments
897	897	100					
1609	1609	100	M2+E3	+0.33 10	0.0127 5		Mult.: A ₂ =+0.47 2 (1978Be17). δ: alternate solution of +2.2 8 is ruled out since T _{1/2} (1609γ) deduced from B(E3) with this δ is inconsistent with the spin-rotation pattern of the 1609γ (1978Be17).
2444	1547	>80					Eγ: assigned by 1972Ha59 as deexciting a level at 3156. Reassigned by the evaluator as deexciting the 2444 level as determined in (t,2nγ).
2493	2493	>95					
2563	2563	>95					
2584	1687	68					
	2584	32					
2600	992		M1 (+E2)	-0.04 4	0.0196		Mult.: A ₂ =+0.27 4 (1978Be17). δ: alternate solution (+0.63 7) is ruled out by 1978Be17 based on a comparison of the experimental B(E2) for each δ solution with the value from a weak-coupling calculation.
2617	1720	60					
	2617	40					

Continued on next page (footnotes at end of table)

²⁰⁸Pb(⁷Li,α2nγ) 1972Ha59,1978Be17 (continued)
γ(²⁰⁹Bi) (continued)

E(level)	Eγ [†]	Iγ [‡]	Mult.§	δ§	α	I(γ+ce)	Comments
2741	140.13					26 2	Eγ: from Adopted Gammas. Not seen directly in (⁷ Li,α2nγ) but presence deduced from γγ (1978Be17). I(γ+ce): from intensity balance at 2600 level in delayed spectrum, I(γ+ce)=48 2 relative to Iγ(1133+2741γ's)=135 6 (1978Be17). Iγ: from I(γ+ce) and α one gets Iγ=9.6 4 for mult=E2 and 5.1 3 for mult=M1. Mult.,8: A ₂ =-0.01 5, A ₄ =-0.02 3 (1978Be17). Mult.: A ₂ =+0.42 3 (1978Be17).
	1133	30 2	M1+E2	+0.14 4	0.0138		
	2741	44 4	E3		0.00243		
2826	1930	40					
	2826	60					
2986	245	100	E2		0.226		Mult.: A ₂ =+0.26 3 (1978Be17). Eγ: from level energy difference. Iγ: transition not seen. Limit is from 1978Be17.
	384	<1					
3120	2224	>95					

[†] From 1972Ha59, except for the transitions from the 2986 level which are taken from 1978Be17.

[‡] From 1972Ha59, except for those for the 2741 and 2986 levels which are from 1978Be17.

[§] From 1978Be17, based on γ(θ).

²⁰⁸Pb(⁷Li,⁶He),(pol ⁷Li,⁶He) 1979Ze03,1993Yo01,1998Mo02

1979Ze03: E=52 MeV ⁷Li beam was produced from the Australian National University 14 UD Pelletron accelerator. Target was enriched ²⁰⁸Pb (>99%) metal with a thickness of about 100 μg/cm² on a thin carbon backing. Reaction products were momentum analyzed with an Enge spectrograph and detected by a resistive-wire gas proportional detector, FWHM=70 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

1993Yo01: E=30 MeV/nucleon ⁷Li beam was produced from the K500 superconducting cyclotron at Michigan State University. Target was an enriched (99.14%) self-supporting 5.84 mg/cm² thick ²⁰⁸Pb metal. Reaction products were momentum analyzed with the S320 broad range magnetic spectrograph and detected by the focal plane detector system, FWHM= 1MeV. Measured σ(θ). Deduced levels, widths.

1998Mo02: E=33 MeV polarized beam was produced from the Daresbury Tandem. Target was 150 μg/cm² self-supporting ²⁰⁸Pb. Reaction products were detected with an array of six silicon telescopes. Measured σ(θ), analyzing powers. Deduced spectroscopic factors.

For a preliminary report on a search for high-J orbitals, see 1988BeZY.

²⁰⁹Bi Levels

E(level) [†]	Jπ [§]	S [‡]	Comments
0.0	9/2-	1.40	S: if configuration=π(1h _{9/2}) ⁺¹ .
896	7/2-	1.19	S: if configuration=π(2f _{7/2}) ⁺¹ , 1.01 10 from 1998Mo02.
1609	13/2+		E=1.4 MeV, Γ=0.7 MeV (1993Yo01).
2826	5/2-	1.07	S: if configuration=π(2f _{5/2}) ⁺¹ , 0.75 4 from 1998Mo02 for unresolved 2826+3120.
3120	3/2-	0.89	S: if configuration=π(3p _{3/2}) ⁺¹ , 0.75 4 from 1998Mo02 for unresolved 2826+3120.
3633	1/2-	0.64	S: if configuration=π(3p _{1/2}) ⁺¹ , 0.54 4 from 1998Mo02.
4400			E(level): doublet from 1998Mo02. S: 0.49 10 for the component with configuration=π(3p _{1/2}) ⁺¹ , 0.10 9 for the component with configuration=π(2f _{7/2}) ⁺¹ (1998Mo02).
8400			E(level): from 1993Yo01.

[†] Rounded-off values from Adopted Levels.

[‡] From DWBA analysis in 1979Ze03.

[§] From Adopted Levels.

²⁰⁸Pb(¹¹B, ¹⁰Be) ¹⁹⁷⁴Fo22

¹⁹⁷⁴Fo22: E=72.2 MeV ¹¹B beam was produced from the Oak Ridge isochronous cyclotron. Target was 100 µg/cm² ²⁰⁸Pb evaporated onto a 40 µg/cm² carbon foil. Reaction products were momentum analyzed with an Elbek spectrograph and detected by a proportional counter, FWHM=185-250 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

Other:

²⁰⁰³Sa54: E=69 MeV beam was produced from the 14 UD BARC-TIER Pelletron accelerator at Mumbai. ΔE-E silicon detector telescopes. Measured σ(θ). Deduced target shell closure effect.

²⁰⁹Bi Levels

E(level) [†]	S [‡]	Comments
0.0	0.47, 0.70	S: if configuration=π(1h _{9/2}) ⁺¹ .
900	0.51, 0.67	S: if configuration=π(2f _{7/2}) ⁺¹ .
1610	0.60, 0.81	S: if configuration=π(1i _{13/2}) ⁺¹ .
2820	0.35, 0.47	S: if configuration=π(2f _{5/2}) ⁺¹ .
3120	0.58, 0.74	S: if configuration=π(3p _{3/2}) ⁺¹ .

[†] From ¹⁹⁷⁴Fo22.

[‡] Calculated using finite-range DWBA with neutron parameters deduced from sub-Coulomb stripping measurements. S(¹¹B=¹⁰Be+p) is taken to be 0.43. The pairs of values shown are based on two different sets of ¹¹B optical-model parameters. See also ¹⁹⁷⁵Lo02 for further analysis of the data of ¹⁹⁷⁴Fo22.

²⁰⁸Pb(¹²C, ¹¹B) ¹⁹⁷⁶To08, ¹⁹⁸⁸Me04

¹⁹⁷⁶To08: E=77.4, 97.9, 116.4 MeV ¹²C beams were produced from the Oak Ridge isochronous cyclotron. Target was a 100 µg/cm² ²⁰⁸Pb evaporated onto a 40 µg/cm² carbon foil. Reaction products were momentum analyzed with an Elbek spectrograph and detected by position-sensitive proportional counters at the focal plane, FWHM=250 keV at E=97.9 MeV (estimated by evaluators). Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

¹⁹⁸⁸Me04: E=480 MeV ¹²C beam was produced from the GANIL cyclotron. Target was 1.7 mg/cm² thick 99% enriched ²⁰⁸Pb foil. Reaction products were momentum analyzed with the energy-loss magnetic spectrometer SPEG, FWHM=200 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

Others: ¹⁹⁷²La38, ¹⁹⁷³Ko09, ¹⁹⁸⁴Vo06, ¹⁹⁸⁹Wi07, ²⁰⁰¹Sa41.

²⁰⁹Bi Levels

E(level) [†]	S [‡]	Comments
0.0	0.84	S: if configuration=π(1h _{9/2}) ⁺¹ . Other: 0.48 (¹⁹⁸⁸ Me04).
900	0.81	S: if configuration=π(2f _{7/2}) ⁺¹ . Other: 0.66 (¹⁹⁸⁸ Me04).
1610	0.75	S: if configuration=π(1i _{13/2}) ⁺¹ . Other: (0.70) (¹⁹⁸⁸ Me04).
2820	0.54	S: if configuration=π(2f _{5/2}) ⁺¹ . Other: 0.80 (¹⁹⁸⁸ Me04).
3120	0.69	S: if configuration=π(3p _{3/2}) ⁺¹ .
3640?		E(level): tentative peak. Possible π(3p _{1/2}) ⁺¹ state seen at 3633 in (³ He,d).
3870	0.017	S: for configuration=π(1i _{13/2}) ⁺¹ as suggested by ¹⁹⁸⁵ Ga01 in (α,t) (at E=3835).
4270	0.063	S: for configuration=π(1j _{15/2}) ⁺¹ as suggested by ¹⁹⁸⁵ Ga01 in (α,t). Peak is probable multiplet consisting of the 4174, 4247, and 4543 levels reported in (α,t).
4990	0.021	S: for configuration=π(1j _{15/2}) ⁺¹ as suggested by ¹⁹⁸⁵ Ga01 in (α,t). Peak is probable doublet consisting of 4886 and 4998 levels reported in (α,t).
5440	0.018	S: for configuration=π(1j _{15/2}) ⁺¹ . Peak is probable multiplet consisting of 5277 and 5380 (configuration=π(1j _{15/2}) ⁺¹) and 5469 and 5580 (configuration=π(1i _{11/2}) ⁺¹), with configurations as suggested by ¹⁹⁸⁵ Ga01 in (α,t).

[†] Values below 3800 are from ¹⁹⁷⁶To08. Values for higher levels are from ¹⁹⁸⁸Me04. In addition to the resolved peaks listed here, broad structures are observed around an excitation energy of 10 MeV in the spectra of ¹⁹⁸⁸Me04.

[‡] From ¹⁹⁷⁶To08 for E(level)<3800. Values are from E=97.9 MeV data with S(¹²C=¹¹B+p)=2.85, a theoretical estimate. Authors also quote spectroscopic values for E=77.4 and 116.4 MeV. Values for higher levels are from ¹⁹⁸⁸Me04 and are normalized to the theoretical value of 0.70 for the 1610 level (¹⁹⁷³Ri13). Values from ¹⁹⁸⁸Me04 for the lower levels are given in comments.

²⁰⁸Pb(¹⁶O,¹⁵N) 1978Pi09

1978Pi09,1978O102: E=104, 138.5, 216.6 and 312.6 MeV ¹⁶O beams were produced from the Lawrence Berkeley Laboratory 88-inch cyclotron. Targets were 95% enriched ²⁰⁸Pb of 100–200 μg/cm² thicknesses on carbon backings. Reaction products were momentum analyzed in a magnetic spectrometer and detected in a focal-plane detector system, FWHM=180–240 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis. See also 1972I01.

1973Ko09: E=104,140 MeV ¹⁶O beams were produced from the Berkeley 88-inch cyclotron. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis.

1987Me05,1986Be41: E=793 MeV ¹⁶O beam was produced from GANIL facility. Target was 300 μg/cm² ²⁰⁸Pb on a carbon backing. Reaction products were momentum analyzed with the energy-loss magnetic spectrometer, FWHM=215 keV. Measured σ(θ). Deduced levels, spectroscopic factors from DWBA analysis. See also 1989Bi01.

1989Bi01: E=95 MeV/nucleon at GANIL. Energy loss spectrometer(SPEG). Measured σ(E,θ). Deduced levels.

Others: 1977O101, 1977Vi02, 1972Ko32, 1971Ba84.

²⁰⁹Bi Levels

E(level) [†]	S [‡]	Comments
0.0	0.95	S: if configuration=π(1h _{9/2}) ⁺¹ .
896	0.74	S: if configuration=π(2f _{7/2}) ⁺¹ .
1609	0.61	S: if configuration=π(1i _{13/2}) ⁺¹ .
2826	0.61	S: if configuration=π(2f _{5/2}) ⁺¹ .
3119	0.55	S: if configuration=π(3p _{3/2}) ⁺¹ .
3634	0.52	S: if configuration=π(3p _{1/2}) ⁺¹ .

[†] Rounded-off values from Adopted Levels.

[‡] From 1978Pi09 normalized to the theoretical value of 0.95 for the ground state (1973Ri13. See also 1978O102). Others: 1973Ko09, 1987Me05.

²⁰⁸Pb(³²S,Xγ) 1993Co01

1993Co01: E=185 MeV ³²S beam was produced from the XTU Tandem accelerator. A target of 500 μg/cm² enriched ²⁰⁸Pb was used. The projectile-like particles were detected with a multiparametric ΔE–E ionization chamber and γ-rays were detected by four Compton-suppressed Ge detectors. Measured γ(fragment)–coin. Deduced levels, population strengths.

²⁰⁹Bi Levels

E(level)	Jπ [†]
0.0	9/2–
896	7/2–
1608	13/2+

[†] From Adopted Levels.

γ(²⁰⁹Bi)

Eγ	E(level)	Comments
896.6	896	dσ/dΩ=2.0 2 (mb/sr).
1608.5	1608	dσ/dΩ=0.8 2 (mb/sr).

209Bi(γ, γ') 1980Ch22, 1977Co10, 1974Sw05

1980Ch22: source=bremsstrahlung from electron beams produced from the University of Illinois accelerator MUSL-2. A 10 cm square target of ²⁰⁹Bi was used. γ -rays were detected by a 55 cm³ Ge(Li) detector. Measured E γ , I γ . Deduced levels, J, widths.

1977Co10: source=bremsstrahlung from electron beams produced from MUSL-1. A square sample of target ²⁰⁹Bi was used. γ -rays were detected by a 50 cm³ Ge(Li) detector. Measured E γ , I γ , resonance fluorescence. Deduced levels, widths.

1974Sw05: source=bremsstrahlung from electrons produced from the Bartol accelerator. γ -rays were detected by a 45 cm³ Ge(Li) detector. Measured E γ , I γ , resonance fluorescence yields. Deduced levels, widths.

1969Me21: source=bremsstrahlung with electron beams from the Bartol Van de Graaff accelerator. γ -rays were detected by a 40 cm³ Ge(Li) detector. Measured E γ , I γ . Deduced levels, widths.

Others:

1967Gi15: source=⁴⁷Ti(n, γ).

1969Be71: source=⁴⁷Ti(n, γ).

1969Ce02: source=⁶³Cu(n, γ).

1969Ra09: source=⁷⁶Se(n, γ).

1971Be22: source=Ti(n, γ).

1972Wo21: source=I(γ +ce)(n, γ).

1973Ak04: source=⁷⁶Se(n, γ).

1973Me07: source=⁵⁹Co(n, γ).

1973Ha38: source=bremsstrahlung.

1973Sw01: source=Doppler-broadened γ 's from ¹⁹F(p, $\alpha\gamma$).

1974Te01: source=⁵⁹Co(n, γ).

1974Wo05: source=Cu(n, γ).

1977Ja13: source=Fe(n, γ) with Cd and Pb scatterers.

1979La01: source=bremsstrahlung.

1980Sh12: source=bremsstrahlung.

1983Ru03, 1979Ru01: source=Ni(n, γ), Cr(n, γ).

1983Ka26: source=Fe(n, γ).

1987Ka43: source=cadmium-109.

1988Da20: source=bremsstrahlung.

1989No03, 1986No06: source=Ni(n, γ).

1994Ka27: source=Ni(n, γ), deduced GDR parameters.

2009HeZW: E=11-30 MeV polarized γ , deduced yields, isovector giant dipole resonance (IVGDR).

2011He18: E=15-26 MeV polarized γ , deduced IVGQR.

209Bi Levels

ϵ , as used below, is defined as the energy difference between the source γ and the excited level.

E(level) [†]	J π	$g\Gamma(\gamma_0)^2/\Gamma^\oplus$	Comments
0.0	9/2-		J π : from Adopted Levels.
896			E(level): rounded-off value from Adopted Levels.
2563 1			$\Gamma(\gamma_0)^2/\Gamma=3.0E-2$ eV 5 (1969Me21) for J=9/2.
2583			$\Gamma(\gamma_0)^2/\Gamma$ LE 0.005 eV (1969Me21) for J=7/2.
2598 2			$\Gamma(\gamma_0)^2/\Gamma=0.0090$ eV 24 (1969Me21) for J=11/2 using.
2826		0.034 $\&$ 4	$\Gamma(\gamma_0)^2/\Gamma=0.699$ eV 25 for J=5/2.
3980 4		0.82 $\&$ 8	
4085		0.28 $\&$ 3	
4144		0.07 $\&$ 2	
4156		0.21 $\&$ 4	
4176		0.21 $\&$ 4	
4206		0.25 $\&$ 3	
4228? $\frac{3}{2}^+$ 5		=3 ^b	
4501? $\frac{3}{2}^+$ 5		=3 ^b	
4757 2		2.8 ^a 4	
4797 2		2.9 ^a 5	
4831 2		1.4 ^a 2	
5183? 4		0.9 3	
5236 2		1.4 3	
5281 2		5.5 11	
5293 2		2.2 6	$g\Gamma(\gamma_0)^2/\Gamma$: $g\Gamma(\gamma_0)^2/\Gamma=12$ 6 for E=5293 keV 5 (1977Co10). This probably includes the 5281-keV and 5293-keV levels.
5314 2		3.0 9	
5354 4		3.3 8	
5410 ^s		3.3 8	$g\Gamma(\gamma_0)^2/\Gamma$: $g\Gamma(\gamma_0)^2/\Gamma=8$ 4 for E=5422 keV 5 (1977Co10).
5424? 4		1.7 5	
5440 4		1.6 5	
5462 4		1.4 4	

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²⁰⁹Bi(γ,γ') 1980Ch22,1977Co10,1974Sw05 (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	Jπ	gΓ(γ ₀) ² /Γ [@]	Comments
5485 2		4.0 ^c 8	
5497 2		4.8 ^c 9	
5509§		6.8 ^c 12	
5536§		4.4 10	gΓ(γ ₀) ² /Γ: gΓ(γ ₀) ² /Γ=7 3 for E=5549 keV 5 (1977Co10).
5554 2		2.6 8	
5573 4		1.7 10	
5590 2		3.2 9	
5609 5	11/2-#		Γ=0.95 eV 20; Γ(γ ₀)/Γ=1 (1974Te01).
5662 2		1.6 4	
6392 8			
6556			
6911? 4		2.4 5	
6945? 4		2.1 6	
6983 4		2.6 5	
7106? 4		1.0 3	
7168	9/2+ [#]		Γ(γ ₀)/Γ=1.0; Γ(γ ₀)=0.82 eV 4 (1972Wo21). Others: 1967Gi15, 1969Be71; ε<2 eV (1967Gi15), 4.5 eV 17 (1969Be71), 5.8 eV 8 (1972Wo21, as quoted by 1974Wo05).
7171 4		4.7 10	
7179? 5		24 5	E(level),gΓ(γ ₀) ² /Γ: from 1973Sw01. Level not confirmed by 1980Ch22.
7202? 5		30 5	E(level),gΓ(γ ₀) ² /Γ: from 1973Sw01. Level not confirmed by 1980Ch22.
7246 4		3.7 8	
7264 4		2.4 9	
7279			gΓ _{γ0} =0.043 eV 8; ε=196 eV (1977Ja13).
7279+x			E(level): x=200 eV based on ε(7279 level)=196 eV, deduced from an absorption spectrum, and ε(7279+x)=20 eV, deduced from a scattering experiment ε=20 eV (1977Ja13).
7287 4		2.6 7	
7360 4		4.3 11	
7416	(9/2)		Jπ: from 1969Ra09 based on γ(θ). Γ(γ ₀)/Γ=0.65 30 (1973Ak04), 0.6 2 (1969Ra09), weighted average=0.62 23; Γ(γ ₀)=0.14 eV 9 (1969Ra09), 0.16 eV 11 (1973Ak04), weighted average=0.15 eV 9; ε=3.4 eV 16 (1969Ra09), 4.5 eV 12 (1973Ak04), weighted average=4.1 eV 12.
7632	(9/2)		Jπ: from γ(θ) and γ(pol) in 1974Wo05. Γ(γ ₀)>0.03 eV; Γ>0.5 eV (1974Wo05); gΓ _{γ0} =0.092 eV 12 (1977Ja13); ε=404 eV (1977Ja13).
13450			E(level): from 1983Ru03. Giant dipole resonance. Other: 1964Ha33. Γ=3.97 MeV (1983Ru03).

[†] From E_γ. See the γ listing for sources. Where correspondence between data of 1977Co10 and 1980Ch22 needs to be made, as pointed out by 1980Ch22, their E_γ values are systematically ≈12 keV lower than those of 1977Co10.

[‡] From 1977Co10. Not confirmed by 1974Sw05 or 1980Ch22.

§ Probable unresolved multiplet (1980Ch22).

From deduced γ-ray transition multipolarities from γ(θ) and γ(pol) in 1972Wo21. Also see 1974Wo05 for E=7168 and 7637 levels.

@ Values are gΓ(γ₀)²/Γ in eV, where Γ(γ₀) is the γ decay width to the ground state and g=(2J+1)/(2J(g.s.)+1). Values are from 1980Ch22 except where noted otherwise, and are corrected for angular distributions under the assumption that the excitations are dipole.

& From 1974Sw05.

^a Weighted average of values of 1974Sw05 and 1980Ch22. 1977Co10 report Σ(gΓ(γ₀)²/Γ)=10 for levels at 4771, 4808, and 4845, which are probably the same as those at 4757, 4797, and 4831 reported by 1974Sw05 and 1980Ch22.

^b From 1977Co10. Authors state uncertainty is in excess of 50%.

^c Σ(gΓ(γ₀)²/Γ)=17 6 for 5485-5509 levels (1977Co10).

γ(²⁰⁹Bi)

Eγ [†]	E(level)	Mult.	Comments
2563 1	2563		E _γ : from 1969Me21.
2583 ^a	2583		E _γ : not seen in 1969Me21. Energy is rounded-off value from Adopted Levels.
2598 2	2598		E _γ : from 1969Me21.
2826§	2826		
3980 4	3980		
4085§	4085		
4144§	4144		
4156§	4156		

Continued on next page (footnotes at end of table)

²⁰⁹Bi(γ,γ') 1980Ch22,1977Co10,1974Sw05 (continued)

γ(²⁰⁹Bi) (continued)

Eγ [†]	E(level)	Mult.	Comments
4176§	4176		
4206§	4206		
4228&c 5	4228?		
4501&c 5	4501?		
4757# 2	4757		
4797# 2	4797		
4831# 2	4831		
5183c 4	5183?		
5236 2	5236		
5281 2	5281		
5293 2	5293		
5314 2	5314		
5354 4	5354		
5410‡	5410		
5424c 4	5424?		
5440 4	5440		
5462 4	5462		
5485 2	5485		
5497 2	5497		
5509‡	5509		
5536‡	5536		
5554 2	5554		
5573 3	5573		
5590 2	5590		
5609 5	5609	M1b	Eγ: from 1973Me07. 1974Te01 report 5603 keV.
5662 2	5662		
6382@	7279+x		
6392 8	6392		Eγ: from 1969Ce02.
6556	6556		Eγ: from 1974Wo05.
6911c 4	6911?		
6945c 4	6945?		
6983 4	6983		
7106c 4	7106?		
7168	7168	E1b	Eγ: from 1972Wo21. 1969Ra09 report 7149. Mult.: A ₂ =+0.20 2 (1972Wo21,1974Wo05), +0.18 7 (1969Ra09). δ: <0.05 if J(7168 level)=9/2 (1972Wo21).
7171 4	7171		Eγ: 1969Ce02 report 7172 4, 1974Wo05 report 7176.
7179c 5	7179?		Eγ: from 1973Sw01. Not confirmed by 1980Ch22.
7202c 5	7202?		Eγ: from 1973Sw01. Not confirmed by 1980Ch22.
7246 4	7246		
7264 4	7264		
7279@	7279		
	7279+x		
7287 4	7287		
7360 4	7360		
7416	7416	(D)	Eγ: from 1969Ra09.
			Mult.: A ₂ =+0.20 3 (1969Ra09).
7632@	7632	(D)	Eγ: 1974Wo05 report 7637.
			Mult.: A ₂ =+0.24 4 (1974Wo05).

[†] From 1980Ch22 except where noted otherwise. No uncertainties are given in 1980Ch22 for Eγ and the evaluators have taken the values from those for level energies.

[‡] Probable unresolved multiplet (1980Ch22).

§ From 1974Sw05.

Other: 1974Sw05. Authors' original value should be increased by 11 keV (private communication from the authors, June 1977). The revised energy agrees well with the value of 1980Ch22.

@ From 1977Ja13.

& From 1977Co10. Transition not confirmed by 1974Sw05 or 1980Ch22.

^a Not seen in 1969Me21. Energy is rounded-off value from adopted Eγ data.

^b From γ(θ) and γ(pol) (1972Wo21).

^c Placement of transition in the level scheme is uncertain.

²⁰⁹Bi(γ,n) 1991Mo25

1991Mo25: E=7.637, 7.915 MeV γ-source was produced from the McMaster Nuclear Reactor. A 2.5 cm diameter, 4 cm long cylindrical target of metallic ²⁰⁹Bi was used. Neutrons were detected by a cylindrical ³He neutron detector, FWHM=15 keV for thermal neutrons and 17 keV at a neutron energy of 177 keV. Measured photoneutron spectra. Deduced J, π, widths, resonance σ, dynamic neutron source possibility for the level at 7637 keV.

Others:

1985Be55: E=7.5-12 MeV, source=bremsstrahlung. Measured cross sections and report resonances (Γ) at 7900 (160), 8200 (130), 8500 (130), 8800 (140), 9300 (190), 10100 (280), and 11300 (410).

1986Bi12: E=7-11.4 MeV, source=(n,γ). Measured angular distributions. Deduced the presence of strong E1-E2 (and possibly also E1-M1) interference effects from the asymmetries from the asymmetries.

1995Be61: E=7-26 MeV. Measured photoneutron yields. Deduced giant quadrupole resonances characteristics.

1979Ba06: E=9-9.7 MeV. Measured photoneutron spectrum.

²⁰⁹Bi Levels

E(level)	Jπ	Comments
7637	9/2+	Γ=40 eV +40-20, Γ ₀ =0.44 eV +40-20 (1991Mo25). 1991Mo25 observed two neutron groups at E _n =177 and 114 keV, with σ=275 mb 40 and 93 mb 14, respectively. Jπ: l _n =0 transitions to 5+ and 4+ states in ²⁰⁸ Bi.

²⁰⁹Bi(γ,p),(e,p): IAR 1981Ue02

E=17-23 MeV bremsstrahlung produced from the electron linear accelerator and the positive ion spectrometer facility of the Nuclear Science at Tohoku University. Measured σ(θ), E(e), E(p). Deduced decay modes for IAR.

Other: 1971Sh07.

²⁰⁹Bi Levels

E(level)	Jπ [†]	Comments
18700 100	9/2+	Γ _r =68 keV 15.
19500 100	(11/2+)	Γ _r =170 keV 26.

[†] From Adopted Levels.

²⁰⁹Bi(e,e'): Giant Resonance 1973Kl01

1973Kl01: E=101-245 MeV electron beams were produced from the Laboratoire de l'Accelérateur Lineaire, Orsay. Target was a 0.12 g/cm² thick ²⁰⁹Bi. Scattered electrons were momentum analyzed with a double-focusing spectrometer and detected with a single Cerenkov Counter, energy resolution=1.6%, θ=67°-81°, momentum transfer=0.8-1.5 fm⁻¹. Measured σ.

For (e,e') data for low-lying excitations see "inelastic scattering".

²⁰⁹Bi Levels

E(level)	Comments
0.0 ≈20000	Γ=8.0 MeV. Excitation form factor consistent with E0 or E2 excitation.

209Bi(e,n): Giant Resonance 1988Ca12

1988Ca12: E=8–22 MeV electrons were produced from the Sao Paulo Electron Linear Accelerator. A 99% enriched ²⁰⁹Bi target was used. Neutrons were detected by four BF₃ counters. Measured σ(E). Deduced transition strengths.

209Bi Levels

The authors conclude that the M1 strength lies below the neutron emission threshold.

E(level)	Comments
10900	Γ=2.7 MeV. %EWSR=50 30. Interpreted by authors as the isoscalar E2 giant resonance.
13450 10	Γ=3.89 MeV 3. Interpreted by authors as the E1 giant resonance.
20200?	Γ=6.0 MeV. %EWSR=200 90. Interpreted by the authors as the isovector giant resonance.

209Bi(n,n'γ) 1984Pr08,1996De48,2008Mi01

1984Pr08: E=reactor fast neutrons were produced from the McMaster University Reactor. Targets were cylindrical samples of ²⁰⁹Bi, 3.5 cm in diam. and 2.5 cm in length. γ-rays were detected by a spectrometer of a 28 cm³ intrinsic Ge detector surrounded by a quadrisected annulus of NaI detector of 15 cm long. Measured Eγ, Iγ. Deduced levels, Jπ, excitation probabilities.

1996De48: E=1.510–4.335 MeV neutrons were produced by the ⁷Li(p,n) and D(d,n) reactions with the pulsed proton beams from the 7 MV Van de Graaff accelerator of the Laboratori Nazionali di Legnaro. Target was 209 g ²⁰⁹Bi. γ-rays were detected by a true coaxial HPGe detector. Measured Eγ, Iγ, γ(t), σ(θ). Deduced levels, Jπ, T_{1/2}.

2008Mi01: E=threshold–20 MeV neutrons were produced from the Gelina facility. Target is 99.5% enriched ²⁰⁹Bi. γ-rays were detected by two large volume HPGe detectors at 110° and 150°. Measured Eγ, Iγ, σ. Deduced levels, branching ratios.

Others:

1961Gr34 (E=2.95 MeV), 1968Wi24 (E=1.8–2.5 MeV), 1971De46 (E=0.6–3.8 MeV), 1975De36 (E=14.7 MeV), 1977Di12 (E=5.4 MeV), 1982Wu02 (E=14.2 MeV), 1994Ch57 (E=radioactive),.

209Bi Levels

E(level) [†]	Jπ [#]	T _{1/2}	Comments
0.0	9/2–		Jπ: from Adopted Levels.
896.16 5	(7/2–)		
1608.57 7	(13/2+)		
2442.84 11	(1/2+)	11.3 ns 4	T _{1/2} : from 1546.7γ(t) (1996De48).
2493.02 10	(3/2+)		
2564.12 10	(9/2+)		
2583.04 8	(9/2+)		
2599.92 10	(11/2+)		
2601.17 12	(13/2+, 15/2+)		
2617.37 8	(5/2+)		
2741.20 8	(15/2+)		
2766.89 19	(3/2+)		
2826.14 15	(5/2–)		
2845.9 4	(1/2+)		
2917.6 6	(5/2+)		
2955.85 24	(3/2+)		
2986.9 5	(21/2–)	17.9 ns 5	T _{1/2} : from 1132.7γ(t) and 2741.1γ(t) from E=2741 level fed by 245.7γ (1996De48).
3039.07 12	(5/2+)		
3089.95 9	(9/2+)		
3119.4 5	(3/2–)		
3133.03 10	(13/2+)		
3135.88 12	(15/2+)		
3152.73 10	(9/2+)		
3154.6 5	(17/2+, 19/2+)		
3159.3 §			
3169.28 12	(11/2+)		
3197.4 §			
3211.9 §			
3221.7 4	(7/2+)		

Continued on next page (footnotes at end of table)

²⁰⁹Bi(n,n'γ) 1984Pr08,1996De48,2008Mi01 (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	Jπ [#]	E(level) [†]	E(level) [†]
3269.6 §		4009.3 4	4796.1 3
3310.75 8	(9/2+)	4036.5 4	4830.3 3
3354.8 §		4046.54 20	4837.6 3
3361.88 12	(3/2+)	4088.34 10	4853.46 20
3378.14 9	(9/2+)	4096.34 17	4879.37 19
3394.48 [‡] 12	(17/2+)	4134.0 20	4948.2 5
3394.90 [‡] 11	(7/2+, 9/2+)	4148.10 15	4967.6 15
3406.28 12	(11/2+)	4158.78 19	4996.2 3
3450.18 21	(3/2-)	4160.9 7	5056.7 6
3464.13 10	(9/2+)	4176.14 10	5167.3 3
3468.0 9		4207.5 4	5182.7 7
3489.58 17	(9/2-)	4222.9 7	5235.1 3
3502.2 §		4233.75 20	5281.9 11
3505.13 20	5/2-, 7/2-	4262.95 20	5293.4 6
3541.73 19	(5/2-)	4297.69 17	5312.6 13
3574.88 21	(7/2+)	4300.75 10	5354.0 4
3579.0 §		4335.3 3	5404.5 6
3597.1 §		4340.7 5	5411.2 6
3601.58 11	(9/2+, 11/2+)	4361.89 21	5424.62 25
3692.14 10	(11/2-)	4376.5 6	5440.2 10
3702.34? [‡] 10	(11/2+)	4381.19 21	5464.6 8
3703.2 [‡] 6	(7/2+, 9/2)	4388.04 19	5484.4 5
3717.64 10	(5/2+)	4397.85 20	5498.0 10
3752.1 3		4409.05 20	5510.53 25
3766.9 3	(5/2+)	4441.7 10	5523.4 5
3782.98 12	(7/2+, 9/2+)	4471.0 3	5538.3 7
3800.71 15	(11/2+)	4484.79 12	5559.5 6
3817.85 21	(11/2+, 13/2+)	4506.85 20	5570.6 7
3849.94 20	(7/2-)	4515.22 11	5589.2 7
3884.3 5		4587.9 6	5609.7 3
3889.5 3	(5/2+)	4602.6 13	5652.6 8
3905.8 3	(9/2+, 11/2+)	4646.1 3	5925.1 17
3921.22 10	(9/2+, 11/2+)	4681.9 8	6944.8 21
3936.74 10	(7/2-)	4750.71 17	7176.6 10
3962.21 22	(9/2-)	4755.76 20	7243.9 13
3980.04 10	(9/2-, 11/2-)	4762.2 3	
4000.71 15	(11/2-)	4789.8 4	

[†] From a least-squares fit to γ-ray energies.

[‡] Doublets at E=3395 and E=3702 proposed by 1996De48. The authors state that the intensities of the de-excitation γ-rays from each doublet can not be reproduced by the theoretical excitation functions if the deexciting γ-rays belong to a single level.

§ Rounded-off value from Adopted Levels.

From comparisons of the measured γ-yields with the theoretical predictions based on the statistical model of the compound nucleus in 1996De48, unless otherwise noted.

γ(²⁰⁹Bi)

Several transitions were assigned to specific levels by the authors of 1984Pr08 on the basis of previously known levels. In several cases, the adopted Jπ values now suggest that such placements are unlikely. In other cases, more precise level energies now available argue against the placement. The evaluators have reassigned these transitions as being unplaced. The individual cases are noted.

Eγ [†]	E(level)	I _γ &	% branching ^a	Comments
79.0@	2845.9		15	
110.5@ 5	2955.85		3	
123.7@ 5	2617.37		3	
131.7@	3221.7		9	
141.3	2741.20		7	
149.5@	2766.89		5	
150.7@ 5	2917.6			
167.7@	3154.6		6	
225.1@	3211.9			

Continued on next page (footnotes at end of table)

²⁰⁹ Bi(n,n'γ) 1984Pr08,1996De48,2008Mi01 (continued)				
γ(²⁰⁹ Bi) (continued)				
Eγ [†]	E(level)	Iγ&	% branching ^a	Comments
243.7@	3159.3		35	
245.7@ 5	2986.9			
265.7@ 5	3221.7		31	
270.4@	3406.28		19	
272.2@	3039.07		35	
273.9@	2766.89		35	
290.4@	3502.2			
313.7@	3468.0		20	
314.2@	3159.3		41	
324.0@	2766.89		55	
338.8@ 5	2955.85		10	
352.3@	3197.4			
392.6@	3159.3		24	
394.7@	3135.88		9	Iγ: I(394.7γ)/I(1527.3γ)=0.175 23 (2008Mi01).
403.7@ 5	2845.9		85	
413.4 5	3154.6	4 1	94	
423.7@	3269.6			
424.9@	3579.0		56	
443.2@	3597.1		16	
455.0@ 5	3221.7		60	
463.5@ 5	2955.85		71	
480.9@	3468.0		80	
513.0@	2955.85		2	
588.1@	3354.8			
592.2@	3579.0		44	
610.3@	3597.1		84	
664.1@ 5	3703.2			
806.4 7	3406.28	0.8 2	26	
808.0 10	3574.88	0.5 2	63	
896.2 1	896.16	100		
921.9 8	3505.13	0.8 2	72	
x949 2		0.4 3		
992.6 1	2601.17	15.9 3		
1132.7 1	2741.20	8.9 2	47	Iγ: I(1132.7γ)/I(2741.1γ)=0.771 35 (2008Mi01).
1253 1	3817.85	0.3 1	48	
1524.6@ 5	3133.03		29	
1527.3 1	3135.88	5.2 1	91	
1546.7# 1	2442.84	7.07 14		
1560.7 1	3169.28	3.62 9		
1608.6 1	1608.57	88.3 18		
1686.8 1	2583.04	4.5 1	69	
1721.2 1	2617.37	2.1 1	63	
1785.9 1	3394.48	1.39 8		
1797.7 1	3406.28	1.01 7	54	
1930.2 2	2826.14	0.65 5	30	Iγ: I(1930.2γ)/I(2825.9γ)=0.371 19 (2008Mi01).
2142.9 1	3039.07	1.26 4	65	
2193.9 2	3089.95	0.33 3	23	
x2199.9 2		0.45 3		
2209.3 2	3817.85	0.32 3	52	
2223.2@ 5	3119.4			
x2282.6 2		0.28 3		
x2356.9 8		0.1 2		
2391.8 2	4000.71	0.21 2	64	
x2398.5 2		0.22 2		
2414.7 1	3310.75	0.63 2	71	
2465.7 1	3361.88	0.5 2		
2482.0 2	3378.14	0.31 2	25	
2488.2 3	4096.34	0.17 2		
2493.0 1	2493.02	5.46 11		
2498.7 1	3394.90	0.79 2	80	
2539.6 2	4148.10	0.20 2		
2554.0 2	3450.18	0.21 2		
2564.1 1	2564.12	5.45 11		

Continued on next page (footnotes at end of table)

²⁰⁹Bi(n,n'γ) 1984Pr08,1996De48,2008Mi01 (continued)

γ(²⁰⁹Bi) (continued)

E _γ [†]	E(level)	I _γ &	% branching ^a	Comments
2583.1 1	2583.04	1.35 3	31	I _γ : I(2583.1γ)/I(1686.8γ)=0.468 18 (2008Mi01).
2593.6 2	3489.58	0.58 2	78	
2599.9 1	2599.92	6.80 14		
2609.0 2	3505.13	0.31 2	28	
2617.4 1	2617.37	1.05 2	34	
2645.3 2	3541.73	0.40 2	84	I _γ : I(2678.7γ)/I(808.0γ)=1.13 7 (2008Mi01).
^x 2671.4 12		0.02 2		
2678.7 2	3574.88	0.29 2	37	
2705.4 1	3601.58	0.60 2	94	
2726.7 3	4335.3	0.11 2		
2741.1 1	2741.20	10.62 21	46	E _γ : placed by 1996De48 and 2008Mi01, unplaced in 1984Pr08.
2753.3 2	4361.89	0.15 2		
^x 2762.6 4		0.09 2		
2766.9 2	2766.89	0.18 2	5	
2806.2 6	3702.34?	0.05 2	8	
2825.9 2	2826.14	1.35 3	70	
2855.9 3	3752.1	0.12 1		
2862.5 3	4471.0	0.18 1		
2876.2 1	4484.79	0.29 1		
2886.8 1	3782.98	0.43 1		
2904.5 2	3800.71	0.20 1	59	
2906.6 1	4515.22	0.31 1		
^x 2920.5 [‡] 1		0.28 1		
^x 2941.2 [§] 2		0.18 1		
2954.7 4	2955.85	0.17 1	14	
3009.6 3	3905.8	0.15 1	84	
3024.5 5	3921.22	0.056 11	20	
3066.1 3	3962.21	0.15 1	55	
3089.9 1	3089.95	1.71 4	77	
^x 3118.8 [‡] 8		0.035 10		E _γ : 1984Pr08 doesn't report a γ-ray of this energy, but in the Fig. 1 this paper, there is an apparent peak at this energy.
3133.0 1	3133.03	2.37 5	71	
3152.7 1	3152.73	2.08 4		
3181.1 5	4789.8	0.050 10		
^x 3225.5 [‡] 6		0.14 1		
3251.6 6	4148.10	0.041 9		
3262.8 5	4158.78	0.052 9		
^x 3282.6 3		0.078 9		
3310.6 1	3310.75	0.30 1	29	
^x 3328.6 4		0.059 8		
^x 3331.8 2		0.11 1		
^x 3341.7 5		0.053 8		
3378.1 1	3378.14	0.71 2	75	
3395.6@ 5	3394.90		20	
3401.6 3	4297.69	0.086 8		
^x 3455.9 7		0.030 8		
^x 3460.0 4		0.061 8		
3464.1 1	3464.13	0.94 2		
3485.0 2	4381.19	0.12 1		
3489.1 3	3489.58	0.21 1	22	
3491.9 2	4388.04	0.13 1		
^x 3499.3 6		0.038 7		
3542.7 4	3541.73	0.077 7	16	
3558.5 3	5167.3	0.090 7		
^x 3577.5 4		0.054 7		
^x 3581.2 2		0.10 1		
3601.7 6	3601.58	0.037 7	6	
^x 3607.2 [‡] 5		0.047 7		
^x 3632.9 [‡] 15		0.020 9		
3692.1 1	3692.14	0.60 1		
3702.3 1	3702.34?	0.55 1	92	
3717.6 1	3717.64	0.27 1		
3766.9 3	3766.9	0.067 6		

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209Bi(n,n'γ) 1984Pr08,1996De48,2008Mi01 (continued)**γ(209Bi) (continued)**

$E\gamma^{\dagger}$	E(level)	$I_{\gamma}^{\&}$	% branching ^a	$E\gamma^{\dagger}$	E(level)	$I_{\gamma}^{\&}$
^x 3774.8 6		0.031 6		4587.8 6	4587.9	0.024 3
3785.4 16	4681.9	0.025 8		^x 4590.8 7		0.020 3
3800.7 2	3800.71	0.14 1	41	4602.5 13	4602.6	0.010 3
3815.9 4	5424.62	0.051 6		^x 4606.0 2		0.060 4
3849.9 2	3849.94	0.19 1		4627.0 5	5523.4	0.025 3
3854.4 2	4750.71	0.15 1		4641.8 8	5538.3	0.017 3
3866.0 3	4762.2	0.058 6		4646.0 3	4646.1	0.041 3
3884.3 5	3884.3	0.041 6		^x 4650.4 3		0.057 3
3889.5 3	3889.5	0.070 6		4663.0 7	5559.5	0.040 3
3902.0 4	5510.53	0.046 6		4682.0 9	4681.9	0.015 3
3905.9 7	3905.8	0.028 6	16	^x 4685.9 5		0.025 3
3921.2 1	3921.22	0.22 1	80	^x 4691.4 $\frac{1}{2}^{\pm}$ 3		0.040 3
3936.7 1	3936.74	0.19 1		^x 4702.2 $\frac{3}{2}^{\pm}$ 4		0.032 3
3941.4 6	4837.6	0.033 5		4713.5 3	5609.7	0.054 3
3962.1 3	3962.21	0.18 1	45	4750.9 3	4750.71	0.050 3
^x 3977.3 1		0.23 1		4755.7 2	4755.76	0.067 3
3980.0 1	3980.04	0.45 1		4762.2 5	4762.2	0.026 3
3983.1 2	4879.37	0.12 1		^x 4766.7 3		0.051 3
^x 3993.2 5		0.038 5		^x 4780.3 5		0.025 3
4001.0 2	4000.71	0.12 1	36	4790.0 6	4789.8	0.050 4
^x 4004.6 2		0.11 1		4796.0 3	4796.1	0.042 3
4009.3 4	4009.3	0.053 5		^x 4801.7 3		0.041 3
^x 4033.0 5		0.038 5		^x 4823.4 8		0.015 3
4036.5 4	4036.5	0.041 5		4830.2 3	4830.3	0.053 3
4046.5 2	4046.54	0.081 5		4837.5 3	4837.6	0.047 3
4051.8 5	4948.2	0.063 5		^x 4848.5 $\frac{1}{2}^{\pm}$ 6		0.022 3
^x 4061.8 2		0.15 1		4853.4 2	4853.46	0.066 3
4088.3 1	4088.34	0.22 1		4879.6 4	4879.37	0.032 3
4096.1 2	4096.34	0.32 1		^x 4912.9 $\frac{3}{2}^{\pm}$ 6		0.020 3
^x 4107.3 4		0.045 5		^x 4923.7 4		0.034 3
4134.2	4134.0	0.011 5		^x 4928.5 3		0.042 3
4148.0 2	4148.10	0.15 1		4948.6 8	4948.2	0.025 3
4158.7 2	4158.78	0.24 1		4967.5 15	4967.6	0.016 4
4160.9 7	4160.9	0.03 1		^x 4985.2 7		0.016 3
4176.1 1	4176.14	0.25 1		4996.1 3	4996.2	0.040 3
^x 4180.4 2		0.12 1		^x 5002.3 2		0.058 3
^x 4195.9 4		0.044 5		^x 5012.4 4		0.032 3
4207.5 4	4207.5	0.23 1		^x 5031.0 3		0.044 3
4222.9 7	4222.9	0.025 5		^x 5035.3 9		0.012 3
4233.7 2	4233.75	0.11 1		5056.6 6	5056.7	0.020 3
^x 4237.7 2		0.10 1		^x 5074.9 5		0.023 3
^x 4248.2 2		0.086 5		^x 5096.6 8		0.014 2
4262.9 2	4262.95	0.095 5		^x 5145.2 5		0.024 2
^x 4281.4 $\frac{1}{2}^{\pm}$ 3		0.10 1		^x 5154.8 5		0.019 2
4297.6 2	4297.69	0.069 4		^x 5163.9 3		0.044 2
4300.7 1	4300.75	0.15 1		5167.6 5	5167.3	0.023 2
^x 4304.6 2		0.087 4		5182.6 7	5182.7	0.017 2
4340.7 5	4340.7	0.026 4		^x 5197.4 6		0.019 2
^x 4354.4 $\frac{1}{2}^{\pm}$ 5		0.029 4		^x 5204.5 7		0.016 2
4376.5 6	4376.5	0.024 4		^x 5209.6 4		0.029 2
4387.7 5	4388.04	0.029 4		^x 5217.6 $\frac{1}{2}^{\pm}$ 3		0.043 2
4397.8 2	4397.85	0.071 4		5235.0 3	5235.1	0.037 2
4409.1 2	4409.05	0.077 4		^x 5245.9 5		0.021 2
^x 4414.1 4		0.035 4		^x 5278.6 4		0.032 2
4441.6 10	4441.7	0.015 4		5281.8 11	5281.9	0.010 2
^x 4454.6 9		0.017 4		5293.3 6	5293.4	0.020 2
4470.5 6	4471.0	0.035 4		5312.5 13	5312.6	0.018 3
4506.8 2	4506.85	0.083 4		^x 5331.3 9		0.012 2
^x 4511.0 9		0.016 4		5353.9 4	5354.0	0.030 2
4515.3 2	4515.22	0.062 4		^x 5358.4 11		0.010 2
^x 4550.2 3		0.042 4		^x 5361.5 $\frac{1}{2}^{\pm}$ 12		0.008 2
^x 4570.4 3		0.042 4		^x 5371.8 $\frac{3}{2}^{\pm}$ 7		0.014 2
^x 4578.6 8		0.070 5		^x 5384.0 4		0.024 2

Continued on next page (footnotes at end of table)

209Bi(n,n'γ) 1984Pr08,1996De48,2008Mi01 (continued)**γ(209Bi) (continued)**

$E\gamma^\dagger$	E(level)	$I_\gamma\&$	$E\gamma^\dagger$	E(level)	$I_\gamma\&$
5404.4 6	5404.5	0.017 2	5589.1 7	5589.2	0.015 2
5411.1 6	5411.2	0.018 2	^x 5602.5 7		0.015 2
5424.6 3	5424.62	0.041 2	^x 5621.2 7		0.014 2
5440.1 10	5440.2	0.010 2	5652.5 8	5652.6	0.012 2
5464.5 8	5464.6	0.013 2	^x 5792.4 7		0.012 2
5484.3 5	5484.4	0.020 2	^x 5820.2 7		0.012 2
5497.9 10	5498.0	0.010 2	^x 5846.1 5		0.017 2
5510.4 3	5510.53	0.032 2	5925.0 17	5925.1	0.010 3
5523.9 9	5523.4	0.011 2	6944.7 21	6944.8	0.003 1
5538.7 10	5538.3	0.010 2	7176.5 10	7176.6	0.008 1
5559.8 8	5559.5	0.025 3	7243.8 13	7243.9	0.005 1
5570.5 7	5570.6	0.013 2			
^x 5580.9 5		0.020 2			

[†] Values with uncertainties are deduced by evaluators from the recoil-corrected energies quoted in 1984Pr08 and those without uncertainties are from level-energy differences, unless otherwise noted.

[‡] Placed by 1984Pr08 as a ground-state transition.

[§] Placed by 1984Pr08 as feeding the first-excited state.

[#] The 1547γ was assigned by 1984Pr08 to a level at 3154; however, the branching relative to the 413γ is not consistent with data from (t,2nγ). Also, Iγ(1546.7) from (t,2nγ) at 13 and 16 MeV are not consistent with placement from the 3154 level. The 1546.7γ is assigned in (t,2nγ) as feeding the first-excited state, and coincidence data in that reaction exhibit no evidence for a 3154 to 1608 cascade. 1996De48 place the transition from the 2442.8 level defining a level at 2442.8.

[@] From 1996De48. No uncertainties are given in 1996De48. The evaluators have assigned ΔE=0.5 keV to those γ energies measured by 1996De48. Values quoted without uncertainties are from level-energy differences.

[&] From 1984Pr08, unless otherwise noted. Some of the uncertainties as given in 1984Pr08 are too small. They should not be smaller than 2% (private communication from the first author). The evaluator has increased the uncertainty to 2% where the published uncertainty is smaller than this value.

^a % branching from each level (1996De48).

^x γ ray not placed in level scheme.

209Bi(p,p') 1975Wa03,1974Cl07,1974Cl06

Target Jπ(209Bi)=9/2-.

1975Wa03: E=35 MeV proton beam was produced from the Michigan State University cyclotron. Thick bismuth targets were used. Scattered protons were momentum analyzed by an Enge split-pole spectrometer and detected in the focal plane detectors, FWHM=5-10 keV, θ=10° to 100°. Measured σ(θ). Deduced levels, L, β_L from DWBA analysis.

1974Cl07: E=14.95, 16.10 MeV proton beams were produced from the Yale MP tandem Van de Graaff. A self-supporting 185 μg/cm² target was used. Scattered protons were momentum analyzed by a multi-gap magnetic spectrograph and detected in nuclear emulsions, FWHM=5-7 keV. Measured σ(θ). Deduced levels, L, β_L from DWBA analysis. See also 1974Cl06.

1974Cl06: E=14.0-15.5 MeV proton beams were produced from the Yale MP tandem Van de Graaff. A self-supporting 350 μg/cm² target was used. Scattered protons were detected by silicon surface-barrier detectors, FWHM=15 keV, θ=90°. Measured σ(θ). Deduced levels, Jπ.

1974Sc20: E=61.2 MeV proton beam was produced from the Oak Ridge Isochronous Cyclotron. A 12 mg/cm² target was used. Scattered protons were momentum analyzed with a broad-range spectrograph and detected in nuclear emulsions, FWHM=40-55 keV. Measured σ(θ). Deduced levels, β_L from collective model analysis.

1966Ha35: E=21 MeV proton beam was produced from the LASL three-stage Van de Graaff accelerator. Scattered protons were momentum analyzed with an Elbek magnetic spectrograph, FWHM=13 keV. Measured σ(θ). Deduced levels.

Others: 1985Se15, 1972Cl02, 1972Co05, 1971Be32, 1970Be15, 1970Fr08.

Data of 1974Cl07 and 1974Cl06 at 14.95 preferentially populate states of 209Bi through decay of the isobaric analogs of states in 210Bi. Based on this proton resonant and the non-resonant scattering data, 1974Cl06 suggest configurations of the type configuration=(²⁰⁸Pb(j'))(p,nlj)J for many of the states seen in (p,p'). See also 1972Cl02, 1972Co05.

209Bi Levels

E(level) [†]	L ^a	β _L ^d	Comments
0.0			
895.9 [‡]	(2)	0.013	L: 4+6 from 1974Sc20. σ(θ) could not be fit with the collective model assuming L=2 transfer. β ₄ =0.0125, β ₆ =0.0134 (1974Sc20).

Continued on next page (footnotes at end of table)

²⁰⁹Bi(p,p') 1975Wa03,1974Cl07,1974Cl06 (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	L ^a	β _L ^d	Comments
1608.1 [‡]	3	0.0230 13	B(E3)↑=2.7×10 ⁻² 3 (1974Sc20). β _L : from 1974Sc20, 0.027 from 1975Wa03. Others: =0.024 (1971Be32), 0.022 (1970Be15). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
2492& 1	3	0.026	configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
2564& 1	3	0.047	configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
2581& 2	3	0.041	configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
2599& 1	3	0.074	configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
2616& 2	3	0.035	B(E3)↑=0.50 5 (1974Sc20). β _L : Others: 0.11 1 (1971Be32) and 0.099 5 (1974Sc20) for a level at E=2650 30. configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
2740.4 [‡]	3	0.057	E(level): 2739 3 (1966Ha35). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
2766 2	(5)		L: L=4 (1975Wa03), L=5 (1974Cl07). β _L : 0.013 for L=4.
2825.1 [‡]	2 ^b		configuration=π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ (1974Cl07). E(level): 2826 4 (1974Cl07).
2847§ 4			configuration=π(1h _{9/2}) ⁺¹ ⊗2 ⁺ (1974Cl07).
2919§ 4			configuration=π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ (1974Cl07).
2956 3	3		configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07). L: L=(4) (1975Wa03), L=3 (1974Cl07). β _L : 0.014 for L=4.
2986 1	5	0.021	configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1974Cl07).
3038 2	5	0.013	configuration=π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ or π(1h _{9/2}) ⁺¹ ⊗5 ₂ ⁻ (1974Cl07).
3091 3	5	0.014	configuration=π(1h _{9/2}) ⁺¹ ⊗5 ⁻ (1974Cl07).
3118 2			3091 3 (1975Wa03), 3091 4 (1974Cl07).
3133.9 [‡]	5	0.036	E(level): 3135 4 (1974Cl07). configuration=π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ (1974Cl07).
3153.4 [‡]	5	0.032	E(level): Probable doublet, based on σ and on the observation that the excitation function appears to resonate at both the Jπ=8-,9- and Jπ=4-,5- isobaric analog resonances. 1974Cl07 report 3154 4. β _L : 0.050 5 from 1971Be32 for a level at E=3150 30. configuration=π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ or π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07).
3168 2	5	0.026	configuration=π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ (1974Cl07).
3211 1	5	0.020	configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ or π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ (1974Cl07).
3222§ 4			configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07).
3310 3	(3)	0.009	configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07).
3359 2			
3379§ 4			
3393§ 4			
3406§ 4			configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07).
3450§ 4			configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07).
3466@ 2	5	0.019	E(level): 3465 4 (1974Cl07). configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07).
3489§ 4			
3502 4			configuration=π(1h _{9/2}) ⁺¹ ⊗4 ⁻ (1974Cl07).
3543§ 4			
3579 3	5	0.012	β _L : 0.029 4 from 1971Be32 for a level at E=3560 50.
3597@ 2	5	0.020	E(level): 3597 4 (1974Cl07). configuration=π(1h _{9/2}) ⁺¹ ⊗5 ₂ ⁻ or π(1h _{9/2}) ⁺¹ ⊗5 ₁ ⁻ (1974Cl07).
3603§ 5			
3634 4			configuration=π(1p _{1/2}) ⁺¹ (1974Cl07).
3684 3	5	0.015	
3692§ 5			configuration=π(1h _{11/2}) ⁻¹ (1974Cl07).
3703# 4	5	0.015	
3719§ 5			
3735§ 5			
3753§ 5			
3765@ 3			E(level): 3763 5 (1974Cl07).
3803 4	(3)	0.013	
3815 2	(7,8)	0.031, 0.026	
3839@ 4			E(level): 3839 5 (1974Cl07).
3855 3			

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$^{209}\text{Bi}(\text{p},\text{p}')$ 1975Wa03,1974Cl07,1974Cl06 (continued) **^{209}Bi Levels (continued)**

E(level) [†]	L ^a	β_{L} ^d	Comments
3880 § 5			
3892 3			
3909 § 5			
3924 @ 5	(3)	0.013	E(level): 3919 5 (1974Cl07).
3937 § 5			
3950 § 5	(3)	0.012	
3962 § 5			
3982 3	2	0.033	β_{L} : 0.049 7 from 1971Be32 for a level at E=3960 50. configuration= $\pi(1\text{h}_{9/2})^{+1}\otimes 2^{+}$ (1974Cl07).
3998 § 5			
4013 5			
4038 § 7			
4048 5			
4079 § 7			
4092 4	2	0.027	configuration= $\pi(1\text{h}_{9/2})^{+1}\otimes 2^{+}$ or $\pi(2\text{f}_{5/2})^{+1}$ (1974Cl07).
4101 § 7			
4116 4	(7)	0.022	
4123 § 7			
4135 § 7			
4156 4	2	0.027	
4162 § 7	c		configuration= $\pi(1\text{h}_{9/2})^{+1}\otimes 2^{+}$ (1974Cl07).
4168 § 7	c		
4178 4	3	0.033	
4211 4			L: L=2 (1974Cl07), L=3 (1975Wa03). β_{L} : 0.029 for L=3. configuration= $\pi(1\text{h}_{9/2})^{+1}\otimes 2^{+}$ (1974Cl07).
4223 § 7			
4236 4			
4257 4			
4263 § 7			
4286 3	4	0.034	L, β_{L} : L=4+6 from 1971Be32, $\beta_4=0.071$ 7, $\beta_6=0.071$ 7 for a level at E=4290 50. The equality of β_4,β_6 is an assumption made by 1971Be32 in the analysis of their data.
4294 § 7			
4301 3	≈7	≈0.033	
4313 § 7			
4326 3			
4333 § 7			
4340 § 7			
4349 § 7			
4363 3	4	0.032	
4373 § 7			
4380 § 7			
4390 § 7			
4397 3			
4411 # 3	≈8	≈0.035	
4441 @ 4	4	0.017	
4469 @ 3			
4485 # 4			
4512 # 5			
4532 @ 4	≈8	≈0.021	
4592 # 6			
4613 @ 5			
≈4700 #			E(level): unresolved multiplet structure in region 4630–4745.
4760 @ 4			
4791 @ 6			
4828 # 5			
4853 # 5			
4949 @ 4			
4965 # 5			
4998 # 6			
5056 @ 5			
5131 @ 6	≈7	≈0.022	
5241 # 7	4		L: from 1971Be32 for a level at E=5200 50.

Continued on next page (footnotes at end of table)

²⁰⁹Bi(p,p') 1975Wa03,1974Cl07,1974Cl06 (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	Comments
5282# 5	
5312@ 5	
5333# 5	
5360@ 6	
5423@ 6	
5463# 5	
5509@ 6	
5569@ 10	
5769# 5	
5795@ 7	
5835@ 8	
≈6200	E(level): from 1971Be32, probable doublet.

[†] Weighted average of values from 1975Wa03 and 1974Cl07, unless otherwise noted. Energies from 1974Cl07 are relative to the 2741 keV level in ²⁰⁹Bi and energies from 1966Ha35 are relative to the 2615 keV level in ²⁰⁸Pb.

[‡] Energy used for calibration by 1975Wa03.

[§] From 1974Cl07 only.

From 1975Wa03 only.

@ Probable multiplet from 1975Wa03.

& Weighted average of values from 1975Wa03, 1974Cl07 and 1966Ha35.

^a From 1975Wa03 based on DWBA analysis. Data of 1975Wa03 and 1974Cl07 are in agreement except for three levels as noted.

^b From 1974Cl07.

^c L=2 for the 4162+4168 levels.

^d Data are β_L from 1975Wa03 where $(\beta_L)^2$ is the ratio of $\sigma(\text{exp})$ to $\sigma(\text{collective model})$. Other: 1974Cl07. For the 7 states with assumed configuration (²⁰⁸Pb 3-)(p,1h9/2)J (see Adopted Levels), the ratio $(\beta_3)^2/(\beta_3)^2(^{208}\text{Pb } 3-)=0.98$ 6. For the ten states with assumed configuration (²⁰⁸Pb 5-)(p,1h9/2)J (see Adopted Levels), the ratio $(\beta_5)^2/(\beta_5)^2(^{208}\text{Pb } 5-)=0.88$ 6.

²⁰⁹Bi(p,p'): Giant Resonance 1975Ma07

1975Ma07: E=155 MeV achromatic proton beam was produced Orsay synchrocyclotron. A target of 100 mg/cm² thick ²⁰⁹Bi was used. Scattered protons were detected in the image plane of a magnetic analyzer by means of a proportional chamber, FWHM=200-250 keV, $\theta=8^\circ-20^\circ$, momentum transfer=0.4-1 fm⁻¹. Measured $\sigma(E_p, \theta)$. Deduced giant resonances, level width.

Others: 1971Be32, 1972Le39.

²⁰⁹Bi Levels

E(level)	L [†]	β_L	Comments
0.0			
9000	(2)	0.028	% energy weighted E2 sum rule=9.
10700	(2)	0.047	$\Gamma=2.2$ MeV. <r ² > ^{1/2} =5.52 fm. % energy weighted E2 sum rule=29.

[†] From DWBA analysis.

²⁰⁹Bi(d,d') 1971Un01,1966Hi02

1971Un01: E=13.1 MeV deuteron beam, FWHM=3-10 keV. Measured $\sigma(\theta)$ at $\theta=120^\circ, 125^\circ, 150^\circ$. Deduced levels.

1966Hi02: E=13 MeV deuterons were produced from the Aldermaston tandem generator. Target was 300 $\mu\text{g}/\text{cm}^2$ ²⁰⁹Bi.

Scattered deuterons were momentum analyzed with a multi-range magnetic spectrograph. Measured $\sigma(E_d, \theta)$.

Deduced levels.

Other:

1968Hi09: E=52 MeV. Measured $\sigma(\theta)$. Deduced deformation parameters.

²⁰⁹Bi Levels

E(level) [†]	Comments
0.0	
900	
1605 [‡] 10	
2487 [‡] 10	
2558 [‡] 10	
2585	
2593 [‡] 10	$\beta_3=0.15$ (1968Hi09). E(level): $\Delta E < 1.6$ keV for separation of members of known 2600 doublet in 1971Un01.
2618	
2733 [‡] 10	
2768	
2828	
2977 [‡] 10	E(level): 2958 from 1971Un01.
2988	
3041	
3091	
3136	E(level): possible doublet because of large σ ; however, levels are not resolved. Energy separation < 3 keV.
3154	E(level): doublet with separation ≈ 4 keV. 3130 20 and 3150 20 from 1966Hi02.
3170	
3210 [‡] 20	E(level): 3213 from 1971Un01.
3308	
3379	
3407	
3466	

[†] From 1971Un01, unless otherwise noted.

[‡] From 1966Hi02.

²⁰⁹Bi(α, α'): Giant Resonance 1979Ha46

1979Ha46, 1977Ha08: E=120 MeV α beam was produced from the KVI cyclotron. A target of 3.40 mg/cm² self-supporting ²⁰⁹Bi, enriched to 99.99%, was used. Scattered α -particles were detected with a ΔE -E telescope of surface-barrier detectors, FWHM=20 keV at $E_\alpha=5.5$ MeV. Measured $\sigma(E_\alpha, \theta)$. Deduced resonances, isoscalar multipole strength from DWBA, collective analysis.

Others:

1997Fa19, 1999Fa19: E=240 MeV α beam was produced from the Superconducting Cyclotron K500 of the Texas A&M University. A target of 4.5 mg/cm² Bi was used. Charged particles, fission fragments, neutrons, and γ -rays were detected in coincidence with α particles by six ΔE -E silicon telescopes, a 4π neutron ball calorimeter, and germanium detectors, respectively. Measured E_α , multiplicities. Deduced GDR parameters vs excitation energy.

1988Ch10: E=50.5 MeV α was from the 224 cm variable-energy cyclotron at Calcutta. α -particles were detected by two Si detectors. Measured $\sigma(E_\alpha, \theta)$. Deduced optical model parameters, deformation lengths. Nearside-Farside decomposition, DWBA analysis, Notch test.

²⁰⁹Bi Levels

Data are from 1979Ha46. The same data are reported in 1978Va22, and a preliminary report is contained in 1977Ha08.

Other: 1978ChYN.

For (α, α') data for low-lying excitations see "inelastic scattering".

E(level)	L	Comments
0.0		
10900 300	2, 2+4	$\Gamma=2.7$ MeV 3, %EWSR=90-150 for L=2, or 50-150 (L=2) + 20-40 (L=4).
13700 300	0, 2, (4)	$\Gamma=2.0$ MeV 4, %EWSR=80-120 (L=0), 30-50 (L=2), with maximum contribution from L=4 giving %EWSR=15-30.

210Bi(d,t): Target=9- Isomer 1980C105Target ²¹⁰mBi J π =9-.

1980C105: E=17 MeV deuteron beam was produced from the Yale MP tandem accelerator. Target was 1.39 mg 99% enriched ²¹⁰mBi on a carbon backing. Tritons were momentum analyzed with a multigap spectrograph and detected on Ilford nuclear emulsion plates, FWHM=15-30. Measured $\sigma(\theta)$. Deduced levels, L, J-transfer, spectroscopic factors from DWBA analysis.

Other: 1960VI01.

209Bi Levels

The authors of 1980C105 suggest that the observed levels are two-particle one-hole states resulting from the coupling of the ²¹⁰Bi(9-) target, with dominant configuration= $\pi(1h_{9/2})^{+1} \otimes \nu(2g_{9/2})^{-1}$, with neutron hole states in ²⁰⁷Pb. They show that the centroids and summed spectroscopic factors for the levels resulting from probable p_{1/2}, p_{3/2}, f_{5/2}, and f_{7/2} transfers agree well with the energies and spectroscopic factors for the corresponding single particle states found in ²⁰⁸Pb(d,t).

E(level) [†]	L [#]	C ² S ^a	E(level) [†]	L [#]	C ² S ^a	E(level) [†]	L [#]	C ² S ^a
2741 5	1	0.14	3912 10	1	0.71	4417 10	1	0.14
2987 [‡]	1	0.98	3960 10			5058 10	3	0.15
3135 5			4002 10	1	0.35	5256 10	3	0.32
3154 5	1	0.61	4021 10			5367 10	3	0.41
3212 5	1	0.48	4065 10	1&	0.92&	5402 10	3	0.56
3469 [§] 5	3	0.27	4084 10	1&	0.92&	5464 10	3	0.83
3597 5	1, 3	0.17, 1.95	4122 10	1&	0.92&	5657 10	3	0.43
3735 10	3@	0.94	4225 10	1	0.14	5924 10	3	0.28
3764 10	1@	0.25	4263 10	1	0.21			
3818 10	3	1.58	4349 10	1	0.97			

[†] Relative to E=2987 taken as the reference level energy (1980C105).[‡] Rounded-off value from Adopted Levels.

[§] Authors of 1980C105 assign level as possible doublet on the basis of their assignment of the level as a member of the configuration= $\nu(2f_{5/2})^{-1} \otimes 9^-$ multiplet, and the consequent disagreement with probable J π =(11/2+) for E=3466 deduced by 1974C106 in (p,p'); however, in (t,2n γ), 1983Ma15 report a level at 3467 with J π probably 19/2+, as well as one at 3464 with J π probably 11/2+.

[#] From comparison of the experimental cross sections with DWBA predictions (1980C105).

@ L=1,3 for the 3735+3764 doublet, but larger σ at forward angles for the 3764 peak allows authors to assign L=1 to this component, and thus L=3 for the 3735 peak.

& L=1 and C²S=0.92 for the 4065+4084+4122 multiplet.

^a Defined by $d\sigma/d\Omega_{\text{exp}} = N \times C^2S / (2J+1) \times d\sigma/d\Omega_{\text{DWBA}}$, with N=3.33 (1980C105) and where J is the total angular momentum of the transferred neutron. L=1 and L=3 are taken as corresponding to p_{3/2} and f_{7/2}, respectively, except for the 2987, 3154, and 3212 levels which are taken as p_{1/2}, and the levels with L=3 below 5 MeV which are taken as f_{5/2}.

210Po(t, α) 1972Ba81Target ²¹⁰Po J π (g.s.)=0+.

1972Ba81: E=20.0 MeV triton beam was produced from the Los Alamos three-stage Van de Graaff facility. Target was 95% enriched 60 $\mu\text{g}/\text{cm}^2$ thick ²¹⁰Po evaporated onto a 50 $\mu\text{g}/\text{cm}^2$ carbon foil. α particles were momentum analyzed in an Elbek-type spectrograph and detected in nuclear emulsions, FWHM=20 keV. Measured $\sigma(E_{\alpha}, \theta)$. Deduced levels, J π , L, spectroscopic factors from DWBA analysis.

Other: 1981Wa03 deduce the rms radius and asymptotic amplitude of the 1h_{9/2} proton wave function.**209Bi Levels**

E(level) [†]	L [‡]	C ² S	Comments
0.0		2.62 [#]	C ² S: if configuration= $\pi(1h_{9/2})^{+1}$.
890 15		0.12 [#]	C ² S: if configuration= $\pi(2f_{7/2})^{+1}$.
1600 15		0.5 [#]	C ² S: if configuration= $\pi(1i_{13/2})^{+1}$.
2430 15	(0)	1.8 [§]	L: The authors of 1972Ba81 noted that the relative maximum of the transition to this level at 40° is consistent with L=0. C ² S: if J π =1/2+.
2480 15		1.8 [§]	configuration= $\pi(3s_{1/2})^{-1} + \pi(2f_{7/2})^{+1} \otimes 3^-$ (1972Ba81). C ² S: if J π =3/2+. configuration= $\pi(2d_{3/2})^{-1} + \pi(1h_{9/2})^{+1} \otimes 3^-$ (1972Ba81).

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210Po(t,α) 1972Ba81 (continued)**209Bi Levels (continued)**

E(level) [†]	C ² S	Comments
2750 15	≤0.2	C ² S: if configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ . configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1972Ba81).
2820 15	≤0.05	C ² S: if Jπ=5/2 ⁻ .
2950 15	2.2	C ² S: if Jπ=3/2 ⁺ . configuration=π(2d _{3/2}) ⁻¹ +π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1972Ba81).
3690 15	10.0	C ² S: if Jπ=11/2 ⁻ . configuration=π(1h _{11/2}) ⁻¹ +π(1h _{9/2}) ⁺¹ ⊗3 ⁻ (1972Ba81).
3970 15		
4000 15	1.8	C ² S: if Jπ=5/2 ⁺ . configuration=π(2d _{5/2}) ⁻¹ +π(2d _{3/2}) ⁻¹ ⊗4 ⁺ (1972Ba81).
4020 15	2.4	C ² S: if Jπ=5/2 ⁺ . configuration=π(2d _{5/2}) ⁻¹ +π(2d _{3/2}) ⁻¹ ⊗4 ⁺ (1972Ba81).
4100 15		
4140 15		
4230 15		
4880 15		

[†] The authors of 1972Ba81 assumed configurations are based on known single-particle states in the case of the first three levels, and on a comparison of energies with the hole states in ²⁰⁷Pb and a comparison of experimental and theoretical spectroscopic factors for the assumed core-coupled configurations for the higher excited states.

[‡] The authors of 1972Ba81 give tentative L values for the strong states, partly on the basis of structure arguments, but point out that the angular distributions are all consistent with L=2, configuration=π(2d_{3/2})⁻¹.

[§] Calculated using local zero-range DWBA with normalization factor N=34 and neutron parameters radius=1.25 fm, diffuseness=0.65 fm, and spin-orbit-coupling strength=32 (1972Ba81). C²S=(2j+1)(σ(θ)_{exp}/σ(θ)_{DWBA})/N, where j is the angular momentum of transferred particle.

[#] From (2J+1)σ(²¹⁰Po(t,α))/σ(²⁰⁸Pb(t,α)), a comparison of ²¹⁰Po(t,α) cross sections with ²⁰⁸Pb(t,α) single-proton hole cross sections measured at the same bombarding energy (1972Ba81)

Coulomb Excitation 1969He07,1970Br12,1973Kr02

1969He07: (α,α'γ) E=18 MeV, (¹⁶O,¹⁶O'γ) E=70 MeV. Target was a thick piece of zone-purified ²⁰⁹Bi. γ-rays were detected by a 32 cm³ Ge(Li) detector, FWHM=4.5 KeV. Measured Eγ, Iγ, Doppler-shift, γ(θ). Deduced levels, T_{1/2}, γ-branching ratios, transition probabilities, μ.

1970Br12: (α,α'γ) E=19 MeV. Targets were thick chemically pure bismuth with a thickness of 0.010 inch. γ-rays were detected by a 25 cm³ lithium-drifted Ge detector. Measured Eγ, Iγ, γ(θ), Doppler-shift. Deduced levels, T_{1/2}, γ-branchings ratios, transition probabilities, configurations. Comparisons with model calculations.

1973Kr02: (α,α'γ) E=15 MeV α beam was produced from the Heidelberg EN tandem accelerator. Natural Bi target. γ-rays were detected by two Ge(Li) detectors. Measured Eγ, Iγ, γ(θ). Deduced levels, mixing ratios, transition probabilities.

1972Ha59: (α,α'γ) E=15-18 MeV α beam was produced from the Chalk River MP tandem accelerator. Natural Bi target. γ-rays were detected by two Ge(Li) detectors. Measured Eγ, Iγ. Deduced levels, transition probabilities.

Others: 1998Wo15, 1985Ze05, 1983Ru03, 1980Sh12, 1965An13, 1963Hr01, 1962Na06.

209Bi Levels

B(E3) values are primarily from 1969He07 and are based on the assumption that unobserved but possible low-energy transitions between multiplet states do not have significant branching. Others: 1970Br12, 1972Ha59, 1973Kr02. Note that the B(E3) value for the combined seven states of the assumed multiplet configuration=π(1h_{9/2})⁺¹⊗3⁻ is 0.55 7, a weighted average of values of 1969He07 (0.45 15) and 1970Br12 (0.57 7).

E(level) [‡]	Jπ [§]	T _{1/2} [@]	L [#]	Comments
0.0	9/2 ⁻			configuration=π(1h _{9/2}) ⁺¹ .
896.5 3	7/2 ⁻	8.2 ps & 12	2	B(E2)↑=0.00261 16. B(E2)↑: weighted average of 0.0018 6 (1969He07), 0.0024 2 (1972Ha59), and 0.00275 14 (1973Kr02). Other: 0.00139 +16-23 (1970Br12), but the bombarding energy was such that the assumption of pure Coulomb excitation may not be valid (1973Kr02). configuration=π(2f _{7/2}) ⁺¹ .

Continued on next page (footnotes at end of table)

Coulomb Excitation 1969He07,1970Br12,1973Kr02 (continued)
²⁰⁹Bi Levels (continued)

E(level) [†]	Jπ [‡]	T _{1/2} [@]	L [#]	Comments
1608.3 4	13/2+	0.23 ns& 13	3	B(E3)↑=0.022 8 (1969He07). B(E3)↑: other: 0.0124 32 in 1970Br12, but see also the comment to the 896-keV level. configuration=π(1i _{13/2}) ⁺¹ .
2492.0 10	3/2+	=31 ps&		B(E3)↑=0.021 3 (1969He07). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ .
2563.0 10	9/2+	0.015 ps 3		B(E3)↑=0.074 11 (1969He07). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ .
2582.5 9	7/2+	0.31 ps 10		B(E3)↑=0.052 8 (1969He07). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ .
2600.3 [†] 6	11/2+	0.036 ps 10		B(E3)↑=0.094 14 (1969He07). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ .
2600.5 [†] 7	13/2+	0.26 ps 11		B(E3)↑=0.108 15 (1969He07). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ .
2615.8 8	5/2+	7.2 ps 11		B(E3)↑=0.034 5 (1969He07). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ .
2741.2 4	15/2+	9.1 ps& 12		B(E3)↑=0.077 10 (1969He07). configuration=π(1h _{9/2}) ⁺¹ ⊗3 ⁻ .
2821.8 8	5/2-	6.9 fs& 9		B(E2)↑=0.029 10 (1970Br12). E(level): from 1970Br12 only. This value is 4 keV lower than the adopted one. configuration=π(2f _{5/2}) ⁺¹ .

[†] From the ¹⁶O-induced spectrum, 1969He07 resolved the 992γ into two components based on the appreciable Doppler-broadening in one member of the doublet. The energy separation was determined to be 2±1 keV and the intensity of the Doppler-broadened component of the doublet relative to the 2600γ (also Doppler broadened) was found to be =0.2. 1969He07 and 1970Br12 suggest that the two Doppler-broadened transitions de-excite the 11/2+ member of the 11/2,13/2 doublet at 2600, while the non-Doppler-broadened component of the 992 doublet de-excites the 13/2+ member.

[‡] From a least-squares fit to γ-ray energies.

[§] From 1969He07 and 1970Br12.

[#] Values for the 896 and 1608 levels are from 1970Br12 based on σ(E). Excitation of levels with E(level)=2493 to 2741 is assumed to be E3. The E1 contribution is estimated to be <1% (1970Br12).

[@] From Adopted Levels.

& From Adopted Levels.

^γ(²⁰⁹Bi)

E(level)	Eγ [†]	Iγ [‡]	Mult.	δ	Comments
896.5	896.5 3	100	M1+E2	-0.95 25	Eγ: weighted average of 896.5 5 in 1969He07, 897.0 5 in 1970Br12, 896.5 3 in 1972Ha59, 896.3 3 in 1973Kr02. δ: from γ(0) (1973Kr02).
1608.3	1608.4 5	100			
2492.0	2492 1	100			
2563.0	2563 1	100			
2582.5	1686 1	67			
	2582.5 15	33			
2600.3	992.0 5	15 [#]			
	2600 1	85			
2600.5	992 1	99			
	2600 1	1			
2615.8	1719 1	59			
	2616 1	41			
2741.2	140				Eγ: from level energies. Transition not reported in Coulomb excitation. I(γ+ce)=29.1% 6 from Adopted Gammas.
	1133.0 5	33 [@]			
	2741.3 5	38 [@]			
2821.8	1925 [‡] 1				
	2822 [‡] 1				

[†] From weighted average of 1969He07 and 1970Br12, unless otherwise noted.

[‡] These values differ by 4–5 keV from adopted values.

Coulomb Excitation 1969He07,1970Br12,1973Kr02 (continued) **$\gamma(^{209}\text{Bi})$ (continued)**

§ From 1969He07 based on the α -induced spectrum, uncertainties=15%. The authors state that the ^{16}O -induced yield at $\theta=90^\circ$ gives essentially the same values. Other: 1970Br12. Values of these authors for the 2582 and 2741 levels are inconsistent with those of 1969He07. Data of 1968Wi24 from (n,n' γ) and of 1972Ha59 from ($^7\text{Li},\alpha 2n\gamma$) support the values of 1969He07.

Based on Doppler-broadening in the ^{16}O -induced spectrum, 1969He07 conclude that the 992 γ is a doublet with energy separation 2 ± 1 keV. The 15% branching shown is tentative since there is an impurity line present at the same energy. See comment on 2599, 2601 levels for a discussion of the level doublet at 2600.

@ 1969He07 report 53% and 47% for the 2741 γ and 1133 γ , respectively. The evaluator has renormalized these values using $I(\gamma+\text{ce})(140\gamma)=29.1\%$ 9 from Adopted Gammas.

Inelastic Scattering 1967Cr06,1966Al07

See also $^{209}\text{Bi}(e,e')$ giant resonance, $^{209}\text{Bi}(e,e')$ charge density, $^{209}\text{Bi}(p,p')$ giant resonance, $^{209}\text{Bi}(p,p)(p,p')(p,\text{pol } p)$, $^{209}\text{Bi}(\alpha,\alpha')$ giant resonance, as well as low-bombarding energy, high-resolution datasets $^{209}\text{Bi}(d,d')$, $^{209}\text{Bi}(p,p')$, and $^{209}\text{Bi}(n,n'\gamma)$.

1967Cr06: (n,n') E=4.1 MeV neutron beam was produced from the Los Alamos Scientific Laboratory. Scattered neutrons were detected with the time-of-flight neutron spectrometer, FWHM=30 keV. Measured $\sigma(E)$. Deduced levels.

1966Al07, 1967Al14: (α,α') E=42 MeV α beam was produced from the University of Washington Cyclotron. Scattered α 's were detected by Li-drifted silicon counters, FWHM=90-110 keV. Measured $\sigma(E_\alpha,\theta)$. Deduced levels, L, β_L from DWBA analysis.

Others:

1961Cr01: (e,e') E=183 MeV.

1962Re07: (n,n') E=14.8 MeV.

1964Ro05: (n,n') E=14 MeV.

1966Cr03: (n,n') E=6, 8 MeV.

1968De23: (n,n') E=1-4 MeV.

1968Zi02: (e,e') E=70 MeV.

1972Ta03: (n,n') E=1.45-3.58 MeV.

1973Ma13: (n,n') E=14.1 MeV.

1980Pr10: (n,n') E=20.6 MeV.

1983Av08: (n,n') E=fast.

1985Fi02,1985An15: (n,n') E=4-7 MeV.

1985Er07: (n,n') E=2.5 MeV.

1985Ze05: ($\alpha,\alpha'\gamma$) E=20 MeV.

1988Ch10: (α,α') E=50.5 MeV.

1991Si04: (α,α') E=69.5 MeV.

1998Sh15: ($^{11}\text{B},^{11}\text{B}'$) E=49.8-84.1 MeV.

2002De67: (n,n') E=1.37-3.76 MeV.

2002Si16: ($^9\text{Be},^9\text{Be}'$) E=40, 42, 44, 46, 48 MeV. Also 2000Si19.

2010Zh34: (n,n') E=37 MeV.

2011Po14: (n,n') E=2-4 MeV.

 ^{209}Bi Levels

E(level) [†]	L [§]	Comments
0.0		
896.4 [‡]		
1609.2 [‡]		
2480		
2580	3	$\beta_3=0.122$ 6 (1967Al14). BE3 $\uparrow=0.067$ 5 (1968Zi02), $\beta_3=0.14$ 2 (1964Ro05), $\beta_3=0.12$ 2 (1966Cr03), $\beta_3=0.16$ 5 (1961Cr01), $\beta_3R=0.76$ 8 (1966Al07), 0.71 5 (1988Ch10), 0.70 3 (1991Si04)
2735		
2820		
2940		
2980		
3040		
3130	5	$\beta_5=0.067$ 4 (1967Al14). $\beta_5R=0.32$ 3 (1966Al07).
3170		
3380		
3450		
4220	4	E(level): From 1988Ch10 and 1991Si04.

Continued on next page (footnotes at end of table)

Inelastic Scattering 1967Cr06,1966Al07 (continued)

²⁰⁹Bi Levels (continued)

E(level) [†]	L [§]	Comments
		L: from 1991Si04 and 1961Cr01. β ₄ R=0.20 7, β ₂ R=0.31 3 (1988Ch10); β ₄ R=0.46 3, β ₂ R=0.37 3 (1991Si04), β ₄ =0.17 6 (1961Cr01).
†		From 1967Cr06. Excited states are incompletely resolved, except for 894 and 1605 states, unless otherwise noted.
‡		From 1985Ze05.
§		From 1966Al07, unless otherwise noted.

γ(²⁰⁹Bi)

Eγ [†]	E(level)
896.4	896.4
1609.2	1609.2

† From 1985Ze05.

Muonic Atom 1972Le07,1974Ba77,1984Ru08

1972Le07: negative muon beam was produced from the Nevis 160-inch 385 MeV synchron-cyclotron. Target was a 8 g/cm² metallic ²⁰⁹Bi foil. x-rays and γ-rays were detected with a Ge(Li) detector. Measured I(x-ray), hfs constants. Deduced levels, μ, quadrupole moment, isomer shift.
1974Ba77,1971Ba11: muon beam was produced at the CERN muon channel. x-rays and γ-rays were detected by Ge(Li) and NaI detectors. Measured Eγ, Iγ, I(x-ray). Deduced isomer shifts.
1984Ru08: muon beam was produced from the SIN accelerator. A 3 g/cm² metallic Bi target was used. x-rays and γ-rays were detected with a Ge(Li) detector. Measured hfs. Deduced isomer shifts.
From a study of the emission of high-energy γ's (>75 MeV), 1988Do05 determine Iγ/μ=0.58×10⁻⁵ 10.

²⁰⁹Bi Levels

Isomer-shift data of 1972Le07 are those quoted by 1974Wa22 and based on muonic E(γ) from 1972Le07, bare nucleus E(γ) of 1974Ba77, and magnetic-shift correction of 1974Ba77. Data are in keV. Values for the 2741 level are means of the values deduced from the crossover to ground-state and cascade to 1608 level transitions.

E(level) [†]	Jπ [‡]	Comments
0.0	9/2-	
1608.6	13/2+	Q=-0.37 3 (1972Le07). Isomer shift=3.7 +6-8 (1974Ba77), 3.5 6 (1972Le07), 3.8 3 (1984Ru08).
2564.2	9/2+	μ=3.5 7 (1972Le07). Q=+0.11 5 (1972Le07). B(E3)↑=0.072 14 (1972Le07). Isomer shift=6.2 5 (1974Ba77), 5.8 5 (1972Le07), 6.6 3 (1984Ru08).
2741.1	15/2+	μ=6.2 12 (1972Le07). Q=-0.03 40 (1972Le07). B(E3)↑=0.106 23 (1972Le07). Isomer shift=6.7 5 (1974Ba77), 6.2 5 (1972Le07), 6.29 18 (1984Ru08). B(E3)↑: Authors' value of 0.075 16 has been corrected by the evaluator for additional branching of the 2741 level via the 141γ (I(γ+ce)=29.1% 9 from Adopted Gammas).

† Rounded-off values from Adopted Levels.

‡ From Adopted Levels.

Adopted Levels, GammasQ(β^-)=-3483.5; S(n)=6967.7 19; S(p)=4784.8 24; Q(α)=4979.2 14 2012Wa38.**209Po Levels****Cross Reference (XREF) Flags**A 209At ϵ DecayB 213Rn α DecayC 204Hg(⁹Be,4n γ)D 207Pb(α ,2n γ)E 208Pb(α ,3n γ)

F 209Bi(p,n),(p,np'): IAS

G 209Bi(d,2n γ)

H 210Po(d,t),(p,d)

E(level)	J $\pi^\dagger$	XREF	T _{1/2}	Comments
0.0	1/2-	ABCDE GH	125.2 y 33	<p>$\% \alpha = 99.546 \pm 7$; $\% \epsilon + \% \beta^+ = 0.454 \pm 7$. J$\pi$: optical spectroscopy (1976Fu06), L(d,t)=1. T_{1/2}: Weighted average of 125.2 y 33 in 2014Co16, based on 30 datasets measured over a period of 20.7 years using a liquid scintillator technique (superseded 128 y 7 by the same collaboration (2007Co07)) and 120 y 6 in 2015Po03, based on measurements of two sources measured for 359 and 369 days. Other: 102 y 5 from 209Po/208Po mass and activity ratios in 1956An05 and the presently adopted T_{1/2}(208Po)=2.898 y 2. Authors in 1956An05 obtained T_{1/2}=103 y using T_{1/2}(208Po)=2.93 y 3. $\% \alpha, \% \epsilon + \% \beta^+$: from measured $\% I(\epsilon) = 0.454 \pm 7$ and $\% I(\epsilon + \beta) + \% I(\alpha) = 100$ (1996Sc24). Others: $\% \alpha = 99.52 \pm 4$ (1989Ma05) and 99.74 (1966Ha29). $\mu = 0.68 \pm 8$ (1966Ch27). μ: from optical spectroscopy (1966Ch27). A value of $\approx +0.77$ quoted by 1989Ra17. Other: 0.61 5 from 1991Ko32 by atomic beam laser spectroscopy. The rms charge radius $\langle r^2 \rangle^{1/2}$: 2013Se03 gives $\delta v(^{209}\text{Po}, ^{196}\text{Po}) = -6.75$ GHz 10, $\delta \langle r^2 \rangle(^{209}\text{Po}, ^{210}\text{Po}) = -0.0813$ fm² 10 and $\langle \beta_2^2 \rangle^{1/2} = 0.09$. The systematic uncertainties from electronic factor and mass-shift calculations not included. configuration=$v(3p_{1/2})^{-1}$. Jπ: L(d,t)=3, 545.0γ E2 to 1/2-. T_{1/2}: from (790.2γ)(545.0γ)(Δt) in 209At $\epsilon + \beta^+$ decay (1971Al31). configuration=$v(2f_{5/2})^{-1}$. Jπ: L(d,t)=1, 554.6γ E2 from 7/2-. Jπ: L(d,t)=3; 1175.3γ E2 to 1/2-. Jπ: L(d,t)=1. Jπ: 781.9γ E2 to 5/2-; see also 1761-keV level. configuration=$\pi(1h_{9/2})^{+2} \otimes v(p_{1/2})^{-1}$. J$\pi$: 233.6$\gamma$ M1(+E2) to 5/2-, 903.0γ E1(+M2) from 9/2+. Jπ: 90.8γ E2 to 9/2-. T_{1/2}: weighted average of 24.8 ns 14 (1974Be74) in 208Pb(α,3nγ), 24.4 ns 15 (1976Ha56) in 207Pb(α,2nγ), 24.8 ns 14 (1971Al31) in 209At $\epsilon + \beta^+$ decay, and 24.1 ns 4 (2009Ni05) in (d,2nγ). $\mu = 6.13 \pm 9$ (1976Ha56); Q=0.126 5 (2009Ni05). μ: from 1976Ha56 by TDPAD, includes corrections for diamagnetism and Knight shift. Q: from 2009Ni05 in (d,2nγ) by TDPAD. configuration=$\pi(1h_{9/2})^{+2} \otimes v(3p_{1/2})^{-1}$. J$\pi$: 54.9$\gamma$ E2 to 13/2-. T_{1/2}: weighted average of values from 207Pb(α,2nγ) (88.5 15) and (d,2nγ) (89.4 5). 208Pb(α,3nγ) gives 98.1 ns 16 by gating on 781.9γ and 545.0γ, which follow the γ decay of the T_{1/2}=24.3 ns isomer at E=1417.66, while 88.5 ns 15 in 207Pb(α,2nγ) is from gating on 54.9γ decay of this level. $\mu = 7.75 \pm 5$; Q=0.659 7. μ: from 1976Ha56, includes corrections for diamagnetism and Knight shift. Q: from 2009Ni05 in (d,2nγ) by TDPAD. (-)0.39 8 from 1983Da01 in (α,3nγ) by TDPAD. configuration=$\pi(1h_{9/2})^{+2} \otimes v(3p_{1/2})^{-1}$.</p>
544.98 8	5/2-	AB DE GH	70 ps 20	
854.35 15	3/2-	A H		
1175.34 8	5/2-	A H		
1213.7 11	1/2-, 3/2-	A H		
1326.85 9	9/2-	A CDE G		
1408.90 9	7/2-	A		
1417.66 9	13/2-	A CDE G	24.2 ns 4	
1472.56 19	17/2-	CDE G	89.3 ns 5	

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Adopted Levels, Gammas (continued)

209Po Levels (continued)

E(level)	J π [†]	XREF	T _{1/2}	Comments
1521.85 9	11/2-	A	70 ps 20	J π : 239.19 γ E1 from 13/2+; 195.0 γ M1+E2 to 9/2-; see also 1761-keV level. T _{1/2} : from (790.2 γ)(781.9 γ)(Δt) in ²⁰⁹ At ϵ + β^+ decay (1971Al31). configuration= $\pi(1h_{9/2})^{+2} \otimes v(3p_{1/2})^{-1}$.
1715.69 9	9/2-	A		J π : 1170.6 γ E2 to 5/2-, 388.8 γ M1(+E2) to 9/2-.
1761.03 9	13/2+	A H		J π : L(d,t)=6, 239.190 γ E1 to 11/2-; 239 γ (ω ,t) in ²⁰⁹ Po ϵ decay, and the E1, M1+E2, E2 cascade from 1761 to 545 (J π =5/2-) uniquely establishes J π (1761)=13/2+, J π (1522)=11/2-, and J π (1326)=9/2-.
1937.66 19	17/2-	C E		J π : 520.0 γ E2 to 13/2-. configuration= $\pi(1h_{9/2})^{+2} \otimes v(2f_{5/2})^{-1}$.
1990.99 9	7/2-	A H		J π : L(d,t)=3, 321 γ E1 from 9/2+.
2029.77 21	19/2-	C E		J π : 557.2 γ M1+E2 to 17/2-. configuration= $\pi(1h_{9/2})^{+2} \otimes v(2f_{5/2})^{-1}$.
2061 $\S$ 10	(5/2-, 7/2-) $\ddagger$	H		
2082 $\S$ 10	(5/2-, 7/2-) $\ddagger$	H		
2166.87 20	21/2-	C E		J π : 137.1 γ M1 to 19/2-, 694.3 (E2) to 17/2-. configuration= $\pi(1h_{9/2})^{+2} \otimes v(2f_{5/2})^{-1}$.
2186 $\S$ 10	(5/2-, 7/2-) $\ddagger$	H		
2206 $\S$ 10	(5/2-, 7/2-) $\ddagger$	H		
2239 $\S$ 10	5/2-, 7/2- $\ddagger$	H		
2312.04 9	9/2+	A E		J π : 790.2 γ E1(+M2) to 11/2-, 1767.0 M2 to 5/2-.
2339 $\S$ 10	5/2-, 7/2- $\ddagger$	H		
2363 $\S$ 10	5/2-, 7/2- $\ddagger$	H		
2654.38 20	(5/2+)	A		J π : 2654.5 γ to 1/2- and 1478.9 γ and 2109.5 γ to 5/2-. But Possible ϵ feeding from 9/2- would be consistent only with 5/2+.
2664 $\S$ 10	5/2-, 7/2- $\ddagger$	H		
2769.89 22	23/2+	C E	2.5 ns 7	J π : 1297.4 γ E3 to 17/2-. T _{1/2} : preliminary value from 603.0 γ (t) in ²⁰⁸ Pb(α ,3n γ) (1974Be74). configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(3p_{1/2})^{-1}$.
2835.67 13	(9/2+, 11/2-)	A		J π : 1427.0 γ to 7/2- and 1074.6 γ to 13/2+.
2864.50 11	11/2+	A		J π : 1103.4 γ M1+E2 to 13/2+ and 552.5 γ M1(+E2) 552.5 γ to 9/2+.
2902.35 11	11/2+	A		J π : 1141.3 γ M1+E2 to 13/2+ and 1575.5 γ E1 to 9/2-.
2908.46 10	(11/2+)	A		J π : 1581.6 γ E1 to 9/2-, 1147.6 γ E2(+M1) to 13/2+; γ (θ) rules out J=7/2, but J π =9/2+ is possible.
2976.39 24	25/2+	C E		J π : 206.5 γ M1 to 23/2+. configuration= $\pi(1h_{9/2})^{+2} \otimes v(1i_{13/2})^{-1}$.
2978.26 10	11/2+	A		J π : 666.1 γ E2(+M1) to 9/2+, 1262.6 γ E1(+M2) to 9/2-, 1217.2 γ M1+E2 to 13/2+.
3072.66 12	(9/2+)	A		J π : 1356.9 γ and 1745.9 γ to 9/2- and 1311.7 γ to 13/2+. Weak γ to 5/2-.
3251.63? 24		A		
3620.3 3	27/2+	C E	<7 ns [#]	J π : 643.9 γ M1+E2 to 25/2+. configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(2f_{5/2})^{-1}$.
4168.4 3	29/2+	C E		configuration= $\pi(1h_{9/2})^{+2} \otimes v(1i_{13/2})^{-1}$. J π : 548.1 γ M1+E2 to 27/2+.
4265.4 3	31/2-	C E	119 ns 4	J π : 96.9 γ E1 to 29/2+ and 1289.1 γ E3 to 25/2+. T _{1/2} : weighted average of 119 4 from ²⁰⁸ Pb(α ,3n γ) (1974Be74) and 110 4 from (⁹ Be,4n γ) (2000Po03). μ =+9.68 8. μ : from ²⁰⁸ Pb(α ,3n γ) (1976Re12). Value includes corrections for diamagnetism and Knight shift. Also quoted by 2011StZZ. configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(2g_{9/2}^{+1}3p_{1/2}^{-2})^3$.
4354.1 3	31/2-	C E	<7 ns [#]	J π : 185.6 γ E1 to 29/2+ and 1377.6 γ (E3) to 25/2+. configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(1i_{13/2})^{-1}$.
4530.9 3	33/2-	C	<7 ns [#]	J π : 176.8 γ M1 to 31/2-. configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(1i_{13/2})^{-1}$.
5355.4 3	35/2-	C	<3.5 ns [#]	J π : 824.6 γ M1 to 33/2-. configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(3p_{1/2}^{-1}2f_{5/2}^{-1}2g_{9/2}^{+1})^3$.
5503.4 3	37/2+	C	<10 ns [#]	J π : 148.0 γ E1 to 35/2- and 1238.0 γ (E3) to 31/2-. configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(3p_{1/2}^{-2}1j_{15/2}^{+1})^3$.
6232.8 4	39/2+	C		J π : 729.4 γ M1 to 37/2+. configuration= $\pi(1h_{9/2}1i_{13/2})^{+2} \otimes v(3p_{1/2}^{-1}2f_{5/2}^{-1}1j_{15/2}^{+1})^3$.
6302.2 4	(39/2+)	C		J π : possible 1771.2 γ E3 to 33/2-.
6463.9 4	(41/2+)	C		J π : 161.5 γ E2(+M1) to (39/2+).

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

²⁰⁹Po Levels (continued)

E(level)	Jπ [†]	XREF	T _{1/2}	Comments
6739.1 4	(43/2+)	C	<7 ns [#]	Jπ: 275.2γ stretched M1 to (41/2+).
6807.4 4	(41/2+)	C		Jπ: 574.6γ (M1) to 39/2+ and 1304.1γ (E2) to 37/2+.
7159.2 4	(45/2+)	C		Jπ: 420.1γ (M1+E2) to (43/2+).
7247.7 5	(43/2+)	C		Jπ: 440.3γ (M1+E2) to (41/2+).
7692.9 4	(47/2+)	C		Jπ: 953.8γ (E2) to (43/2+).
8390.5 6	(47/2-)	C		Jπ: 1231.3γ (E1) to (45/2+).
16324 13	(9/2-)	F		Jπ: analog of ²⁰⁹ Bi g.s. from (p,n) and (p,np') data. Widths determined from the two reactions do not agree. 1974Fi14, in (p,n) show that both σ and Γ are sensitive to the choice of line shape for the resonance and background. They suggest that the discrepancy may be due to difficulties with experimental precision and reduction of data. For alternate explanations see 1973Gr13, 1974Wo04.

[†] From deduced γ-ray transition multipolarities based on ce data and γ(θ,T) in ²⁰⁹At ε+β⁺ decay, γ(θ) and γ(lin pol) in (⁹Be,4nγ), γ(θ) in (α,3nγ), combined with angular distributions in particle-transfer reactions of (d,t) and (p,d), unless otherwise noted.

[‡] From L(d,t)=3 or (3) (1979Bh01).

[§] From (d,t) and (p,d) (1979Bh01).

[#] Limits from 2000Po03 in (⁹Be,4nγ) based on γ(t).

γ(²⁰⁹Po)

E(level)	Eγ [†]	Iγ [†]	Mult. [#]	δ@	α	Comments
544.98	545.0 1	100	E2		0.0262	B(E2)(W.u.)=2.2 7. Mult.: α(K)exp=0.019 (1971Al31), α(K)exp=0.0178 11 and α(L)exp=0.0054 5 (1973Af01) A ₂ =-0.50 7 (1987Si14), A ₂ =-0.335 2 and A ₄ =-0.128 2 (1983Ha51) in ²⁰⁹ At ε+β ⁺ decay; A ₂ =+0.16 2, A ₄ =-0.01 4 (1974Be74), A ₂ =+24 2, A ₄ =+0.01 3 (1968Ya08) in (α,3nγ).
854.35	854.4 2	100	M1		0.0313	Mult.: α(K)exp=0.026 5 (1974Ja26), α(L)exp=0.0034 (1973Af01) in ²⁰⁹ At ε+β ⁺ decay.
1175.34	630.3 1	35.7 14	M1		0.0691	Mult.: α(L)exp=0.014 4 (1974Ja26); α(K)exp=0.08, α(L)exp=0.016 5 (1973Af01) in ²⁰⁹ At ε+β ⁺ decay.
	1175.3 1	100 5	E2		0.00540	Mult.: α(K)exp=0.0049 8 from 1974Ja26, α(K)exp=0.005 3 from 1971Al31, α(K)exp=0.0047 10, α(L)exp=0.00067 17 from 1973Af01 in ²⁰⁹ At ε+β ⁺ decay.
1213.7	1213.7 11	100				
1326.85	151.4 2	0.097 18	[E2]		1.319	
	781.9 1	100 3	E2		0.01200	Mult.: α(K)exp=0.0091 7, α(L)exp=0.0019 2 (1974Ja26), α(K)exp=0.0100 8 (1971Al31), α(K)exp=0.0089 8, α(L)exp=0.00184 21 (1973Af01) in ²⁰⁹ At ε+β ⁺ decay; A ₂ =+0.16 2, A ₄ =-0.02 4 (1974Be74), A ₂ =+0.24 2, A ₄ =+0.01 3 (1968Ya08) in (α,3nγ).
1408.90	233.6 1	49 4	M1 (+E2)	-0.30 +22-30	0.95 14	Mult.: α(K)exp=0.76 5, α(L)exp=0.136 10 (1974Ja26), α(K)exp=0.75 10 (1971Al31), α(K)exp=0.79 12, α(L)exp=0.17 3 (1973Af01) in ²⁰⁹ At ε+β ⁺ decay δ; sign from δ=-0.1 5 by γ(θ,T) (1987Si14) in ²⁰⁹ At ε+β ⁺ decay.

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Po})$ (continued)

E(level)	$E_{\gamma}^{\dagger}$	$I_{\gamma}^{\dagger}$	Mult.#	$\delta^{\oplus}$	α	Comments
1408.90	554.6 2	28 5	E2		0.0252	Mult.: $\alpha(K)\text{exp}=0.022$ (1973Af01) in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
	863.9 1	100 5	M1 (+E2)	-0.4 +3-4	0.028 6	Mult.: $\alpha(K)\text{exp}=0.027$ 5, $\alpha(L)\text{exp}=0.0028$ 8 (1973Af01) in ²⁰⁹ At $\varepsilon+\beta^+$ decay. δ : sign from $\gamma(\theta,T)$ (1987Si14) in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
1417.66	90.8 1	100	E2		10.77	Mult.: $\alpha(L12)\text{exp}/\alpha(L3)\text{exp}=1.34$ 10 (1974Ja26), $\alpha(L)\text{exp}=8.7$ 11 (1973Af01) and $\alpha(L2)\text{exp}/\alpha(L3)\text{exp}=1.25$ 6 (1971Al31) in ²⁰⁹ At $\varepsilon+\beta^+$ decay; $A_2=+0.27$ 3 (1976Ha56) in $(\alpha,2n\gamma)$. B(E2)(W.u.)=4.37 10.
1472.56	54.9 § 2	100 $\frac{1}{2}$	E2		120 3	Mult.: $A_2=+0.27$ 2 (1976Ha56) in $(\alpha,2n\gamma)$, $T_{1/2}$ rules out mult=M2. B(E2)(W.u.)=1.43 5.
1521.85	104.187 3	10.1 16	M1		9.87	Mult.: $\alpha(L1)\text{exp}=2.4$ 4 (1971Al31) in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
	113.1 1	0.78 16	E2		4.29	B(M1)(W.u.)=0.008 3. B(E2)(W.u.)=13 5.
	195.0 1	100 5	M1+E2	+0.40 +17-22	1.51 13	Mult.: from $\alpha(K)\text{exp}=1.0$ 6 (1971Al31) in ²⁰⁹ At $\varepsilon+\beta^+$ decay. Mult.: $\alpha(K)\text{exp}=1.17$ 12, $\alpha(L)\text{exp}=0.22$ 2, $\alpha(M)\text{exp}=0.061$ 7 (1974Ja26), $\alpha(K)\text{exp}=1.18$ 10 (1971Al31), $\alpha(K)\text{exp}=1.21$ 8, $\alpha(L)\text{exp}=0.24$ 3 (1973Af01) in ²⁰⁹ At $\varepsilon+\beta^+$ decay. δ : From ce data. Sign from $\delta=+0.090$ 6 by $\gamma\gamma(\theta)$ (1985BuZQ) and +0.08 5 by $\gamma(\theta,T)$ (1987Si14) in ²⁰⁹ At $\varepsilon+\beta^+$ decay. B(M1)(W.u.)=0.010 4; B(E2)(W.u.)=15 12.
1715.69	388.8 1	16.4 9	M1 (+E2)	≤ 0.6	0.23 4	Mult.: $\alpha(K)\text{exp}=0.19$ 2 (1974Ja26), $\alpha(K)\text{exp}=0.20$ 9 (1971Al31), $\alpha(K)\text{exp}=0.19$ 4, $\alpha(L)\text{exp}=0.028$ 7 (1973Af01) in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
	1170.6 1	100 3	E2		0.00544	Mult.: $\alpha(K)\text{exp}=0.0046$ 6, $\alpha(L)\text{exp}=0.00094$ 32 (1974Ja26), $\alpha(K)\text{exp}=0.0030$ 15 (1971Al31), $\alpha(K)\text{exp}=0.0036$ 8, $\alpha(L)\text{exp}=0.00067$ 17 (1973Af01) in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
1761.03	239.190 18	100	E1		0.0533	Mult.: $\alpha(K)\text{exp}=0.037$ 4, $\alpha(L)\text{exp}=0.005$ 1 (1974Ja26), $\alpha(K)\text{exp}=0.038$ 3 (1971Al31), $\alpha(K)\text{exp}=0.041$ 7, $\alpha(L)\text{exp}=0.0069$ 15 (1973Af01) in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
1937.66	465.1 § 2	61 $\frac{1}{2}$ 18	M1+E2	1.16 20	0.088 11	Mult., δ : $A_2=+0.16$ 12, $A_4=-0.20$ 17 (1974Be74) in $(\alpha,3n\gamma)$.
	520.0 § 2	100 $\frac{1}{2}$	E2		0.0293	Mult.: $A_2=+0.33$ 7, $A_4=+0.02$ 10 (1974Be74) in $(\alpha,3n\gamma)$.
1990.99	815.6 1	49 10	M1+E2	0.6 4	0.029 6	Mult.: $\alpha(K)\text{exp}=0.029$ 8 (tentative) from 1974Ja26, $\alpha(K)\text{exp}=0.022$ 5 from 1973Af01 in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
	1446.1 1	100 3	M1+E2	1.2 +8-4	0.0055 10	Mult.: $\alpha(K)\text{exp}=0.0044$ 10 (tentative) from 1974Ja26; $\alpha(K)\text{exp}=0.0044$ 10 from 1973Af01 in ²⁰⁹ At $\varepsilon+\beta^+$ decay.
2029.77	557.2 § 1	100 $\frac{1}{2}$	M1+E2	0.53 5	0.080 3	Mult.: $A_2=-0.32$ 3, $\text{pol}=0.15$ 8 from 2000Po03 in (³ Be,4n γ). δ : from 1974Be74 in $(\alpha,3n\gamma)$. Other: $\delta=1.67$ 16 from 1974Be74 in $(\alpha,3n\gamma)$.
2166.87	137.1 § 1	100 $\frac{1}{2}$	M1		4.52	Mult.: $\alpha(\text{exp})=3.9$ 8 from 1974Be74 in $(\alpha,3n\gamma)$. I γ : I(137 γ)/I(694 γ)=66/100 from $(\alpha,3n\gamma)$.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Po})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult.#	$\delta^{\oplus}$	α	Comments
2166.87	694.3 § 1	54 $\frac{1}{2}$ 9	(E2)		0.01536	Mult.: A ₂ =+0.11 6, A ₄ =-0.01 8 (1974Be74) in (α ,3n γ). I γ : I(137 γ)/I(694 γ)=66/100 from (α ,3n γ).
2312.04	321.1 1	0.99 4	E1		0.0268	Mult.: α (K)exp=0.026 15 (tentative) from 1974Ja26, α (K)exp=0.027 from 1973Af01 in ²⁰⁹ At ϵ + β^+ decay.
	551.0 1	7.7 3	(E2)		0.0256	Mult.: α (K)exp=0.0183 from 1974Ja26; α (K)exp=0.018 (tentative) from 1971Al31; α (K)exp=0.024 4 from 1973Af01 in ²⁰⁹ At ϵ + β^+ decay. K-conversion electrons of 551.0 γ and 552.5 γ are not resolved.
	596.2 & 1	1.03 & 6	(E1+M2)		0.0093 21	Mult.: α (K)exp=0.031 5 from 1974Ja26 and α (K)exp=0.018 5 from 1973Af01 for the 596.2 γ doublet in ²⁰⁹ At ϵ + β^+ decay.
	790.2 1	100 3	E1 (+M2)	-0.02 +4-3	0.00422 21	Mult.: α (K)exp=0.0033 3, α (L)exp=0.00050 7 from 1974Ja26, α (K)exp=0.0040 4 from 1971Al31; α (K)exp=0.0034 3, α (L)exp=0.00056 14 from 1973Af01 in ²⁰⁹ At ϵ + β^+ decay. δ : from γ (θ ,T) (1987Si14) in ²⁰⁹ At ϵ + β^+ decay.
	903.0 1	5.79 17	E1 (+M2)	+0.10 +6-16	0.0039 10	Mult.: α (K)exp=0.0033 4 from 1974Ja26, 0.0025 13 from 1971Al31, α (K)exp=0.0028 3 from 1973Af01 in ²⁰⁹ At ϵ + β^+ decay. δ : from γ (θ ,T) (1987Si14) in ²⁰⁹ At ϵ + β^+ decay.
	985.2 1	1.35 14	E1		0.00279	Mult.: α (K)exp=0.003 1 from 1973Af01, α (K)exp<0.003 from 1971Al31 in ²⁰⁹ At ϵ + β^+ decay.
	1136.5 3	0.107 14	(M2)		0.0356	Mult.: α (K)exp=0.037 12 (tentative) from 1974Ja26 in ²⁰⁹ At ϵ + β^+ decay.
	1767.0 1	0.80 4	M2		0.01151	Mult.: α (K)exp=0.0096 20 from 1974Ja26, α (K)exp=0.0045 from 1973Af01 in ²⁰⁹ At ϵ + β^+ decay.
2654.38	1478.9 3 2109.5 3	98 9 100 9				E γ : from 1974Ja26. 1973Af01 report 2108.2 6, 1971Al31 report 2111 1.
	2654.4 4	6.7 22				
2769.89	603.0 § 1	100 $\frac{1}{2}$	E1		0.00703	Mult.: A ₂ =-0.23 4, A ₄ =+0.03 5 from 1974Be74 in (α ,3n γ). B(E1)(W.u.)=3.1 $\times$ 10 ⁻⁷ 9.
	1297.4 § 2	14 $\frac{1}{2}$ 3	E3		0.00972	Mult.: A ₂ =+0.09 18, A ₄ =-0.30 26, pol=0.4 8 from 2000Po03 in (⁹ Be,4n γ), A ₂ =+0.46 3, A ₄ =-0.03 5 from 1974Be74 in (α ,3n γ). T _{1/2} rules out mult=M3. B(E3)(W.u.)=3.7 13.
2835.67	1074.6 1	100 9				
	1427.0 3	14 3				
2864.50	552.5 2	29 3	M1 (+E2)	<0.4	0.093 6	Mult.: α (K)exp=0.086 10 from 1974Ja26, α (K)exp=0.070 25 from 1971Al31 in ²⁰⁹ At ϵ + β^+ decay.
	1103.4 1	100 3	M1+E2	1.6 +8-5	0.0089 18	Mult., δ : α (K)exp=0.0090 9, α (L)exp=0.0016 4 from 1974Ja26, α (K)exp=0.0085 17 from 1971Al31, α (K)exp=0.0059 10, α (L)exp=0.00081 21 from 1973Af01 in ²⁰⁹ At ϵ + β^+ decay. δ =2.2 6 from γ (θ ,T) (1987Si14) in ²⁰⁹ At ϵ + β^+ decay.
	1148.8 3 1537.7 1	14.5 17 8.9 7	[E1]		0.00213	

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Po})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult.#	$\delta^{\oplus}$	α	Comments
2864.50	2319.6 4	0.13 3				
2902.35	1141.3 1	37.5 21	M1+E2	1.2 +7-4	0.0094 19	Mult.: $\alpha(\text{K})_{\text{exp}}=0.019$ 6 from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.0069$ 15 from 1973Af01 in ²⁰⁹ At $\epsilon+\beta^+$ decay.
	1484.7 2	10.4 11	[E1]		1.52×10^{-3}	
	1575.5 1	100 5	E1		1.46×10^{-3}	Mult.: $\alpha(\text{K})_{\text{exp}}=0.00116$ from 1973Af01, $A_2=+0.349$ 14, $A_4=-0.012$ 25 from 1983Ha51 in ²⁰⁹ At $\epsilon+\beta^+$ decay.
2908.46	2357.7 6	0.62 21				
	596.2& 1	36.4& 10	(M1+E2)		0.05 3	Mult.: $\alpha(\text{K})_{\text{exp}}=0.031$ 5 from 1974Ja26 and $\alpha(\text{K})_{\text{exp}}=0.018$ 5 from 1973Af01 for the 596.2 γ doublet in ²⁰⁹ At $\epsilon+\beta^+$ decay.
	1147.6 1	76 5	E2 (+M1)		0.010 5	Mult.: $\alpha(\text{K})_{\text{exp}}=0.005$ 1 (tentative) from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.005$ 3 from 1971Al31, $\alpha(\text{K})_{\text{exp}}=0.0038$ 7 from 1973Af01 in ²⁰⁹ At $\epsilon+\beta^+$ decay.
	1192.8 2	9.1 10	[E1]		0.00200	
	1490.8 1	15.2 10	[E1]		1.52×10^{-3}	
	1581.6 1	100 4	E1		1.45×10^{-3}	Mult.: $A_2=+0.319$ 8, $A_4=+0.020$ 13 from 1983Ha51 and $\alpha(\text{K})_{\text{exp}}=0.00087$ 40 (tentative) from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.00076$ from 1973Af01 in ²⁰⁹ At $\epsilon+\beta^+$ decay.
2976.39	2363.7 4	0.76 10				
	206.5& 1	100 $\frac{1}{2}$	M1		1.421	Mult.: $\alpha(\text{exp})=1.6$ 4, $A_2=-0.27$ 5, $A_4=+0.11$ 7 from 1974Be74 in ($\alpha, 3n\gamma$).
2978.26	666.1 1	99 3	E2 (+M1)	>+3.6	0.0183 16	Mult.: δ : $\alpha(\text{K})_{\text{exp}}=0.013$ 2, $\alpha(\text{L})_{\text{exp}}=0.0030$ 8 from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.0140$ 14 from 1973Af01, sign of mixing ratio from $\gamma(0, \text{T})$ (1987Si14) in ²⁰⁹ At $\epsilon+\beta^+$ decay.
	1217.2 1	59 4	M1+E2	1.0 +12-6	0.009 3	Mult.: δ : $\alpha(\text{K})_{\text{exp}}=0.0071$ 20 (tentative) from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.0094$ from 1973Af01 in ²⁰⁹ At $\epsilon+\beta^+$ decay.
	1262.6 1	100 4	E1 (+M2)	+0.09 +12-27	0.0020 9	Mult.: $\alpha(\text{K})_{\text{exp}}=0.0018$ 4 from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.00102$ 22 from 1973Af01 in ²⁰⁹ At $\epsilon+\beta^+$ decay. δ : from $\gamma(0, \text{T})$ (1987Si14) in ²⁰⁹ At $\epsilon+\beta^+$ decay.
	1456.6 2	6.3 5				
	1651.3 3	2.17 19				
3072.66	2433.44 20	0.72 10				
	1311.7 2	33 3				
	1356.9 1	100 6				
	1745.9 2	51 3				
	2528.1 6	1.7 6				
3251.63?	415.8 6	100 33				
	939.5 3	83 17				
	1730.0 4	22 3				
3620.3	643.9& 1	100 $\frac{1}{2}$	M1+E2	0.12 2	0.0647 10	Mult.: $A_2=-0.26$ 4, $\text{pol}=-0.46$ 17 from 2000Po03 in (⁹ Be,4n γ), $A_2=-0.42$ 4, $A_4=+0.03$ 5 from 1974Be74 in ($\alpha, 3n\gamma$). δ : from 1974Be74 in ($\alpha, 3n\gamma$). $B(\text{M1})(\text{W.u.}) > 1.1 \times 10^{-5}$, $B(\text{E2})(\text{W.u.}) > 8.9 \times 10^{-5}$.
4168.4	548.1& 1	100 $\frac{1}{2}$	M1+E2		0.06 4	Mult.: $A_2=-0.29$ 5, $\text{pol}=-0.19$ 23 from 2000Po03 in (⁹ Be,4n γ).
4265.4	96.9& 1	43 $\frac{1}{2}$ 10	E1		0.485	$B(\text{E1})(\text{W.u.}) = 4.6 \times 10^{-7}$ 12. Mult.: $\alpha(\text{exp})=0.2$ 4 from 1974Be74 in ($\alpha, 3n\gamma$).

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Po})$ (continued)

E(level)	E $\gamma^\dagger$	I $\gamma^\ddagger$	Mult.#	$\delta^\oplus$	α	Comments
4265.4	1289.1 § 2	100 $\ddagger$	E3		0.00986	Mult.: A ₂ =+0.10 7, A ₄ =-0.18 10, pol=0.48 34 from 2000Po03 in (⁹ Be,4n γ); A ₂ =+0.27 5, A ₄ =+0.05 7 from 1974Be74 in (α ,3n γ). B(E3)(W.u.)=0.40 4.
4354.1	185.6 § 1	100 $\ddagger$	E1		0.0984	Mult.: A ₂ =-0.24 11 from 2000Po03 in (⁹ Be,4n γ). B(E1)(W.u.)>3.6 $\times 10^{-6}$.
	1377.6 § 4	9 $\ddagger$ 4	E3		0.00857	Mult.: from 2000Po03 in (⁹ Be,4n γ) but no $\gamma(\theta)$ and $\gamma(\text{pol})$ data are given. B(E3)(W.u.)>0.54.
4530.9	176.8 $\ddagger$ 1	100 $\ddagger$	M1		2.20	Mult.: A ₂ =+0.05 1, $\alpha(\text{exp})$ =1.7 6 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>0.00016.
	265.6 $\ddagger$ 2	25 $\ddagger$ 7	M1		0.706	Mult.: A ₂ =-0.02 12, pol=-0.7 6 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>1.2 $\times 10^{-5}$.
5355.4	824.6 $\ddagger$ 1	100 $\ddagger$	M1		0.0343	Mult.: A ₂ =-0.12 7, pol=-0.14 24 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>1.1 $\times 10^{-5}$.
5503.4	148.0 $\ddagger$ 2	43 $\ddagger$ 8	E1		0.1719	Mult.: $\alpha(\text{exp})$ <0.37 from 2000Po03 in (⁹ Be,4n γ). B(E1)(W.u.)>1.7 $\times 10^{-6}$.
	1238.0 $\ddagger$ 2	100 $\ddagger$	E3		0.01075	Mult.: from 2000Po03 in (⁹ Be,4n γ) but no $\gamma(\theta)$ and $\gamma(\text{pol})$ data are given. B(E3)(W.u.)>6.9.
6232.8	729.4 $\ddagger$ 1	100 $\ddagger$	M1		0.0472	Mult.: A ₂ =-0.46 12, pol=-0.86 27 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>9.2 $\times 10^{-5}$.
6302.2	1771.2 $\ddagger$ 2	100 $\ddagger$	(E3)		0.00518	Mult.: A ₂ =0.00 17 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>9.2 $\times 10^{-5}$.
6463.9	161.5 $\ddagger$ 2	37 $\ddagger$ 7	M1+E2	>1.0	1.5 5	Mult., δ : $\alpha(\text{exp})$ =1.4 5 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>9.2 $\times 10^{-5}$.
	1108.6 $\ddagger$ 2	100 $\ddagger$	(E3)		0.01370	Mult.: from 2000Po03 in (⁹ Be,4n γ) but no $\gamma(\theta)$ and $\gamma(\text{pol})$ data are given.
6739.1	275.2 $\ddagger$ 1	100 $\ddagger$	M1		0.640	Mult.: A ₂ =-0.26 7, pol=-0.83 26 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>9.2 $\times 10^{-5}$.
6807.4	574.6 $\ddagger$ 2	100 $\ddagger$	(M1)		0.0882	Mult.: from 2000Po03 in (⁹ Be,4n γ) but no $\gamma(\theta)$ and $\gamma(\text{pol})$ data are given.
	1304.1 $\ddagger$ 4	67 $\ddagger$ 12	(E2)		0.00446	Mult.: from 2000Po03 in (⁹ Be,4n γ) but no $\gamma(\theta)$ and $\gamma(\text{pol})$ data are given.
7159.2	420.1 $\ddagger$ 1	100 $\ddagger$	(M1+E2)		0.13 8	Mult.: from 2000Po03 in (⁹ Be,4n γ) but no $\gamma(\theta)$ and $\gamma(\text{pol})$ data are given.
7247.7	440.3 $\ddagger$ 2	100 $\ddagger$	(M1+E2)		0.11 7	Mult.: from 2000Po03 in (⁹ Be,4n γ) but no $\gamma(\theta)$ and $\gamma(\text{pol})$ data are given.
7692.9	953.8 $\ddagger$ 2	100 $\ddagger$	(E2)		0.00807	Mult.: A ₂ =+0.10 36, pol=-0.37 116 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>9.2 $\times 10^{-5}$.
8390.5	1231.3 $\ddagger$ 4	100 $\ddagger$	(E1)		0.00191	Mult.: A ₂ =-0.16 22 from 2000Po03 in (⁹ Be,4n γ). B(M1)(W.u.)>9.2 $\times 10^{-5}$.

 $\dagger$ From ²⁰⁹At $\epsilon+\beta^+$ decay, unless otherwise noted.

 $\ddagger$ From ²⁰⁴Hg(⁹Be,4n γ).

 $\S$ From weighted average of values from (α ,3n γ) and (⁹Be,4n γ).

 $\#$ From ce data in ²⁰⁹At $\epsilon+\beta^+$ decay and (⁹Be,4n γ), $\gamma(\theta)$ and $\gamma(\text{lin pol})$ in (⁹Be,4n γ), unless otherwise noted.

 $\oplus$ From ce data in ²⁰⁹At $\epsilon+\beta^+$ decay using the BrIccMixing program, unless otherwise noted.

 $\&$ Multiply placed; undivided intensity given.

²⁰⁹At ϵ Decay 1974Ja26

Parent ²⁰⁹At: E=0.0; J π =9/2-; T_{1/2}=5.42 h 5; Q(g.s.)=3483 5; % ϵ +% β^+ decay=95.9 5.

²⁰⁹At-Q(ϵ): From 2012Wa38.

The decay scheme is that of 1974Ja26 based on extensive coincidence data.

1974Ja26: ²⁰⁹At sources were produced by the reaction of ²⁰⁹Bi(α ,4n) with 47-51 MeV α beams on bismuth metal targets of thicknesses 30-59 mg/cm² at the Berkeley lab. γ -ray single spectra were measured by a 35 cm³ coaxial Ge(Li) detector (FWHM=2.6 keV at 1332 keV), a 10 cm³ planar Ge(Li) (FWHM=1.5 keV at 122 keV) and a 0.784 cm² by 5 mm Si(Li) detector (FWHM=0.8 keV at 60 keV); $\gamma\gamma$ -coincidences were measured with two 35 cm³ coaxial Ge(Li) detectors; conversion electrons were detected with the Si(Li) detector. Measured E γ , I γ , $\gamma\gamma$ -coin, I_{ce}. Deduced levels, J π , conversion coefficients, γ -multipolarities, decay branchings, log ft.

1973Af01: ²⁰⁹At sources were produced from a thorium target bombarded by a 660 MeV proton beam from the synchrocyclotron of the Nuclear Problems Laboratory. γ -rays were detected with Ge(Li) detectors and conversion electrons were detected with two Si(Li) β -spectrometers. Measured E γ , I γ , E_{ce}, I_{ce}. Deduced levels, γ -branchings, γ -multipolarities, conversion coefficients.

1971Al31: ²⁰⁹At source was produced from the ISOLDE facility at CERN using ²³²Th(p,spall) reactions. γ -rays were detected by Ge(Li) detectors and β -particles were detected by a double-focusing magnetic spectrometer (up to 210 keV) and by a 2 mm thick Si(Li) detector (up to 1500 keV). Measured E γ , I γ , $\gamma\gamma$ -coin, delayed-coin., E β , I β . Deduced levels, T_{1/2}, γ -branchings, γ -multipolarities, conversion coefficients.

1987Si14: ²⁰⁹At were produced by the reaction of ²⁰⁹Bi(³He,Xn) with the ³He beam from the U-200 cyclotron at JINR. γ -rays were detected by two 30 cm³ coaxial Ge(Li) detectors. Measured E γ , I γ , $\gamma\gamma$ (θ). Deduced levels, J π , mixing ratios.

2011Ma75: ²⁰⁹At nuclei were produced from a 47.6 MeV ⁹Be beam on a Tl₂CO₃ target and from a 46 MeV ⁷Li beam on a PbNO₃ target. γ -rays were detected with a high-purity germanium detector (FWHM=2.13 keV at 1.33 MeV). Measured production yields, E γ , I γ .

Others: 1985BuZQ, 1983Ha51, 1969Go23.

²⁰⁹Po Levels

E(level) [†]	J π [‡]	T _{1/2}	Comments
0.0	1/2-		
544.98 8	5/2-	70 ps 20	T _{1/2} : from (790.2 γ)(545.0 γ)(Δ t) (1971Al31).
854.35 15	3/2-		
1175.34 8	5/2-		
1213.70? 10	1/2-, 3/2-		
1326.85 9	9/2-		
1408.90 9	7/2-		
1417.66 9	13/2-	24.8 ns 14	T _{1/2} : from (90.8 γ -ce(L)) (239.190 γ)(Δ t) (1971Al31).
1521.85 9	11/2-	70 ps 20	T _{1/2} : from (790.2 γ)(781.9 γ)(Δ t) (1971Al31).
1715.69 9	9/2-		
1761.03 9	13/2+		
1990.99 9	7/2-		
2312.04 9	9/2+		
2654.38 20	(5/2+)		
2835.67 13	(9/2+, 11/2-)		
2864.50 11	11/2+		
2902.35 11	11/2+		
2908.46 10	11/2+		
2978.26 10	11/2+		
3072.66 12	(9/2+)		
3251.63? 24			

[†] From a least-squares fit to γ -ray energies.

[‡] From Adopted Levels.

β^+, ϵ Data

E ϵ	E(level)	I β^+ [‡]	I ϵ [‡]	Log ft	I(ϵ + β^+) ^{†‡}
(231 5)	3251.63?		0.112 21	7.25 9	0.112 21
(410 5)	3072.66		0.304 12	7.475 22	0.304 12
(505 5)	2978.26		5.08 13	6.468 16	5.08 13
(575 5)	2908.46		4.59 13	6.643 16	4.59 13
(581 5)	2902.35		1.30 5	7.201 20	1.30 5
(619 5)	2864.50		8.4 3	6.453 18	8.4 3
(647 5)	2835.67		0.17 3	8.19 8	0.17 3
(829 5)	2654.38		0.084 6	8.74 4	0.084 6

Continued on next page (footnotes at end of table)

²⁰⁹At ε Decay 1974Ja26 (continued)

β⁺,ε Data (continued)

Eε	E(level)	Iβ ⁺ [‡]	Iε [‡]	Log <i>ft</i>	I(ε+β ⁺) ^{†‡}
(1171 5)	2312.04		70.9 19	6.138 13	70.9 19
(1492 5)	1990.99		0.17 7	8.98 18	0.17 7
(1961 5)	1521.85	0.05 4	8 6	7.6 4	8 6

[†] From I(γ+ce) imbalance at each level.

[‡] Absolute intensity per 100 decays.

γ(²⁰⁹Po)

Iγ normalization: Σ(I(γ+ce) to ground state)=100% by assuming no direct feedings to the ground state.

Eγ [†]	E(level)	Iγ [‡] e	Mult. ^d	δ ^d	α	Comments
90.8 1	1417.66	2.01 [#] 20	E2		10.77	Iγ: I(γ+ce)=22 1 in 1971Al31. Mult.: from α(L12)exp/α(L3)exp=1.34 10 (1974Ja26), α(L)exp=8.7 11 (1973Af01), α(L2)exp/α(L3)exp=1.25 6 (1971Al31).
104.187& 3	1521.85	2.6 [#] 4	M1		9.87	Iγ: 1.4 1 from 1971Al31. 1973Af01 propose a doublet at Eγ=113 based on conversion data arguments. The evaluators feel that the data are consistent with a single transition. No doublet is reported by 1974Ja26. Mult.: from α(L1)exp=2.4 4 from 1971Al31 A ₂ =+0.4 4 (1987Si14).
113.1 1	1521.85	0.20 ^{\$} 4	E2		4.29	Eγ: 1973Af01 report two γ-rays at E=112.6 3 and 113.35 30 with I(112.6γ)=0.120 19, I(113.35γ)=0.144 16. 1974Ja26 report no evidence for a doublet. Mult.: from α(K)exp=1.0 6 (1971Al31), one gets mult=M1+E2 with δ=3.1 4. The uncertainty in I(ce(K)) due to the required window absorption correction is not included.
^x 126.0 5		0.051 ^a 16				
^x 149.5 5		0.056 ^a 12				
151.4 2	1326.85	0.089 [#] 16	[E2]		1.319	
^x 161.2 4		0.076 ^a 16				
^x 191.0 2		0.45 ^a 5				
195.0 1	1521.85	25.8 12	M1+E2	+0.40 +17-22	1.51 13	Mult.: α(K)exp=1.17 12, α(L)exp=0.22 2, α(M)exp=0.061 7 from 1974Ja26; α(K)exp=1.18 10 from 1971Al31; α(K)exp=1.21 8, α(L)exp=0.24 3 from 1973Af01. A ₂ =+0.15 5 (1987Si14). δ: +0.090 6 in γγ(θ) (1985BuZQ) and +0.08 5 from γ(θ,T) (1987Si14).
233.6 1	1408.90	1.10 9	M1 (+E2)	-0.30 +22-30	0.95 14	Mult.: α(K)exp=0.76 5, α(L)exp=0.136 10, α(M)exp=0.028 10 (tentative) from 1974Ja26; α(K)exp=0.75 10 from 1971Al31; α(K)exp=0.79 12, α(L)exp=0.17 3 from 1973Af01. A ₂ =+0.5 4 (1987Si14). δ: -0.1 5 from γ(θ,T) (1987Si14).

Continued on next page (footnotes at end of table)

²⁰⁹At ε Decay 1974Ja26 (continued)

 $\gamma(^{209}\text{Po})$ (continued)

$E\gamma^{\dagger}$	E(level)	$I\gamma^{\ddagger e}$	Mult. ^d	δ^d	α	Comments
239.190 & 18	1761.03	13.8 5	E1		0.0533	Mult.: $\alpha(K)\text{exp}=0.037\ 4$, $\alpha(L)\text{exp}=0.005\ 1$ from 1974Ja26; $\alpha(K)\text{exp}=0.038\ 3$ from 1971Al31; $\alpha(K)\text{exp}=0.041\ 7$, $\alpha(L)\text{exp}=0.0069\ 15$ from 1973Af01 $A_2=+0.28\ 8$ (1987Si14). δ : 0.00 4 from $\gamma(0,T)$ (1987Si14).
^x 242.2 4 321.1 1	2312.04	0.24 ^a 4 0.69 3	E1		0.0268	Mult.: $\alpha(K)\text{exp}=0.026\ 15$ (tentative) from 1974Ja26; $\alpha(K)\text{exp}=0.027$ from 1973Af01.
^x 342.87 & 8		0.57 3				I γ : from 1974Ja26. 1973Af01 report a doublet with energies 342.2 4 and 343.3 4, with $I\gamma=0.45\ 7$ and 0.29 5, respectively. 1974Ja26 report no evidence for a doublet, and do not confirm the placements of 1973Af01. Mult.: from $\alpha(K)\text{exp}=0.11\ 1$ (1974Ja26) and $\alpha(K)\text{exp}=0.087\ 22$ (1973Af01) using the BrIccMixing program, one obtains mult=E1+M2 with $\delta=0.33\ 2$, or mult=M1+E2 with $\delta=1.8\ 2$.
^x 379.9 7		0.18 ^a 5				Mult.: from $\alpha(K)\text{exp}=0.20\ 5$ (1973Af01), one obtains mult=E1+M2 with $\delta=0.64\ 12$, or mult=M1(+E2) with $\delta=0.3\ +5-3$.
388.8 1	1715.69	0.54 3	M1 (+E2)	≤ 0.6	0.22 3	Mult.: $\alpha(K)\text{exp}=0.19\ 2$ from 1974Ja26; $\alpha(K)\text{exp}=0.20\ 9$ from 1971Al31; $\alpha(K)\text{exp}=0.19\ 4$, $\alpha(L)\text{exp}=0.028\ 7$ from 1973Af01.
415.8 6 ^x 433.8 3 ^x 447.6 1	3251.63?	0.06 [@] 2 0.08 [@] 2 0.29 2	M1+E2	0.5 3	0.145 25	E γ : Placed by 1973Af01 from an 1865 level. This level is not confirmed by 1974Ja26. Mult., δ : $\alpha(K)\text{exp}=0.13\ 2$ from 1974Ja26; $\alpha(K)\text{exp}=0.10\ 3$ from 1973Af01.
^x 515.1 3 ^x 523.0 3		0.05 [@] 2 0.04 [@] 2	(M2)		0.320	Mult.: $\alpha(K)\text{exp}=0.32\ 8$ (tentative) from 1974Ja26.
545.0 1	544.98	100	E2		0.0262	Mult.: $\alpha(K)\text{exp}=0.019$ from 1971Al31; $\alpha(K)\text{exp}=0.0178\ 11$, $\alpha(L)\text{exp}=0.0054\ 5$ from 1973Af01 $A_2=-0.50\ 7$ (1987Si14).
551.0 1	2312.04	5.4 2	(E2)		0.0256	Mult.: $\alpha(K)\text{exp}=0.0183$ from 1974Ja26; $\alpha(K)\text{exp}=0.018$ (tentative) from 1971Al31; $\alpha(K)\text{exp}=0.024\ 4$ from 1973Af01. K-conversion electrons of 551.0 γ and 552.5 γ are not resolved. 1974Ja26 and 1971Al31 assume mult(551 γ)=E2.
552.5 2	2864.50	1.7 2	M1 (+E2)	<0.4	0.093 6	Mult.: K-conversion electrons of 551.0 γ and 552.5 γ are not resolved. 1974Ja26 and 1971Al31 assume mult=E2 for the 551 γ , as required by the decay scheme, and deduce $\alpha(K)(552\gamma)=0.086\ 10$ and 0.070 25, respectively, giving mult(552 γ)=M1(+E2).
554.6 2	1408.90	0.63 10	E2		0.0252	Mult.: $\alpha(K)\text{exp}=0.022$ from 1973Af01.

Continued on next page (footnotes at end of table)

²⁰⁹At ε Decay 1974Ja26 (continued)

^γ(²⁰⁹Po) (continued)

E _γ [†]	E(level)	I _γ [‡] e	Mult. ^d	δ ^d	α	Comments
596.28 1	2312.04	≤0.76 c g	(E1+M2)		0.0093 21	Mult.: α(K)exp=0.031 5 from 1974Ja26 and α(K)exp=0.018 5 from 1973Af01 for the 596.2γ doublet.
	2908.46	≤0.76 c g	(M1+E2)		0.0800	Mult.: α(K)exp=0.031 5 from 1974Ja26 and α(K)exp=0.018 5 from 1973Af01 for the 596.2γ doublet.
630.3 1	1175.34	0.75 3	M1		0.0691	Mult.: α(L)exp=0.014 4 from 1974Ja26; α(K)exp=0.08, α(L)exp=0.016 5 from 1973Af01.
666.1 1	2978.26	2.05 7	E2(+M1)	>+3.6	0.0183 16	Mult.: α(K)exp=0.013 2, α(L)exp=0.0030 8 from 1974Ja26; α(K)exp=0.0140 14 from 1973Af01 A ₂ =-0.54 26 (1987Si14). δ: sign from γ(θ,T) (δ=+4.7 +390-18) (1987Si14).
*719.6 3		0.08@ 1	(M2)		0.1254	Mult.: α(K)exp=0.13 4 (tentative) from 1974Ja26.
*750.9 2		0.07@ 1				
781.9 1	1326.85	91.6 26	E2		0.01200	Mult.: α(K)exp=0.0091 7, α(L)exp=0.0019 2 from 1974Ja26; α(K)exp=0.0100 8 from 1971Al31; α(K)exp=0.0089 8, α(L)exp=0.00184 21 from 1973Af01 A ₂ =-0.433 (1987Si14).
790.2 1	2312.04	69.8 20	E1(+M2)	-0.02 +4-3	0.00422 21	Mult.: α(K)exp=0.0033 3, α(L)exp=0.00050 7 from 1974Ja26; α(K)exp=0.0040 4 from 1971Al31; α(K)exp=0.0034 3, α(L)exp=0.00056 14 from 1973Af01 A ₂ =+0.13 4 (1987Si14). δ: from γ(θ,T) (1987Si14).
*799.1 2		0.11@ 2				
*807.4 f 2		0.2 b 1				
*809.8 3		0.036@ 8				
815.6 1	1990.99	0.29 6	M1+E2	0.6 4	0.029 6	Mult.: α(K)exp=0.029 8 (tentative) from 1974Ja26; α(K)exp=0.022 5 from 1973Af01.
*817.6 2		0.18 4	(M1+E2)	<0.5	0.0326 25	Mult.,δ: α(K)exp=0.016 8 (tentative) from 1974Ja26.
*826.8 3		0.05@ 1				
854.4 2	854.35	0.71 6	M1		0.0313	Mult.: α(K)exp=0.026 5 from 1974Ja26, α(L)exp=0.0034 from 1973Af01, A ₂ =+0.5 7 (1987Si14).
863.9 1	1408.90	2.26 10	M1(+E2)	-0.4 +3-4	0.028 6	Mult.: α(K)exp=0.027 5, α(L)exp=0.0028 8 from 1973Af01 A ₂ =+0.92 22 (1987Si14). δ: from γ(θ,T) (1987Si14). α(K)exp of 1973Af01 is consistent with pure M1; however, the ce(K) line is not fully resolved from ce(L)(790γ).
*895.0 f 2		0.21 b 5				
903.0 1	2312.04	4.04 12	E1(+M2)	+0.10 +6-16	0.0039 10	Mult.: α(K)exp=0.0033 4 from 1974Ja26; 0.0025 13 from 1971Al31; α(K)exp=0.0028 3 from 1973Af01 A ₂ =+0.18 13 (1987Si14). δ: from γ(θ,T) (1987Si14).
*910.7 5		0.077@ 11				
*922.2 2		0.078§ 10				
939.5 3	3251.63?	0.05@ 1				
985.2 1	2312.04	0.94# 10	E1		0.00279	Mult.: α(K)exp=0.003 1 from 1973Af01, α(K)exp<0.003 from 1971Al31.
*999.6 2		0.17@ 1				
*1008.4 4		0.038@ 9				

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²⁰⁹At ε Decay 1974Ja26 (continued)

γ(²⁰⁹Po) (continued)

Eγ [†]	E(level)	Iγ [‡] e	Mult. ^d	δ ^d	α	Comments
^x 1037.8 4		0.030 [@] 6				
^x 1043.45 20		0.12 ^a 2				
1074.6 1	2835.67	0.22 2				
^x 1084.0 4		0.037 [@] 5				
^x 1092.8 4		0.049 [@] 7				
^x 1096.0 2		0.15 ^b 3				
1103.4 1	2864.50	5.93 20	M1+E2	1.6 +8-5	0.0089 18	Mult.: α(K)exp=0.0090 9, α(L)exp=0.0016 4 from 1974Ja26; α(K)exp=0.0085 17 from 1971Al31; α(K)exp=0.0059 10, α(L)exp=0.00081 21 from 1973Af01 A ₂ =+0.83 12 (1987Si14). δ: 2.2 6 from γ(θ,T) (1987Si14).
^x 1112.9 6		0.022 [@] 6				
1136.5 3	2312.04	0.075 [@] 10	(M2)		0.0356	Mult.: α(K)exp=0.037 12 (tentative) from 1974Ja26.
1141.3 1	2902.35	0.36 2	M1+E2	1.2 +7-4	0.0094 19	Mult.: α(K)exp=0.019 6 from 1974Ja26; α(K)exp=0.0069 15 from 1973Af01.
1147.6 1	2908.46	1.50 10	E2 (+M1)		0.01459	Mult.: α(K)exp=0.005 1 (tentative) from 1974Ja26; α(K)exp=0.005 3 from 1971Al31; α(K)exp=0.0038 7 from 1973Af01. K-conversion electrons of 1147.6γ and 1148.8γ are not resolved. 1974Ja26 assumed mult(1148.8γ)=E1, divided the I(ceK) intensity accordingly, and deduced α(K)(1147.6γ). Iγ: from 1974Ja26. 2.4 1 from 1971Al31 and 2.4 2 from 1973Af01 are for the doublet.
1148.8 3	2864.50	0.86 [@] 10	[E1]		0.00213	Mult.: α(K)exp=0.0018 (tentative) from 1974Ja26, K-conversion electrons of 1147.6γ and 1148.8γ are not resolved. 1974Ja26 assumed mult(1148.8γ)=E1 and divided the I(ceK) intensity accordingly.
1170.6 1	1715.69	3.3 1	E2		0.00544	Mult.: α(K)exp=0.0046 6, α(L)exp=0.00094 32 from 1974Ja26; α(K)exp=0.0030 15 from 1971Al31; α(K)exp=0.0036 8, α(L)exp=0.00067 17 from 1973Af01.
1175.3 1	1175.34	2.1 1	E2		0.00540	Mult.: α(K)exp=0.0049 8 from 1974Ja26; α(K)exp=0.005 3 from 1971Al31; α(K)exp=0.0047 10, α(L)exp=0.00067 17 from 1973Af01; A ₂ =-0.314 1, A ₄ =-0.285 16 from 1983Ha51.
^x 1183.1 2		0.15 ^{\$} 2				
1192.8 2	2908.46	0.18 2	[E1]		0.00200	
^x 1202.3 4		0.022 [@] 6				
^x 1210.2 4		0.047 [@] 10				
1213.7 ^f 11	1213.70?	0.48 4				Mult.: α(K)exp=0.0068 20 (tentative) from 1974Ja26, α(K)exp=0.0094 from 1973Af01.
1217.2 1	2978.26	1.22 8	M1+E2	1.0 +12-6	0.009 3	Mult.: α(K)exp=0.0071 20 (tentative) from 1974Ja26, α(K)exp=0.0036 from 1973Af01, A ₂ =+0.6 3 (1987Si14).
^x 1243.9 2		0.18 2				
1262.6 1	2978.26	2.07 8	E1 (+M2)	+0.09 +12-27	0.0020 9	Mult.: α(K)exp=0.0018 4 from 1974Ja26; α(K)exp=0.00102 22 from 1973Af01 A ₂ =+0.2 2 (1987Si14). δ: from γ(θ,T) (1987Si14).
^x 1272.9 2		0.24 2				

Continued on next page (footnotes at end of table)

^{209}At ϵ Decay 1974Ja26 (continued) $\gamma(^{209}\text{Po})$ (continued)

$E\gamma^{\dagger}$	E(level)	$I\gamma^{\ddagger e}$	Mult. ^d	δ^d	α	Comments
$^{x}1295.8\ 4$		0.026@ 6				
$^{x}1299.0\ 4$		0.022@ 6				
1311.7 2	3072.66	0.060 6				
$^{x}1333.4\ 3$		0.15 ^b 6				
$^{x}1342.9\ 3$		0.071@ 6				
1356.9 1	3072.66	0.18 1				
$^{x}1361.7\ 6$		0.009@ 4				
$^{x}1409.0\ 6$		0.019@ 8				
$^{x}1411.1\ 4$		0.058@ 8				
$^{x}1419.4\ 4$		0.042@ 9				
$^{x}1421.5\ 5$		0.023@ 8				
1427.0 3	2835.67	0.031@ 6				
1446.1 1	1990.99	0.59 2	M1+E2	1.2 +8-4	0.0055 10	Mult.: $\alpha(\text{K})_{\text{exp}}=0.0044\ 10$ (tentative) from 1974Ja26; $\alpha(\text{K})_{\text{exp}}=0.0044\ 10$ from 1973Af01.
1456.6 2	2978.26	0.13 1				
1478.9 3	2654.38	0.044@ 4				
1484.7 2	2902.35	0.10 1	[E1]		1.52×10^{-3}	
1490.8 1	2908.46	0.30 2	[E1]		1.52×10^{-3}	
$^{x}1510\ 1$		0.06 ^a 2				
$^{x}1529.4\ 5$		0.016@ 5				
$^{x}1533.1\ 2$		0.18 2				
1537.7 1	2864.50	0.53 4				
1575.5 1	2902.35	0.96 5	E1		1.46×10^{-3}	Mult.: $\alpha(\text{K})_{\text{exp}}=0.00116$ from 1973Af01 $A_2=+0.4\ 4$ (1987Si14).
1581.6 1	2908.46	1.98 7	E1		1.45×10^{-3}	Mult.: $\alpha(\text{K})_{\text{exp}}=0.00087\ 40$ (tentative) from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.00076$ from 1973Af01, $A_2=+0.36\ 20$ (1987Si14). δ : 0.0 2 from $\gamma(\theta, \text{T})$ (1987Si14).
$^{x}1622.4\ 1$		0.19 1				
1651.3 3	2978.26	0.045# 4				
$^{x}1687.3\ 1$		0.41 2	(E2)		0.00289	$\alpha(\text{K})_{\text{exp}}=0.00167$ from 1973Af01.
$^{x}1706.1\ 7$		0.006@ 3				
1730.0 4	3251.63?	0.013@ 2				
1745.9 2	3072.66	0.091 5				
1767.0 1	2312.04	0.56 3	M2		0.01151	Mult.: $\alpha(\text{K})_{\text{exp}}=0.0096\ 20$ from 1974Ja26, $\alpha(\text{K})_{\text{exp}}=0.0045$ from 1973Af01.
$^{x}1786.5\ 1$		0.13 1				
$^{x}1804.1\ 1$		0.062 6				
$^{x}1810.0\ 2$		0.047# 5				
$^{x}1861.4\ 5$		0.008@ 2				
$^{x}1947.7\ 4$		0.015@ 2				
$^{x}2102.0\ 4$		0.008@ 3				
$^{x}2105\ 1$		0.04 ^b 1				
2109.5 3	2654.38	0.045# 4				$E\gamma$: from 1974Ja26. 1973Af01 report 2108.2 6, 1971Al31 report 2111 1.
$^{x}2204\ 1$		0.04 ^b 1				
$^{x}2245.8\ 6$		0.007@ 1				
$^{x}2292.3\ 5$		0.020# 7				
2319.6 4	2864.50	0.008@ 2				
$^{x}2342.9\ 4$		0.021@ 5				
2357.7 6	2902.35	0.006@ 2				
2363.7 4	2908.46	0.015@ 2				
$^{x}2368.3\ 4$		0.012@ 2				
2433.44 20	2978.26	0.015@ 2				
$^{x}2448\ 1$		0.02 ^b 1				
2528.1 6	3072.66	0.003@ 1				
$^{x}2555.4\ 4$		0.002@ 1				
$^{x}2588.9\ 4$		0.021@ 3				
$^{x}2645.6\ 3$		0.012# 3				
2654.4 4	2654.38	0.003@ 1				

Footnotes continued on next page

 ^{209}At ϵ Decay 1974Ja26 (continued)

 $\gamma(^{209}\text{Po})$ (continued)

[†] Weighted average of values from 1974Ja26, 1973Af01, 1972Ch09, 1971Al31.

[‡] Weighted average of values from 1974Ja26, 1973Af01 and 1971Al31, unless otherwise noted. Normalized to $I(545\gamma)=100$.
Others: 1972Ch09,.

[§] Weighted average of values from 1974Ja26 and 1971Al31.

[#] Weighted average of values from 1974Ja26 and 1973Af01.

[@] Reported only by 1974Ja26.

[&] From 1974Ja26.

^a Reported only by 1973Af01.

^b Reported only by 1971Al31. Not seen by 1974Ja26.

^c 1974Ja26 report $E\gamma=596.4$ with $I\gamma=0.72$ 4 doubly placed from the from the 2312 and 2908 levels. $\alpha(K)$ for the doublet is consistent with mult=E1+M2 with $\delta=0.33$ or mult=M1+E2 with $\delta=1.5$. From $\gamma\gamma$, the authors favor placement from the 2312 level, requiring $\Delta\pi=\text{yes}$; however, the M2 component is rather large.

^d From Adopted Gammas, unless otherwise noted. Conversion coefficients are obtained in 1974Ja26, 1973Af01 and 1971Al31, based on relative $I(\gamma)$ and $I(\text{ce}(K))$ data normalized to $\alpha(K)(545\gamma)=0.0187$ (E2); other: 1972Ch09. Mixing ratios obtained in 1987Si14 are from $\gamma(\theta,T)$ measured with a low-temperature, polarized source.

^e For absolute intensity per 100 decays, multiply by 0.909 5.

^f Placement of transition in the level scheme is uncertain.

^g Multiply placed; undivided intensity given.

^x γ ray not placed in level scheme.

^{209}At ϵ Decay $^{1974}\text{Ja26}$ (continued)

Decay Scheme

Intensities: I(γ +ce) per 100 parent decays
& Multiply placed; undivided intensity given

$^{209}_{85}\text{At}_{124}$ 5.42 h
9/2- 0.0
% ϵ +% β^+ =95.9 5
 $Q^+=3483^5$

^{209}At ϵ Decay 1974Ja26 (continued)

Decay Scheme (continued)

Intensities: I(γ +ce) per 100 parent decays
& Multiply placed; undivided intensity given

$^{209}_{85}\text{At}_{124}$ 5.42 h
9/2- 0.0
% ϵ +% β^+ =95.9 5
 $Q^+=3483^5$

²¹³Rn α Decay 2000He17,2001Ku07,1970Va13

Parent ²¹³Rn: E=0.0; Jπ=(9/2+); T_{1/2}=19.5 ms 1; Q(g.s.)=8244 3; %α decay=100.

²¹³Rn-Q(α): From Eα=8089 keV 3 determined in the present evaluation.

²¹³Rn-J, T_{1/2}: From Adopted Levels of ²¹³Rn.

2000He17: ²¹³Rn was produced by the ²⁰⁸Pb(¹²C,X) reaction with E=100 MeV ¹²C beam from the UNILAC accelerator.

α-particles were detected by a position sensitive 16-strip pips detector and γ-rays were detected by two planar Ge detectors. Measured Eα, σ(Eα), αγ-coin, α(t). Deduced levels, t, Q, α-branchings.

2001Ku07: ²¹³Rn activity was produced from ²²Ne beam on ²⁰⁸Pb target with E=92 MeV beam from the JYFL K130 heavy ion cyclotron. Evaporation residues are implanted into a position sensitive pips Si detector. Measured Eα, σ(Eα), α(t). Deduced levels, t, Q, α-branchings.

1970Va13: ²¹³Rn activity was produced by bombarding the targets of ²⁰⁸Pb, ²⁰⁶Pb and ²⁰⁹Bi by various beams of Ne, F, O, N and C from the Berkeley heavy-ion linear accelerator (HILAC). α-particles were detected by silicon surface-barrier detectors. Measured Eα, σ(Eα), α(t). Deduce levels, t, Q, α-branching.

Others: 2005Li17, 2003Ni10, 1974Ho27, 1983Fa03, 1970TaZS, 1966Ro12, 1962Gr20.

²⁰⁹Po Levels

E(level) [†]	Jπ [‡]
0.0	1/2-
545.00 10	5/2-
854.00 20	3/2-

[†] From a least-squares fit to Eγ.

[‡] From Adopted Levels.

α radiations

Eα	E(level)	Iα [‡]	HF [†]	Comments
7252 4	854.00	1.04 12	21 5	Eα: weighted average of 7252 10 from 2000He17 and 7252 4 from 2001Ku07. Iα: weighted average of 1.1 1 from 2000He17 and 0.8 2 from 2001Ku07.
7554 4	545.00	0.71 10	302 65	Eα: weighted average of 7550 15 from 1970Va13, 7550 15 from 2000He17 and 7555 4 from 2001Ku07. Iα: weighted average 0.67 7 of from 2000He17 and 1.0 2 from 2001Ku07.
8089 3	0.0	98.2 2	87 14	Eα: weighted average of 8085 10 from 1970Va13, 8090 8 from 1974Ho27, 8088 10 from 2000He17, and 8090 3 from 2001Ku07. Other: 8064 41 from 2005Li17. Iα: weighted average of 98.2 2 from 2000He17 and 98.2 12 from 2001Ku07.

[†] Using r₀=1.48 5, unweighted average of r₀=1.4343 24 for ²⁰⁸Po and 1.532 6 for ²¹⁰Po, deduced from HF=1.

[‡] Absolute intensity per 100 decays.

γ(²⁰⁹Po)

Eγ [†]	E(level)	Iγ [‡]	Mult.	α	Comments
545.0 1	545.00	0.69 10	E2	0.0262	Eγ: Other: Eγ=540.3 keV 4 from αγ-coin by 2000He17, but the energy is inconsistent with Eγ=545.0 keV 1 from Adopted Gammas.
854.0 2	854.00	1.01 12	M1	0.0313	

[†] From Adopted Gammas.

[‡] From Iα and α.

Decay Scheme

204Hg(9Be,4nγ) 2000Po03

2000Po03: E=62 MeV ⁹Be beam was produced from the ANU 14 UD Pelletron accelerator. A enriched target of ²⁰⁴Hg. γ-rays were detected by the CAESAR array of Compton suppressed Ge detectors. Measured E_γ, I_γ, γγ, γ(θ), γγ(t), γ(lin pol). Deduced levels, Jπ, half-lives, γ-branchings, γ-multipolarities. Comparisons with shell-model calculations.

209Po Levels

E(level) [†]	Jπ [‡]	T _{1/2} [§]	Comments
0.0	1/2-		configuration=v(3p _{1/2}) ⁻¹ . Jπ: from Adopted Levels.
545.10 10	5/2-		configuration=v(2f _{5/2}) ⁻¹ .
1327.10 15	9/2-		configuration=π(1h _{9/2}) ⁺² ⊗v(3p _{1/2}) ⁻¹ .
1418.00 25	13/2-		configuration=π(1h _{9/2}) ⁺² ⊗v(3p _{1/2}) ⁻¹ .
1472.9 3	17/2-		configuration=π(1h _{9/2}) ⁺² ⊗v(3p _{1/2}) ⁻¹ .
1937.9 3	17/2-		configuration=π(1h _{9/2}) ⁺² ⊗v(2f _{5/2}) ⁻¹ .
2030.1 3	19/2-		configuration=π(1h _{9/2}) ⁺² ⊗v(2f _{5/2}) ⁻¹ .
2167.2 3	21/2-		configuration=π(1h _{9/2}) ⁺² ⊗v(2f _{5/2}) ⁻¹ .
2770.2 4	23/2+		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2}) ⁻¹ .
2976.7 4	25/2+		configuration=π(1h _{9/2}) ⁺² ⊗v(1i _{13/2}) ⁻¹ .
3620.6 4	27/2+	<7 ns	configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(2f _{5/2}) ⁻¹ .
4168.6 4	29/2+		configuration=π(1h _{9/2}) ⁺² ⊗v(1i _{13/2}) ⁻¹ .
4265.6 4	31/2-	119 ns 4	T _{1/2} : from 1289.0γ(t), 206.5γ(t) and 603.0γ(t) (2000Po03). configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(2g _{9/2} ⁺¹ 3p _{1/2} ⁻²) ³ .
4354.3 4	31/2-	<7 ns	configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(1i _{13/2}) ⁻¹ .
4531.1 4	33/2-	<7 ns	configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(1i _{13/2}) ⁻¹ .
5355.6 4	35/2-	<3.5 ns	configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 2f _{5/2} ⁻¹ 2g _{9/2} ⁺¹) ³ .
5503.6 4	37/2+	<10 ns	configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 1j _{15/2} ⁺¹) ³ .
6233.0 4	39/2+		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 2f _{5/2} ⁻¹ 1j _{15/2} ⁺¹) ³ .
6302.4 4	(39/2+)		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 1i _{13/2} ⁻¹ 2g _{9/2} ⁺¹) ³ .
6464.1 4	(41/2+)		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 2f _{5/2} ⁻¹ 1j _{15/2} ⁺¹) ³ .
6739.3 5	(43/2+)	<7 ns	configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 1i _{13/2} ⁻¹ 2g _{9/2} ⁺¹) ³ .
6807.6 5	(41/2+)		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 1i _{13/2} ⁻¹ 2g _{9/2} ⁺¹) ³ .
7159.4 5	(45/2+)		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 1i _{13/2} ⁻¹ 2g _{9/2} ⁺¹) ³ .
7247.9 5	(43/2+)		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(3p _{1/2} ⁻¹ 2f _{5/2} ⁻¹ 1j _{15/2} ⁺¹) ³ .
7693.1 5	(47/2+)		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(2f _{5/2} ⁻¹ 1i _{13/2} ⁻¹ 2g _{9/2} ⁺¹) ³ .
8390.7 6	(47/2-)		configuration=π(1h _{9/2} 1i _{13/2}) ⁺² ⊗v(1i _{13/2} ⁻² 2g _{9/2} ⁺¹) ³ .

[†] From a least-squares fit to γ-ray energies.

[‡] From deduced γ transition multipolarities using γ(θ) and γ(lin pol) (for E_γ≥250 keV), unless otherwise noted.

[§] Limits from γ(t) in 2000Po03.

γ(209Po)

E _γ	E(level)	I _γ [§]	Mult. [†]	δ	Comments
54.9 2	1472.9		(E2) [‡]		
88.6# 2	4354.3		(M1) [‡]		I _γ : I(γ+ce)=37 3.
90.9 2	1418.00		(E2) [‡]		
92.1# 2	2030.1		(M1) [‡]		I _γ : I(γ+ce)=16 2.
96.9 1	4265.6	70	(E1) [‡]		Mult.: A comparison of the I _γ and I(γ+ce) is consistent with mult=E1 not with M1. M1 given in the 2000Po03 could be a typo since it is inconsistent with the spin-party assignments of the connecting levels. I _γ : I(γ+ce)=30 5.
137.1 1	2167.2	350	M1		Mult.: A ₂ =-0.03 22.
148.0 2	5503.6	47	E1		Mult.: α(exp)<0.37, from intensity balances.
161.5 2	6464.1	35	E2(+M1)	>1.0	Mult.: δ: from α(exp)=1.4 5, from intensity balances.
176.8 1	4531.1	109	M1		Mult.: A ₂ =+0.05 1, α(exp)=1.7 6, from intensity balances.
185.6 1	4354.3	300	E1		Mult.: A ₂ =-0.24 11. I _γ : I(γ+ce)=58 3.
206.5 1	2976.7	470	M1		Mult.: A ₂ =-0.12 4.
265.6 2	4531.1	27	(M1)		Mult.: A ₂ =-0.02 12, pol=-0.7 6.
275.2 1	6739.3	120	M1		Mult.: A ₂ =-0.26 7, pol=-0.83 26.
x299.9 2		30			
420.1 1	7159.4	52	(M1+E2) [‡]		
440.3 2	7247.9	26	(M1+E2) [‡]		

Continued on next page (footnotes at end of table)

²⁰⁴Hg(⁹Be,4n γ) 2000Po03 (continued)

 γ (²⁰⁹Po) (continued)

E γ	E(level)	I γ [§]	Mult. [†]	Comments
^x 444.7 2		40		
465.1 2	1937.9	25	(M1)	Mult.: A ₂ =+0.01 5.
^x 467.1 2		30		
519.9 2	1937.9	40	(E2) [‡]	
545.1 1	545.10	1000	E2	Mult.: from Adopted Gammas. A ₂ =-0.03 2, pol=-0.8 8.
548.0 1	4168.6	215	M1+E2	Mult.: A ₂ =-0.29 5, pol=-0.19 23.
557.2 1	2030.1	450	M1+E2	Mult.: A ₂ =-0.32 3, pol=+0.15 8. I γ : I(γ +ce)=84 2.
574.6 2	6807.6	40	(M1) [‡]	
603.0 1	2770.2	670	E1	Mult.: A ₂ =+0.28 3.
643.9 1	3620.6	260	M1+E2	Mult.: A ₂ =-0.26 4, pol=-0.46 17.
^x 654.0 1		60		
694.3 1	2167.2	190	(E2) [‡]	
729.4 1	6233.0	80	M1	Mult.: A ₂ =-0.46 12, pol=-0.86 27.
^x 752.8 2		50		
782.0 1	1327.10	980	E2	Mult.: from Adopted Gammas. A ₂ =0.00 1, pol=+0.5 5.
824.6 1	5355.6	145	M1	Mult.: A ₂ =-0.12 7, pol=-0.14 24.
953.8 2	7693.1	45	(E2)	Mult.: A ₂ =+0.10 36, pol=-0.37 116.
^x 1028.7 4		50		
1108.6 2	6464.1	80	(E3) [‡]	
1231.3 4	8390.7	25	(E1)	Mult.: A ₂ =-0.16 22.
1238.0 2	5503.6	110	(E3) [‡]	
1289.0 2	4265.6	230	E3	Mult.: A ₂ =+0.10 7, A ₄ =-0.18 10, pol=+0.48 34. I γ : I(γ +ce)=70 5.
1297.3 2	2770.2	90	E3	Mult.: A ₂ =+0.09 18, A ₄ =-0.30 26, pol=+0.4 8.
1304.1 4	6807.6	27	(E2) [‡]	
1377.6 4	4354.3	30	(E3) [‡]	I γ : I(γ +ce)=5 2.
1771.2 2	6302.4	95	(E3)	Mult.: A ₂ =0.00 17.

[†] From 2000Po03 based on γ (θ) and γ (lin pol), unless otherwise noted. The quoted α (exp) are from intensity balances.

[‡] No γ (θ) or γ (lin pol) values are given by the authors.

[§] From 2000Po03.

[#] Placement of transition in the level scheme is uncertain.

^x γ ray not placed in level scheme.

²⁰⁷Pb(α ,2n γ) 1976Ha56

1976Ha56: E=25 MeV α beam was produced from the Chalk River Nuclear Laboratories. Natural Pb targets. γ -rays were detected with two large coaxial Ge(Li) detectors. Measured I γ (θ ,H,t). Deduced g-factor, half-life.

Others: 1983Da01, 1981Da01, 1973Na18, 1970Ya03, 1966AlZZ.

²⁰⁹Po Levels

g-factors are from γ (θ ,H,t) in 1976Ha56, H=22.93 kG. Values are not corrected for Knight shift or diamagnetism.

Quoted uncertainties do not include an $\approx$ 0.15% uncertainty in absolute time and magnetic-field calibration (1976Ha56).

E(level) [†]	J π [‡]	T _{1/2}	Comments
0.0	1/2-		
545.00 10	5/2-		
1326.90 15	9/2-		
1417.70 18	13/2-	24.4 ns 15	T _{1/2} : from 90.8 γ (t) (1976Ha56). g=0.938 8 (1976Ha56). μ =6.13 9. μ : from g-factor obtained using the Time Dependent Perturbed Angular Distribution (TDPAD) in 1976Ha56 with corrections for diamagnetism and Knight shift.
1472.6 3	17/2-	88.5 ns 15	g=0.907 1 (1976Ha56). T _{1/2} : from 54.9 γ (t) (1976Ha56). μ =7.75 5; Q=(-)0.39 8. μ : from g-factor in 1976Ha56 using TDPAD method.

Continued on next page (footnotes at end of table)

²⁰⁷Pb(α,2nγ) ¹⁹⁷⁶Ha56 (continued)
²⁰⁹Po Levels (continued)

E(level) [†]	Jπ [‡]	T _{1/2}	Comments
Q: from 1983Da01 using TDPAD method. g: Other: 0.897 15 (1973Na18).			
† From a least-squares fit to E _γ . ‡ From Adopted Levels.			

γ(²⁰⁹Po)

E _γ [†]	E(level)	Mult.	Comments
54.9 2	1472.6	E2	Mult.: A ₂ =+0.27 2 (1976Ha56), T _{1/2} rules out M2.
90.8 1	1417.70	E2	Mult.: A ₂ =+0.27 3 (1976Ha56), T _{1/2} rules out M2.
545.0 1	545.00		
781.9 1	1326.90		
† From Adopted Gammas.			

²⁰⁸Pb(α,3nγ) ¹⁹⁷⁴Be74

¹⁹⁷⁴Be74: E=33-43 MeV α beams were produced from the Stockholm 225-cm cyclotron. γ-rays were detected with Ge(Li) detectors of various sizes. Measured E_γ, I_γ, γ(θ), γγ(θ), γ(t). Deduced levels, Jπ, half-lives, γ-branchings, mixing ratios, multipolarities.

¹⁹⁷⁶Re12: E=41-51 MeV α beam. Natural lead target. γ-rays were detected by two big Ge(Li) detectors placed at ±135° relative to the incident beam direction. Measured E_γ, γ(θ,H,t). Deduced levels, g-factors.

¹⁹⁷⁵WiZR: E=40 MeV. Measured E_γ, γγ-coin, σ(E_γ,θ). Deduced levels, γ-multipolarities.

¹⁹⁸³Da01: E=24, 35 MeV. Measured E_γ, γγ(θ,H,t). Deduced quadrupole moment.

Others: 1966AlZZ, 1968Ya08, 1973Ab09.

Data and level scheme are from ¹⁹⁷⁴Be74 except for the 4354 level and its de-exciting γ's (¹⁹⁷⁵WiZR) and the g-factor data (¹⁹⁷⁶Re12).

²⁰⁹Po Levels

E(level) [†]	Jπ [‡]	T _{1/2}	Comments
0.0	1/2-§		
545.10 20	5/2-§		
1326.9 3	9/2-§		
1417.8 4	13/2-§	24.8 ns 14	T _{1/2} : from 90.9γ(t) (¹⁹⁷⁴ Be74).
1472.7 5	17/2-	98.1 ns 16	T _{1/2} : from 545γ(t) and 782γ(t). 100 ns 25 from 54.9γ(t). Q=(-)0.39 8 (1983Da01). g=0.89 5. Q: from 1983Da01 using TDPAD method. g: weighted average of 0.90 5 (1973Ab09) and 0.88 5 (1968Ya08).
1937.8 4	17/2-		
2029.9 6	19/2-		
2167.1 6	21/2-		
2311.9 11			
2770.1 6	23/2+	2.5 ns 7	T _{1/2} : preliminary value from 603γ(t).
2976.7 6	25/2+		
3620.6 6	27/2+		
4168.7 7	29/2+		
4265.8 6	31/2-	119 ns 4	g=0.625 5. T _{1/2} : weighted average of values from ¹⁹⁷⁴ Be74 (118 ns 3) and ¹⁹⁷⁶ Re12 (132 ns 10). g: from α,γ(σ,H,t) H=8.4-25.5 kG (¹⁹⁷⁶ Re12). Value includes corrections for diamagnetism and knight shift.
4354.3 7	31/2-		

† From a least-squares fit to γ energies.

‡ From deduced γ-ray transition multipolarities, using γ(θ) and comparisons with shell-model calculations.

§ From Adopted Levels.

$^{208}\text{Pb}(\alpha, 3n\gamma)$ $^{1974}\text{Be74}$ (continued) $\gamma(^{209}\text{Po})$

$E\gamma^\dagger$	E(level)	$I\gamma^\#$	Mult. §	δ	α	$I(\gamma+\text{ce})$	Comments
54.9 5	1472.7	0.59	[E2]		120 6	73	$I\gamma$: from $I(\gamma+\text{ce})$ and conversion coefficient. $I(\gamma+\text{ce})$: from intensity balance at 1472.7 ($I(\gamma+\text{ce})\geq 66$) and at 1417.8 ($I(\gamma+\text{ce})\leq 79$), with internal conversion taken into account for all transitions.
90.9 2	1417.8	6.6	E2 $^\oplus$		10.71 19		
97.0 5	4265.8	2.0	E1		0.484 9		Mult.: from $\alpha(\text{exp})=0.2$ 4 based on intensity balance at the 4169 level in a delayed spectrum (1974Be74).
137.2 2	2167.1	6.9	M1		4.51		Mult.: from $\alpha(\text{exp})=3.9$ 8 based on intensity balance at the 2030 level in a delayed spectrum (1974Be74). $A_2=-0.31$ 8 and $A_4=+0.02$ 10 consistent with stretched dipole (1974Be74).
185.6 ‡ 5	4354.3		D $^\&$				
206.6 2	2976.7	16.1	M1		1.419		Mult.: from $\alpha(\text{exp})=1.6$ 4 based on intensity balance at the 2770 level in a delayed spectrum (1974Be74). $A_2=-0.27$ 5, $A_4=+0.11$ 7 consistent with stretched dipole (1974Be74).
465.1 5	1937.8	1.9	(M1+E2)	1.16 20			Mult., δ : $A_2=+0.16$ 12, $A_4=-0.20$ 17 (1974Be74).
520.0 2	1937.8	6.3	(E2)				Mult.: $A_2=+0.33$ 7, $A_4=+0.02$ 10 (1974Be74).
545.1 2	545.10	100.0	E2		0.0262		Mult.: $A_2=+0.16$ 2, $A_4=-0.01$ 4 (1974Be74) and $A_2=0.24$ 2; , $A_4=0.01$ 3 (1968Ya08) are consistent with stretched quadrupole.
548.1 2	4168.7	7.8					
557.2 2	2029.9	43.8	(M1+E2)	0.53 5	0.080 3		Mult., δ : $A_2=-0.84$ 4, $A_4=+0.10$ 6, $\delta=0.53$ 5 or 1.67 16 (1974Be74). 1974Be74 choose mult=M1+E2 rather than E1+M2 based on expectation from theory of 19/2- but not 19/2+ level at this energy.
603.0 2	2770.1	44.9	(E1)		0.00703		Mult.: $A_2=-0.23$ 4 and $A_4=+0.03$ 5 consistent with stretched dipole (1974Be74).
643.9 2	3620.6	12.5	(M1+E2)	0.12 2			Mult., δ : $A_2=-0.42$ 4, $A_4=+0.03$ 5 consistent with stretched dipole with a small quadrupole admixture (1974Be74).
694.3 2	2167.1	10.5	(E2)				$A_2=+0.11$ 6; $A_4=-0.01$ 8. Mult.: $A_2=+0.11$ 6, $A_4=-0.01$ 8 (1974Be74). But 1974Be74 gives mult=M1+E2 with $\delta=0.21$ 6, inconsistent with the $J\pi$ predictions of 21/2- to 17/2-.
781.8 2	1326.9	99.0	E2		0.01200		Mult.: $A_2=+0.16$ 2, $A_4=-0.02$ 4 (1974Be74) and $A_2=0.24$ 2, $A_4=0.01$ 3 (1968Ya08) are consistent with stretched quadrupole.
985 1	2311.9						$E\gamma$: The author of 1974Be74 has seen a peak at $E\gamma=985$ keV but not placed it. The evaluators made this placement based on adopted level scheme, assuming an uncertainty of 1 keV.
1289.1 2	4265.8	8.0	E3		0.00986		Mult.: $A_2=+0.27$ 5, $A_4=+0.05$ 7 (1974Be74).
1297.4 2	2770.1	5.9	E3		0.00972		Mult.: $A_2=+0.46$ 3, $A_4=-0.03$ 5, consistent with octupole transition (1974Be74). M3 is excluded because it would imply a too long half-life.
1377.7 ‡ 5	4354.3		(E3) $^\&$				

† From 1974Be74, unless otherwise noted. A uncertainty of 0.2 keV is assumed by evaluators for strong transitions and 0.5 keV for weak ones.

‡ From 1975WiZR, uncertainty=0.5 keV assigned by evaluators.

§ From $\gamma(0)$ in 1974Be74, unless otherwise noted.

$^\#$ From prompt spectrum of 1974Be74. Authors also quote $I\gamma$ from delayed spectrum.

$^\oplus$ From ^{209}At $\text{ec}+\beta^+$ decay.

$^\&$ From $\gamma(0)$ (1975WiZR).

²⁰⁹Bi(p,n),(p,np'): IAS

1972Cr07: E=25 MeV proton beam was produced from the Michigan State University Cyclotron. Targets of 1 to 6 cm/cm² isotopic bismuth. Neutrons were detected by a liquid scintillator. Measured tof, $\sigma(E_n)$. Deduced width of the analog state. Also see 1972Cr04.

1973Gr13: E=25, 27 MeV. Measured $\sigma(\theta)$. Deduced level-width of IAS.

1974Fi14,1974Sc31: E=25.8 MeV. Measured $\sigma(E_n)$. Deduced level-width of IAS.

1983Ha33: E=27 MeV. Measured $\sigma(\theta)$. Deduced IAS excitation.

Others: 1970Cr05, 1970Be41.

Coulomb energy difference=19030 25 (1974Fi14), 19011 21 (1972Cr07), 18991 12 (1972Cr04), 18917 33 (1970Cr05).

Weighted average of these data gives $\Delta E(C)=18994$ 12.

²⁰⁹Po Levels

E(level)	Comments
16319 12	E(level): from $\Delta E(C)=18994$ 12 and $Q(^{209}\text{Po})=1892.6$ 16 (2012Wa38). Analog of ²⁰⁹ Bi g.s.. $\Gamma=257$ keV 35, 299 keV 35 (1974Fi14, for Breit-Wigner, Gaussian line shapes, respectively), 235 keV 50 (1973Gr13), 151 keV 34 (1972Cr07, Breit-Wigner), 380 keV 80 (1970Cr05, Breit-Wigner). $\Gamma=327$ keV 31 from 1972Cr04 and partial widths for decay to states in ²⁰⁸ Bi with assumed configuration neutron hole lj coupled to an h _{9/2} proton are 60, 36 3, 68 4 for p _{1/2} , f _{5/2} , p _{3/2} hole states, respectively. These partial widths are normalized to 60 for the p3/2 hole state, a calculated value quoted by 1969Ig01. The weighted average of these values is 263 keV 31, which gives $T_{1/2}=1.7 \times 10^{-6}$ fs.

²⁰⁹Bi(d,2n γ) 2009Ni05

2009Ni05: E=13 MeV pulsed deuteron beam was produced from the U-120 cyclotron in Bucharest. γ -rays were detected by a 3 inch by 3 inch NaI(Tl) detector with a resolution <8% at 663 keV. Measured E γ , time-differential perturbed angular distributions (TDPAD). Deduced spectroscopic electric quadrupole moments and half-lives.

²⁰⁹Po Levels

E(level) [†]	J π [‡]	T _{1/2} [§]	Comments
0.0	1/2-		
545.00 10	5/2-		
1326.90 15	9/2-		
1417.70 18	13/2-	24.1 ns 4	T _{1/2} : weighted average of 24.5 ns 4 from data at 45° and 23.6 ns 5 at 90° (2009Ni05). Q=0.126 5 (2009Ni05). Q: obtained using TDPAD method.
1472.6 3	17/2-	89.4 ns 5	T _{1/2} : weighted average of 89.8 ns 5 from data at 45° and 88.7 ns 7 at 90° (2009Ni05). Q=0.659 7 (2009Ni05). Q: obtained using TDPAD method.

[†] From a least-squares fit to E γ .

[‡] From Adopted Levels.

[§] From 2009Ni05 from fitted results of half-lives and quadrupole frequencies for data at 45° and 90° relative to the beam.

$\gamma(^{209}\text{Po})$

E γ [‡]	E(level)	Mult. [†]
54.9 2	1472.6	E2
90.8 1	1417.70	E2
545.0 1	545.00	E2
781.9 1	1326.90	E2

[†] From Adopted Gammas.

[‡] Rounded-off values from Adopted Gammas.

²¹⁰Po(d,t),(p,d) 1979Bh01

Target ²¹⁰Po J π (g.s.)=0+.

1979Bh01: E_d=17.0 MeV and E_p=17.8 MeV beams were produced from two-stage tandem facility at the University of Pittsburgh. A target of about 100 $\mu\text{g}/\text{cm}^2$ 95% ²¹⁰Po metal on a 50 $\mu\text{g}/\text{cm}^2$ carbon foil. Reaction products were momentum analyzed with a split-pole magnetic spectrograph (FWHM=15, estimated by evaluator) and detected in emulsions. Measured $\sigma(E_d, E_p, \theta)$. Deduced levels, J π , L, spectroscopic factors from a DWBA analysis.

²⁰⁹Po Levels

$N \times g \times C^2S = \sigma(\theta)_{\text{exp}} / \sigma(\theta)_{\text{DWBA}}$, where N is the normalization factor and $g=1/(2j+1)$ for (d,t) and (p,d) reactions with j the angular momentum of the transferred nucleon. N=1.53 (1979Bh01).

E(level)	L [†]	C ² S/(2j+1) [†]	E(level)	L [†]	C ² S/(2j+1) [†]	E(level)	L [†]	C ² S/(2j+1) [†]
0.0	1	1.05	1765 10	6	0.69	2206 10	(3)	
547 10	3	1.05	1996 10	3	0.07	2239 10	3	0.22
857 10	1	0.81	2061 10	(3)		2339 10	3	0.09
1174 10	3	0.07	2082 10	(3)		2363 10	3	0.11
1214 10	1	0.14	2186 10	(3)		2664 10	3	0.19

[†] From the comparisons of the measured angular distributions from (d,t) with the DWBA predictions. Some S values are also given by the authors for (p,d). In order to extract C²S, the authors assume the correspondence p_{3/2} for L=1, except p_{1/2} for the gs, f_{7/2} for L=3, except f_{5/2} for the 547 and 1174 levels, and i_{13/2} for L=6. Relative spectroscopic factors are also available from (p,d).

Adopted Levels, Gammas

Q(β^-)=-3954 21; S(n)=8484 10; S(p)=2702 5; Q(α)=5756.9 20 2012Wa38.
S(2n)=15798 13, S(2p)=7406 6, Q(ϵ p)=-1302 5, Q(β^- n)=-11298 12 (2012Wa38).

209At Levels**Cross Reference (XREF) Flags**

A 209Rn ϵ Decay
B 213Fr α Decay
C 205Tl(9Be,5n γ)
D 206Pb(6Li,3n γ)

E 209Bi(π^+ , π^-)
F 209Bi(3He,3n γ)
G 209Bi(α ,4n γ)

E(level) [†]	J π	XREF	T _{1/2}	Comments
0.0	9/2-	ABCD FG	5.42 h 5	% α =4.1 5; % ϵ +% β^+ =95.9 5. J π : favored α -decay (HF=1.2) to 205Bi g.s. (J π =9/2-). T _{1/2} : weighted average of 5.41 h 5 (1968GuZX), 5.5 h 2 (1951Ba14) and 5.4 h 5 (1969Go23). % α : from 1968GuZX. Q: Q(209At)/Q(210At)=1.47 7 from (α ,4n γ) (1983Ha51). configuration= $\pi(1h_{9/2})^{+1}$. E α (decay to 205Bi g.s.)=5647 2 (1969Go23).
408.37 3	7/2-	AB D F		J π : 408.32 γ E2(+M1) to 9/2-, direct feeding in 209Rn ϵ decay (J π =5/2-), $\gamma\gamma(\theta)$ from 209Rn ϵ decay rules out J=5/2.
577.08 7	11/2-	AB D FG		J π : 577.07 γ M1+E2 to 9/2-, 147.97 γ M1(+E2) from 13/2-.
725.07 8	13/2-	CD FG		configuration= $\pi(1h_{9/2})^{+1}\otimes 2^+$. J π : 725.05 γ stretched E2 to 9/2-.
745.81 4	7/2-	A D F		configuration= $\pi(1h_{9/2})^{+1}\otimes 2^+$. J π : 745.78 γ M1(+E2) to 9/2- and direct feeding in 209Rn ϵ decay (J π =5/2-).
789.07 21	(9/2)-	D F		J π : 380.7 γ M1(+E2) to 7/2-, no direct feeding in 209Rn ϵ decay (J π =5/2-).
794.62 5	5/2-	A F		J π : 794.68 γ E2 to 9/2-, 386.43 γ (M1) to 7/2-, probable direct feeding in 209Rn ϵ decay (J π =5/2-).
934.51? 13	(7/2)-	A		J π : 526.8 γ M1+E2 to 7/2-, 357.38 γ to 11/2-, probable direct feeding in 209Rn ϵ decay (J π =5/2-).
1081.22 5	(5/2, 7/2)-	A F		J π : 672.84 γ E2(+M1) to 7/2-, 1082 γ to 9/2-, probable direct feeding in 209Rn ϵ decay (J π =5/2-).
1093.13 16	(7/2)-	A		J π : 684.75 γ (E0+M1+E2) to 7/2-, probable direct feeding in 209Rn ϵ decay (J π =5/2-).
1097.74 5	(7/2)-	A F		J π : 689.30 γ M1(+E2) to 7/2-, probable direct feeding in 209Rn ϵ decay (J π =5/2-), (698 γ)(408 γ)(θ) from 1985BuZT in 209Rn ϵ decay, given $\delta(408\gamma)>10$ and $\delta(698\gamma)<0.28$, is consistent with J=7/2 and 9/2, not with J=5/2.
1131.11 11	(5/2, 7/2)-	A F		J π : 722.74 γ M1(+E2) to 7/2-, probable direct feeding in 209Rn ϵ decay (J π =5/2-).
1214.28 13	11/2-, 13/2-	D F		J π : 489.2 γ M1(+E2) to 13/2-, 637.2 γ M1(+E2) to 11/2- and 1214.3 γ to 9/2-.
1242.36 11	(13/2-)	D F		J π : 517.2 γ (E2) to 13/2-, 665.3 γ (M1) to 11/2-; strong population of this level in (6Li,3n γ) argues against J π =9/2-.
1269.84 17	(11/2, 13/2)-	F		J π : 692.8 γ M1+E2 to 11/2-.
1321.57 13	17/2-	CD FG		J π : 596.50 γ stretched E2 to 13/2-.
1339.57 22	(13/2, 15/2)-	F		configuration= $\pi(1h_{9/2})^{+3}$. J π : 614.5 γ M1+E2 to 13/2-.
1393.57 13	(13/2, 15/2)-	F		J π : 668.5 γ M1 to 13/2-.
1394.16 6	(7/2)-	A		J π : 1394.50 γ E2(+M1) to 9/2-, direct feeding in 209Rn ϵ decay (J π =5/2-).
1427.67 16	21/2-	CD FG	25.3 ns 7	μ =+9.9 2; Q=0.78 8. J π : 106.10 γ stretched E2 to 17/2-.
				T _{1/2} : weighted average of 29 ns 2 (1976Sj01) from (6Li,3n γ), and 25 ns 1 (1975Be39) and 24 ns 2 (1983Ma08) from (α ,4n γ), 24 ns 2 from 1985Ra21 from (3He,3n γ). μ : from g-factor=+0.94 2 weighted average of +0.88 6 (1975Be39) in 209Bi(α ,4n γ) and +0.95 2 (1976Sj01) in 206Pb(6Li,3n γ). Q: from 1983Ma08 in (α ,4n γ) by TDPAD. configuration= $\pi(1h_{9/2})^{+3}$.
1516.90 14		F		

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Adopted Levels, Gammas (continued)

209At Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
1659.97 22		F		
1772.56 13	(15/2-)	D F		J π : 530.2 γ M1+E2 to (13/2-).
1851.72 19	23/2-	CD FG		J π : 424.5 γ stretched M1 to 21/2-.
				configuration= $\pi(1h_{9/2}^2, 2f_{7/2}^1)^{+3}$.
1907.27 16	(19/2-) $\frac{1}{2}^+$	FG		J π : 585.7 γ M1+E2 to 17/2-.
1953.52 6	7/2+	A		J π : direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-), 855.77 γ E1 to (7/2)-, 1954.3 γ to 9/2-.
2075.87 24	(19/2-) $\frac{3}{2}^+$	FG		configuration= $\pi(1h_{9/2}^2, 2f_{7/2}^1)^{+3}$.
				J π : 754.3 γ (M1) to 17/2-.
2086.36 24		F		
2135.81 6	(5/2, 7/2)+	A		J π : 1037.95 γ E1(+M2) to (7/2)-, probable direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-).
2183.2 6	(23/2-)	G		J π : 755.5 γ (M1) to 21/2-.
2238.3 3	25/2- $\frac{1}{2}^+$	FG		J π : 810.6 γ stretched E2 to 21/2- and 386.6 γ D+Q to 23/2-.
				configuration= $\pi(1h_{9/2}^2)^{+3} \otimes 2^+$.
2402.8 6	(21/2-)	G		J π : 326.9 γ (M1) to (19/2-).
2415.01 9	5/2+, 7/2+	A		J π : direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-) and 461.47 γ M1(+E2) to 7/2+.
2429.32 22	29/2+	CD FG	0.916 μ s 10	μ =15.38 14; Q=1.50 15. J π : 577.60 γ E3 to 23/2-.
				T _{1/2} : weighted average of 0.88 μ s 10 (1975Be39) and 0.794 μ s 20 (1983Ma08) from (α ,4n γ), 0.933 μ s 11 (1987Dr01) from ²⁰⁵ Tl(⁹ Be,5n γ), and 0.860 μ s 20 (1985Ra21) in (³ He,3n γ). Other: 0.68 μ s 8 (1976Sj01) in (⁶ Li,3n γ).
				μ : from weighted average of g-factor=1.061 10 (1987Ca23) and 1.060 20 (1975Be39) in (α ,4n γ) by TDPAD.
				Q: from (α ,4n γ) by TDPAD (1983Ma08).
2516.70 11	(5/2 to 9/2)+	A		configuration= $\pi(1h_{9/2}^2, 1i_{13/2}^1)^{+3}$.
2522.27 8	(5/2+, 7/2+)	A		J π : M1(+E2) 380.83 γ to (5/2, 7/2)+, 1771.2 γ to 7/2-.
				J π : 386.43 γ (M1) to (5/2, 7/2)+, direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-), 2114.05 γ to 7/2-.
2569.2 3	(3/2-, 5/2, 7/2)	A		J π : 2160.7 γ to 7/2-, 1774.3 γ to 5/2-; direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-).
2581.13 15	(3/2, 5/2, 7/2)	A		J π : direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-).
2605.4 3	(25/2+) $\frac{1}{2}^+$	FG		J π : 753.7 γ (E1) to 23/2-.
				configuration= $\pi(1h_{9/2}^2, 2i_{13/2}^1)^{+3}$.
2612.0 3	(25/2-)	FG		J π : 760.3 γ (M1) to 23/2-.
2677.4 8		G		
2683.9 6	(27/2-) $\frac{1}{2}^+$	G		J π : 445.6 γ (M1) to 25/2-.
2689.92 24	(3/2-, 5/2, 7/2)	A		J π : direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-), 2281.7 γ to 7/2-.
2712.9 5	(3/2-, 5/2, 7/2)	A		J π : 1616.0 γ to (7/2-); direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-).
2821.9 5	(5/2, 7/2)	A		J π : 868.43 γ to 7/2+, 2413.5 γ to 7/2-; probable direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-).
3140.44 13	(5/2, 7/2)	A		J π : direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-), 1186.91 γ to 7/2+, 2394.7 γ to 7/2-.
3172.3 3	(3/2-, 5/2, 7/2)	A		J π : 2426.0 γ to 7/2-; direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-).
3188.6 3	(31/2+) $\frac{1}{2}^+$	FG		J π : 759.3 γ (M1) to 29/2+.
3292.9 8	(29/2-) $\frac{1}{2}^+$	G		
3388.44 20	(3/2-, 5/2, 7/2)	A		J π : 2642.9 γ to 7/2-; direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-).
3544.40 17	(5/2, 7/2)	A		J π : probable direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-); 3136.0 γ to 7/2-; 1129 γ to 5/2+, 7/2+.
3551.4 3	(5/2, 7/2, 9/2)	A		J π : 1597.4 γ to 7/2+, and 3143.7 γ to 7/2-.
3592?	(33/2+) $\frac{1}{2}^+$	G		E(level): the relative order of the 405.4 γ and 583.7 γ has not been established. These cascade transitions could define a level at 3771 instead of at 3592.
				J π : 405.4 γ (M1) to (31/2+).
3627.0 4	(3/2-, 5/2, 7/2)	A		J π : direct feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-); 3218.0 γ to 7/2-.
3748.7 6	(33/2+) $\frac{1}{2}^+$	G		
3753.7 3	(5/2, 7/2)	A		J π : direct allowed feeding in ²⁰⁹ Rn ϵ decay (J π =5/2-); 3007.5 γ to 7/2-; 1338.0 γ to 5/2+, 7/2+.
3812.6 6	(33/2+) $\frac{1}{2}^+$	G		J π : 624.0 γ (M1) to (31/2+).
3899.1 6	(33/2+) $\frac{1}{2}^+$	G		J π : 710.5 γ (M1) to (31/2+).
4176	(35/2+) $\frac{1}{2}^+$	G		J π : 583.7 γ (M1) to (33/2+).

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Adopted Levels, Gammas (continued) ^{209}At Levels (continued)

E(level) [†]	J π	XREF	Comments			
4376.6 8		G				
4506?	(35/2+)	G	J π : 759.0 γ (M1) to (33/2+).			
4696.9 12		G				
35 $\times 10^3$ 1	(9/2-)	E	J π : possible double isobaric analog of the ^{209}Bi g.s. (1980Mo20) from (π^+ , π^-).			
[†] From a least-squares fit to the γ -ray energies.						
[‡] From (α ,4n γ) (1990Mu04) based on $\gamma(\theta)$.						
$\gamma(^{209}\text{At})$						
E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^f	δ^h	α	Comments
408.37	408.32 4	100	E2 (+M1)		0.238	Mult.: $\alpha(\text{K})\text{exp}=0.0348$ 17, K:L:M=163 6:73 5:20.3 23 in ^{209}Rn ϵ decay (1974Vy01), $\alpha(\text{K})\text{exp}=0.035$ 2, $A_2=-0.03$ 1 and $A_4=-0.01$ 1 in (^3He ,3 γ) (1985Ra21).
577.08	577.07 [‡] 8	100	M1+E2	0.8 1	0.067 5	Mult., δ : $\alpha(\text{K})\text{exp}=0.050$ 7 from 1974Vy01 in ^{209}Rn ϵ decay; $\alpha(\text{K})\text{exp}=0.055$ 3, $A_2=-0.25$ 1, $A_4=+0.01$ 1 from 1985Ra21 in (^3He ,3n γ), $\alpha(\text{exp})=0.07$ 1, $A_2=-0.133$ 22 from 1975Be39 in (α ,4n γ), for 577.07+577.60 doublet.
725.07	147.97 10	7.5 9	M1 (+E2)	<0.25	3.89 9	I γ : weighted average of values from (^6Li ,3n γ) and (^3He ,3n γ). E γ : weighted average of values from (α ,4n γ), (^6Li ,3n γ) and (^3He ,3n γ). Mult.: $\alpha(\text{L})\text{exp}=0.52$ 5, $A_2=-0.11$ 1, $A_4=+0.01$ 2 from 1985Ra21 in (^3He ,3n γ), $\alpha(\text{exp})=3.9$ 5 and $A_2=-0.044$ 43 from 1975Be39 in (α ,4n γ).
	725.05 10	100	E2		0.01472	E γ : weighted average from (α ,4n γ), (^6Li ,3n γ) and (^3He ,3n γ). Mult.: $\alpha(\text{K})\text{exp}=0.011$ 1, $A_2=+0.11$ 1, $A_4=-0.03$ 1 from 1985Ra21 in (^3He ,3n γ), $\alpha(\text{exp})=0.016$ 3, $\alpha(\text{K})\text{exp}/\alpha(\text{L})\text{exp}=4.5$ 4, $A_2=+0.091$ 8 from 1975Be39 in (α ,4n γ), $A_2=+0.27$ 2, $A_4=-0.06$ 4 from 1976Sj01 in (^6Li ,3n γ).
745.81	337.47 [‡] 4	64 [‡] 3	M1 (+E2)	<0.4	0.378 22	Mult.: $\alpha(\text{K})\text{exp}=0.329$ 24, K:L:M=443 26:71 6:18.6 13 (1974Vy01), $\alpha(\text{K})\text{exp}=0.32$ 3 (1973Jo14) from ^{209}Rn ϵ decay, $\alpha(\text{K})\text{exp}=0.33$ 3, $A_2=+0.11$ 5, $A_4=+0.05$ 8 (1985Ra21) from (^3He ,3n γ).
	745.78 [‡] 4	100 [‡] 3	M1 (+E2)	<0.4	0.0459 25	Mult., δ : $\alpha(\text{K})\text{exp}=0.036$ 3, K:L:M=75 6:13.1 17:3.7 11 (1974Vy01), $\alpha(\text{K})\text{exp}=0.04$ 1 (1973Jo14) from ^{209}Rn ϵ decay, $\alpha(\text{K})\text{exp}=0.040$ 2 (1985Ra21) from (^3He ,3n γ).
789.07	380.7& 2	100	M1 (+E2)	<0.4	0.273 16	E γ : weighted average of values from (^6Li ,3n γ) and (^3He ,3n γ). Mult.: $\alpha(\text{K})\text{exp}=0.24$ 3, $A_2=+0.02$ 5, $A_4=+0.01$ 8 from 1985Ra21 in (^3He ,3n γ).
794.62	386.43 ^{bci} 7	61 ⁱ 4	(M1)		0.276	E γ : weighted average of 386.43 7 for a doublet from ^{209}Rn ϵ decay and 386.4 2 for a doublet from (^3He ,3n γ). Mult.: $\alpha(\text{K})\text{exp}=0.229$ 21 for a doublet from 1974Vy01, 0.2 1 from 1973Jo14 in ^{209}Rn ϵ decay.
	794.68 7	100 7	E2		0.01219	Mult.: $\alpha(\text{K})\text{exp}=0.0077$ from 1974Vy01 in ^{209}Rn ϵ decay.
934.51?	188.4 3	37 10	[M1]		2.00	

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{At})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^f	δ^h	α	Comments
934.51?	357.38 15 526.8 5	100 30 63 20	[E2] M1+E2	 =0.7	0.0796 =0.0907	Mult.: $\alpha(\text{K})\text{exp}=0.075$ (1974Vy01) from ²⁰⁹ Rn ϵ decay.
1081.22	=147 ^a 286.59 10 672.84 [‡] 4	<3 9.2 30 100 3	[M1] E2 (+M1)		=2.8 0.624 0.0632	Mult.: $\alpha(\text{K})\text{exp}=0.0115$ 24 (1974Vy01) from ²⁰⁹ Rn ϵ decay.
1093.13	1082 1 684.75 15	3.3 17 100	[M1, E2] (E0+M1+E2)		0.0184 0.121 21	Mult.: $\alpha(\text{K})\text{exp}=0.100$ 17 (1974Vy01), $\alpha(\text{K})\text{exp}=0.08$ 6 (1973Jo14) from ²⁰⁹ Rn ϵ decay $\alpha(\text{K})\text{exp}=0.100$ 17 is much larger than the M1 value suggesting a E0 component. α : 0.121 21 from $\alpha(\text{K})\text{exp}=0.100$ 17 and assumption that $\text{ce}(\text{K})/(\gamma+\text{ce})=0.826$ for M1 transition.
1097.74	302.98 13 689.30 [‡] 6	5.8 15 100 3	M1 (+E2) M1 (+E2)	<0.6 <0.4	0.48 6 0.056 3	Mult., δ : $\alpha(\text{K})\text{exp}=0.43$ 12 (1974Vy01), 0.5 2 (1973Jo14) from ²⁰⁹ Rn ϵ decay. Mult., δ : $\alpha(\text{K})\text{exp}=0.049$ 3, K:L=44.5 20:7.3 17 (1974Vy01); $\alpha(\text{K})\text{exp}=0.06$ 2 (1973Jo14) from ²⁰⁹ Rn ϵ decay.
1131.11	1097.55 25 722.74 [‡] 10	2.44 22 100	M1 (+E2)	<0.4	0.050 3	Mult., δ : $\alpha(\text{K})\text{exp}=0.049$ 8 (1974Vy01) from ²⁰⁹ Rn ϵ decay, $\alpha(\text{K})\text{exp}=0.04$ 1 (1985Ra21) from (³ He,3n γ).
1214.28	489.2 [#] 2 637.2 [#] 2	50 [#] 10 100 [#] 10	M1 (+E2) M1 (+E2)	<0.3 <0.3	0.142 5 0.0707 25	Mult.: $\alpha(\text{K})\text{exp}=0.14$ 2 (1985Ra21) from (³ He,3n γ). E γ : 635.3 5 from (⁶ Li,3n γ). Mult.: $\alpha(\text{K})\text{exp}=0.062$ 5, $A_2=+0.02$ 7, $A_4=0.0$ 1 (1985Ra21) from (³ He,3n γ).
1242.36	1214.3 [#] 2 517.2 [#] 2 665.3 [#] 1	50 [#] 10 17 [#] 3 100 [#] 6	(E2) (M1)		0.0310 0.0651	Mult.: $\alpha(\text{K})\text{exp}=0.03$ 2 (1985Ra21) from (³ He,3n γ). E γ : 664.2 5 from (⁶ Li,3n γ). Mult.: $A_2=-0.07$ 1, $A_4=-0.02$ 2 from ²⁰⁹ Bi(³ He,3n γ) (1985Ra21); $A_2=-0.25$ 6, $A_4=-0.3$ 2 from ²⁰⁶ Pb(⁶ Li,3n γ) (1976Sj01).
1269.84	692.8 [#] 2	100	M1+E2	1.3 3	0.032 6	Mult., δ : $\alpha(\text{K})\text{exp}=0.026$ 3 (1985Ra21) from (³ He,3n γ).
1321.57	596.5 [§] 1	100	E2		0.0224	Mult.: $\alpha(\text{K})\text{exp}=0.017$ 1, $A_2=+0.10$ 1, $A_4=-0.01$ 1 (1985Ra21) from (³ He,3n γ), $\alpha(\text{exp})=0.0222$, $\alpha(\text{K})\text{exp}/\alpha(\text{L})\text{exp}=3.3$ 3 and $A_2=-0.091$ 12 (1975Be39) from (α ,4n γ), $A_2=+0.3$ 1, $A_4=-0.1$ 1 (1976Sj01) in (⁶ Li,3n γ).
1339.57	614.5 [#] 2	100	M1+E2	0.48 14	0.069 6	Mult., δ : $\alpha(\text{K})\text{exp}=0.056$ 4, $A_2=+0.06$ 8, $A_4=-0.06$ 11 (1985Ra21) from (³ He,3n γ).
1393.57	668.5 [#] 1	100	M1 (+E2)	<0.2	0.0634 13	Mult.: $\alpha(\text{K})\text{exp}=0.057$ 4 (1985Ra21) from (³ He,3n γ).
1394.16	296.6 4 599.87 12 986.06 10 1394.50 9	33 5 59 6 55 6 100 5	M1+E2 M1 (+E2) E2 (+M1) E2 (+M1)	1.6 +7-4 <0.3 >2 >1.1	0.26 6 0.083 3 0.0095 16 0.0054 13	Mult., δ : $\alpha(\text{K})\text{exp}=0.18$ 5 (1974Vy01) from ²⁰⁹ Rn ϵ decay. Mult., δ : $\alpha(\text{K})\text{exp}=0.072$ 15 (1974Vy01) from ²⁰⁹ Rn ϵ decay. Mult.: $\alpha(\text{K})\text{exp}=0.0072$ 18 (1974Vy01) from ²⁰⁹ Rn ϵ decay. Mult., δ : $\alpha(\text{K})\text{exp}=0.0041$ 11 (1974Vy01) from ²⁰⁹ Rn ϵ decay.

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{At})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^f	δ^h	α	Comments
1427.67	106.1 $\S$ 1	100	E2		6.03	Mult.: from $\alpha(\text{exp})$ based on intensity balance and I(γ) in delayed spectrum in 1976Sj01 from (⁶ Li,3n γ), A ₂ =+0.08 1, A ₄ =+0.02 2 (1985Ra21) from (³ He,3n γ), $\alpha(\text{exp})$ =6.3 8 (1975Be39) from (α ,4n γ). B(E2)(W.u.)=3.21 10.
1516.90	247.1 $\#$ 2 791.8 $\#$ 2 939.8 $\#$ 2	33 $\#$ 7 100 $\#$ 20 67 $\#$ 13				
1659.97	934.9 $\#$ 2	100				
1772.56	530.2 $\#$ 1	100 $\#$ 5	M1+E2	0.57 5	0.097 4	Mult., δ : $\alpha(\text{K})\text{exp}$ =0.078 2, A ₂ =-0.30 3, A ₄ =-0.00 5 (1985Ra21) from (³ He,3n γ), A ₂ =-0.59 15, A ₄ =-0.05 5 (1976Sj01) in (⁶ Li,3n γ).
1851.72	1047.5 $\#$ 2 424.05 $\S$ 10	20 $\#$ 4 100	M1		0.215	Mult.: $\alpha(\text{K})\text{exp}$ =0.183, A ₂ =-0.21 2, A ₄ =-0.03 2 (1985Ra21) from (³ He,3n γ), $\alpha(\text{exp})$ =0.23 2, $\alpha(\text{K})\text{exp}/\alpha(\text{L})\text{exp}$ =5.9 4 and A ₂ =-0.123 14 (1975Be39) from (α ,4n γ), A ₂ =-0.26 12, A ₄ =-0.4 3 (1976Sj01) from (⁶ Li,3n γ).
1907.27	585.7 $\#$ 1	100	M1+E2	1.8 3	0.039 5	Mult., δ : $\alpha(\text{K})\text{exp}$ =0.030 3, A ₂ =-0.33 4, A ₄ =+0.04 5 (1985Ra21) from (³ He,3n γ).
1953.52	855.77 5	100 5	E1		0.00375	Mult.: $\alpha(\text{K})\text{exp}$ =0.0055 (1974Vy01), $\alpha(\text{K})\text{exp}$ <0.007 (1973Jo14) from ²⁰⁹ Rn ϵ decay.
	872.40 15	14 5	[E1]		0.00362	
	1158.86 10	17.2 11	[E1]		0.00219	
	1207.4 4	5.0 5	[E1]		0.00205	
	1954.3 10	2.7 3	[E1]		1.39 $\times 10^{-3}$	
2075.87	754.3 d 2	100	(M1)		0.0469	Mult.: $\alpha(\text{K})\text{exp}$ =0.03 1 and A ₂ =-0.38 5, A ₄ =-0.01 8 for the 753.7+754.4 doublet (1985Ra21) in (³ He,3n γ).
2086.36	313.8 $\#$ 2	100				
2135.81	182.23 12 1037.95 6	5.9 13 100 5	[M1] E1 (+M2)	<0.09	2.20 0.00283 19	Mult.: $\alpha(\text{K})\text{exp}$ =0.0020 4 (1974Vy01), $\alpha(\text{K})\text{exp}$ <0.005 (1973Jo14) from ²⁰⁹ Rn ϵ decay.
	1054.52 7	39.3 21	E1 (+M2)	<0.123	0.0029 4	Mult.: $\alpha(\text{K})\text{exp}$ =0.0029 9 (1974Vy01) from ²⁰⁹ Rn ϵ decay.
	1341.86 13	11.9 10	[E1]		1.76 $\times 10^{-3}$	
	1727.5 bi 7	<2.6 i	[E1]		1.43 $\times 10^{-3}$	
2183.2	755.5 @ 5	100	(M1) g		0.0467	
2238.3	386.6 c 2	100 6	M1+E2		0.276	Mult.: D+Q from $\gamma(0)$ (1990Mu04), $\Delta\pi$ =no required by level scheme.
	810.6 $\S$ 4	68 4	E2		0.01171	I γ : from (α ,4n γ). Mult.: $\alpha(\text{K})\text{exp}$ =0.008 2, A ₂ =+0.21 6, A ₄ =+0.06 9 (1985Ra21) in (³ He,3n γ). I γ : from (α ,4n γ), I(386.6 γ)/I(810.6 γ)=5/6.7 from (³ He,3n γ).
2402.8	326.9 @ 5	100	(M1) g		0.435	
2415.01	279.20 10	77 8	M1 (+E2)	<0.4	0.64 4	Mult.: $\alpha(\text{K})\text{exp}$ =0.62 10 (1974Vy01), $\alpha(\text{K})\text{exp}$ =0.6 3 (1973Jo14) from ²⁰⁹ Rn ϵ decay.
	461.47 9	100 5	M1 (+E2)	<0.6	0.154 18	Mult.: $\alpha(\text{K})\text{exp}$ =0.129 11, K:L=17.2 10:2.97 20 (1974Vy01); $\alpha(\text{K})\text{exp}$ =0.2 1 (1973Jo14) from ²⁰⁹ Rn ϵ decay.
	1317.8 a 8	<7	[E1]		0.00180	
	1669.5 10	8.2 11	[E1]		1.45 $\times 10^{-3}$	

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{At})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. ^f	δ^h	α	Comments
2429.32	577.60 [§] 10	100	E3		0.0750	Mult.: $\alpha(\text{K})_{\text{exp}}=0.055$ 3, $A_2=-0.25$ 1, $A_4=+0.01$ 1 (1985Ra21) from (³ He,3n γ), $\alpha(\text{exp})=0.07$ 1, $\alpha(\text{K})_{\text{exp}}/\alpha(\text{L})_{\text{exp}}=2.0$ 2, $A_2=-0.133$ 22 (1975Be39) from (α ,4n γ), for 577.07+577.60 doublet; $T_{1/2}=0.89$ μs 3 implies mult=E3. B(E3)(W.u.)=22.17 25.
2516.70	380.83 10	100 31	M1 (+E2)	≈ 0.6	≈ 0.229	Mult.: $\alpha(\text{K})_{\text{exp}}=0.18$ (1974Vy01) from ²⁰⁹ Rn ϵ decay.
	1722.5 10	25 3	[E1]		1.43×10^{-3}	
	1771.2 5	34 2	[E1]		1.42×10^{-3}	
2522.27	386.43 ^b i 7		(M1)		0.276	I γ : ≤ 625 39 for this multiply placed transition if normalized to I(2114.05 γ)=100 4. Mult.: $\alpha(\text{K})_{\text{exp}}=0.229$ 21 for a doublet from 1974Vy01, 0.2 1 from 1973Jo14 in ²⁰⁹ Rn ϵ decay.
	1429 ^a 1	<30				
	1727.5 ^a b i 7	<30 i				
	2114.05 20	100 4				
2569.2	1471.8 5	100 12				
	1635.0 10	38 11				
	1774.3 5	68 8				
	1823 ^a 1	<75				
	2160.7 6	60 8				
2581.13	1186.91 ^b 15	100 8				
	1500.2 4	21 3				
	1786.6 ^a 5	≈ 26				
	1836 ^a 1	<26				
2605.4	753.7 ^d 2	100	(E1)		0.00475	Mult.: $\alpha(\text{K})_{\text{exp}}=0.03$ 1 and $A_2=-0.38$ 5, $A_4=-0.01$ 8 for the 753.7+754.4 doublet (1985Ra21) in (³ He,3n γ).
2612.0	760.3 [§] 2	100	(M1)		0.0459	Mult.: $\alpha(\text{K})_{\text{exp}}=0.05$ 1 and $A_2=-0.38$ 6, $A_4=-0.01$ 9 for the 759.3+760.3 doublet (1985Ra21) in (³ He,3n γ), mult=D from $\gamma(0)$ (1990Mu04) in (α ,4n γ).
2677.4	494.2 [@] 5	100				
2683.9	445.6 [@] 5	100	(M1) ^g		0.188	
2689.92	1592.1 3	100 6				
	1608.5 10	34 5				
	2281.7 4	59 6				
2712.9	1616.0 10	100 21				
	1631.5 10	88 26				
	1778.2 ^b 5					
2821.9	868.43	$\approx 100^e$				
	1741.0 10	11 4				
	1887.0 10	19 8				
	2413.5 6	20.3 23				
3140.44	1186.91 ^b 15	100 8				
	1746.1 3	35 3				
	2043.5 ^a 10	<26				
	2205.2 10	15 3				
	2346.0 3	28 3				
	2394.7 6	20.3 23				
3172.3	1778.2 ^b 5	≤ 80				
	2074.5 3	100 12				
	2426.0 10	≈ 34				
3188.6	759.3 ^d 2	100	(M1) ^g		0.0461	Mult.: $\alpha(\text{K})_{\text{exp}}=0.05$ 1 and $A_2=-0.38$ 6, $A_4=-0.01$ 9 for the 759.3+760.3 doublet (1985Ra21) in (³ He,3n γ), mult=D from $\gamma(0)$ (1990Mu04) in (α ,4n γ).
3292.9	609.0 [@] 5	100				
3388.44	2290.5 3	23 4				

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Adopted Levels, Gammas (continued) $\gamma(^{209}\text{At})$ (continued)

E(level)	$E\gamma^{\dagger}$	$I\gamma^{\dagger}$	Mult. ^f	α	Comments
3388.44	2306.0 15	≈ 9			
	2453.5 ^b 5	<23			I γ : 19 4 from this doubly placed γ -ray.
	2642.9 3	100 10			
	2981.0 10	6.2 21			
3544.40	1027.55 20	100 24			
	1129 1	94 12			
	2150.0 10	83 8			
	2446.9 4	36 6			
	2463.7 6	55 7			
	2750.3 6	27 6			
	2798.1 10	36 4			
	3136.0 8	71 7			
3551.4	1415.5 ^a 10	≈ 110			
	1597.4 6	100 12			
	2453.5 ^b 5	<74			I γ : 62 12 from this doubly placed γ -ray.
	3143.7 8	65 8			
3592?	405.4 ^{@j}	100	(M1) g	0.243	
3627.0	1110.2 4	100 42			
	2233 ^a 1	<83			
	2833.5 10	≈ 21			
	2881.0 10	35 8			
	3218.0 15	19 4			
3748.7	560.1 [@] 5	100			
3753.7	202.3 ^a 4	<69			
	1338.0 8	100 13			
	2656.4 4	39 8			
	3007.5 6	35 4			
3812.6	624.0 [@] 5	100	(M1) g	0.0770	
3899.1	710.5 [@] 5	100	(M1) g	0.0548	
4176	583.7 ^{@j} 5	100	(M1) g	0.0919	
4376.6	564.0 [@] 5	100			
4506?	759.0 ^{dj}	100	(M1) g	0.0461	Mult.: $\alpha(K)\text{exp}=0.05$ 1 and $A_2=-0.38$ 6, $A_4=-0.01$ 9 for the 759.3+760.3 doublet (1985Ra21) in ($^3\text{He},3n\gamma$), mult=D from $\gamma(\theta)$ (1990Mu04) in ($\alpha,4n\gamma$).
4696.9	797.8 [@]	100			

[†] From ^{209}Rn ϵ decay, unless otherwise noted.[‡] Weighted average of values from ^{209}Rn ϵ decay and ($^3\text{He},3n\gamma$).[§] Weighted average of values from ($^3\text{He},3n\gamma$) and ($\alpha,4n\gamma$).[#] From ($^3\text{He},3n\gamma$).[@] From ($\alpha,4n\gamma$).[&] Weighted average of values from ($^6\text{Li},3n\gamma$) and ($^3\text{He},3n\gamma$).^a Assignment to ^{209}At (from ϵ decay) not definitely established.^b Doublets at 386, 1187, 1727, 1778 and 2453 from ^{209}Rn ϵ decay.^c Doublet at 386 from ($^3\text{He},3n\gamma$).^d Doublets at 754 from ($^3\text{He},3n\gamma$) and ($\alpha,4n\gamma$), at 759 from ($\alpha,4n\gamma$).^e Transition shown on drawing in ^{209}Rn ϵ decay (1974Vy01), but not in authors' table of gammas. Intensity deduced by evaluator based on intensity balance at 2822 level. The deduced value is thus actually a lower limit; however, 1974Vy01 show $\log ft > 8.5$ to the 2822 level; thus, $I(\epsilon) < 0.03\%$.^f From ce data in ^{209}Rn ϵ decay and ($^3\text{He},3n\gamma$), unless otherwise noted.^g From 1990Mu04 in ($\alpha,4n\gamma$), based on $\gamma(\theta)$.^h From measured ce data in ^{209}Rn ϵ decay and ($^3\text{He},3n\gamma$) using the BrIccMixing program, unless otherwise noted.ⁱ Multiply placed; undivided intensity given.^j Placement of transition in the level scheme is uncertain.

²⁰⁹Rn ε Decay 1974Vy01,1973Jo14

Parent ²⁰⁹Rn: E=0.0; Jπ=5/2-; T_{1/2}=28.8 min 10; Q(g.s.)=3954 21; %ε+%β⁺ decay=83 2.

²⁰⁹Rn-J,T_{1/2}: From Adopted Levels of ²⁰⁹Rn.

²⁰⁹Rn-Q(ε): From 2012Wa38.

1974Vy01: ²⁰⁹Rn isotopes were produced by bombarding a Th target with proton beams produced from the JINR synchrocyclotron. γ-rays were detected with three Ge(Li) detectors with volumes 0.5, 8.2 and 3.7 cm³ (FWHM=1.5, 2.5 and 2.3 keV at Eγ=1332 keV) and conversion electrons were detected with surface-barrier Si(Li) detectors (FWHM= 2-4 keV). Measured Eγ, Iγ, I(ce), γγ-coin. Deduced levels, Jπ, α, log ft, γ-ray branching ratios, γ-ray transition multipolarities.

1973Jo14: ²⁰⁹Rn isotopes were produced by bombarding a Th target with proton beams produced from the synchrocyclotron at the ISOLDE facility at CERN. γ-rays were detected with two Ge(Li) detectors (FWHM=1.9-2.2 keV) and electrons were detected with a 2 mm thick Si(Li) (FWHM= 2.7 keV at 500 keV). Measured Eγ, Iγ, I(ce), γγ-coin. Deduced levels, Jπ, γ-ray branching ratios, γ-ray transition multipolarities, conversion coefficients.

Others: 1971KhZU, 1973KeZP, 1985BuZT, 1988Ki03, 2007Ta17, 2008Ta11.

²⁰⁹At Levels

The decay scheme is that of 1974Vy01 except that the 577γ is placed by evaluators from a 577 level, rather than from the 2712 level and the 722γ is placed from an 1131 level, rather than from the 3544 level. Both of these alternate placements are suggested by the in-beam studies. If Jπ(577) is 11/2-, no direct ε feeding is expected. The evaluators propose a level at 934 keV to partially account for the feeding of the 577 level. The introduction of this level accommodates seven previously unplaced transitions, and provides an alternate placement for the 1778γ and 2453γ.

E(level) [†]	Jπ [‡]	E(level) [†]	Jπ [‡]	E(level) [†]	Jπ [‡]
0.0	9/2-	1394.45 6	(7/2)-	2821.9 5	(5/2, 7/2)
408.34 3	7/2-	1953.51 6	7/2+	3140.48 13	(5/2, 7/2)
577.15 8	11/2-	2135.78 6	(5/2, 7/2)+	3172.3 3	(3/2-, 5/2, 7/2)
745.79 4	7/2-	2414.99 9	5/2+, 7/2+	3388.43 20	(3/2-, 5/2, 7/2)
794.61 5	5/2-	2516.68 11	(5/2 to 9/2)+	3544.38 17	(5/2, 7/2)
934.55? 14	(7/2)-	2522.37 19	(5/2+, 7/2+)	3551.3 3	(5/2, 7/2, 9/2)
1081.19 5	(5/2, 7/2)-	2569.2 3	(3/2-, 5/2, 7/2)	3627.0 4	(3/2-, 5/2, 7/2)
1093.10 16	(7/2)-	2581.37 15	(3/2, 5/2, 7/2)	3753.7 3	(5/2, 7/2)-
1097.72 5	(7/2)-	2689.90 24	(3/2-, 5/2, 7/2)		
1131.11 11	(5/2, 7/2)-	2712.9 5	(3/2-, 5/2, 7/2)		

[†] From a least-squares fit to γ-ray energies.

[‡] From Adopted Levels.

β⁺,ε Data

The log ft values are given as approximate since the unplaced γ-ray transition intensity is about 14%.

Eε	E(level)	Iβ ⁺ [‡]	Iε [‡]	Log ft	I(ε+β ⁺) ^{†‡}	Comments
(200 21)	3753.7		≈0.4	≈5.5	≈0.4	
(327 21)	3627.0		≈0.3	≈6.2	≈0.3	
(403 21)	3551.3		≈0.2	≈6.6	≈0.2	
(410 21)	3544.38		≈1.0	≈5.9	≈1.0	
(566 21)	3388.43		≈0.5	≈6.6	≈0.5	
(782 21)	3172.3		≈0.2	≈7.3	≈0.2	
(814 21)	3140.48		≈0.9	≈6.7	≈0.9	
(1132 21)	2821.9		≈0.5	≈7.2	≈0.5	
(1241 21)	2712.9		≈0.2	≈7.7	≈0.2	
(1264 21)	2689.90		≈0.4	≈7.4	≈0.4	
(1373 21)	2581.37		≈0.7	≈7.3	≈0.7	
(1385 21)	2569.2		≈0.5	≈7.4	≈0.5	
(1432 21)	2522.37		≈3.2	≈6.6	≈3.2	
(1437 21)	2516.68		≈0.7	≈7.3	≈0.7	
(1539 21)	2414.99	≈0.0020	≈3.4	≈6.7	≈3.4	
(1818 21)	2135.78	≈0.0065	≈2.0	≈7.1	≈2.0	
(2000 21)	1953.51	≈0.025	≈3.6	≈6.9	≈3.6	
(2560 21)	1394.45	≈0.057	≈1.7	≈7.4	≈1.8	
(2823 21)	1131.11	≈0.03	≈0.5	≈8.1	≈0.5	
(2856 21)	1097.72	≈0.054	≈0.95	≈7.8	≈1.0	
(2861 21)	1093.10	≈0.071	≈1.2	≈7.7	≈1.3	
(2873 21)	1081.19	≈0.089	≈1.5	≈7.6	≈1.6	
(3019 21)	934.55?	≈0.03	≈0.4	≈8.3	≈0.4	

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²⁰⁹Rn ε Decay 1974Vy01,1973Jo14 (continued)

β⁺,ε Data (continued)

Eε	E(level)	Iβ ⁺ ‡	Iε‡	Log ft	I(ε+β ⁺)†‡	Comments
(3159 21)	794.61	=0.19	=2.0	=7.6	=2.2	
(3208 21)	745.79	=4.0	=40	=6.3	=44	measured E(β ⁺)=2160 40, I(β ⁺)=2.35% 50 from I(511γ) (1974Vy01).
(3546 21)	408.34	=3.0	=20	=6.7	=23	measured E(β ⁺)=2620 120, I(β ⁺)=0.85% 27 from I(511γ) (1974Vy01).

† From I(γ+ce) imbalance at each level, given as approximate due to a large amount of unplaced transitions.

‡ Absolute intensity per 100 decays.

γ(²⁰⁹At)

Measured relative x-ray intensities: %(Kα₂ x ray)=21.7 15, %(Kα₁ x ray)=38.8 19, %(Kβ₁' x ray)=14.0 10, %(Kβ₂' x ray)=4.1 5 (1974Vy01). From the decay scheme, one obtains %(Kα₂ x ray)=20.7 3, %(Kα₁ x ray)=34.4 5, %(Kβ x ray)=15.7 2 using the RadList program.

Total intensity of unplaced γ-ray transitions ≈14%.

Iγ normalization: From Σ(I(γ+ce))=100% by assuming no direct feedings to the ground state.

Eγ†	E(level)	Iγ†&	Mult.®	δ®	α	Comments
≈147#	1081.19	<1.0#			≈2.8	
x=152#		<1.0#				
182.23\$ 12	2135.78	2.3 5	[M1]		2.20	
188.4 3	934.55?	1.1 3	[M1]		2.00	
202.3# 4	3753.7	<1.0#			0.9 8	
x206.2# 4		<1.0#				
x211.7# 4		<1.0#				
x224.8# 6		<1.0#				
x230.4# 8		<1.0#				
x249.3# 4		<1.0#				
x256.3# 4		<1.0#				
x263.1# 4		<1.0#				
x265.2# 6		<1.0#				
x275.90 25		3.3 7				
279.20\$ 10	2414.99	10.3 11	M1 (+E2)	<0.4	0.64 4	
286.59\$ 10	1081.19	2.8 9	[M1]		0.624	
296.6 4	1394.45	3.0 4	M1+E2	1.6 +7-4	0.26 6	
302.98\$ 13	1097.72	5.2 13	M1 (+E2)	<0.6	0.48 6	
x324.9# 4		<1.0#				
337.46\$ 4	745.79	135 4	M1 (+E2)	<0.4	0.378 22	anisotropy R=0.903 14 (1988Ki03).
357.38 15	934.55?	3.0 9	[E2]		0.0796	
380.83\$ 10	2516.68	5.2 16	M1 (+E2)	=0.6	=0.229	
386.43a 7	794.61	19.2a 12	(M1)		0.276	Eγ: for the doublet.
	2522.37	19.2a 12	(M1)		0.276	Eγ: for the doublet.
408.32\$ 4	408.34	468 14	E2 (+M1)		0.238	anisotropy R=1.009 7 (1988Ki03).
461.47\$ 9	2414.99	13.4 7	M1 (+E2)	≤0.6	0.154 18	
x497.2# 4		=1.0#				
526.8 5	934.55?	1.9 6	M1+E2	=0.7	=0.0907	
577.14\$ 8	577.15	9.1 6	M1+E2	0.8 1	0.067 5	Eγ: transition is placed from the 2712 level by 1974Vy01; however, this placement is not consistent with the γγ data of 1973Jo14 where the 577γ is not seen in coincidence with the 1038γ. The 577γ is placed as a ground-state transition in the in-beam studies.
599.87\$ 12	1394.45	5.4 5	M1 (+E2)	<0.3	0.083 3	
x605.4 5		1.59 16	M1 (+E2)	=0.3	=0.0783	Mult.: α(K)exp=0.063 (1974Vy01).
x625.2# 7		<1.0#				
x635.3# 4		<1.0#				
x642.0# 6		<1.0#				
x656.8# 5		<1.0#				
672.83\$ 4	1081.19	30.4 10	E2 (+M1)		0.0632	
684.75\$ 15	1093.10	10.8 13	(E0+M1+E2)		0.121 21	α: From Adopted Gammas.

Continued on next page (footnotes at end of table)

^{209}Rn ε Decay 1974Vy01,1973Jo14 (continued) $\gamma(^{209}\text{At})$ (continued)

$E\gamma^{\dagger}$	E(level)	$I\gamma^{\dagger}\&$	Mult. @	δ°	α	Comments
689.29\$ 6	1097.72	90 3	M1 (+E2)	<0.4	0.056 3	anisotropy R=1.079 22 (1988Ki03).
*695.9 3		2.20 22	M1 (+E2)	=0.8	=0.0415	Mult.: $\alpha(K)\text{exp}=0.034$ (1974Vy01).
*705.50 20		2.46 25	(E1, E2)			Mult.: $\alpha(K)\text{exp}<0.028$ (1974Vy01).
722.77\$ 10	1131.11	3.84 22	M1 (+E2)	<0.4	0.050 3	E γ : placed by 1974Vy01 from the 3544 level. In ($^3\text{He},3n\gamma$), the 722 γ is placed from the 1131 level. The agreement in energy in the measured $\alpha(K)\text{exp}$ suggests that the same transition is being observed in the two experiments.
*731.0 3		2.38 14				
745.78\$ 4	745.79	212 6	M1 (+E2)	<0.4	0.0459 25	anisotropy R=1.129 14 (1988Ki03).
*761.59 8		5.2 4	M1 (+E2)	<0.5	0.042 4	Mult.: $\alpha(K)\text{exp}=0.058$ 16 (1974Vy01).
794.68\$ 7	794.61	31.3 21	E2		0.01219	
*806.3# 4		=1.0#				
*819.1# 5		=1.0#				
855.77\$ 5	1953.51	45.3 24	E1		0.00375	
868.43	2821.9	=3.1				I γ : transition shown on the level scheme in 1974Vy01, but not in table of gammas. Intensity deduced by evaluators based on intensity balance at the 2822 level.
872.40 15	1953.51	6.5 23	[E1]		0.00362	
*921.6# 4		=1.0#				
*948.7 10		2.3 $\pm$ 5	(M1+E2)		0.0258	Mult.: $\alpha(K)\text{exp}=0.025$ 8 (1974Vy01) for (948.7+951.5) doublet.
*951.5 8		2.3 $\pm$ 5	(M1+E2)		0.0256	Mult.: $\alpha(K)\text{exp}=0.025$ 8 (1974Vy01) for (948.7+951.5) doublet.
986.06\$ 10	1394.45	5.0 5	E2 (+M1)	>2	0.0095 16	
*1021.5 5		1.7 3	M1+E2	1.1 +19-6	0.014 5	Mult.: $\alpha(K)\text{exp}=0.011$ 4 (1974Vy01).
1027.55 20	3544.38	1.7 4	[E1]		0.00270	
1037.95\$ 6	2135.78	38.7 20	E1 (+M2)	<0.09	0.00283 19	
1054.52\$ 7	2135.78	15.2 8	E1 (+M2)	≤ 0.23	0.0037 12	
*1059.35\$ 10		5.2 4	E2		0.00692	Mult.: $\alpha(K)\text{exp}=0.0054$ 18 (1974Vy01).
*1065.57\$ 7		15.8 8	M1+E2	0.7 2	0.0151 16	Mult.: $\alpha(K)\text{exp}=0.0123$ 14 (1974Vy01).
1082 1	1081.19	1.0 5	[M1, E2]		0.0184	
*1085 1		1.4 5				
1097.55 25	1097.72	2.20 20	[M1]		0.01770	
1110.2 4	3627.0	1.2 5				
*1119 1		0.47 20				
1129 1	3544.38	1.59 21	[E1]		0.00228	
*1135.2 3		1.92 25				
*1143.5# 8		<1.0#				
1158.86\$ 10	1953.51	7.8 5	[E1]		0.00219	
1186.91\$ ^a 15	2581.37	3.9 ^a 3				
	3140.48	3.9 ^a 3				
*1192.0# 10		<1.0#				
1207.4 4	1953.51	2.26 21	[E1]		0.00205	
*1252#		<1.0#				
*1258#		<1.0#				
*1265#		=1.0#				
*1272#		<1.0#				
*1278.8 5		0.83 11				
*1291.2 7		0.43 11				
*1298.2 4		2.02 20				
1317.8# 8	2414.99	<1.0#				
*1323.0 6		0.38 18				
1338.0 8	3753.7	1.44 19	[E1]		1.77×10^{-3}	
1341.86\$ 13	2135.78	4.6 4	[E1]		1.76×10^{-3}	
*1349.1# 8		<1.0#				
*1377.0 6		0.88 8				
1394.50\$ 9	1394.45	9.1 4	E2 (+M1)	<1.1	0.0081 15	
1415.5# 10	3551.3	=1.0#				

Continued on next page (footnotes at end of table)

^{209}Rn ϵ Decay 1974Vy01,1973Jo14 (continued) $\gamma(^{209}\text{At})$ (continued)

$E\gamma^{\dagger}$	E(level)	$I\gamma^{\dagger}\&$	Mult. @	α
$^x1420.5^{\#} 10$		$<1.0^{\#}$		
$1429^{\#} 1$	2522.37	$<1.0^{\#}$		
$^x_{\approx}1439^{\#}$		$<1.0^{\#}$		
$1471.8 5$	2569.2	1.33 16		
$^x1497.8 8$		0.88 14		
$1500.2 4$	2581.37	0.80 10		
$^x1512.6^{\#} 7$		$<1.0^{\#}$		
$^x1516.8^{\#} 10$		$<1.0^{\#}$		
$^x1543.18^{\S} 13$		7.5 5		
$^x1555.5^{\#} 10$		$<1.0^{\#}$		
$^x_{\approx}1559^{\#}$		$<1.0^{\#}$		
$^x1568^{\#} 1$		$\approx 1.0^{\#}$		
$1592.1 3$	2689.90	1.75 11		
$^x1594^{\#} 1$		$<1.0^{\#}$		
$1597.4 6$	3551.3	0.91 11		
$^x1603.0 10$		0.47 12		
$1608.5 10$	2689.90	0.60 8		
$1616.0 10$	2712.9	0.58 12		
$1631.5 10$	2712.9	0.51 15		
$1635.0 10$	2569.2	0.50 15		
$^x1665.5 10$		0.65 13		
$1669.5 10$	2414.99	1.10 15	[E1]	1.45×10^{-3}
$^x1692.8 6$		0.45 12		
$^x1700.2 6$		0.41 11		
$^x1709.3^{\S} 3$		6.2 5		
$1722.5 10$	2516.68	1.30 15	[E1]	1.43×10^{-3}
$1727.5^{\#a} 7$	2135.78	$<1.0^{\#a}$		
	2522.37	$<1.0^{\#a}$		
$1741.0 10$	2821.9	0.33 12		
$1746.1 3$	3140.48	1.36 11		
$^x1761.0^{\#} 7$		$<1.0^{\#}$		
$1771.2 5$	2516.68	1.78 11	[E1]	1.42×10^{-3}
$1774.3 5$	2569.2	0.91 10		
$1778.2^a 5$	2712.9	$\approx 0.7^a$		
	3172.3	$\approx 0.7^a$		
$1786.6^{\#} 5$	2581.37	$\approx 1.0^{\#}$		
$^x1796.5 3$		1.53 10		
$^x1812.5^{\#} 10$		$\approx 1.0^{\#}$		
$1823^{\#} 1$	2569.2	$<1.0^{\#}$		
$1836^{\#} 1$	2581.37	$<1.0^{\#}$		
$^x_{\approx}1848^{\#}$		$<1.0^{\#}$		
$^x_{\approx}1858^{\#}$		$<1.0^{\#}$		
$^x_{\approx}1865^{\#}$		$<1.0^{\#}$		
$^x1875.0 10$		0.43 17		
$^x_{\approx}1883^{\#}$		$<1.0^{\#}$		
$1887.0 10$	2821.9	0.60 23		
$^x1912.0 7$		0.57 23		
$^x1925.7 3$		2.52 16		
$^x1950.0 10$		0.46 10		
$1954.3 10$	1953.51	1.21 12	[E1]	1.39×10^{-3}
$2043.5^{\#} 10$	3140.48	$<1.0^{\#}$		
$2074.5 3$	3172.3	0.87 10		
$2114.05 20$	2522.37	3.07 11		
$^x2121.2 5$		0.70 14		
$^x2130.5 10$		0.61 12		
$^x2133.8 10$		0.52 8		
$^x2145.0 10$		0.56 17		
$2150.0 10$	3544.38	1.41 14	[M1]	0.00370
$2160.7 6$	2569.2	0.80 10		
$^x2176.5 4$		0.67 11		
$^x2195.5 4$		1.02 10		
$2205.2 10$	3140.48	0.58 11		
$2233^{\#} 1$	3627.0	$<1.0^{\#}$		

Continued on next page (footnotes at end of table)

^{209}Rn ε Decay 1974Vy01,1973Jo14 (continued) $\gamma(^{209}\text{At})$ (continued)

$E\gamma^\dagger$	E(level)	$I\gamma^\ddagger\&$	Mult. @	α
$^x2251^\#$		$<1.0^\#$		
2281.7 4	2689.90	1.03 10		
2290.5 3	3388.43	0.68 11		
2306.0 15	3388.43	≈ 0.25		
$^x2317.2$ 4		0.78 11		
$^x2335.7^\#$ 8		$<1.0^\#$		
2346.0 3	3140.48	1.08 11		
$^x2369.5^\#$ 10		$<1.0^\#$		
2394.7 6	3140.48	0.79 9		
$^x=2404^\#$		$<1.0^\#$		
2413.5 6	2821.9	0.63 7		
2426.0 10	3172.3	≈ 0.3		
$^x=2437^\#$		$<1.0^\#$		
2446.9 4	3544.38	0.61 10	[M1]	0.00303
2453.5 ^a 5	3388.43	0.56 ^a 11		
	3551.3	0.56 ^a 11		
$^x2460.8$ 6		1.61 11		
2463.7 6	3544.38	0.93 11	[M1]	0.00300
$^x2475.5$ 4		0.93 14		
$^x2485.7$ 4		0.89 23		
$^x=2496^\#$		$<1.0^\#$		
$^x2536.7$ 7		0.38 10		
$^x2555.7$ 3		1.06 8		
$^x2638.8$ 6		0.66 13		
2642.9 3	3388.43	2.9 3		
$^x2646.4$ 8		0.75 15		
2656.4 4	3753.7	0.56 12	[M1, E2]	0.00275
$^x2667.0$ 10		0.28 10		
$^x2694.9$ 6		0.42 10		
2750.3 6	3544.38	0.46 10	[M1]	0.00265
$^x2762.5$ 7		0.55 9		
2798.1 10	3544.38	0.62 7	[M1]	0.00261
$^x=2810^\#$		$<1.0^\#$		
$^x2824.3$ 10		≈ 0.25		
2833.5 10	3627.0	≈ 0.25		
2881.0 10	3627.0	0.42 10		
$^x=2932^\#$		$<1.0^\#$		
$^x2937.0$ 10		0.28 10		
$^x2942.0$ 3		1.22 19		
2981.0 10	3388.43	0.18 6		
3007.5 6	3753.7	0.51 6	[M1, E2]	0.00248
$^x3088.5$ 10		0.38 12		
$^x3118.0$ 15		≈ 0.15		
$^x3123.5$ 15		≈ 0.15		
3136.0 8	3544.38	1.20 12	[M1, E2]	0.00242
3143.7 8	3551.3	0.59 7		
$^x3169.5$ 15		0.18 5		
$^x3183.0$ 15		0.20 5		
3218.0 15	3627.0	0.23 5		

 † From 1974Vy01, unless otherwise noted. ‡ 1974Vy01 report $I\gamma=2.3$ 5 for the 948.7 γ +951.5 γ doublet. $\S$ Weighted average of values from 1974Vy01 and 1973Jo14. $^\#$ Assignment to decay of ^{209}Rn by 1974Vy01, not definitely established. $^\circ$ From Adopted Gammas. Those for unplaced γ transitions are from ce data in 1974Vy01. $\&$ For absolute intensity per 100 decays, multiply by 0.108 4.^a Multiply placed; undivided intensity given.^x γ ray not placed in level scheme.

^{209}Rn ϵ Decay 1974Vy01,1973Jo14 (continued)

Decay Scheme

Intensities: I(γ +ce) per 100 parent decays
& Multiply placed; undivided intensity given

$^{209}_{86}\text{Rn}_{123}$ 28.8 min
5/2- 0.0
% ϵ +% β^+ =83.2
 $Q^+=3954^{+21}$

^{209}Rn ϵ Decay 1974Vy01,1973Jo14 (continued)

Decay Scheme (continued)

Intensities: I(γ +ce) per 100 parent decays
& Multiply placed; undivided intensity given

5/2- 0.0 28.8 min
 $^{209}_{86}\text{Rn}_{123}$
% ϵ +% β^+ =83.2
 $Q^+=3954^{21}$

^{209}Rn ϵ Decay 1974Vy01,1973Jo14 (continued)

Decay Scheme (continued)

Intensities: I(γ +ce) per 100 parent decays
 & Multiply placed; undivided intensity given

$^{209}_{86}\text{Rn}_{123}$ 28.8 min
 $5/2^- \quad 0.0$
 $\% \epsilon + \% \beta^+ = 83.2$
 $Q^+ = 3954^{21}$

²¹³Fr α Decay 2005Ku06

Parent ²¹³Fr: E=0.0; Jπ=9/2-; T_{1/2}=34.6 s 3; Q(g.s.)=6904.8 12; %α decay=99.45 3.

²¹³Fr-J,T_{1/2}: From Adopted Levels of ²¹³Fr.

²¹³Fr-Q(α): From 2012Wa38.

²¹³Fr-%α decay: From weighted average of electron capture branching ratios: 0.0057 3 from 1967Va20 and 0.0052 3 from 1964Gr04. %ε=0.9 1 from 1974Ho27 is much higher probably due to an unnoticed escape of Rn activity in cases where it is not trapped by implantation.

2005Ku06: Francium isotopes were produced by ²⁰⁹Bi(¹²C,xn) with the ¹²C beam produced from the UNILAC at GSI.

Evaporation residues were separated by the velocity filter SHIP and implanted into a position sensitive 16-strip PIPS Si detectors (FWHM=22 keV at 8 MeV). γ-rays were detected with a Ge-Clover detector (4.5(3)% absolute efficiency at 1.3 MeV). Measured Eγ, Iγ, Eα, Iα, αγ-coin, γγ-coin. Deduced level, α-branchings, hindrance factors.

Others:

1982Bo04: Francium isotopes were produced at the LBL Bevatron. α particles were detected by silicon surface-barrier detectors. Measured Eα, α(t). Deduced levels, T_{1/2}.

1974Ho27: Francium isotopes were produced in the ISOLDE facility. α particles were detected by a silicon surface barrier detector (FWHM=20 keV). Measured Eα, Iα, α(t). Deduced levels, T_{1/2}, α-branchings.

1967Va20: Francium isotopes were produced at the Berkeley heavy-ion linear acceleration (HILAC). α particles were detected by a Si(Au) surface barrier detectors. Measured Eα, Iα, α(t). Deduced levels, T_{1/2}, α-branchings.

1964Gr04: Francium isotopes were produced at the Berkeley heavy-ion linear acceleration (hilac). α particles were detected by an ionization chamber. Measured Eα, Iα, α(t). Deduced levels, T_{1/2}, α-branchings.

Others: 2012No08, 1980Li22.

²⁰⁹At Levels

E(level) [†]	Jπ [‡]
0.0	9/2-
408.2 2	7/2-
577.1 2	11/2-

[†] From a least-squares fit to Eγ.

[‡] From Adopted Levels.

α radiations

Eα [†]	E(level)	Iα [‡] #	HF [§]	Comments
6211 5	577.1	0.10 3	6.4 20	
6378 5	408.2	0.12 3	27 7	
6775 2	0.0	99.78 17	1.33 5	Eα: weighted average of 6775 4 (2005Ku06), 6775 2 (1982Bo04), 6779 5 (1974Ho27), 6773 5 (1967Va20) and 6770 10 (1964Gr04).

[†] From 2005Ku06, unless otherwise noted.

[‡] Relative intensities normalized to 100 for the total α intensity, values extracted indirectly from αγ-coin data (2005Ku06).

[§] r₀=1.445 11, unweighted average of r₀(²⁰⁸Po)=1.4343 34 and r₀(²¹⁰Rn)=1.4552 21 deduced using HF=1.0.

[#] For α intensity per 100 decays, multiply by 0.9945 3.

γ(²⁰⁹At)

Eγ [†]	E(level)
408.2 2	408.2
577.1 2	577.1

[†] From 2005Ku06.

Decay Scheme

1987Dr01: E=55 MeV ^9Be pulsed beam was produced from the ANU 14 UD Pelletron accelerator. Target is 13 mg/cm² ^{205}Tl (enriched to 96.4%). γ -rays were detected with three Ge detectors. Measured E_γ , $\gamma\gamma$ -coin, $\gamma(t)$. Deduced levels, $T_{1/2}$.

 ^{209}At Levels

E(level) [†]	Jπ [‡]	T _{1/2}	Comments
0.0	9/2-		
577.01 19	11/2-		
725.09 19	13/2-		
1321.6 3	17/2-		
1427.7 6	21/2-		
1851.8 6	23/2-		configuration=π(1h ² _{9/2} ,2f ¹ _{7/2}) ⁺ ₃ .
2429.2 7	29/2+	0.933 μs 11	configuration=π(1h ² _{9/2} ,1i ¹ _{13/2}) ⁺ ₃ . T _{1/2} : from 424γ(t), 597γ(t) and 725γ(t) (1987Dr01).

[†] From a least-squares fit to γ -ray energies.

‡ From 1987Dr01.

 $\gamma(^{209}\text{At})$

$E_\gamma^\dagger$	$E(\text{level})$
106.1 5	1427.7
148.0 5	725.09
424.1 2	1851.8
577.0 2	577.01
577.4 2	2429.2
596.5 2	1321.6
725.1 2	725.09

[†] The evaluators have assigned uncertainties of 0.2 keV for strong γ -rays and 0.5 keV for weak γ -rays based on the γ -ray spectrum in 1987Dr01.

²⁰⁶Pb(⁶Li,3n γ) ¹⁹⁷⁶Sj01

¹⁹⁷⁶Sj01: E=29-34 MeV ⁶Li beams were produced from the Stony Brook tandem Van de Graaff accelerator. Targets were enriched metallic foils of ²⁰⁶Pb (99%). γ -rays were detected by several Ge(Li) detectors (=12% efficiency and FWHM=2-3 keV at E=1.33 MeV; FWHM=0.5 keV for E γ <150 keV). Measured E γ , I γ , γ (θ ,H,t), $\gamma\gamma$ -coin. Deduced levels, J π , γ -multipolarities, g-factor, T_{1/2}, transition strengths.

²⁰⁹At Levels

E(level) [†]	J π [§]	T _{1/2} [‡]	Comments
0.0	9/2-		J π : from Adopted Levels.
408.7 5	(7/2-) [#]		
576.7 4	11/2-		
724.7 4	13/2-		
746.3 7	(7/2-) [#]		
789.0 7	(9/2)-		J π : from Adopted Levels.
1212.0 7			
1240.9 7	(13/2-) [#]		
1321.0 7	17/2-		
1427.1 7	21/2-	29 ns 2	g=+0.95 2. g: from γ (H,t) using TDPAD (¹⁹⁷⁶ Sj01), corrected for diamagnetism and Knight shift. T _{1/2} : from 596.3 γ (t), 576.6 γ (t) and 724.8 γ (t) (¹⁹⁷⁶ Sj01).
1771.5 8	(15/2-) [#]		
1851.0 9	(23/2-) [#]		
2428.0 13	(29/2+) [#]	0.68 μ s 8	T _{1/2} : from 423.9 γ (t) (¹⁹⁷⁶ Sj01).

[†] From a least-squares fit to γ -ray energies.

[‡] T_{1/2}≤5 ns for all excited levels except the 1427 and 2428.

[§] rom ¹⁹⁷⁶Sj01, based on deduced γ -ray transition multipolarities, unless otherwise noted.

[#] Tentative assignment by ¹⁹⁷⁸Sj01.

 γ (²⁰⁹At)

E γ	E(level)	I γ [†]	Mult. [§]	α	I(γ +ce)	Comments
106.1 2	1427.1	5.8 12	E2	6.03 10	41 [‡] 8	I γ : from I(γ +ce) and theoretical conversion coefficient. Mult.: from conversion coefficient based on intensity balance and I(γ) in delayed spectrum (¹⁹⁷⁶ Sj01).
147.9 2	724.7	9.9 20	(M1)	3.97	49 [‡] 10	I γ : from I(γ +ce) and theoretical conversion coefficient assuming mult=M1. Mult.: lifetime limit T _{1/2} <5 ns rules out a pure E2 multipolarity (¹⁹⁷⁶ Sj01).
337.6 5	746.3					
380.3 5	789.0	18 2	(M1+E2) [@]			A ₂ =-0.07 9, A ₄ =-0.4 3 (¹⁹⁷⁶ Sj01).
^x 386.9 5						
408.7 5	408.7	36 4				
423.9 5	1851.0	18 2	(M1+E2)			Mult.: A ₂ =-0.26 12, A ₄ =-0.4 3 (¹⁹⁷⁶ Sj01).
530.6 5	1771.5	8 1	(M1+E2) [@]			Mult.: A ₂ =-0.59 15, A ₄ =-0.05 5 (¹⁹⁷⁶ Sj01).
576.6 5	576.7	100 10	(M1+E2)			Mult.: A ₂ =-0.40 32, A ₄ =-0.05 6 for 576.6 γ +577 γ , implies a dipole component (¹⁹⁷⁶ Sj01).
577 1	2428.0	6.0 6				
596.3 5	1321.0	70 21	E2 [#]			Mult.: A ₂ =+0.3 1, A ₄ =-0.1 1 (¹⁹⁷⁶ Sj01).
635.3 5	1212.0					
664.2 5	1240.9	31 3	(M1+E2) [@]			Mult.: A ₂ =-0.25 6, A ₄ =-0.3 2 (¹⁹⁷⁶ Sj01).
724.8 5	724.7	100	E2 [#]			Mult.: A ₂ =+0.27 2, A ₄ =-0.06 4 (¹⁹⁷⁶ Sj01).

[†] From prompt spectrum normalized to 100 for the 724.8 γ , unless otherwise noted.

[‡] Obtained by ¹⁹⁷⁶Sj01 from intensity balance in delayed spectrum.

[§] From ¹⁹⁷⁶Sj01 based on γ (θ), unless otherwise noted.

[#] Stretched quadrupole transition based on γ (θ) data. The lifetime limits rule out mult=M2.

[@] γ (θ) suggests D+Q, but M1/E2 assignment is most probable based on the lifetime limits.

^x γ ray not placed in level scheme.

$^{209}\text{Bi}(\pi^+, \pi^-)$ 1980Mo20

1980Mo20: E=292 MeV pion beam at $\theta=5^\circ$ was produced using the EPICS facility at the Clinton P. Anderson Meson Physics Facility. Measured $\sigma(\theta)$. Deduced Isobaric Analog State (IAS).

 ^{209}At Levels

E(level)	J π	Comments
35×10^3 1	(9/2-)	<p>$\Gamma=1000$ keV.</p> <p>Jπ: possible double isobaric analog of the ^{209}Bi g.s.</p> <p>Based on the agreement of the observed and calculated energies, the authors suggest that the observed peak is the double isobaric analog state (DIAS).</p> <p>Cross section to this state is 0.46 ± 0.15 $\mu\text{b/sr}$.</p>

 $^{209}\text{Bi}(^3\text{He}, 3n\gamma)$ 1985Ra21, 1978Ad05

1985Ra21: E=19.0–27.6 MeV ^3He beams were produced from the 90 cm cyclotron of the Physics Department of Jyvaskyla University (JYFL). Pure ^{209}Bi target was used. γ -rays were detected by medium-sized (6–13% efficiency) Ge(Li) detectors and conversion electrons were detected by the jyfl electron spectrometer. Measured $E\gamma$, $I\gamma$, $\gamma(\theta)$, $\gamma(t)$, $\gamma\gamma$ -coin, $I(\text{ce})$, pulsed beam. Deduced levels, J π , $T_{1/2}$, γ -branchings, γ -ray transition multiplicities, conversion coefficients, configuration.

1978Ad05: E=28 and 26 MeV ^3He beams were produced from the U-120 cyclotron of the Nuclear Physics Institute in Rez. A monoisotopic target of about 10 mg/cm² thickness was used. γ -rays were detected by Ge(Li) detectors with volumes of 34 and 7 cm³. Measured $E\gamma$, $I\gamma$, $\gamma\gamma$ -coin. Deduced levels, J π .

 ^{209}At Levels

E(level) [†]	J π [‡]	$T_{1/2}$	Comments
0.0	9/2-		J π : from Adopted Levels.
408.29 9	7/2-		
577.01 8	11/2-		configuration= $\pi(1h_{9/2})^{+1} \otimes 2^+$.
725.01 8	13/2-		configuration= $\pi(1h_{9/2})^{+1} \otimes 2^+$.
745.85 15	(9/2)-		
789.09 22	(5/2, 7/2)-		
794.70 15	(5/2, 7/2)-		
1081.49 22	(5/2-, 7/2-)		
1097.69 22	(5/2-, 7/2-)		
1130.89 22	(5/2, 7/2)-		
1214.24 13	(11/2, 13/2)-		
1242.29 11	(13/2-)		
1269.77 18	(11/2, 13/2)-		J π : 1985Ra21 assigns J $\pi=15/2-$ from 692.8 γ to 11/2- with mult=pure E2, however, the measured $\alpha(K)_{\text{exp}}=0.026$ 3 in 1985Ra21 gives mult=M1+E2 with $\delta(E2/M1)=1.3$ 3.
1321.51 13	17/2-		configuration= $\pi(1h_{9/2})^{+3}$.
1339.51 22	(13/2, 15/2)-		
1393.51 13	(13/2, 15/2)-		
1427.61 24	21/2-	24 ns 2	$T_{1/2}$: from 596.5 $\gamma(t)$ and 725.0 $\gamma(t)$ in 1985Ra21. configuration= $\pi(1h_{9/2})^{+3}$.
1516.83 15	(13/2-, 15/2-)		
1659.91 22			
1772.50 13	(15/2-)		
1851.6 3	23/2-		configuration= $\pi(1h_{9/2}^2 2f_{7/2}^1)^{+3}$.
1907.21 17	19/2-		
2075.91 24	(19/2-)		configuration= $\pi(1h_{9/2}^2 2f_{7/2}^1)^{+3}$.
2086.30 24			
2238.3 3	25/2-		
2429.3 3	29/2+	860 ns 20	$T_{1/2}$: from 577.7 $\gamma(t)$ in 1985Ra21. configuration= $\pi(1h_{9/2}^2 1i_{13/2}^1)^{+3}$.
2605.3 4	(25/2+)		configuration= $\pi(1h_{9/2}^2 1i_{13/2}^1)^{+3}$.
2611.9 4	(25/2-)		
3188.6 4	(31/2+)		

[†] From a least-squares fit to γ -ray energies.

[‡] From 1985Ra21, based on deduced γ -ray transition multiplicities, unless otherwise noted.

²⁰⁹Bi(³He,3n)^γ 1985Ra21,1978Ad05 (continued)

^γ (²⁰⁹ At)						
E ^γ †	E(level)	I ^γ †	Mult.‡	δ#	α	Comments
106.1 [±] 2	1427.61	9 1	E2		6.03 10	Mult.: from 1975Be39 in (α,4n ^γ). Also, A ₂ =+0.08 1, A ₄ =+0.02 2 (1985Ra21), T _{1/2} =24 ns 2 rules out mult=pure M2.
147.9 [±] 2	725.01	7.0 7	M1		3.97	Mult.: α(L)exp=0.52 5, A ₂ =-0.11 1, A ₄ =+0.01 2 (1985Ra21).
247.1 2	1516.83	1.0 2				
313.8 2	2086.30	2.0 4				
337.6 [±] 2	745.85	5.0 5	M1 (+E2)	<0.4	0.378 22	Mult.,δ: α(K)exp=0.33 3, A ₂ =+0.11 5, A ₄ =+0.05 8 (1985Ra21).
380.8 [±] 2	789.09	5.0 5	M1 (+E2)	<0.4	0.272 16	Mult.,δ: α(K)exp=0.24 3, A ₂ =+0.02 5, A ₄ =+0.01 8 (1985Ra21).
386.4 2	794.70	≈2@	(M1+E2)@		0.17 11	I ^γ : from I ^γ (386 ^γ)/I ^γ (795 ^γ)=0.61 in ε decay.
386.6 2	2238.3	≈5@	(M1+E2)@		0.17 11	I ^γ : from I ^γ for the doublet and I ^γ (386.4 ^γ) determined from branching in ε decay. 4 2 for 386.3 ^γ in 1978Ad05.
408.3 [±] 1	408.29	36.0 4	E2		0.0557	Mult.: α(K)exp=0.035 2, A ₂ =-0.03 1, A ₄ =-0.01 1 (1985Ra21).
424.0 [±] 1	1851.6	25.0 3	M1		0.215	Mult.: α(K)exp=0.183, A ₂ =-0.21 2, A ₄ =-0.03 2 (1985Ra21).
489.2 2	1214.24	3.0 6	M1 (+E2)	<0.3	0.142 5	Mult.,δ: α(K)exp=0.14 2 (1985Ra21).
517.2 [±] 2	1242.29	3.0 6	(E2)		0.0310	Mult.: α(K)exp=0.03 2 (1985Ra21).
530.2 [±] 1	1772.50	10.0 5	M1+E2	0.57 5	0.097 4	Mult.,δ: α(K)exp=0.078 2, A ₂ =-0.30 3, A ₄ =-0.00 5 (1985Ra21).
577.0 [±] 1	577.01	95 1	M1+E2	0.71 11	0.071 5	Mult.,δ: from α(K)exp=0.055 3, A ₂ =-0.25 1, A ₄ =+0.01 1 for 577.0+577.7 and I(577.0 ^γ)/I(577.7 ^γ)=95/11 given mult(577.7 ^γ) is E3 from 1975Be39 in (α,4n ^γ). α(K)exp=0.55 in 1985Ra21 is a typographical error.
577.7 [±] 1	2429.3	11.0 6	E3		0.0749	Mult.: from 1975Be39 in (α,4n ^γ).
585.7 [±] 1	1907.21	11.0 6	M1+E2	1.8 3	0.039 5	Mult.,δ: from α(K)exp=0.030 3, but A ₂ =-0.33 4 and A ₄ =+0.04 5 imply a stretched dipole (1985Ra21).
596.5 [±] 1	1321.51	77 1	E2		0.0224	Mult.: α(K)exp=0.017 1, A ₂ =+0.10 1, A ₄ =-0.01 1 (1985Ra21).
614.5 2	1339.51	6.0 6	M1+E2	0.48 14	0.069 6	Mult.: α(K)exp=0.056 4, A ₂ =+0.06 8, A ₄ =-0.06 11 (1985Ra21).
637.2 [±] 2	1214.24	6.0 6	M1 (+E2)	<0.3	0.0707 25	Mult.,δ: α(K)exp=0.062 5, A ₂ =+0.02 7, A ₄ =0.0 1 (1985Ra21).
665.3 1	1242.29	18 1	D			Mult.: A ₂ =-0.07 1, A ₄ =-0.02 2 (1985Ra21).
668.5 1	1393.51	11.0 6	M1 (+E2)	<0.2	0.0634 13	Mult.,δ: α(K)exp=0.057 4 (1985Ra21).
673.2 2	1081.49	1.0 2				
689.4 2	1097.69	3.0 6				
692.8 [±] 2	1269.77	12 1	M1+E2	1.3 3	0.032 6	Mult.: α(K)exp=0.026 3 (1985Ra21), mult=pure E2 assigned by 1985Ra21.
722.6 2	1130.89	4.0 8	M1 (+E2)	≤0.9		Mult.,δ: α(K)exp=0.04 1 (1985Ra21).
725.0 [±] 1	725.01	100	E2		0.01472	Mult.: α(K)exp=0.011 1, A ₂ =+0.11 1, A ₄ =-0.03 1 (1985Ra21).
745.8 [±] 2	745.85	7.0 7	M1 (+E2)	<0.3	0.0468 16	Mult.: α(K)exp=0.040 2 (1985Ra21).
753.7 2	2605.3	4.0 8	(E1)&		0.00475	
754.4 2	2075.91	3.0 6	(M1)&		0.0468	
759.3 2	3188.6	2.0 4	(M1) ^a		0.0461	
760.3 2	2611.9	3.0 6	(M1) ^a		0.0459	
791.8 2	1516.83	3.0 6				
794.7 2	794.70	3.0 6				
810.8 [±] 4	2238.3	7.0 7	E2		0.01170	Mult.: α(K)exp=0.008 2, A ₂ =+0.21 6, A ₄ =+0.06 9 (1985Ra21).
934.9 2	1659.91	3.0 6				
939.8 2	1516.83	2.0 4				
1047.5 2	1772.50	2.0 4				
1214.3 2	1214.24	3.0 6				

† From 1985Ra21, unless otherwise noted. 1985Ra21 states that the uncertainties in E^γ are 0.1–0.2 keV. The evaluators have assigned uncertainties for E^γ from 1985Ra21 of 0.1 keV where I^γ is ≥10 and 0.2 keV for I^γ<10. 1985Ra21 states that uncertainties in I^γ range from 1–20%. The evaluators have assigned uncertainties for I^γ from 1985Ra21 as follows: 1% for I^γ≥20, 5% for I^γ≥10, 10% for I^γ≥5 and 20% for I^γ<5. I^γ is normalized to I(725^γ)=100.

²⁰⁹Bi(³He,3n γ) 1985Ra21,1978Ad05 (continued)

 $\gamma(^{209}\text{At})$ (continued)

‡ Weighted average of values from 1985Ra21 and 1978Ad05.

§ From I γ and I(ce(K)) data in 1985Ra21 (except I(ce(L)) for the 148 γ), normalized to M1 value 0.183 for the 424 γ , unless otherwise noted.

From measured ce data using the BrIccMixing program.

@ I γ (386.4+386.6 γ 's)=7. A₂=-0.04 2, A₄=-0.06 3, α (K)exp= 0.10 4 for 386.4+386.6 γ 's (1985Ra21). The intensities were divided by using branching from ϵ decay.

& α (K)exp=0.03 1 and A₂=-0.38 5, A₄=-0.01 8 from γ (θ) for the 753.7+754.4 γ 's (1985Ra21).

^a α (K)exp=0.05 1 and A₂=-0.38 6, A₄=-0.01 9 from γ (θ) for the 759.3+760.3 γ 's (1985Ra21).

²⁰⁹Bi(α ,4n γ) 1975Be39,1990Mu04

1975Be39: E=42-51 MeV α particles were produced from the Stockholm 225-cm cyclotron. Targets were metallic Bi.

γ -rays were detected by a coaxial Ge(Li) detector (θ =90°-150°) and conversion electrons were detected by a Si(Li) detector in a spectrometer (FWHM=2.1 keV at about 500 keV). Measured E γ , I γ , γ (q), γ (t), E(ce), I(ce), pulsed beam. Deduced levels, J π , γ -branchings, γ -ray transition multipolarities, conversion coefficients, half-lives, g-factors. ce data of 1975Be39 also reported in 1975Li12.

1990Mu04: E=44-54 MeV α particles were produced from the Variable Energy Cyclotron at Calcutta. An extremely pure rolled Bi target was used. γ -rays were detected by two n-type Ge detectors at θ =90°, 106°, 120° and 130°. Measured E γ , I γ , γ (q), γ -coin. Deduced levels, J π , γ -ray transition multipolarities.

Others:

1990Ha30,1991Sc15: α beams were produced at the cyclotron Cyclone at Louvain-la-neuve at Belgium. Detectors were placed in 0° and 90°. Measured quadrupole moments using the Level Mixing spectroscopy (LEMS) method.

1983Ma08: E=60 MeV α particles were produced from the VICKSI accelerator at the Hahn-Meitner-Institut. γ -rays were detected with Ge(Li) detectors (θ =0° to 90°). Measured E γ , γ (θ ,H,t). Deduced half-lives, quadrupole moments of isomers.

1983Ha51: E=45 MeV α particles were produced from the cyclotron at Karlsruhe. A target of $\approx$ 2 mg/cm² Bi evaporated onto a 4 mg/cm² Cu foil was used. Measured E γ , I γ , γ (θ). Deduced levels, quadrupole moment ratio of Q(²⁰⁹At)/Q(²¹⁰At).

²⁰⁹At Levels

E(level) [†]	J π [‡]	T _{1/2}	Comments
0.0	9/2-		J π : from Adopted Levels. Q: Q(²⁰⁹ At)/Q(²¹⁰ At)=1.47 7 (1983Ha51). configuration= $\pi(1h_{9/2})^{+1}$. configuration= $\pi(1h_{9/2})^{+1} \otimes 2^{+}$. configuration= $\pi(1h_{9/2})^{+1} \otimes 2^{+}$. configuration= $\pi(1h_{9/2})^{+3}$. g=0.88 6 (1975Be39). Q=0.78 8 (1983Ma08). Q: measured using the TDPAD method (1983Ma08). T _{1/2} : weighted average of 25 ns 1 from 106 γ (t), 148 γ (t), 577 γ (t), 596 γ (t) 725 γ (t) in 1975Be39 and 24 ns 2 from 596 γ (t) and 725 γ (t) in 1983Ma08. g-factor: from γ (θ ,H,t) using the TDPAD method with Knight-shift and diamagnetic shielding corrections applied (1975Be39). configuration= $\pi(1h_{9/2})^{+3}$. configuration= $\pi(1h_{9/2} 2f_{7/2}^1)^{+3}$.
577.07 12	11/2-§		
725.08 10	13/2-§		
1321.59 14	17/2-§		
1427.69 17	21/2-§	25 ns 1	
1851.78 20	23/2-§		
1907.5 6	19/2-		
2075.6 6	(19/2-)		
2183.2 6			
2238.2 4	25/2-		
2402.5 8			
2429.2 3	29/2+§	0.794 μ s 20	g=1.061 10. Q=1.50 15 (1983Ma08). Q: measured using the TDPAD method (1983Ma08). T _{1/2} : from 424 γ (t) in 1983Ma08. Other: 0.88 μ s 10 from 577 γ (t), 596 γ (t), and 725 γ (t) in 1975Be39. configuration= $\pi(1h_{9/2} 2i_{13/2}^1)^{+3}$. g-factor: weighted average of 1.061 10 (1987Ca23) and 1.060 20 (1975Be39) using the TDPAD method.
2605.8 6	25/2+		
2611.4 3	25/2-		

Continued on next page (footnotes at end of table)

²⁰⁹Bi(α,4nγ) 1975Be39,1990Mu04 (continued)

²⁰⁹At Levels (continued)

E(level) [†]	Jπ [‡]	Comments
2677.4 8		
2683.8 7	(27/2-)	
3188.2 4	31/2+	
3292.8 8	(29/2-)	
3592?	33/2+	E(level): the relative order of the 405.4γ and 583.7γ has not been established. These cascade transitions could define a level at 3771 instead of at 3592.
3748.3 6	(33/2+)	
3812.2 6	(35/2+, 33/2+)	
3898.7 6	33/2+	
4176	35/2+	
4376.2 8		
4506?		
4696.5 8		

[†] From a least-squares fit to γ-ray energies.

[‡] From 1990Mu04, except where noted otherwise.

[§] Assignments are also from 1975Be39 based on stretched-cascade arguments and the absence or presence of crossover transitions, and the γ-ray transition multipolarity arguments.

γ(²⁰⁹At)

Eγ [†]	E(level)	Iγ [§]	Mult. [@]	α	Comments
106.1 [‡] 1	1427.69	11.8 [‡]	E2&	6.03	Mult.: α(exp)=6.3 8 from an intensity balance at the 1321.6 level using delayed intensities (1975Be39).
148.0 [‡] 1	725.08	5.9 [‡]	M1&	3.96	Mult.: α(exp)=3.9 5, A ₂ =-0.044 43 from 1975Be39.
326.9 5	2402.5	3.8 2	M1	0.435	
386.5 5	2238.2	10.7 6	M1+E2	0.17 11	
405.4 ^b 5	3592?	9.2 10	M1	0.243	
424.1 [‡] 1	1851.78	62 [‡]	M1&	0.215	Mult.: α(exp)=0.23 2 from intensity balance in delayed spectrum, α(K)exp/α(L)exp=5.9 4, A ₂ =-0.123 14 from 1975Be39.
445.6 5	2683.8	7.8 4	M1	0.188	
494.2 5	2677.4	3.5 2			
560.1 5	3748.3	6.1 5			
564.0 5	4376.2	5.6 5			
577.0 [‡] 2	577.07	40 [‡]	M1&	0.0947	Mult.: α(K)exp/α(L)exp=2.0 2 and A ₂ =-0.133 22 for the 577.0+577.4 doublet from 1975Be39.
577.4 [‡] 2	2429.2	50 [‡]	E3&	0.0750	Mult.: α(exp)=0.07 1 from intensity balances, and also α(K)exp/α(L)exp=2.0 2 and A ₂ =-0.133 22 for the 577.0+577.4 doublet from 1975Be39.
583.7 ^b 5	4176	11.5 7	M1	0.0919	
585.9 5	1907.5	7.2 5	M1(+E2)	0.06 4	
596.5 [‡] 1	1321.59	100	E2	0.0224	Mult.: α(exp)=0.0222, α(K)exp/α(L)exp=3.3 3, A ₂ =-0.091 12 from 1975Be39.
609.0 5	3292.8	7.3 10			
624.0 5	3812.2	6.4 4	M1	0.0770	
710.5 5	3898.7	5.5 3	M1	0.0548	
725.1 [‡] 1	725.08	82.5 [‡]	E2&	0.01471	Mult.: α(exp)=0.016 3, α(K)exp/α(L)exp=4.5 4, A ₂ =+0.091 8 from 1975b39. γ-branching: I(148γ)/I(725γ)=0.072 from singles spectrum; 0.051 from delayed spectrum; 0.054 18 from authors' deduced I(γ+ce) for the 725.1γ and 577.0γ based on intensity-balance arguments, the requirement I(γ+ce 148.0γ)=I(γ+ce 577.0γ), and adopted α's.
754.0 ^a 5	2075.6	18 ^a 2			
	2605.8	18 ^a 2			
755.5 5	2183.2	11 1	M1	0.0467	
759.0 ^a 2	3188.2	41 ^{#a} 4	M1	0.0461	
	4506?	41 ^{#a} 4	M1	0.0461	
759.6 2	2611.4	22 2	M1	0.0460	
797.8 5	4696.5	3.2 2			
810.4 5	2238.2	7.3 4	E2	0.01171	

Footnotes continued on next page

 $^{209}\text{Bi}(\alpha, 4n\gamma)$ $^{1975}\text{Be39}, ^{1990}\text{Mu04}$ (continued)

 $\gamma(^{209}\text{At})$ (continued)

† From 1990Mu04. The evaluators have assigned uncertainties of 0.2 keV for strong γ -rays and 0.5 keV for weak γ -rays based on the γ -spectrum in 1990Mu04, unless otherwise noted.

‡ From 1975Be39, γ -ray intensities normalized to $I(596\gamma)=100$.

§ From 1990Mu04, normalized to $I(596\gamma)=100$, unless otherwise noted.

From intensity balance at the 3747 level, $I\gamma(759\gamma \text{ from } 4506)$ is expected to be <66. The major fraction of the intensity of this transition thus appears to be from the 3187 level (1990Mu04).

@ From 1990Mu04, except where noted otherwise. Authors' assignments are based on $\gamma(0)$. Since the basis for distinguishing M1 from E1, etc., is not stated, the assignments are tentative.

& From ce data in 1975Be39.

^a Multiply placed; undivided intensity given.

^b Placement of transition in the level scheme is uncertain.

Adopted Levels, GammasQ(β^-)=-5161 25; S(n)=7345 23; S(p)=3748 22; Q(α)=6155.5 20 2012Wa38.**209Rn Levels****Cross Reference (XREF) Flags**

A 209Fr ϵ Decay
 B 213Ra α Decay (2.73 min)
 C 213Ra α Decay (2.18 ms)
 D 198Pt(16O,5n γ)

E(level) [†]	J π	XREF	T _{1/2}	Comments
0.0	5/2-	ABCD	28.8 min 10	$\% \alpha = 17.2$; $\% \epsilon + \% \beta^+ = 83.2$. $J\pi$: from collinear laser spectroscopy (1987Bo29,1987OtZW); favored α -decay to 205Po g.s. ($J\pi = 5/2^-$). $T_{1/2}$: weighted average of 28.5 min 10 (1971Go35) and 30 min 3 (1955Mo68). $\% \alpha, \% \epsilon + \% \beta^+$: from measured $\% \alpha = 17.2$ (1971Go35) and $\% I(\epsilon + \beta) + \% I(\alpha) = 100$. $\mu = 0.8388$ 4 (1988Ki03); $Q = +0.31$ 3 (1987OtZW). μ : measured using the NMR technique (1988Ki03). Other: 0.82 from 1987Bo29 using the Collinear Fast beam Laser Spectroscopy technique. Q : measured using the Collinear Fast Beam Laser Spectroscopy technique. configuration= $v(f_{5/2})^{-1}$. $E\alpha$ (decay to 205Po g.s.)=6039 3 (1971Go35), 6037 3 (1955Mo69). $J\pi$: 110.3 γ E2 to 5/2-; favored α decay from 213Ra g.s. ($J\pi = 1/2^-$). configuration= $v(p_{1/2})^{-1}$. $J\pi$: 104.8 γ M1(+E2) to 1/2- and 214.9 γ M1(+E2) to 5/2-. configuration= $v(p_{3/2})^{-1}$. $J\pi$: 218.1 γ M1 to 1/2- and 328.3 γ M1(+E2) to 5/2-. $J\pi$: 272.1 γ to 1/2-, 382.3 γ to 5/2-. $J\pi$: 183.0 γ and 296.4 γ M1 to 3/2-.
110.25 8	1/2-	ABC		
214.93 9	3/2-	BC		
328.31 9	3/2-	B		
382.33 15	(3/2-) [‡]	A		
511.32 14	(1/2, 3/2, 5/2)-	B		
547.10 20	(7/2-) [‡]	A		
652.60 21	(5/2-) [‡]	A		
690.1 3	(1/2-, 3/2-) [‡]	A		
797.83 10	9/2- [‡]	A D		$J\pi$: 797.8 γ E2 to 5/2-.
867.70 18	(7/2, 9/2-)	A		$J\pi$: 867.7 γ to 5/2-; possible feeding in $\epsilon + \beta^+$ decay ($J\pi = 9/2^-$).
1020.7 4		A		
1174.01 13	13/2+	A D	13.4 μ s 13	$J\pi$: 376.2 γ stretched M2 to 9/2-. $T_{1/2}$: from 376.2 γ (t) and 797.8 γ (t) in 198Pt(16O,5n γ) (1985Po08). configuration: $v(i_{13/2})^{-1}$. $J\pi$: 529.5 γ to 9/2- and 1327.7 γ to 5/2-.
1327.45 18	(5/2-, 7/2, 9/2-)	A		
1352.7 3		A		
1383.2 3		A		
1388.2 3		A		
1465.56 13	13/2-	A D		$J\pi$: 667.7 γ stretched E2 to 9/2-.
1561.58 13	15/2-	D		$J\pi$: 96.02 γ M1+E2 $\Delta J=1$ to 13/2- and 387.5 γ E1 to 13/2+.
1588.41 24		A		
1610.70 14	17/2-	D		$J\pi$: 49.12 γ M1(+E2) to 15/2-.
1687.43 15	19/2-	D	0.69 ns 21	$J\pi$: 76.75 γ stretched M1 to 17/2-. $T_{1/2}$: from 76.75 γ (t) and 96.02 γ (t) from 198Pt(16O,5n γ) (1985Po08). configuration= $v(f_{5/2})^{-1} \otimes \pi(h_{9/2})^{+4}_{8+}$.
1767.0 4		A		
1931.3 4		A		
2238.18 17	21/2-	D		$J\pi$: 550.8 γ M1(+E2) to 19/2-, 627.2 E2 to 17/2-.
2418.74 18	21/2+	D	8.73 ns 21	$J\pi$: 731.3 γ stretched E1 to 19/2-. $T_{1/2}$: from 731.3 γ (t) from 198Pt(16O,5n γ) (1985Po08). configuration= $v(li_{13/2})^{-1} \otimes \pi(h_{9/2})^{+4}_{4+}$. $J\pi$: 813.9 γ E2 to 19/2-. $J\pi$: 325.4 γ M1+E2 to 21/2+.
2501.32 17	23/2-	D		$J\pi$: 610.3 γ E2 to 21/2-.
2744.17 21	(23/2)+	D		
2848.51 18	25/2-	D		
2864.6 3		D		
2957.61 18	27/2-	D		$J\pi$: 456.3 γ E2 to 23/2-.
3050.0 4		D		
3157.51 21	29/2-	D	13.9 ns 21	$J\pi$: 199.9 γ M1+E2 to 27/2-. $T_{1/2}$: from 199.9 γ (t) from 198Pt(16O,5n γ) (1985Po08). configuration= $v(p_{1/2})^{-1} \otimes \pi((h_{9/2})^{+3}(f_{7/2})^{+1})^{+4}_{14+}$.

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Adopted Levels, Gammas (continued)
²⁰⁹Rn Levels (continued)

E(level) [†]	J π	XREF	T _{1/2}	Comments
3400.7 3		D		
3539.9 3	(27/2)+	D		J π : 795.7 γ E2 to (23/2)+.
3636.81 23	35/2+	D	3.0 μ s 3	J π : 479.3 γ E3 to 29/2-.
				T _{1/2} : from 479.3 γ (t) and 199.9 γ (t) from ¹⁹⁸ Pt(¹⁶ O,5n γ) (1985Po08).
				configuration= $v(p_{1/2})^{-1} \otimes \pi((h_{9/2})^{+3}(i_{13/2})^{+1})^4_{17-}$.
3671.5 4	(29/2)+	D		J π : 131.6 γ M1 to (27/2)+.
3987.0 4	(31/2)+	D		J π : 315.5 γ M1 to (29/2)+.
4182.4 4	(33/2)+	D		J π : 195.4 γ M1+E2 to (31/2)+.
4583.6 4	(35/2)+	D		J π : 401.3 γ M1+E2 to 33/2+.
4833.7 3	41/2-	D	10.0 ns 4	J π : 1196.9 γ E3 to 35/2+.
				T _{1/2} : from 1196.9 γ (t) in ¹⁹⁸ Pt(¹⁶ O,5n γ) (1985Po08).
				configuration= $v(p_{1/2})^{-1} \otimes \pi((h_{9/2})^{+2}(i_{13/2})^{+2})^4_{20+}$.
4988.0 4	(37/2)+	D		J π : 404.4 γ M1+E2 to (35/2)+.
5216.9? 4	41/2+	D		E(level): the order of 383.2 γ and 602.8 γ is not well determined, and reversing the order of the two transitions would place a level of J π =(43/2-) at 5437 keV (1985Po08).
				J π : 383.2 γ to 41/2- is consistent with a $\Delta J=0$ pure dipole (from $\gamma(0)$); 602.8 γ M1+E2 from 43/2+.
5819.8 4	43/2+	D		J π : 986.1 γ stretched E1 to 41/2-.
6538.0 5	47/2+	D		J π : 718.2 γ E2 to 43/2+.
6772.1 6	49/2+	D		J π : 234.1 γ M1+E2 to 47/2+.
6826.1 6	49/2+	D		J π : 288.1 γ M1+E2 to 47/2+.
7307.7 7	51/2	D		J π : 481.6 γ D to 47/2+.

[†] From a least-squares fit to E γ .

[‡] From 1996Xu02 in ²⁰⁹Fr ϵ decay. The authors proposed configuration= $v(f_{5/2})^{-1} \otimes 2^+$ for the levels of 382.33, 547.10, 652.60, 690.1 and 797.8 from comparisons with the low-lying states in ²⁰⁷Po and ²⁰⁵Pb. The assignments are tentative.

 $\gamma(^{209}\text{Rn})$

E(level)	E γ [†]	I γ [†]	Mult. [@]	δ &	α	Comments
110.25	110.3# 1	100	E2		5.48	Mult.: $\alpha(\text{exp})=5.1\ 9$ from ²¹³ Ra α decay (2.73 min) (2006Ku26).
214.93	104.8# 2	29# 8	M1(+E2)	≤ 0.8	10.8 12	I γ : from ²¹³ Ra α decay (2.73 min). I γ /I γ (215 γ)=0.12 11 in ²¹³ Ra α decay (2.15 ms) (2006Ku26).
	214.9# 1	100# 20	M1(+E2)	< 1.2	1.2 4	Mult., δ : $\alpha(K)\text{exp}=8.1\ 24$ in ²¹³ Ra α decay (2.73 min) (2006Ku26). Mult., δ : from estimated E2 admixture $< 58\%$ based on intensity balance in ²¹³ Ra α decay (2.73 min) (2006Ku26).
328.31	(113.3# 2)	$< 15\#$				E γ ,I γ : Not observed, but inferred in ²¹³ Ra α decay (2.73 min) (2006Ku26) from intensity balance at the 328 level. Intensity limit of I(113.3 γ)/I(328.3 γ) < 0.15 in 2006Ku26 is based upon systematics of N=123 isotones.
	218.1# 2	49# 21	M1		1.444	Mult.: $\alpha(K)\text{exp}=1.7\ 16$ from ²¹³ Ra α decay (2.73 min) (2006Ku26).
	328.3# 1	100# 36	M1(+E2)		0.467	Mult.: Estimated by 2006Ku26 from intensity balance, life-time limit, and ce data. M1+E2 is not excluded from ²¹³ Ra α decay (2.73 min).
382.33	272.1§ 2	100§ 25				
	382.3§ 2	75§ 25				
511.32	183.0# 2	29# 16	M1		2.36	Mult.: $\alpha(\text{exp})=2.5\ 18$ from ²¹³ Ra α decay (2.73 min) (2006Ku26).
	296.4# 2	100# 51	M1		0.617	Mult.: $\alpha(\text{exp})=0.9\ 6$ from ²¹³ Ra α decay (2.73 min) (2006Ku26).
	401.6#a 6	3.1# 24				
	511.3# 3	49# 27				
547.10	547.1§ 2	100				

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Adopted Levels, Gammas (continued) $\gamma(^{209}\text{Rn})$ (continued)

E(level)	$E\gamma^{\dagger}$	$I\gamma^{\dagger}$	Mult. @	$\delta\&$	α	Comments
652.60	652.6 § 3	100				
690.1	690.1 § 3	100				
797.83	797.8 I	100	E2		0.01269	Mult.: $\alpha(\text{K})_{\text{exp}}=0.010$ I, $A_2=+0.13$ I, $A_4=-0.02$ I from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
867.70	215.1 § 2	100 § 7				
	867.7 § 2	53 § 20				
1020.7	330.6 § 2	100				
1174.01	376.2 I	100	M2		1.029	Mult.: $\alpha(\text{exp})=1.10$ 6, $\alpha(\text{K})_{\text{exp}}=0.89$ 7, $\alpha(\text{L})_{\text{exp}}=0.27$ 3, $A_2=+0.06$ 2, $A_4=-0.01$ 2 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08). B(M2)(W.u.)=0.0043 5.
1327.45	529.5 § 2	80 § 40				
	1327.7 § 3	100 § 40				
1352.7	805.6 § 2	100				
1383.2	836.1 § 2	100				
1388.2	841.1 § 2	100				
1465.56	667.7 I	100	E2		0.0184	Mult.: $\alpha(\text{K})_{\text{exp}}=0.014$ I, $A_2=+0.16$ I, $A_4=-0.03$ I from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
1561.58	96.02 5	82 $\frac{1}{2}$	M1+E2	0.22 +10-17	3.2 4	Mult.: $\alpha(\text{exp})=3.2$ 3 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
	387.6 I	100 $\frac{1}{2}$	(E1)		0.0188	Mult.: $\alpha(\text{K})_{\text{exp}}<0.22$, $A_2=-0.05$ 2, $A_4=-0.01$ 2. $\alpha(\text{K})_{\text{exp}}$ is consistent with E1 or E2(+M1); the placement in the level scheme requires $\Delta\pi=\text{yes}$.
1588.41	414.4 § 2	100				
1610.70	49.12 5	100	M1 (+E2)	≤ 0.14		Mult.: $\alpha(\text{exp})=22$ 2 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
1687.43	76.75 5	100	M1		5.51	Mult.: $\alpha(\text{exp})=5.4$ 9 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08). B(M1)(W.u.)=0.011 4.
1767.0	178.6 § 2	100				
1931.3	1384.2 § 3	100				
2238.18	550.8 I	100 $\frac{1}{2}$	M1 (+E2)	≤ 0.7	0.11 3	Mult.: $\alpha(\text{K})_{\text{exp}}=0.09$ 2, $A_2=-0.45$ 4, $A_4=+0.06$ 4 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
	627.2 2	22 $\frac{1}{2}$	[E2]		0.0210	Mult.: $A_2=+0.03$ 7, $A_4=-0.07$ 8 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
2418.74	731.3 I	100	E1		0.00522	B(E1)(W.u.)= 5.60×10^{-8} 14. Mult.: $\alpha(\text{K})_{\text{exp}}=0.003$ I, $A_2=-0.05$ 2; $A_4=+0.01$ 2 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
2501.32	813.9 I	100	E2		0.01219	Mult.: $\alpha(\text{K})_{\text{exp}}=0.012$ 2, $A_2=+0.15$ 2, $A_4=-0.03$ 2 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
2744.17	325.4 I	100	M1+E2	0.6 3	0.38 7	Mult.: $\alpha(\text{K})_{\text{exp}}=0.30$ 6, $A_2=-0.38$ 5, $A_4=+0.02$ 2 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
2848.51	347.2 I	35 $\frac{1}{2}$	M1 (+E2)	<1.6	0.29 12	Mult.: $\alpha(\text{exp})=0.5$ 2, $A_2=-0.14$ 6, $A_4=-0.09$ 6 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
	610.3 I	100 $\frac{1}{2}$	E2		0.0223	Mult.: $\alpha(\text{K})_{\text{exp}}=0.019$ 6, $A_2=+0.11$ 3, $A_4=-0.02$ 3 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
2864.6	446.2 3	100				
2957.61	109.10 7	29 $\frac{1}{2}$	M1 (+E2)	≤ 0.16	9.1 2 I	Mult.: $\alpha(\text{exp})=9$ 2 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
	456.3 I	100 $\frac{1}{2}$	E2		0.0439	Mult.: $\alpha(\text{K})_{\text{exp}}$ is consistent with D or E2. The placement in the level scheme requires mult=E2 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08). $A_2=+0.20$ 5, $A_4=+0.03$ 5 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
3050.0	185.4 I	100				
3157.51	199.9 I	100	M1+E2	1.6 4	0.89 17	Mult.: $\alpha(\text{exp})=0.9$ I, $A_2=-0.13$ 3, $A_4=+0.02$ 3 from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08). B(M1)(W.u.)= 2.9×10^{-5} 12; B(E2)(W.u.)=0.66 15.
3400.7	656.3 3	100				
3539.9	139.2 2	≈ 62				
	382.0 ^a 3	88				
	490.6 4	88				

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Adopted Levels, Gammas (continued)

 $\gamma(^{209}\text{Rn})$ (continued)

E(level)	E $\gamma^\dagger$	I $\gamma^\dagger$	Mult. @	$\delta\&$	α	Comments
3539.9	795.7 2	100	E2		0.01276	Mult.: $\alpha(\text{K})_{\text{exp}}=0.007\ 6$, $A_2=+0.18\ 7$; $A_4=-0.05\ 7$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
3636.81	479.3 1	100	E3		0.1415	B(E3)(W.u.)=23.5 24. Mult.: $\alpha(\text{K})_{\text{exp}}=0.071\ 10$, $\alpha(\text{L})_{\text{exp}}=0.056\ 7$, $A_2=+0.10\ 1$, $A_4=+0.01\ 1$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
3671.5	131.6 2	100	M1		6.01	Mult.: $\alpha(\text{exp})=8\ 1$, $A_2=-0.15\ 5$, $A_4=-0.05\ 5$, from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
3987.0	315.5 1	100	M1		0.520	Mult.: $\alpha(\text{K})_{\text{exp}}=0.46\ 3$, $A_2=-0.23\ 2$, $A_4=-0.02\ 2$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
4182.4	195.4 1	100	M1+E2	0.6 5	1.6 4	Mult.: $\alpha(\text{exp})=1.6\ 4$, $A_2=-0.53\ 7$, $A_4=+0.02\ 7$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
4583.6	401.3 1	100	M1 (+E2)			Mult.: $\alpha(\text{K})_{\text{exp}}=0.32\ 8$, $A_2=-0.51\ 2$, $A_4=+0.11\ 2$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
4833.7	596.2 3 1196.9 2	50 100	E3		0.01295	B(E3)(W.u.)=13.1 6. Mult.: M1 or E3 from $\alpha(\text{K})_{\text{exp}}=0.011\ 2$, $\alpha(\text{L})_{\text{exp}}=0.005\ 1$, $A_2=+0.30\ 3$, $A_4=-0.02\ 3$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08); $T_{1/2/2}$ rules out M1.
4988.0	404.4 1	100	M1+E2		0.265	Mult.: $A_2=-0.58\ 9$, $A_4=+0.24\ 10$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
5216.9?	805.1 8 383.2 2	56 100	(E1)		0.0193	Mult.: $A_2=+0.33\ 5$, $A_4=+0.00\ 6$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$, consistent with a $\Delta J=0$ pure dipole (1985Po08); $\Delta\pi=\text{yes}$ from level scheme.
5819.8	602.8 3 986.1 2	89 100	M1+E2 E1	0.8 +10-6	0.06 3 0.00302	Mult.: $\alpha(\text{K})_{\text{exp}}=0.05\ 2$, $A_2=-0.40\ 5$, $A_4=+0.05\ 5$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08). Mult.: $\alpha(\text{K})_{\text{exp}}=0.002\ 1$, $A_2=-0.20\ 5$, $A_4=-0.06\ 5$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
6538.0	718.2 3	100	E2		0.01574	Mult.: $\alpha(\text{K})_{\text{exp}}=0.016\ 5$, $A_2=+0.29\ 7$, $A_4=-0.01\ 6$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
6772.1	234.1 3	100	M1+E2		1.185 18	Mult.: $A_2=-0.33\ 5$, $A_4=+0.05\ 5$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
6826.1	288.1 3	100	M1+E2		0.668	Mult.: $A_2=-0.31\ 4$, $A_4=+0.05\ 4$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).
7307.7	481.6 3	100	D			Mult.: $A_2=-0.20\ 9$, $A_4=+0.10\ 11$ from $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08).

† From $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08), unless otherwise stated.

‡ From γ -ray branching ratios given in Table 4 in 1985Po08 ($^{198}\text{Pt}(^{16}\text{O},5n\gamma)$).

§ From ^{209}Fr ϵ decay.

$^\#$ From ^{213}Ra α decay.

$^\textcircled{a}$ From $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08) and ^{213}Ra α decay (2006Ku26), based on ce and/or $\gamma(\theta)$ data.

$^\&$ From ce data in $^{198}\text{Pt}(^{16}\text{O},5n\gamma)$ (1985Po08) and ^{213}Ra α decay (2006Ku26) using the BrIccMixing program, unless otherwise stated.

$^\text{a}$ Placement of transition in the level scheme is uncertain.

209Fr ϵ Decay 1996Xu02

Parent ^{209}Fr : $E=0.0$; $J\pi=9/2^-$; $T_{1/2}=50.5\ \text{s}$ 7; $Q(\text{g.s.})=5161\ 25$; $\% \epsilon + \% \beta^+$ decay=11 3.

$^{209}\text{Fr}-J, T_{1/2}$: From Adopted Levels of ^{209}Fr .

$^{209}\text{Fr}-Q(\epsilon)$: From 2012Wa38.

$^{209}\text{Fr}-\% \epsilon + \% \beta^+$ decay: From Adopted Levels of ^{209}Fr . Other: $\% \epsilon + \% \beta^+=3.0\ 15$ in 1996Xu02.

1996Xu02: ^{209}Fr activities were produced by bombarding a 1.7 mg/cm² self-supporting ^{197}Au foil with a 102 MeV ^{16}O beam from the SFC accelerator of IMP at Lanzhou. γ -rays were detected with two coaxial HPGe (GMX) detectors and x-rays were detected with a planar HPGe detector. Measured $E\gamma$, $I\gamma$, $I(\text{x-ray})$, $\gamma\gamma$ -coin, $\gamma(\text{x-ray})$ -coin. Deduced levels, $J\pi$, configurations, ϵ - and β^+ -branching ratios.

Other: 1980Li22.

The decay scheme is incomplete and multipolarities for many transitions are not known, so no $\epsilon + \beta^+$ branchings and log ft values were deduced.

²⁰⁹Fr ε Decay ¹⁹⁹⁶Xu02 (continued)

²⁰⁹Rn Levels

E(level) [†]	Jπ [‡]	E(level) [†]	Jπ [‡]	E(level) [†]	Jπ [‡]
0.0	5/2-	797.90 1	9/2-	1383.2 3	
110.27 17	1/2-	867.70 18	(7/2, 9/2-)	1388.2 3	
382.33 17	(3/2-)	1020.7 4		1465.5 4	13/2-
547.10 20	(7/2-)	1174.0 3	13/2+	1588.4 4	
652.60 21	(5/2-)	1327.49 21	(5/2-, 7/2, 9/2-)	1767.0 4	
690.1 3	(1/2-, 3/2-)	1352.7 3		1931.3 4	

[†] From a least-squares fit to E_γ.

[‡] From Adopted Levels.

γ(²⁰⁹Rn)

E _γ [†]	E(level)	I _γ [†]	E _γ [†]	E(level)	I _γ [†]	E _γ [†]	E(level)	I _γ [†]
110.3 2	110.27	9 2	414.4 2	1588.4	10 2	805.6 2	1352.7	15 5
178.6 2	1767.0	3 1	529.5 2	1327.49	4 2	836.1 2	1383.2	6 2
215.1 2	867.70	15 1	547.1 2	547.10	100 3	841.1 2	1388.2	6 2
272.1 2	382.33	4 1	652.6 3	652.60	38 4	867.7 2	867.70	8 3
330.6 2	1020.7	6 3	667.6 3	1465.5	4 1	1327.7 3	1327.49	5 2
376.1 2	1174.0	29 2	690.1 3	690.1	15 3	1384.2 3	1931.3	16 6
382.3 2	382.33	3 1	797.8 2	797.90	111 4			

[†] from 1996Xu02. I_γ were normalized to I_γ(547.1γ)=100.

Decay Scheme

Intensities: relative I_γ

213Ra α Decay (2.73 min) 2006Ku26,1976Ra37,1967Va22

Parent ²¹³Ra: E=0.0; J π =1/2-; T_{1/2}=2.73 min 5; Q(g.s.)=6861.3 23; % α decay=80 5.

²¹³Ra-J,T_{1/2}: From Adopted Levels of ²¹³Ra.

²¹³Ra-Q(α): From E α =6732.3 keV 23, as evaluated in the present work. 6861.8 keV 23 in 2012Wa38.

²¹³Ra-% α decay: From Adopted Levels of ²¹³Ra.

2006Ku26: ²¹³Ra isotopes were produced by the ¹⁷⁰Er(⁵⁰Ti,xn) reaction with the E=4.35 MeV/nucleon ⁵⁰Ti beam from the UNILAC at GSI, Darmstadt. Evaporation residues were separated by the velocity filter ship and implanted into a position-sensitive 16-strips pips detector. γ -rays were detected with a Ge-Clover detector (5.0(5)% efficiency at 1.3 MeV) consisting of four individual crystals. Measured E γ , I γ , E α , I α , $\gamma\gamma$ -coin, $\gamma\gamma\gamma$ -coin, $\alpha\gamma$ -coin, I(ce). Deduced levels, J π , γ - and α -branchings, conversion coefficients.

1976Ra37: ²¹³Ra isotopes were produced by ²⁰⁹Bi(¹⁰B,6n γ) and Pb(¹²C,xn γ) reactions with E=60-100 MeV beams from the Yale University's Heavy Ion Accelerator (HILAC). α particles were detected with an Si(Au) surface barrier detector and γ -rays were detected with two Ge(Li) detectors. Measured E γ , I γ , E α , I α , I(x-ray), $\gamma\gamma$ -coin. Deduced levels, J π , γ -branchings, α -branchings, conversion coefficients.

1967Va22: ²¹³Ra isotopes were produced by ¹⁹⁷Au(¹⁹F,xn) and ²⁰⁶Pb(¹²C,xn) with E(¹⁷F) up to 197 MeV and E(¹²C) up to 125 MeV beams from the Berkeley Heavy Ion Linear Accelerator (HILAC). Reaction products were detected with a Si(Au) barrier detector. Measured E α , I α , σ (E). Deduced levels, α -branchings.

Others: 1961Gr42, 1968Lo15, 1970TaZS, 1984Gu29, 1987Ar20, 1989He03.

209Rn Levels

E(level) [†]	J π [‡]
0.0	5/2-
110.26 9	1/2-
214.94 9	3/2-
328.30 9	3/2-
511.32 14	(1/2, 3/2, 5/2)-

[†] From a least-squares fit to E γ .

[‡] From Adopted Levels.

 α radiations

E α [†]	E(level)	I α [‡] #	HF [§]	Comments
6230 6	511.32	0.14 7	15 8	E α ,I α : From 2006Ku26.
6413 3	328.30	0.34 6	36 7	E α : weighted average of 6411.9 keV 50 (1976Ra37, corrected by +0.9 keV, as suggested in 1991Ry01) and 6413 keV 4 (2006Ku26). Other: 6408 keV (1967Va22). I α : weighted average of 0.4 2 (1967Va22), 0.5 1 (1976Ra37) and 0.22 8 (2006Ku26).
6521.9 23	214.94	5.8 6	6.2 8	E α : 6520 keV 20 (1968Lo15), 6520 keV 5 (1967Va22), 6522 keV 5 (1976Ra37) and 6622 keV 3 (2006Ku26). I α : weighted average of 6 1 (1967Va22), 6 1 (1976Ra37) and 5.4 9 (2006Ku26).
6624.7 23	110.26	48.5 17	1.93 16	E α : 6620 keV 20 (1968Lo15), 6623 keV 5 (1967Va22), 6624 keV 5 (1976Ra37) and 6625 keV 3 (2006Ku26). I α : 49 2 (1967Va22) and 47 3 (1976Ra37).
6732.3 23	0.0	45.5 17	5.5 5	E α : 6730 keV 20 (1968Lo15), 6730 keV 5 (1967Va22), 6731 keV 5 (1976Ra37) and 6733 keV 3 (2006Ku26). I α : 45 2 (1967Va22) and 46 3 (1976Ra37).

[†] Weighted average of values from 2006Ku26, 1976Ra37 and 1967Va22, except for the E=511 keV level, where data are from 2006Ku26 only. Values from 1976Ra37 and 1967Va22 were corrected by +0.7 keV and +0.9 keV, respectively, as suggested in 1991Ry01.

Originally measured (uncorrected) E α are given as comments.

[‡] Recommended by 1991Ry01, unless otherwise stated.

[§] r₀(²⁰⁹Rn)=1.456 8, weighted average of r₀(²⁰⁸Rn)=1.466 8 and r₀(²¹⁰Rn)=1.4552 21, both deduced from HF=1.

For α intensity per 100 decays, multiply by 0.80 5.

 γ (²⁰⁹Rn)

E γ [†]	E(level)	I γ [‡] @	Mult.#	δ [#]	α	Comments
104.8 [§] 2	214.94	0.20 4	M1 (+E2)	≤ 0.8	10.6 10	I γ : 0.42 15 from 1976Ra37 per 100 α decays. I(104.8 γ)/I(214.9 γ)=29 5/100 3 (2006Ku26). Mult.: α (exp)=8.1 24 in 2006Ku26.
110.3 [§] 1	110.26	7.5 3	E2		5.48	I γ : Other: 8 2 from 1976Ra37 per 100 α decays. Mult.: α (exp)=5.1 9 in 2006Ku26.

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²¹³Ra α Decay (2.73 min) 2006Ku26,1976Ra37,1967Va22 (continued)
 $\gamma(^{209}\text{Rn})$ (continued)

$E_{\gamma}^{\dagger}$	E(level)	$I_{\gamma}^{\ddagger @}$	Mult.#	$\delta^{\#}$	α	Comments
(113.3 2)	328.30	<0.012	[M1]		9.20	E_{γ}, I_{γ} : transition not observed, it is inferred by 2006Ku26 from intensity balance at the 328 level. Intensity limit of $I(113.3\gamma)/I(328.3\gamma) < 0.15$ in 2006Ku26 is based upon systematics of N=123 isotones.
183.0 2	511.32	0.013 7	M1		2.36	I_{γ} : $I(183.0\gamma)/I(296.4\gamma) = 29 \text{ 8/100 12}$ (2006Ku26). Mult.: $\alpha(\text{exp}) = 2.5 \text{ 18}$ in 2006Ku26.
214.9 § 1	214.94	1.6 4	M1 (+E2)	<1.2	1.2 4	I_{γ} : 1.2 3 from 1976Ra37 per 100 α decays.
218.1 2	328.30	0.062 14	M1		1.444	I_{γ} : $I(218.1\gamma)/I(328.3\gamma) = 48 \text{ 11/100 9}$ (2006Ku26). Mult.: $\alpha(\text{exp}) = 1.7 \text{ 16}$ in 2006Ku26.
296.4 2	511.32	0.045 23	M1		0.617	Mult.: $\alpha(\text{exp}) = 0.9 \text{ 6}$ in 2006Ku26.
328.3 1	328.30	0.13 3	M1 (+E2)		0.467	
401.6 & 6	511.32	0.0014 11				I_{γ} : $I(401.6\gamma)/I(296.4\gamma) = 3 \text{ 2/100 12}$ (2006Ku26).
511.3 3	511.32	0.022 12				I_{γ} : $I(511.3\gamma)/I(296.4\gamma) = 48 \text{ 10/100 12}$ (2006Ku26).

[†] From 2006Ku26, unless otherwise stated.

[‡] From intensity balances using I_{α} and the branching ratios in 2006Ku26.

[§] Weighted average of values from 2006Ku26 and 1976Ra37.

[#] From Adopted Gammas.

[@] For absolute intensity per 100 decays, multiply by 0.80 5.

[&] Placement of transition in the level scheme is uncertain.

Decay Scheme

Intensities: relative I_{γ}

²¹³Ra α Decay (2.18 ms) 2006Ku26,1976Ra37

Parent ²¹³Ra: E=1770 5; $J\pi=(17/2-)$; $T_{1/2}=2.18 \text{ ms 4}$; $Q(\text{g.s.})=6861.3 \text{ 23}$; $\% \alpha \text{ decay}=0.6 \text{ 4}$.

²¹³Ra-E: from 2006Ku26.

²¹³Ra- $T_{1/2}$: weighted average of 2.1 ms 1 (1976Ra37), 2.2 ms 1 (2004He25) and 2.20 ms 5 (2006Ku26).

²¹³Ra- $Q(\alpha)$: From $E_{\alpha}=6732.3 \text{ keV 23}$, as evaluated in the present work. 6861.8 keV 23 in 2012Wa38.

²¹³Ra- $\% \alpha$ decay: from Adopted Levels of ²¹³Ra.

2006Ku26: ²¹³Ra isotopes were produced by the ¹⁷⁰Er(⁵⁰Ti,xn) reaction with the E=4.35 MeV/nucleon ⁵⁰Ti beam from the UNILAC at GSI, Darmstadt. Evaporation residues were separated by the velocity filter ship and implanted into a position-sensitive 16-strips pips detector. γ -rays were detected with a Ge-Clover detector (5.0(5)% efficiency at 1.3 MeV). Measured E_{γ} , I_{γ} , E_{α} , I_{α} , $\gamma\gamma$ -coin, $\gamma\gamma$ -coin, $\alpha\gamma$ -coin, $I(\text{ce})$. Deduced levels, $J\pi$, γ - and α -branchings, conversion coefficients.

1976Ra37: ²¹³Ra isotopes were produced by ²⁰⁹Bi(¹⁰B,6n γ) and Pb(¹²C,xn γ) reactions with E=60–100 MeV beams from the Yale University's Heavy Ion Accelerator (hilac). α particles were detected with an Si(Au) surface barrier detector and γ -rays were detected with two Ge(Li) detectors. Measured E_{γ} , I_{γ} , E_{α} , I_{α} , $I(\text{x-ray})$, $\gamma\gamma$ -coin. Deduced levels, $J\pi$, γ -branchings, α -branchings, conversion coefficients.

²¹³Ra α Decay (2.18 ms) 2006Ku26,1976Ra37 (continued)

²⁰⁹Rn Levels

E(level) [†]	Jπ [‡]
0.0	5/2-
110.1 1	1/2-
214.7 2	3/2-

[†] From a least-squares fit to E_γ.

[‡] From Adopted Levels.

α radiations

Eα	E(level)	Iα [‡]	HF [†]	Comments
8267 10	214.7	3.5 20	1.6×10 ⁰⁴ 15	Eα: weighted average of 8266 10 (1976Ra37) and 8270 20 (2006Ku26). Iα: from 3 2 (1976Ra37) and 4 2 (2006Ku26).
8356 9	110.1	29 6	3800 2700	Eα: weighted average of 8358 10 (1976Ra37) and 8355 9 (2006Ku26). Iα: weighted average of 28 6 (1976Ra37) and 33 13 (2006Ku26).
8468 5	0.0	68 7	3200 2200	Eα: weighted average of 8467 5 (1976Ra37) and 8469 6 (2006Ku26). Iα: weighted average of 69 7 (1976Ra37) and 63 13 (2006Ku26).

[†] r₀(²⁰⁹Rn)=1.461 5, average of r₀(²⁰⁸Rn)=1.466 8 and r₀(²¹⁰Rn)=1.4552 21, deduced from HF=1.0.

[‡] For α intensity per 100 decays, multiply by 0.006 4.

γ(²⁰⁹Rn)

Eγ [†]	E(level)	Iγ [‡] #	Mult.§	δ§	α	Comments
104.8 2	214.7	0.18 11	M1(+E2)	≤0.8	10.6 10	Iγ: I(104.8γ)/I(214.9γ)=29 5/100 3 (2006Ku26).
110.2 1	110.1	4.8 10	E2		5.50	
214.9 1	214.7	0.6 4	M1(+E2)	<1.2	1.2 4	

[†] Weighted average of values from 2006Ku26 and 1976Ra37.

[‡] Deduced by the evaluators from intensity balances, Iα and conversion coefficients. Relative photon intensity with respect to I(1063γ in ²¹³Ra)=100 were measured in 1976Ra37. However, those values probably include contributions from the 2.73-min ²¹³Ra α decay, since they are found to be inconsistent with the Iα values.

§ From Adopted Gammas.

For absolute intensity per 100 decays, multiply by 0.006 4.

Decay Scheme

Intensities: relative I_γ

(17/2-) 1770 2.18 ms
²¹³₈₈Ra₁₂₅ ↓ %α=0.6 4
Q_α(g.s.)=6861.3²³

198Pt(16O,5nγ) 1985Po08

1985Po08: E=81-94 MeV ¹⁶O beams were produced from the ANU 14 UD Pelletron accelerator. Targets were enriched Pt foils. γ-rays were detected by three Ge(Li) detectors and one intrinsic Ge low-energy photon spectrometer (LEPS), conversion electrons were detected by a cooled Si(Li) detector and neutrons were detected by a NE213 liquid scintillator. Measured E_γ, I_γ, I(ce), γγ-coin, γγ(t), nγ-coin, nγ(t), γ(θ). Deduced levels, J_π, T_{1/2}, configurations, conversion coefficients, yrast states. Two other experiments were also performed for measurements of γ(θ) and conversion coefficients: ¹⁹⁸Pt(¹⁷O,6nγ) with E=87-95 MeV and ²⁰⁵Tl(¹⁰B,6nγ) with E=63-75 MeV.

209Rn Levels

E(level) [†]	J _π [‡]	T _{1/2} [§]	Comments
0.0	5/2-		configuration=v(f _{5/2}) ⁻¹ . J _π : from Adopted Levels.
797.80 10	9/2-		configuration=dominant v(f _{5/2}) ⁻¹ ⊗π(h _{9/2}) ⁺⁴ ₂₊ .
1173.98 13	13/2+	13.4 μs 13	T _{1/2} : from 376.2γ(t) and 797.8γ(t). configuration=v(i _{13/2}) ⁻¹ .
1465.53 13	13/2-		
1561.55 14	15/2-		
1610.67 15	17/2-		
1687.41 15	19/2-	0.69 ns 21	T _{1/2} : from 76.75γ(t) and 96.02γ(t). configuration=v(f _{5/2}) ⁻¹ ⊗π(h _{9/2}) ⁺⁴ ₈₊ .
2238.16 17	21/2-		
2418.71 18	21/2+	8.73 ns 21	T _{1/2} : from 731.3γ(t). configuration=v(i _{13/2}) ⁻¹ ⊗π(h _{9/2}) ⁺⁴ ₄₊ .
2501.29 18	23/2-		
2744.15 21	(23/2+)		
2848.48 18	25/2-		
2864.6 3			
2957.58 18	27/2-		
3049.9 4			
3157.48 21	29/2-	13.9 ns 21	T _{1/2} : from 199.9γ(t). configuration=v(p _{1/2}) ⁻¹ ⊗π((h _{9/2}) ⁺³ (f _{7/2}) ⁺¹) ₁₄₊ .
3400.6 3			
3539.9 3	(27/2+)		
3636.78 23	35/2+	3.0 μs 3	T _{1/2} : from 479.3γ(t) and 199.9γ(t). configuration=v(p _{1/2}) ⁻¹ ⊗π((h _{9/2}) ⁺³ (i _{13/2}) ⁺¹) ₁₇₋ .
3671.5 4	(29/2+)		
3987.0 4	(31/2+)		
4182.4 4	(33/2+)		
4583.6 4	(35/2+)		
4833.7 3	41/2-	10.0 ns 4	T _{1/2} : from 1196.9γ(t). configuration=v(p _{1/2}) ⁻¹ ⊗π((h _{9/2}) ⁺² (i _{13/2}) ⁺²) ₂₀₊ .
4988.0 4	(37/2+)		
5216.9? 4	41/2+		E(level): The order of 383.2γ and 602.8γ is not well determined, and reversing the order of the two transitions would place a level of J _π =(43/2-) at 5437 keV (1985Po08).
5819.8 4	43/2+		
6538.0 5	47/2+		
6772.1 6	49/2+		
6826.1 6	49/2+		
7307.7 7	51/2		

[†] From a least-squares fit to E_γ.

[‡] From 1985Po08, based on deduced γ-ray transition multipolarities.

[§] T_{1/2}<1.4 ns for all excited levels where no value is given explicitly (1985Po08).

γ(209Rn)

E _γ [†]	E(level)	I _γ [†]	Mult. [‡]	δ [§]	α	Comments
49.12 5	1610.67	50	M1 (+E2)	≤0.14		Mult.: α(exp)=22 2 (1985Po08).
76.75 5	1687.41	120	M1		5.51	Mult.: α(exp)=5.4 9 (1985Po08).
96.02 5	1561.55	200	M1+E2	0.22 +10-17	3.2 4	Mult.,δ: α(exp)=3.2 3 (1985Po08).
109.10 7	2957.58	≈20	M1 (+E2)	≤0.16		Mult.: α(exp)=9 2 (1985Po08).
131.6 2	3671.5	≈50	M1			Mult.: α(exp)=8 1 is larger than the calculated value for M1; A ₂ =-0.15 5, A ₄ =-0.05 5 (1985Po08).
139.2 2	3539.9	≈50				A ₂ =+0.02 9, A ₄ =+0.12 9 (1985Po08).

Continued on next page (footnotes at end of table)

¹⁹⁸Pt(¹⁶O,5nγ) ¹⁹⁸⁵Po08 (continued)

γ(²⁰⁹Rn) (continued)

Eγ [†]	E(level)	Iγ [†]	Mult. [‡]	δ [§]	α	Comments
185.4 1	3049.9	≈30				A ₂ =+0.20 5, A ₄ =+0.03 5 (1985Po08).
195.4 1	4182.4	100	M1 (+E2)	0.6 5		Mult.: α(exp)=1.6 4, A ₂ =-0.53 7, A ₄ =+0.02 7 (1985Po08).
199.9 1	3157.48	130	M1+E2	1.6 4	0.89 17	Mult.: α(exp)=0.9 1, A ₂ =-0.13 3, A ₄ =+0.02 3 (1985Po08).
234.1 3	6772.1	40	M1+E2		0.7 5	Mult.: A ₂ =-0.33 5, A ₄ =+0.05 5 (1985Po08).
288.1 3	6826.1	60	M1+E2		0.4 3	Mult.: A ₂ =-0.31 4, A ₄ =+0.05 4 (1985Po08).
315.5 1	3987.0	190	M1			Mult.: α(K)exp=0.46 3, A ₂ =-0.23 2, A ₄ =-0.02 2 (1985Po08).
325.4 1	2744.15	≈110	M1+E2	0.6 3	0.38 7	Mult.: α(K)exp=0.30 6, A ₂ =-0.38 5, A ₄ =+0.02 2 (1985Po08).
347.2 1	2848.48	50	M1 (+E2)	<1.6	0.33 7	Mult.: α(exp)=0.5 3, A ₂ =-0.14 6, A ₄ =-0.09 6 (1985Po08).
376.2 1	1173.98	200	M2		1.029	Mult.: α(exp)=1.10 6, α(K)exp=0.89 7, α(L)exp=0.27 3, A ₂ =+0.06 2, A ₄ =-0.01 2 (1985Po08).
382.0# 3	3539.9	70	[E1]			Eγ: unassigned in Table 2 and not shown in the level scheme, but included in the table of branching ratios (Table 4) in 1985Po08. Mult.: A ₂ =-0.02 8, A ₄ =0.00 9 (1985Po08) in consistent with D, the level scheme requires Mult. E1.
383.2 2	5216.9?	50	(E1)		0.0193	Mult.: A ₂ =+0.33 5, A ₄ =+0.00 6 (1985Po08), consistent with J to J D.
387.6 1	1561.55	280	(E1)		0.0188	Mult.: α(K)exp<0.22, A ₂ =-0.05 2, A ₄ =-0.01 2. α(K)exp is consistent with E1 or E2(+M1). The placement in the level scheme requires Δπ=yes.
401.3 1	4583.6	160	M1 (+E2)			Mult.: α(K)exp=0.32 8, A ₂ =-0.51 2, A ₄ =+0.11 2 (1985Po08).
404.4 1	4988.0	90	M1+E2		0.16 11	Mult.: A ₂ =-0.58 9, A ₄ =+0.24 10 (1985Po08).
446.2 3	2864.6	70				A ₂ =-0.08 6, A ₄ =0.00 5 (1985Po08).
456.3 1	2957.58	70	E2		0.0439	Mult.: α(K)exp<0.41 is consistent with D or E2. The placement in the level scheme requires mult=E2. A ₂ =+0.08 4, A ₄ =-0.03 5 (1985Po08).
479.3 1	3636.78	200	E3		0.1415	Mult.: α(K)exp=0.071 10, α(L)exp=0.056 7, A ₂ =+0.10 1, A ₄ =+0.01 1 (1985Po08).
481.6 3	7307.7	20	D			Mult.: A ₂ =-0.20 9, A ₄ =+0.10 11 (1985Po08).
490.6 4	3539.9	70				A ₂ =-0.12 4, A ₄ =+0.09 5 (1985Po08).
550.8 1	2238.16	230	M1 (+E2)	≤0.7		Mult.: α(K)exp=0.09 2, A ₂ =-0.45 4, A ₄ =+0.06 4 (1985Po08).
596.2 3	4583.6	80	[E2]		0.0235	
602.8 3	5819.8	80	M1+E2	0.8 +10-6		Mult.: α(K)exp=0.05 2, A ₂ =-0.40 5, A ₄ =+0.05 5 (1985Po08).
610.3 1	2848.48	140	E2		0.0223	Mult.: α(K)exp=0.019 6, A ₂ =+0.11 3, A ₄ =-0.02 3 (1985Po08).
627.2 2	2238.16	50	[E2]		0.0210	Mult.: A ₂ =+0.03 7, A ₄ =-0.07 8 (1985Po08).
656.3 3	3400.6	40				A ₂ =-0.23 6, A ₄ =+0.07 6 (1985Po08).
667.7 1	1465.53	650	E2		0.0184	Mult.: α(K)exp=0.014 1, A ₂ =+0.16 1, A ₄ =-0.03 1 (1985Po08).
718.2 3	6538.0	50	E2		0.01574	Mult.: α(K)exp=0.016 5, A ₂ =+0.29 7, A ₄ =-0.01 6 (1985Po08).
731.3 1	2418.71	260	E1		0.00522	Mult.: α(K)exp=0.003 1, A ₂ =-0.05 2, A ₄ =+0.01 2 (1985Po08).
795.7 2	3539.9	80	E2		0.01276	Mult.: α(K)exp=0.007 6, A ₂ =+0.18 7, A ₄ =-0.05 7 (1985Po08).
797.8 1	797.80	1000	E2		0.01269	Mult.: α(K)exp=0.010 1, A ₂ =+0.13 1, A ₄ =-0.02 1 (1985Po08).
805.1 8	4988.0	50				
813.9 1	2501.29	180	E2		0.01219	Mult.: α(K)exp=0.012 2, A ₂ =+0.15 2, A ₄ =-0.03 2 (1985Po08).
986.1 2	5819.8	90	E1		0.00302	Mult.: α(K)exp=0.002 1, A ₂ =-0.20 5, A ₄ =-0.06 5 (1985Po08).
1196.9 2	4833.7	100	E3		0.01295	Mult.: M1 or E3 from α(K)exp=0.011 2, α(L)exp=0.005 1, A ₂ =+0.30 3, A ₄ =-0.02 3 (1985Po08); T _{1/2} rules out M1.

[†] From 1985Po08. Relative intensities normalized to Iγ(797.8γ)=1000, for ¹⁶O bombardment at 94 MeV.

[‡] From ce and γ(θ) data in 1985Po08. α(exp) were determined from intensity balances using Iγ from delayed spectra.

[§] From ce data in 1985Po08.

[#] Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Q(β^-)=-5620 50; S(n)=9173 19; S(p)=1402 18; Q(α)=6777 4 2012Wa38.

209Fr Levels

Cross Reference (XREF) Flags

A 213Ac α Decay
 B 176Yb($^{37}\text{Cl}, 4n\gamma$)
 C 197Au($^{16}\text{O}, 4n\gamma$)

E(level) [†]	J $\pi^{\ddagger}$	XREF	T _{1/2} [§]	Comments
0.0	9/2-	A C	50.5 s 7	<p>%α=89 3; %ϵ+%β^+=11 3. Jπ: J from atomic beam magnetic resonance (1978Ek02, 1978Ek05, 1985Co24, 1986Ek02). π from μ. T_{1/2}: weighted average of 50.0 s 3 ($\alpha(t)$, 1974Ho27), 52.0 s 20 ($\alpha(t)$, 1967Va20), 51.3 s 8 ($\alpha(t)$, 1996Xu02) and 54.7 s 10 ($\alpha(t)$, 1964Gr04). %α: from 1974Ho27, deduced from the growth and decay of 209Fr and 209Rn α groups, with the assumption that %α(209Rn)=17 2. Other: %α=97.0% 15 using %ϵ+β^+=3.0% 15 (1996Xu02), but no convincing evidence was presented. μ=+3.95 2 (1985Co24); μ=+3.95 8 (1986Ek02). Q=-0.24 2 (1985Co24). μ,Q: from atomic beam laser spectroscopy. configuration=$\pi(h_{9/2})^{+1}$. $\delta(r^2)(^{209}\text{Fr}, ^{212}\text{Fr})=-0.13043 \text{ fm}^2$ 8 (1987Co19). Others: 1985Co24, 1980Li22, 1978Ek05. Eα=6646 5 (1974Ho27), 6647 5 (1967Va20), 6650 20 (1964Gr04).</p>
606.06 18	13/2-	C		<p>Jπ: 606.0γ stretched E2 to 9/2-. configuration=dominant $\pi(h_{9/2})^{+1}\otimes v(f_{5/2})^{-2}_{4+}$.</p>
622.64 18	11/2-	C		J π : 622.7 γ M1+E2 to 9/2-, 466.3 γ E2 from 15/2-.
1088.88 21	15/2-	C		<p>Jπ: 482.7γ M1(+E2) to 13/2-, 466.3γ E2 to 11/2- and 136.1γ M1(+E2) from 17/2-. configuration=$\pi(h_{9/2})^{+1}\otimes v(f_{5/2})^{-2}_{4+}$.</p>
1224.97 23	17/2-	C		<p>Jπ: 538.7γ E2 from 21/2- and 618.9γ E2 to 13/2-. configuration=$\pi(h_{9/2})^{+1}\otimes v(f_{5/2})^{-2}_{4+}$.</p>
1330.46 25	17/2-	C		<p>Jπ: 724.4γ stretched E2 to 13/2-. configuration=$\pi(h_{9/2})^{+3}$.</p>
1763.7 3	21/2-	BC		<p>Jπ: 433.2γ and 538.7γ stretched E2 to 17/2-. configuration=$\pi(h_{9/2})^{+3}$.</p>
1928.6 4	23/2-	C	<1.0 ns	<p>Jπ: 164.9γ M1+E2 to 21/2-, the absence of transitions to levels with Jπ<21/2- rules out the 19/2- and 21/2- alternatives. configuration=$\pi((h_{9/2})^{+2}(f_{7/2})^{+1})^3$.</p>
2130.5 4	25/2+	BC	35 ns 3	<p>Jπ: 201.9γ E1 to 23/2-, the absence of transitions to levels with Jπ<23/2- rules out the 21/2+ and 23/2+ alternatives. T_{1/2}: weighted average of 33.3 ns 2I (2009Dr04) and 39 ns 3 (2011Ka37) in 197Au($^{16}\text{O}, 4n\gamma$), both using 409γ+515γ+619γ-202γ(Δt). configuration: $\pi(h_{9/2})^{+1}\otimes v((f_{5/2})^{-1}(i_{13/2})^{-1})_{9-}$.</p>
2175.9 4	25/2+	BC	<0.69 ns	<p>Jπ: 247.6γ E1 to 23/2-, 45.4γ M1 to 25/2+, the absence of transitions to levels with Jπ<23/2- rules out the 23/2+ alternative. configuration=$\pi((h_{9/2})^{+2}(i_{13/2})^{+1})^3$.</p>
2245.1 4	23/2(+)	C		<p>Jπ: 481.4γ (E1) to 21/2-, the absence of transitions to levels with Jπ<21/2- rules out the J=19/2 alternatives.</p>
2407.6 5	27/2+	C		<p>Jπ: 231.7γ M1 to 25/2+. configuration=$\pi((h_{9/2})^{+2}(i_{13/2})^{+1})^3$.</p>
2424.7 5	29/2+	C	<0.69 ns	<p>Jπ: 248.8γ E2 to 25/2+. configuration=$\pi((h_{9/2})^{+2}(i_{13/2})^{+1})^3$.</p>
2559.1 5	25/2(-)	C		<p>Jπ: 630.5γ (M1+E2) to 23/2-. configuration=$\pi(h_{9/2})^{+5}$.</p>
2599.1 5	27/2-	C		<p>Jπ: 670.5γ E2 to 23/2-. configuration=$\pi((h_{9/2})^{+4}(f_{7/2})^{+1})^5$.</p>
2696.7 5	27/2+	C		<p>Jπ: 566.2γ M1+E2 to 25/2+, the absence of transitions to levels with Jπ<25/2+ rules out the 23/2+ and 25/2+ alternatives. configuration=$\pi(h_{9/2})^{+1}\otimes v((f_{5/2})^{-1}(i_{13/2})^{-1})_{9-}$.</p>
2717.4 5	(29/2)	C		J π : 309.8 γ to 27/2+.
2857.7? 6		C		
2903.3? 5	29/2+	C		J π : 727.4 γ E2 to 25/2+.
2917.9 5	29/2(+)	C		J π : 787.4 γ (E2) to 25/2+.
2937.8 5	(27/2)	C		J π : 692.7 γ to 23/2+.

Continued on next page (footnotes at end of table)

Adopted Levels, Gammas (continued)

²⁰⁹Fr Levels (continued)

E(level) [†]	Jπ [‡]	XREF	T _{1/2} [§]	Comments
3027.4 6	31/2+	C		Jπ: 602.7γ M1+E2 to 29/2+, the absence of transitions to levels with Jπ<29/2+ rules out the 27/2+ and 29/2+ alternative. configuration=π((h _{9/2}) ⁺ 4(i _{13/2}) ⁺ 1) ⁵ .
3115.4 5	33/2+	BC		Jπ: 690.7γ stretched E2 to 29/2+. configuration=π((h _{9/2}) ⁺ 4(i _{13/2}) ⁺ 1) ⁵ .
3127.4 6	31/2-	C		Jπ: 528.3γ E2 to 27/2-. configuration=π((h _{9/2}) ⁺ 4(f _{7/2}) ⁺ 1) ⁵ .
3153.1 5	31/2	C		Jπ: 745.5γ Q to 27/2+.
3234.5 5	31/2(+)	C		Jπ: 331.2γ (M1+E2) to 29/2+.
3369.6 6	33/2+	C		Jπ: 342.2γ M1+E2 to 31/2+.
3409.4 6	33/2(+)	C		Jπ: 174.9γ M1+E2 to 31/2(+).
3415.9 6	33/2(-)	C	≈ 62 ns	Jπ: 181.4γ E1+(M2) 31/2(+). T _{1/2} : from 181γ(t), consistent with 810γ(t), in (2009Dr04). possible configuration=π(h _{9/2}) ⁺ 1⊗v((i _{13/2}) ⁻ 2) ₁₂ ⁺ .
3630.9 6	37/2+	BC		Jπ: 515.5γ stretched E2 to 33/2+. configuration=π((h _{9/2}) ⁺ 4(i _{13/2}) ⁺ 1) ⁵ .
3923.4 7	35/2(+)	C		Jπ: 514.0γ (M1+E2) to 33/2(+).
3968.7 7	35/2	C		Jπ: 559.3γ D+Q to 33/2(+).
4039.6 6	39/2+	BC		Jπ: 408.7γ M1+E2 to 37/2+. configuration=π((h _{9/2}) ⁺ 3(f _{7/2}) ⁺ 1(i _{13/2}) ⁺ 1) ⁵ .
4166.4 7	(37/2)	C		
4324.3 7	41/2+	C		Jπ: 284.7γ M1+E2 to 39/2+. configuration=π((h _{9/2}) ⁺ 3(f _{7/2}) ⁺ 1(i _{13/2}) ⁺ 1) ⁵ .
4364.1 6	39/2+	C		Jπ: 733.2γ M1+E2 to 37/2+.
4423.6 6	41/2(+)	C		Jπ: 792.7γ (E2) to 37/2+.
4659.8 7	45/2-	BC	420 ns 18	Jπ: 620.2γ E3 to 39/2+. T _{1/2} : from 232γ+409γ+620γ(t) in 2009Dr04. Selected γ's as gates were not contaminated in the γ-ray spectra. Other: 360 ns 140 from from 433.5γ(t) in ¹⁷⁶ Yb(³⁷ Cl,4nγ) (2006Me03). configuration=π((h _{9/2}) ⁺ 3(i _{13/2}) ⁺ 2) ⁵ .
5046.2? 7		C		
5069.3 7	(43/2)	C		Jπ: 745.0γ to 41/2+.
5194.6 7	47/2(-)	C		Jπ: 534.8γ (M1+E2) to 45/2-.
5302.1 7	(47/2)	C		Jπ: 642.3γ D+Q to 45/2-.
5399.5 7	49/2-	C		Jπ: 739.7γ E2 to 45/2-.
5413.9? 7		C		
5480.3? 7		C		
5488.5 7	47/2-	C		Jπ: 828.7γ M1+E2 to 45/2-.
5657.2 7	47/2(-)	C		Jπ: 997.4γ (M1+E2) to 45/2(-).
5765.2 7	(47/2)	C		Jπ: 1105.4γ (D+Q) to 45/2-.
5903.4 8	49/2-	C		Jπ: 414.9γ M1+E2 to 47/2-.

[†] From a least-squares fit to E_γ.

[‡] From 2009Dr04 in ¹⁹⁷Au(¹⁶O,4nγ), based on deduced γ-ray transition multipolarities, multiple γ-ray decay branches and transition strengths, unless otherwise stated.

[§] From 2009Dr04 in ¹⁹⁷Au(¹⁶O,4nγ), unless otherwise stated.

γ(²⁰⁹Fr)

E(level)	E _γ [†]	I _γ [†]	Mult. [§]	δ [#]	α	Comments
606.06	606.0 2	100	E2		0.0238	Mult.: α(K)exp=0.016 2, α(L)exp=0.007 1, A ₂ =+0.27 3 (2009Dr04).
622.64	622.7 2	100	M1+E2	0.64 11	0.071 5	Mult.,δ: from α(K)exp=0.057 4 (2009Dr04). Also A ₂ =-0.43 10 (2009Dr04).
1088.88	466.3 2	100 3	E2		0.0436	Mult.: α(K)exp=0.031 3, A ₂ =+0.21 5 (2009Dr04).
	482.7 3	36.8 22	M1(+E2)	<1.8	0.13 6	Mult.,δ: from α(K)exp>0.054 (2009Dr04). Also A ₂ =-0.48 17 (2009Dr04).
1224.97	136.1 3	26 4	M1(+E2)	<0.4	5.7 3	Mult.,δ: from α(exp)=7.0 10 (2009Dr04). Also A ₂ =-0.31 7 (2009Dr04).
	618.9 2	100 13	E2		0.0227	Mult.: α(K)exp=0.017 3, A ₂ =+0.23 9 (2009Dr04).

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Adopted Levels, Gammas (continued)

 $\gamma(^{209}\text{Fr})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. §	$\delta^{\#}$	α	Comments
1330.46	724.4 2	100	E2		0.01624	Mult.: $\alpha(\text{K})_{\text{exp}}=0.012$ 2, $\alpha(\text{L})_{\text{exp}}=0.0022$ 4, $A_2=+0.23$ 4 (2009Dr04).
1763.7	433.2 2	100.0 15	E2		0.0524	E γ : 433.5 4 from $^{176}\text{Yb}(^{37}\text{Cl},4n\gamma)$ (2006Me03). Mult.: $\alpha(\text{K})_{\text{exp}}=0.032$ 2, $\alpha(\text{M})_{\text{exp}}=0.003$ 1, $A_2=+0.26$ 5 (2009Dr04).
1928.6	538.7 2 164.9 2	26.7 11 100	E2 M1+E2	0.44 +9-8	0.0310 3.08 14	Mult.: $\alpha(\text{K})_{\text{exp}}=0.019$ 3, $A_2=+0.20$ 9 (2009Dr04). Mult., δ : from $\alpha(\text{exp})=3.08$ 11 (2009Dr04). Also $A_2=-0.24$ 4 (2009Dr04). B(M1)(W.u.)>0.00091; B(E2)(W.u.)>1.6.
2130.5	201.9 2	100	E1		0.0862	E γ : 202.1 4 from $^{176}\text{Yb}(^{37}\text{Cl},4n\gamma)$ (2006Me03). Mult.: $\alpha(\text{exp})\leq 0.14$ (2009Dr04), combined analysis for 201.9 γ and 247.3 γ , with the main contribution being from the latter. $A_2=-0.12$ 5 (2009Dr04). B(E1)(W.u.)=6.1 $\times 10^{-7}$ 6.
2175.9	45.4 3 247.3 2	5.1 9 100 3	M1 E1		28.3 7 0.0533	Mult.: $\alpha(\text{exp})=28.0$ 8 (2009Dr04). B(M1)(W.u.)>0.0066. E γ : 247.4 4 from $^{176}\text{Yb}(^{37}\text{Cl},4n\gamma)$ (2006Me03). Mult.: $\alpha(\text{exp})\leq 0.14$ (2009Dr04), combined analysis for 201.9 γ and 247.3 γ , with the main contribution being from the latter. $A_2=-0.24$ 4 (2009Dr04). B(E1)(W.u.)>7.2 $\times 10^{-6}$.
2245.1	481.4 3	100	(E1)		0.01231	Mult.: $A_2=-0.34$ 17 (2009Dr04).
2407.6	231.7 2	100 8	M1(+E2)	<0.4	1.26 8	E γ : 231.4 4 from $^{176}\text{Yb}(^{37}\text{Cl},4n\gamma)$ (2006Me03). Mult., δ : from $\alpha(\text{exp})=1.33$ 13 (2009Dr04). Also $A_2=-0.58$ 4 (2009Dr04).
2424.7	(17.1 7)	9.5 19	[M1]		126 17	E γ : from level energy differences. B(M1)(W.u.)>0.037.
	248.8 3	100 19	E2		0.261	Mult.: $A_2=+0.18$ 11 (2009Dr04). B(E2)(W.u.)>0.87.
2559.1	630.5 3	100	(M1+E2)		0.0881	Mult.: $A_2=-0.60$ 12 (2009Dr04).
2599.1	670.5 3	100	E2		0.0191	Mult.: $A_2=+0.33$ 9 (2009Dr04).
2696.7	566.2 3	100	M1+E2		0.1171	Mult.: $A_2=-0.65$ 14 (2009Dr04).
2717.4	309.8 3	100				
2857.7?	140.3@ 3	100				
2903.3?	727.4 $\frac{1}{2}$ 3	100	E2		0.01610	Mult.: $A_2=+0.26$ 9 (2009Dr04).
2917.9	787.4 3	100	(E2)		0.01369	Mult.: $A_2=+0.30$ 11.
2937.8	692.7 3	100				
3027.4	602.7 3	100	M1+E2		0.0992	Mult.: $A_2=-0.57$ 8 (2009Dr04).
3115.4	690.7 2	100	E2		0.0179	E γ : 690.9 4 from $^{176}\text{Yb}(^{37}\text{Cl},4n\gamma)$ (2006Me03). Mult.: $A_2=+0.25$ 5 (2009Dr04).
3127.4	528.3 3	100	E2		0.0324	Mult.: $A_2=+0.44$ 16 (2009Dr04).
3153.1	435.7 3					
	728.4 3	100 33				
	745.5 3	73 7	Q			Mult.: $A_2=+0.22$ 11 (2009Dr04).
3234.5	331.2 $\frac{1}{2}$ 3	44 3	(M1+E2)		0.496	Mult.: $A_2=-0.40$ 13 (2009Dr04).
	809.8 3	100 9	(M1+E2)		0.0456	Mult.: $A_2=-0.10$ 8 (2009Dr04).
3369.6	342.2 3	100	M1+E2		0.454	Mult.: $A_2=-0.45$ 20 (2009Dr04).
3409.4	174.9 3	100	M1+E2	1.1 +4-3	1.8 4	Mult.: $\alpha(\text{exp})=0.24$ 15, $A_2=-0.19$ 20 (2009Dr04).
3415.9	181.4 3	100	E1(+M2)	≤ 0.15	0.25 14	Mult., δ : from $\alpha(\text{exp})=0.24$ 15 (2009Dr04). Also $A_2=-0.19$ 20 (2009Dr04). B(E1)(W.u.)>4.1 $\times 10^{-7}$?; B(M2)(W.u.)<1.3?
3630.9	515.5 2	100	E2		0.0343	E γ : 515.2 4 from $^{176}\text{Yb}(^{37}\text{Cl},4n\gamma)$ (2006Me03). Mult.: $A_2=+0.38$ 10 (2009Dr04).
3923.4	514.0 3	100	(M1+E2)		0.1515	Mult.: $A_2=-0.53$ 24 (2009Dr04).
3968.7	559.3 3	100	D+Q			$A_2=-0.19$ 4 (2009Dr04).
4039.6	408.7 2	100	M1+E2	1.10 +17-15	0.160 19	E γ : 408.8 4 from $^{176}\text{Yb}(^{37}\text{Cl},4n\gamma)$ (2006Me03). Mult., δ : from $\alpha(\text{K})_{\text{exp}}=0.145$ 14, $\alpha(\text{L})_{\text{exp}}=0.012$ 4 (2009Dr04). Also $\alpha(\text{exp})=0.25$ 13 and $A_2=-0.46$ 7 (2009Dr04).
4166.4	757.0 3	100				
4324.3	284.7 3	100	M1+E2		0.752	Mult.: $A_2=-0.32$ 13 (2009Dr04).

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Adopted Levels, Gammas (continued)
 $\gamma(^{209}\text{Fr})$ (continued)

E(level)	E $\gamma^{\dagger}$	I $\gamma^{\dagger}$	Mult. §	α	Comments
4364.1	733.2 3	100	M1+E2	0.0592	Mult.: A ₂ =-0.63 17 (2009Dr04).
4423.6	792.7 3	100	(E2)	0.01351	Mult.: A ₂ =+0.33 14 (2009Dr04).
4659.8	335.5@ 3	13 3	(M2)	1.602	Mult.: A ₂ =+0.1 3 (2009Dr04).
	620.2 3	100 7	E3	0.0686	B(M2)(W.u.)=0.046 12. E γ : 619.5 5 from ¹⁷⁶ Yb(³⁷ Cl,4n γ) (2006Me03). Mult.: α (K) _{exp} =0.042 8, K/L=1.6 3, A ₂ =+0.07 12 (2009Dr04). B(E3)(W.u.)=22 3.
5046.2?	386.4@ 3	100			
5069.3	745.0 3	100			
5194.6	534.8 3	100	(M1+E2)	0.1363 20	Mult.: A ₂ =-0.45 11 (2009Dr04).
5302.1	642.3 3	100	D+Q		Mult.: A ₂ =-0.23 19 (2009Dr04).
5399.5	739.7 3	100	E2	0.01556	Mult.: A ₂ =+0.39 8 (2009Dr04).
5413.9?	754.1@ 3	100			
5480.3?	820.5@ 3	100			
5488.5	828.7 3	100	M1+E2	0.0429	Mult.: A ₂ =-0.66 6 (2009Dr04).
5657.2	997.4 3	100	(M1+E2)	0.0265	Mult.: A ₂ =-0.56 13 (2009Dr04).
5765.2	1105.4 3	100	(D+Q)		Mult.: A ₂ =-0.32 13 (2009Dr04).
5903.4	414.9 3	100	M1+E2	0.269	Mult.: A ₂ =-0.50 16 (2009Dr04).

$\dagger$ From 2009Dr04 in ¹⁹⁷Au(¹⁶O,4n γ).

$\ddagger$ The ordering of the 331 γ -727 γ cascade is not firmly established.

$\S$ From 2009Dr04 in ¹⁹⁷Au(¹⁶O,4n γ), based on ce data, anisotropies and transition strengths.

From 2009Dr04 in ¹⁹⁷Au(¹⁶O,4n γ), based on measured ce data.

@ Placement of transition in the level scheme is uncertain.

²¹³Ac α Decay 1968Va04,2000He17

Parent ²¹³Ac: E=0.0; J π =9/2-; T_{1/2}=738 ms 16; Q(g.s.)=7501 6; % α decay=100.

²¹³Ac-J: Assuming a favored α -decay to ²⁰⁹Fr g.s. (J π =9/2-).

²¹³Ac-Q(α): From E α =7360 keV 6.

1968Va04: ²¹³Ac activities were produced by the ¹⁹⁷Au(²⁰Ne,6n), ²⁰⁹Bi(¹²C,8n) and ²⁰³Tl(¹⁶O,8n) reactions at beam energies of 99 MeV ²⁰Ne, 118 MeV ¹²C, and 112 and 135 MeV ¹⁶O from the Berkeley heavy-ion linear accelerator (HILAC). α particles were detected by a Si(Au) surface-barrier detector. Measured single E α , α (t).

2000He17: ²¹³Ac activities were produced using various heavy-ion reactions at GSI. Reaction products were separated by a velocity filter (SHIP). 16-strip position-sensitive silicon detector was used to implant the recoils and correlate subsequent α decay events. Measured single E α , α (t).

²⁰⁹Fr Levels

E(level)	J π	T _{1/2}	Comments
0.0	9/2-	50.5 s 7	J π , T _{1/2} : from Adopted Levels.

 α radiations

E α	E(level)	I $\alpha^{\ddagger}$	HF †	Comments
7360 6	0.0	100	≈ 0.94	E α : weighted average of 7356 10 (2000He17) and 7364 8 (1968Va04). The value from 1968Va04 has been increased by 2 keV by the evaluators to account for the changes in calibration energies, as recommended in 1991Ry01. Other: 7420 (1961Gr42).

$\dagger$ r₀(²⁰⁹Fr)=1.471 11, weighted average of r₀(²⁰⁸Rn)=1.466 8 and r₀(²¹⁰Ra)=1.492 16, both deduced by using HF=1.

$\ddagger$ For α intensity per 100 decays, multiply by ≈ 1.00 .

¹⁷⁶Yb(³⁷Cl,4n γ) 2006Me03

2006Me03: E=173, 179, 185 MeV ³⁷Cl beams were produced at the Wright Nuclear Structure Laboratory at Yale University. A target of 1 mg/cm² ¹⁷⁶Yb foil was used. Evaporation residues were separated by the Small Angle Separator System at Yale for Evaporation Residues (SASSYER) and γ -rays were detected by an array of six Compton-suppressed clover HPGe detectors each with about 150% relative efficiency. Measured E γ , I γ , $\gamma(\theta)$, $\gamma\gamma$ -coin, $\gamma(t)$, excitation functions. Deduced levels, J π , configurations, isomer T_{1/2}.

²⁰⁹Fr Levels

2006Me03 has misassigned the γ -ray transitions of ²⁰⁸Fr to ²⁰⁹Fr, and the ones of ²⁰⁹Fr to ²¹⁰Fr. Therefore, the reported level scheme of ²⁰⁹Fr in 2006Me03 is incorrect. In fact, it is that of ²⁰⁸Fr. No $\gamma\gamma$ -coincidences were measured in 2006Me03 and thus the level schemes can not be firmly established.

E(level)	T _{1/2}	Comments
x		
x+433.5	0.36 ms 14	T _{1/2} : from 433.5 $\gamma(t)$ (2006Me03).

$\gamma(^{209}\text{Fr})$

E $\gamma^{\dagger}$	E(level)	I $\gamma^{\ddagger}$
x202.1 4		0.5 1
x231.4 4		0.4 1
x247.4 4		0.6 1
x408.8 4		1.1 1
433.5 4	x+433.5	1.0 1
x515.2 4		1.1 2
x619.5 5		1.1 3
x690.9 4		1.3 1

$\dagger$ assigned to ²¹⁰Fr in 2006Me03, but associated with ²⁰⁹Fr, as reported in 2009Dr04. Since no $\gamma\gamma$ -coincidences were measured, the placements of these γ -ray transitions in the level scheme can not be established based on the 2006Me03 data alone.

$\ddagger$ Relative intensities normalized to I(433.5 γ)=1.0.

x γ ray not placed in level scheme.

¹⁹⁷Au(¹⁶O,4n γ) 2009Dr04

2009Dr04: E=95 MeV ¹⁶O beam was produced from the 14 UD Pelletron accelerator. A 5.5 mg/cm² thick target was used. γ -rays were detected with the caesar array comprised of six Compton-suppressed high-purity Ge detectors and with two LEPS detectors; conversion electrons were detected with a superconducting solenoid and a Si(Li) detector. Measured E γ , I γ , $\gamma\gamma$ -coin, $\gamma(\theta)$, $\gamma(t)$, $\gamma\gamma(t)$, I(ce). Deduced levels, J π , T_{1/2}, γ -multipolarities, conversion coefficients, transition strengths, configurations. Comparisons with shell-model calculations.

Others:

2011Ka37: Measured T_{1/2} for E=2130 level.

1976BaXJ: Measured $\sigma(E)$ of the ¹⁹⁷Au(¹⁶O,4n) reaction.

1970Bj02: No SF isomers with 2 ns≤T_{1/2}≤2000 s (σ <0.07 μ b) observed from search for fission fragments following bombardment of ¹⁹⁷Au with 85- to 165-MeV ¹⁶O.

²⁰⁹Fr Levels

configuration proposed by 2009Dr04.

E(level) †	J $\pi^{\ddagger}$	T _{1/2} ‡	Comments
0.0	9/2-	50.5 s 7	J π , T _{1/2} : from Adopted Levels. configuration= $\pi(h_{9/2})^{+1}$.
606.06 18	13/2-		configuration=dominant $\pi(h_{9/2})^{+1} \otimes \nu(f_{5/2})^{-2}_{2+}$.
622.64 18	11/2-		configuration=dominant $\pi(h_{9/2})^{+1} \otimes \nu(f_{5/2})^{-2}_{2+}$.
1088.88 21	15/2-		configuration=dominant $\pi(h_{9/2})^{+1} \otimes \nu(f_{5/2})^{-2}_{4+}$.
1224.97 23	17/2-		configuration=dominant $\pi(h_{9/2})^{+1} \otimes \nu(f_{5/2})^{-2}_{4+}$.
1330.46 25	17/2-		configuration= $\pi(h_{9/2})^{+3}$.
1763.7 3	21/2-		configuration= $\pi(h_{9/2})^{+3}$.
1928.6 4	23/2-	<1.0 ns	configuration= $\pi((h_{9/2})^{+2}(f_{7/2})^{+1})^3$.

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¹⁹⁷Au(¹⁶O,4nγ) 2009Dr04 (continued)

²⁰⁹Fr Levels (continued)

E(level) [†]	Jπ [‡]	T _{1/2} [‡]	Comments
2130.5 4	25/2+	35 ns 3	T _{1/2} : weighted average of 33.3 ns 21 (2009Dr04) and 39 ns 3 (2011Ka37), both using 409γ+515γ+619γγ-202γ(Δt). possible configuration=π((h _{9/2}) ⁺¹ ⊗v((f _{5/2}) ⁻¹ (i _{13/2}) ⁻¹) ₉ ⁻ . configuration=π((h _{9/2}) ⁺² (i _{13/2}) ⁺¹) ₃ .
2175.9 4	25/2+	<0.69 ns	
2245.1 4	23/2(+)		
2407.6 5	27/2+		configuration=π((h _{9/2}) ⁺² (i _{13/2}) ⁺¹) ₃ .
2424.7 5	29/2+	<0.69 ns	configuration=π((h _{9/2}) ⁺² (i _{13/2}) ⁺¹) ₃ .
2559.1 5	25/2(-)		configuration=π((h _{9/2}) ⁺⁵ .
2599.1 5	27/2-		configuration=π((h _{9/2}) ⁺⁴ (f _{7/2}) ⁺¹) ₅ .
2696.7 5	27/2+		configuration=π((h _{9/2}) ⁺¹ ⊗v((f _{5/2}) ⁻¹ (i _{13/2}) ⁻¹) ₉ ⁻ .
2717.4 5	(29/2)		
2857.?? 6			
2903.3? 5	29/2+		
2917.9 5	29/2(+)		
2937.8 5	(27/2)		
3027.4 6	31/2+		configuration=π((h _{9/2}) ⁺⁴ (i _{13/2}) ⁺¹) ₅ .
3115.4 5	33/2+		configuration=π((h _{9/2}) ⁺⁴ (i _{13/2}) ⁺¹) ₅ .
3127.4 6	31/2-		configuration=π((h _{9/2}) ⁺⁴ (f _{7/2}) ⁺¹) ₅ .
3153.1 5	31/2		Jπ: negative parity listed for this level in Table I, but none given in the level scheme, by 2009Dr04.
3234.5 5	31/2(+)		
3369.6 6	33/2+		
3409.4 6	33/2(+)		
3415.9 6	33/2(-)	=62 ns	T _{1/2} : from 181.4γ(t), consistent with 809.8γ(t), in 2009Dr04. possible configuration=π((h _{9/2}) ⁺¹ ⊗v((i _{13/2}) ⁻²) ₁₂ ⁺ . configuration=π((h _{9/2}) ⁺⁴ (i _{13/2}) ⁺¹) ₅ .
3630.9 6	37/2+		
3923.4 7	35/2(+)		
3968.7 7	35/2		
4039.6 6	39/2+		configuration=π((h _{9/2}) ⁺³ (f _{7/2}) ⁺¹ (i _{13/2}) ⁺¹) ₅ .
4166.4 7	(37/2)		
4324.3 7	41/2+		configuration=π((h _{9/2}) ⁺³ (f _{7/2}) ⁺¹ (i _{13/2}) ⁺¹) ₅ .
4364.1 6	39/2+		
4423.6 6	41/2(+)		
4659.8 7	45/2-	420 ns 18	T _{1/2} : from 232γ+409γ+620γ(t) in 2009Dr04. Selected γ's as gates were not contaminated in the γ-ray spectra. configuration=π((h _{9/2}) ⁺³ (i _{13/2}) ⁺²) ₅ .
5046.2? 7			
5069.3 7	(43/2)		
5194.6 7	47/2(-)		
5302.1 7	(47/2)		
5399.5 7	49/2-		
5413.9? 7			
5480.3? 7			
5488.5 7	47/2-		
5657.2 7	47/2(-)		
5765.2 7	(47/2)		
5903.4 8	49/2-		

[†] From a least-squares fit to Eγ.

[‡] From 2009Dr04, unless otherwise stated. Jπ are based on the deduced γ-ray transition multipolarities and observed multiple γ-ray decay branches, unless otherwise stated.

γ(²⁰⁹Fr)

Eγ [†]	E(level)	Iγ [†]	Mult. [§]	δ [#]	α	Comments
(17.1 7)	2424.7	0.40 8	[M1]		126 17	Eγ: from level-energy difference. Iγ: from I(γ+ce)= 51 10, implied from the intensity balance, and α.
45.4 3	2175.9	1.8 3	M1		28.3 7	Mult.: α(exp)=28.0 8.
136.1 3	1224.97	4.2 6	M1 (+E2)	<0.4	5.7 3	Mult.,δ: from α(exp)=7.0 10. Also A ₂ =-0.31 7.
140.3@ 3	2857.7?					

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¹⁹⁷Au(¹⁶O,4n γ) 2009Dr04 (continued)

 $\gamma(^{209}\text{Fr})$ (continued)

E $\gamma^{\dagger}$	E(level)	I $\gamma^{\dagger}$	Mult. ^{\$}	$\delta^{\#}$	α	Comments
164.9 2	1928.6	26.1 11	M1+E2	0.44 +8-9	3.08 13	Mult.: δ : from $\alpha(\text{exp})=3.08$ 11. Also $A_2=-0.24$ 4.
174.9 3	3409.4	2.6 2	M1+E2	1.1 +4-3	1.8 4	Mult.: δ : from $\alpha(\text{exp})=1.8$ 3. Also $A_2=-0.45$ 12.
181.4 3	3415.9	1.3 2	E1 (+M2)	≤ 0.15	0.25 14	Mult.: δ : from $\alpha(\text{exp})=0.24$ 15. Also $A_2=-0.19$ 20.
201.9 2	2130.5	51.0 10	E1		0.0862	Mult.: $\alpha(\text{exp})\leq 0.14$, combined analysis for 201.9 γ and 247.3 γ , with the main contribution being from the latter. $A_2=-0.12$ 5.
231.7 2	2407.6	26.1 8	M1 (+E2)	< 0.4	1.26 8	Mult.: from $\alpha(\text{exp})=1.33$ 13. Also $A_2=-0.58$ 4.
247.3 2	2175.9	35.0 10	E1		0.0533	Mult.: $\alpha(\text{exp})\leq 0.14$, combined analysis for 201.9 γ and 247.3 γ , with the main contribution being from the latter. $A_2=-0.24$ 4.
248.8 3	2424.7	4.2 8	E2		0.261	Mult.: $A_2=+0.18$ 11.
284.7 3	4324.3	2.6 2	M1+E2		0.752	Mult.: $A_2=-0.32$ 13.
309.8 3	2717.4					
331.2 $\frac{1}{2}$ 3	3234.5	4.1 3	(M1+E2)		0.496	Mult.: $A_2=-0.40$ 13.
335.5 $^{\oplus}$ 3	4659.8	1.0 2	(M2)		1.602	Mult.: $A_2=+0.1$ 3.
342.2 3	3369.6	1.5 2	M1+E2		0.454	Mult.: $A_2=-0.45$ 20.
386.4 $^{\oplus}$ 3	5046.2?	0.3 1				
408.7 2	4039.6	13.1 6	M1+E2	1.11 +17-15	0.159 16	Mult.: δ : from $\alpha(\text{K})\text{exp}=0.145$ 14, $\alpha(\text{L})\text{exp}=0.012$ 4. Also $\alpha(\text{exp})=0.25$ 13, $A_2=-0.46$ 7.
414.9 3	5903.4	0.9 2	M1+E2		0.269	Mult.: $A_2=-0.50$ 16.
433.2 2	1763.7	93.7 14	E2		0.0524	Mult.: $\alpha(\text{K})\text{exp}=0.032$ 2, $\alpha(\text{M})\text{exp}=0.003$ 1, $A_2=+0.26$ 5.
435.7 3	3153.1					
466.3 2	1088.88	18.2 5	E2		0.0436	Mult.: $\alpha(\text{K})\text{exp}=0.031$ 3, $A_2=+0.21$ 5.
481.4 3	2245.1	4.6 4	(E1)		0.01231	Mult.: $A_2=-0.34$ 17.
482.7 3	1088.88	6.7 4	M1 (+E2)	< 1.8	0.13 6	Mult.: δ : from $\alpha(\text{K})\text{exp}>0.054$. Also $A_2=-0.48$ 17.
514.0 3	3923.4	4.8 9	(M1+E2)		0.1515	Mult.: $A_2=-0.53$ 24.
515.5 2	3630.9	23.1 9	E2		0.0343	Mult.: $A_2=+0.38$ 10.
528.3 3	3127.4	6.1 5	E2		0.0324	Mult.: $A_2=+0.44$ 16.
534.8 3	5194.6	0.6 1	(M1+E2)		0.1363 20	Mult.: $A_2=-0.45$ 11.
538.7 2	1763.7	25.0 10	E2		0.0310	Mult.: $\alpha(\text{K})\text{exp}=0.019$ 3, $A_2=+0.20$ 9.
559.3 3	3968.7	6.0 8	D+Q			Mult.: $A_2=-0.19$ 4.
566.2 3	2696.7	4.5 5	M1+E2		0.1171	Mult.: $A_2=-0.65$ 14.
602.7 3	3027.4	8.5 4	M1+E2		0.0992	Mult.: $A_2=-0.57$ 8.
606.0 2	606.06	100.0 16	E2		0.0238	Mult.: $\alpha(\text{K})\text{exp}=0.016$ 2, $\alpha(\text{L})\text{exp}=0.007$ 1, $A_2=+0.27$ 3.
618.9 2	1224.97	15.9 20	E2		0.0227	Mult.: $\alpha(\text{K})\text{exp}=0.017$ 3, $A_2=+0.23$ 9.
620.2 3	4659.8	7.5 5	E3		0.0686	Mult.: $\alpha(\text{K})\text{exp}=0.042$ 8, $\text{K/L}=1.6$ 3, $A_2=+0.07$ 12. E γ : 620.0 γ in Table II of 2009Dr04.
622.7 2	622.64	22.8 8	M1+E2	0.64 11	0.071 5	Mult.: δ : from $\alpha(\text{K})\text{exp}=0.057$ 4. Also $A_2=-0.43$ 10.
630.5 3	2559.1	3.3 3	(M1+E2)		0.0881	Mult.: $A_2=-0.60$ 12.
642.3 3	5302.1	0.5 1	D+Q			Mult.: $A_2=-0.23$ 19.
670.5 3	2599.1	5.2 4	E2		0.0191	Mult.: $A_2=+0.33$ 9.
690.7 2	3115.4	27.5 11	E2		0.0179	Mult.: $A_2=+0.25$ 5.
692.7 3	2937.8	1.3 2				
724.4 2	1330.46	98.9 17	E2		0.01624	Mult.: $\alpha(\text{K})\text{exp}=0.012$ 2, $\alpha(\text{L})\text{exp}=0.0022$ 4, $A_2=+0.23$ 4.
727.4 $\frac{1}{2}$ 3	2903.3?	6.0 10	E2		0.01610	Mult.: $A_2=+0.26$ 9.
728.4 3	3153.1	3.0 10				
733.2 3	4364.1	2.1 3	M1+E2		0.0592	Mult.: $A_2=-0.63$ 17.
739.7 3	5399.5	1.7 2	E2		0.01556	Mult.: $A_2=+0.39$ 8.
745.0 3	5069.3	1.5 3				
745.5 3	3153.1	2.2 2	Q			Mult.: $A_2=+0.22$ 11.
754.1 $^{\oplus}$ 3	5413.9?	0.2 1				
757.0 3	4166.4	1.5 2				
787.4 3	2917.9	6.0 3	(E2)		0.01369	Mult.: $A_2=+0.30$ 11.
792.7 3	4423.6	3.4 3	(E2)		0.01351	Mult.: $A_2=+0.33$ 14.
809.8 3	3234.5	9.3 8	(M1+E2)		0.0456	Mult.: $A_2=-0.10$ 8.
820.5 $^{\oplus}$ 3	5480.3?	0.2 1				

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¹⁹⁷Au(¹⁶O,4n γ) 2009Dr04 (continued)

$\gamma(^{209}\text{Fr})$ (continued)

$E\gamma^\dagger$	E(level)	$I\gamma^\ddagger$	Mult.§	α	Comments
828.7 3	5488.5	1.7 2	M1+E2	0.0429	Mult.: $A_2=-0.66$ 6.
997.4 3	5657.2	0.5 1	(M1+E2)	0.0265	Mult.: $A_2=-0.56$ 13.
1105.4 3	5765.2	0.4 1	(D+Q)		Mult.: $A_2=-0.32$ 13.

[†] From 2009Dr04. The authors state that the $\Delta E\gamma$ range from 0.15 keV for strong lines and 0.25 keV for weak lines. The evaluators make the division between strong and weak at $I\gamma=10$.

[‡] The ordering of the 331 γ -727 γ cascade is not firmly established.

§ From 2009Dr04, based on ce data, γ -ray anisotropies and deduced transition strengths.

Deduced by evaluators from the ce data.

@ Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Q(β⁻)=-6990 70; S(n)=7930 50; S(p)=2770 50; Q(α)=7143.0 27 2012Wa38.

²⁰⁹Ra Levels

Cross Reference (XREF) Flags

A ²¹³Th α Decay
B ¹⁷⁴Yb(⁴⁰Ar,5nγ)
C ¹⁸⁴W(³⁰Si,5nγ)

E(level) [†]	Jπ [‡]	XREF	T _{1/2}	Comments
0.0	5/2-	ABC	4.8 s 2	%α=100. Jπ: from collinear LASER spectroscopy (1988Ah02). π from μ. T _{1/2} : weighted average of 4.7 s 2 (α(t),1967Va22), 4.5 s 3 (α(t), 1968Lo15) and 5.1 s 2 (238-KLMα(t)+644.0γα(t), 2008Ha12). Since ²⁰⁹ Ra and ²¹⁰ Ra have similar Eα, different beam energies were used to differentiate production of ²⁰⁹ Ra and ²¹⁰ Ra in 1967Va22 and 1968Lo15. μ=+0.852 16; Q=+0.39 4. μ,Q: measured using Collinear Fast Beam Laser Spectroscopy. μ is weighted average of +0.865 13 (1988Ah02,1987Ar20) and +0.832 16 (1987We03); Q is weighted average of +0.38 4 (1988Ah02,1987We03) and +0.40 4 (1989Ne03). configuration=v(f _{5/2}) ⁻¹ . δ(r ²)(²⁰⁹ Ra, ²¹⁴ Ra)=-0.253 fm ² 25 (1988Ah02). Eα=7008 keV 5 (1967Va22), 7003 keV 10 (2003He06), and 7005 keV 4 (2008Ha12). configuration: v(f _{5/2}) ⁻¹ ⊗2 ⁺ . Jπ: 644.0γ E2 to 5/2-.
644.0 5	9/2-	BC		
882.4 7	13/2+	BC	117 μs 5	Jπ: 238.4γ M2 to 9/2-; systematics of known Jπ=13/2+ isomeric states in neighboring N=121 isotones. T _{1/2} : weighted average of 115 μs 7 from 644.0γ(t) and 118 μs 6 from from 238-KLM(t) in ¹⁷⁴ Yb(⁴⁰ Ar,5nγ) (2008Ha12). Other: 88 μs 31 from 238.4γ(t) in ¹⁷⁴ Yb(⁴⁰ Ar,5nγ) (2008Ha12). configuration: v(i _{13/2}) ⁻¹ .
1014.8 [‡] 7	(11/2-)	C		
1409.3 [‡] 7	(13/2-)	C		
1450.9 9	(17/2+)	C		
1888.1 10	(21/2+)	C		
2223.7 12	(25/2+)	C		
2452.8? 13	(27/2+)	C		
2760? 15	(29/2+)	C		

[†] From a least-squares fit to E_γ.

[‡] Fed from a long-lived (a few μs or longer) isomeric state, since 378.8γ, 643.6γ and 765.3γ were observed at the mass separator focal plane in ¹⁸⁴W(³⁰Si,5nγ) (2004Re04).

[§] From 2004Re04 in ¹⁸⁴W(³⁰Si,5nγ), based on the deduced γ-ray transition multipolarities and systematics arguments, unless otherwise stated.

γ(²⁰⁹Ra)

E(level)	Eγ [†]	Iγ [†]	Mult. [§]	α	Comments
644.0	644.0 5	100	E2	0.0218	Eγ: weighted average of 643.6 keV 5 from ¹⁸⁴ W(³⁰ Si,5nγ) and 644.4 keV 5 from ¹⁷⁴ Yb(⁴⁰ Ar,5nγ). Mult.: ²⁰⁹ Ra cg M; α(K)exp<0.034 and K/L>3 in ¹⁷⁴ Yb(⁴⁰ Ar,5nγ) (2008Ha12) are consistent with E1 or E2, but E1 is ruled out, since the placement in the level scheme requires Mult.=E2; γ-ray anisotropy measurements in ¹⁸⁴ W(³⁰ Si,5nγ) (2004Re04) suggest also Mult.=E2.
882.4	238.4 5	100	M2	5.38	Eγ,Iγ: from ¹⁷⁴ Yb(⁴⁰ Ar,5nγ) 2008Ha12. Mult.: from α(K)exp=4.0 5 in ¹⁷⁴ Yb(⁴⁰ Ar,5nγ) (2008Ha12). B(M2)(W.u.)=0.00153 7.
1014.8	370.8 [‡] 5	100	(M1)	0.397	
1409.3	765.3 [‡] 5	100	(E2)	0.01525	
1450.9	568.5 5	100	(E2)	0.0288	
1888.1	437.2 5	100	(E2)	0.0537	
2223.7	335.6 5	100	(E2)	0.1093	
2452.8?	229.1 5	100	(M1)	1.496 23	

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Adopted Levels, Gammas (continued) $\gamma(^{209}\text{Ra})$ (continued)

E(level)	$E\gamma^\dagger$	Mult.§	α
2760?	306#	(M1)	0.671

† From $^{184}\text{W}(^{30}\text{Si}, 5n\gamma)$ (2004Re04), unless otherwise stated.

‡ Observed at the focal plane and, therefore, fed from an isomeric state with a half-life of a few μs or longer in $^{184}\text{W}(^{30}\text{Si}, 5n\gamma)$ (2004Re04) (not placed in the level scheme).

§ From 2004Re04 in $^{184}\text{W}(^{30}\text{Si}, 5n\gamma)$, based on the measured γ -ray anisotropies (D=M1 and Q=E2 were assumed), unless otherwise stated.

Placement of transition in the level scheme is uncertain.

 ^{213}Th α Decay 1968Va18, 1980Ve01

Parent ^{213}Th : E=0.0; $J\pi=(5/2-)$; $T_{1/2}=144$ ms 21; Q(g.s.)=7837 7; % α decay=100.

^{213}Th -Q(α): From 2012Wa38.

1968Va18: ^{213}Th activities were produced by bombarding 166 MeV ^{16}O beam from the hilac accelerator on a ^{206}Pb target. α particles were detected by a surface barrier detector. Measured $E\alpha$, $I\alpha$, $\alpha(t)$. Deduced $T_{1/2}$ of ^{213}Th .

1980Ve01: ^{213}Th activities were produced by the $^{40}\text{Ar}+^{177}\text{Hf}$ reaction with E(^{40}Ar)=170–200 MeV reaction products were separated by the velocity filter SHIP at the GSI heavy ion accelerator UNILAC. α particles were detected by a surface-barrier silicon detector (FWHM=20 keV). Measured $E\alpha$, $\alpha(t)$. Deduced $T_{1/2}$ of ^{213}Th .

 ^{209}Ra Levels

E(level)	$J\pi$	$T_{1/2}$	Comments
0.0	5/2-	4.8 s 2	$J\pi, T_{1/2}$: from Adopted Levels.

 α radiations

$E\alpha$	E(level)	$I\alpha^\ddagger$	HF †	Comments
7690 7	0.0	100	≈ 1.6	$E\alpha$: weighted average of 7690 10 (1968Va18) and 7689 10 (1980Ve01). Note, that 1991Ry01 reduced the reported $E\alpha$'s in 1968Va18 by -0.5 keV, but such a correction was not applied in the present work, given the large $\Delta E\alpha$. HF: 1.62 25, if % α =100.

† $r_0(^{209}\text{Ra})=1.497$ 14, weighted average of $r_0(^{208}\text{Ra})=1.510$ 27 and $r_0(^{210}\text{Ra})=1.492$ 16, both deduced from HF=1.

‡ For α intensity per 100 decays, multiply by ≈ 1.00 .

 $^{174}\text{Yb}(^{40}\text{Ar}, 5n\gamma)$ 2008Ha12

2008Ha12: E=192 MeV (at mid-target) beam provided by the U400 cyclotron at JINR, Dubna. Target is 350 $\mu\text{g}/\text{cm}^2$ Yb_2O_3 (98.1% enriched) on a 1.5 μm Ti backing. Evaporation residues were transported by the VASSILISSA separator and implanted into a 16-strip Si detector of the GABRIELA setup. γ -rays were detected by 7 Ge detectors. Measured $E\gamma$, $I\gamma$, $\gamma(t)$, $E\alpha$, $\alpha(t)$, E(ce), I(ce), ce(t). Deduced levels, $T_{1/2}$, γ -ray transition multiplicities, conversion coefficients.

 ^{209}Ra Levels

E(level) †	$J\pi^\ddagger$	$T_{1/2}^\ddagger$	Comments
0.0	5/2-	4.8 s 2	
644.4 5	9/2-		
882.8 7	13/2+	117 μs 5	$T_{1/2}$: from 2008Ha12, weighted average of 115 μs 7 from 644.4 $\gamma(t)$ and 118 μs 6 from 238-KLM(t). Other: 88 μs 31 from 238.4 $\gamma(t)$. configuration: $v(i_{13/2})^{-1}$.

† From a least-squares fit to $E\gamma$.

‡ From Adopted Levels, unless otherwise stated.

¹⁷⁴Yb(⁴⁰Ar,5n γ) 2008Ha12 (continued)
 $\gamma(^{209}\text{Ra})$

$E\gamma^\dagger$	E(level)	Mult.	α	Comments
238.4 5	882.8	M2	5.38	Mult.: from $\alpha(\text{K})_{\text{exp}}=4.0$ 5 (2008Ha12).
644.4 5	644.4	E2	0.0218	Mult.: $\alpha(\text{K})_{\text{exp}}<0.034$ and $\text{K/L}>3$ (2008Ha12) are consistent with E1 or E2, but E1 is ruled out, since the placement in level scheme requires E2 Mult.

[†] From 2008Ha12.

Level Scheme

¹⁸⁴W(³⁰Si,5n γ) 2004Re04

2004Re04: E=148 MeV ³⁰Si beams were produced from the ESTU tandem accelerator at the Wright Nuclear Structure Laboratory. Target is two stacked 200 $\mu\text{g}/\text{cm}^2$ ¹⁸⁴W. Reaction recoils were separated in the Small Angle Separator System at Yale for Evaporation Residues (SASSYER) and γ -rays were detected with the YRAST Ball array comprising of 8 clover HPGe detectors (at 90° and 140° rings). Delayed γ -rays, depopulating isomeric states, were detected within 6 μs following a recoil implantation were detected with 5 additional HPGe detectors that were placed around the focal plane chamber. Measured $E\gamma$, $I\gamma$, $\gamma\gamma$ -coin. Deduced level scheme. See also 2005Re02.

²⁰⁹Ra Levels

E(level) [†]	$J\pi^\S$	$T_{1/2}$	Comments
0.0	5/2-	4.8 s 2	$J\pi, T_{1/2}$: from Adopted Levels.
643.6 $\frac{5}{2}$	(9/2-)		
882.4 7	13/2+	117 μs 5	E(level), $J\pi$: from Adopted Levels. 2004Re04 suggest an isomer with $J\pi=13/2+$ at 900 keV, ≈ 250 keV above the 643.6 level, based on systematics of such states in ²⁰⁵ Po and ²⁰⁷ Rn isotones. $T_{1/2}$: from Adopted Levels. ≈ 50 μs is suggested by 2004Re04, based on the systematics of such isomers in ²⁰⁵ Po and ²⁰⁷ Rn.
1014.4 $\frac{7}{2}$	(11/2-)		
1408.9 $\frac{7}{2}$	(13/2-)		
1450.9 9	(17/2+)		
1888.1 10	(21/2+)		
2223.7 12	(25/2+)		
2452.8? 13	(27/2+)		
2760? 15	(29/2+)		

[†] From a least-squares fit to $E\gamma$, unless otherwise stated.

$\frac{5}{2}$ Fed from a long-lived (a few μs or longer) isomeric state, since 378.8 γ , 643.6 γ and 765.3 γ were observed at the focal plane.

$\S$ From 2004Re04, based on systematics and the deduced γ -ray transition multipolarities, unless otherwise stated.

¹⁸⁴W(³⁰Si,5n γ) 2004Re04 (continued)

 $\gamma(^{209}\text{Ra})$

$E\gamma^\dagger$	E(level)	$I\gamma^\dagger$	Mult. [§]	Comments
229.1 5	2452.8?	8 2	(M1)	
238.4 5	882.4		M2	$E\gamma$, Mult.: from Adopted Gammas.
306 [#]	2760?		(M1)	
335.6 5	2223.7	10 1	(E2)	
370.8 $\frac{5}{2}$	1014.4	18 1	(M1)	$I\gamma$: delayed intensity=3.1 7 (2004Re04).
437.2 5	1888.1	66 2	(E2)	
568.5 5	1450.9	192 6	(E2)	
643.6 $\frac{5}{2}$	643.6	76 3	(E2)	$I\gamma$: delayed intensity=26 2 (2004Re04).
765.3 $\frac{5}{2}$	1408.9	31 2	(E2)	$E\gamma$: 764.9 5 from 2005Re02.
				$I\gamma$: delayed intensity=16 2 (2004Re04).
^x 835.3 5		64 3		

[†] From 2004Re04, unless otherwise stated. Intensities are relative to $I\gamma(518\gamma, ^{210}\text{Ra})=100$. Additional γ -rays that were not assigned to ²⁰⁹Ra are tabulated in 2004Re04.

$\frac{5}{2}$ Observed in the focal plane and, therefore, fed from an isomeric state with a half-life of a few μs or longer (2004Re04).

[§] From 2004Re04 based on measured γ -ray anisotropies, unless otherwise stated. Quadrupole (assumed E2) for $R=I\gamma(140^\circ)/I\gamma(90^\circ)>1$ and dipole (assumed M1) for $R<1$.

[#] Placement of transition in the level scheme is uncertain.

^x γ ray not placed in level scheme.

Adopted Levels

$Q(\beta^-) = -7.69 \times 10^3$ 10; S(n)=9990 80; S(p)=160 50; $Q(\alpha) = 7730$ 50 2012Wa38.

²⁰⁹Ac Levels

Cross Reference (XREF) Flags

A ²¹³Pa α Decay

E(level)	J π	XREF	T _{1/2}	Comments
0.0	(9/2-)	A	0.87 s +12-9	<p>%α=100.</p> <p>Jπ: assumed a favored α decay to the ²⁰⁵Fr g.s. (Jπ=(9/2-)). No E(α1)- E(α2) correlations are known. Jπ=7/2- is predicted in 1997Mo25.</p> <p>T_{1/2}: weighted average of 0.10 s 5 using 7585α(t) in 1968Va04, 0.091 +21-14 using 7581α(t) in 1994Le05, 0.082 +18-13 using 7580α(t) in 1996Ik01, and 0.098 s +59-27 using 7577α(t) in 2000He17.</p> <p>E(α)=7585 keV 15 (1968Va04), 7581 keV 15 (1994Le05), 7580 keV 50 (1996Ik01), and 7577 keV 10 (2000He17).</p>

²¹³Pa α Decay 2000He17,1996An21

Parent ²¹³Pa: E=0.0; J π =(9/2-); T_{1/2}=5.3 ms +40-16; Q(g.s.)=8390 50; % α decay=100.

²¹³Pa-J: Favored α decay to ²⁰⁹Ac g.s. (J π =(9/2-)).

2000He17: ²¹³Pa activities were produced by ¹⁷⁰Er(⁵⁰Ti,7n) with E=215-235 MeV ⁵⁰Ti beams from the UNILAC accelerator at GSI. Reaction products were separated by the velocity filter SHIP. Measured E α , T_{1/2}.

1996An21,1995Ni05: ²¹³Pa activities were produced by ¹⁷⁰Er(⁵¹V,8n). Measured E α , I α , T_{1/2}.

²⁰⁹Ac Levels

E(level)	J π	T _{1/2}	Comments
0.0	(9/2-)	0.87 s +12-9	J π , T _{1/2} : from Adopted Levels.

α radiations

E α	E(level)	I $\alpha^{\ddagger}$	HF †	Comments
8236 15	0.0	100	2.0 8	<p>Eα: from 2000He17. Other: 8236 keV 20 in 1995Ni05.</p> <p>HF: symmetrized from HF=1.5 +12-4.</p>

† $r_0(^{209}\text{Ac}) = 1.51$ 3, taken from the known value for the ²⁰⁸Ra, N=120 isotone, which is deduced from HF(7802 α)=1.

‡ Absolute intensity per 100 decays.

Adopted Levels

S(n)=8210 90; S(p)=1510 100; Q(α)=8270 50 2012Wa38.

²⁰⁹Th Levels

E(level)	Jπ	T _{1/2}	Comments
0 . 0 + x	(13 / 2 +)	2 . 5 ms +17-7	<p>%α=100.</p> <p>E(α)=8123 25 keV (2010He25) and 8080 keV 50 (1996Ik01).</p> <p>E(level): given the proposed Jπ=(13/2+) this is most likely an isomeric state, based on systematics in neighboring N=119 isotones: ²⁰⁷Ra (E=554 keV, 59 ms), ²⁰⁵Rn(657 keV, >10 s), ²⁰³Po (611 keV, 45 s) and ²⁰¹Pb(629 keV, 60.8 s), thus x=600 keV 200.</p> <p>Jπ=(5/2-) would be expected for the ground state from systematics, while Jπ=1/2- is predicted in 1997Mo25.</p> <p>Jπ: E(α1)=(8123α,²⁰⁹Th)-E(α2)(7379α,²⁰⁵Ra)-E(α3)(6787α,²⁰¹Rn)- E(α4)(6384α,¹⁹⁷Po) correlations (2010He25) suggest favored α decays via the chain of Jπ=(13/2+) isomers in ²⁰⁵Ra, ²⁰¹Rn and ¹⁹⁷Po.</p> <p>T_{1/2}: deduced by 2010He25 by coupling together four events from 2010He25 and two events from 1996Ik01. T_{1/2}=1.9 ms +19-7 using the four events in 2010He25 and 3.8 ms +69-15 using the two events in 1996Ik01.</p> <p>configuration: v(i_{13/2})⁻¹. The assignment is tentative.</p>

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