^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34

Parent: ^{147}Nd: E=0.0; $J^\pi=5/2^-$; $T_{1/2}$=11.03 d *3*; Q(β^-)=895.5 *5*; %β^- decay=100.0

^{147}Nd-J^π: From ^{147}Nd Adopted Levels.

^{147}Nd-$T_{1/2}$: weighted average (NRM) of 11.26 d *1* (2019Br01, decay curve for 91.1-keV γ, also 11.27 d *2* from decay curve for 120.5-keV γ, uncertainty gets increased to 0.11 d in averaging procedure, note that no details are given in the paper about counting losses and systematic uncertainties); 10.98 d *1* (1971Ba28, proportional counter, uncertainty gets increased to 0.03 d in the averaging procedure); 11.02 d *5* (1963Ho15, proportional counter); 11.14 d *6* (1960Al33, β counting); and 11.06 d *4* (1957Wr37, ionization chamber). Regular weighted average is 11.12 d *7*, but with reduced χ^2=100, which implies a discrepant dataset, primarily due to the value in 2019Br01. Unweighted average is 11.09 d *9*. NRM=Normalized Residuals Method. Other (less precise) measurements: 11.2 d *2* (1999Po32, from decay curve for γ rays, 95% confidence level, no details provided); 11.5 d *5* (1960Wi10, proportional counter); 11.9 d *3* (1952Ru10, β with magnetic spectrometer); 11.1 d *5* (1951Em23, β spectrometer); 11.6 d *3* (1951Ko01,1952Ko27, β spectrometer); 11.0 d *3* (1951MaZZ, 1947Ma28, integral β,γ counting); 11.1 d *2* (1946Bo25). Weighted average (NRM) of all the values is 11.05 d *3*, with the same inflation of uncertainties for values from 2019Br01 and 1971Ba28 as above. Regular weighted average is 11.12 d *5*, but with reduced χ^2=37. Unweighted average is 11.24 d *21*.

^{147}Nd-Q(β^-): from 2017Wa10.

Evaluation of ^{147}Nd decay data by Balraj Singh (McMaster University) with coverage of literature up to Oct 31, 2019.

This work forms a part of the IAEA-NDS project of evaluation of decay data for the long-lived fission products in connection with the needs of the CTBTO in their radioactivity monitoring program.

The ^{147}Nd isotope was identified by 1946Bo25 in ^{146}Nd(n,γ),E=thermal reaction, with measurement of its half-life as 11.1 d *2*, in agreement with the recommended value of 11.03 d *3*. Earlier, 1941La01 (also 1942Ku03) had identified a 10-d activity in neodymium formed by bombarding Pr, Nd and Sm metals by α particles, 10-MeV deuterons, neutrons and γ rays. From current half-life values for Nd isotopes, this activity could only belong to ^{147}Nd. Firm confirmation for the isotopic assignment of 11-d activity to ^{147}Nd was made by 1947Ma28.

^{147}Nd source was prepared using ^{146}Nd(n,γ),E=thermal reaction in almost all the studies. This decay is important in reactor applications and in monitoring activity from fission fragments. In particular, there is need to know more precisely and accurately the emission probability of the 531-keV gamma ray. In this context, it has come to evaluator's attention that two independent studies of the decay of ^{147}Nd have recently been carried out in order to improve the knowledge of gamma-ray intensities from this decay: 1. Livermore + U.C., Irvine + Texas A&M +ANL collaboration; 2. LNE-LNHB, CEA, Saclay. I have been in touch with both these groups, but the results of these studies have not yet been made available. Ph.D. thesis by A.M. Hennessy (University of California, Irvine, 2018), describes the methodology used by the Livermore group, where the activity was produced in fission at the CARIBU facility at ANL, and the counting was done at Texas A&M using an HPGe detector with its efficiency response curve defined to 0.5% in 50-2000 keV region, and a 4π gas counter for the detection of β and conversion electrons. Preliminary results are given in the thesis, while, according to the spokesperson of this experiment, complete analysis of data is still proceeding. No results are yet available from the Saclay group.

Previous ENSDF/NDS evaluations: 2009Ni02, 1992De38, 1978Ha22, 1967Ew01.

2013BeZP: DDEP evaluation of ^{147}Nd decay, with a literature coverage up to March 2011. The evaluation presented in this dataset differs in many ways from the DDEP evaluation, even when there are no new experimental data since 2011.

Main references for Eγ, Iγ, $\gamma(\theta)$ and $\gamma\gamma(\theta)$ data:

1997Sa53: measured Eγ, Iγ, E(ce), I(ce) using HPGe and miniorange spectrometer. A total of 27 γ rays were reported based on singles data only. Evaluator has omitted six of these in this dataset, as these were either not confirmed in complementary decay decay or in-beam γ-ray studies, or were too low in energy resulting in severe transition-intensity imbalances.

1995Go44: measured Eγ, Iγ, $\gamma\gamma$-coin. Total of 15 γ rays reported.

1979Se05: measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma\gamma(\theta)$ using Ge(Li) detectors; deduced mixing ratios. Total of 22 γ rays reported.

1979Vo09 (also 1975VoZR): measured Eγ, Iγ, β, ce, $\gamma\gamma$-coin, $\gamma\gamma(\theta)$. A total of 14 γ rays were reported. The γ-ray energies were measured with reference to previous Eγ values from.

1977Al34: measured $\gamma(\theta$,T) from polarized ^{147}Nd nuclei, and using low temperature orientation method. Also measured $\gamma\gamma(\theta)$ using Ge and Ge(Li) detectors; deduced Jπ and mixing ratios.

1974HeYW (Atlas of γ rays): measured Eγ, Iγ of 14 γ rays.

1974Ra30: measured Eγ, Iγ using Ge(Li) detector, and sum-coin spectrometer using NaI(Tl) detectors. A total of 13 γ rays reported from Ge(Li) singles data, and another 19 reported from sum-coincidence. None of the latter 19 γ rays has been confirmed in other studies, thereby rejecting levels proposed at 182, 228, 275, 319 and 725 keV.

^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34 (continued)

1971Si20: measured Eγ, Iγ, level half-lives by $\beta\gamma$(t) and $\gamma\gamma$(t). Total of 16 γ rays reported. A 723 level decaying by a 312.6 *10* (Iγ=0.24 *9*) reported in this work is discarded as 312.6γ is not confirmed in other studies. A γ ray of Eγ=299.7 *8* and Iγ=0.67 *28* is also discarded, as no such γ ray was seen in more recent studies.

1967Hi04: measured Eγ, Iγ, $\gamma\gamma$-coin for 14 γ rays. Energies of eight γ-rays were measured using curved-crystal diffraction spectrometer. Other γ rays were measured using Ge(Li) detector. In authors' Table 2, measured upper limits (relative to 100 for 531γ) for the following γ rays which were reported in various studies (1964Sa33,1963Sp07,1961Gu04,1960We06,1958Ev81) using NaI(Tl) detectors, but not confirmed by 1967Hi04: 41.7 (<2.0), 78.8 (<0.2), another 91 (<2.0), 149 (<0.1), 154.9 (<0.1), 182 (<0.1), 189 (<0.1), 191 (<0.1), 230 (<0.2), 260 (<0.2), 270 (<0.4), 300 (<0.3), 310 (<0.3), 351 (<0.4), 508 (<0.06), 723 (<0.01).

1967Ja05: measured Eβ, Eγ, Iβ, Iγ, $\beta\gamma$ and $\gamma\gamma$-coin. Total of 13 γ rays reported. A 77 *1* γ with Iγ=5 *3* is discarded as not confirmed in more recent studies.

1967Do07: measured Eγ, Iγ for 13 γ rays.

1967Ca18: measured Eγ, Iγ for 12 γ rays, Eβ, β shape factor.

1967Ba21 (also 1967Ba22): measured Eγ, Iγ, ce, β-polarization.

1967Ki08: measured Eγ, Iγ for 11 γ rays.

1966Ar16 (also 1967Ar04): measured Eγ, Iγ for 16 γ rays.

Other measurements:

2003Zh47: measured Eγ, Iγ, x-rays, α(91γ)-coin. Deduced penetration parameter.

1999Po32: measured Eγ, Iγ, half-life of ^{147}Nd decay. Total of eight γ rays reported, and intensities listed for four of these.

1984Wa23: measured Eβ, Iβ using Siegbahn-Slatis magnetic spectrometer. Authors deduced Iβ(896)/Iβ(804)=0.0026 *10*.

1978Ma51: measured Eβ, Iβ using a magnetic spectrometer.

1976Si08: measured $\beta\gamma$(t), $\gamma\gamma$(t), $\gamma\gamma(\theta)$, $\gamma\gamma(\theta$,t), $\gamma\gamma(\theta$,H), $\gamma\gamma(\theta$,H,t), g factors, and level lifetimes using NaI(Tl) detectors.

1975Si01: measured γ spectrum, $\gamma\gamma$(t); deduced lifetime of 410 level.

1974Bh02 (also 1974BhZJ): measured $\gamma\gamma(\theta)$ using NaI(Tl) detectors; deduced δ.

1973Su05: measured $\beta\gamma(\theta)$.

1972Si49: measured $\gamma\gamma(\theta$,H), $T_{1/2}$, μ.

1971Ya12: measured $\beta\gamma(\theta)$.

1971Na11: measured Eβ, Iβ; deduced β-shape factor, quadrupole moment.

1970Va06: calculated penetration factors for 91-keV transition.

1970Bl12: measured $\gamma\gamma$-coin, $\gamma\gamma(\theta)$ using Ge(Li)-NaI(Tl) detectors; deduced δ.

1969Gr32: measured Eγ, Iγ for 91-keV and 120-keV γ rays.

1969Ba32: measured $\gamma(\theta)$ from oriented nuclei using Ge(Li) detector; deduced δ.

1968Ra28: measured $\gamma\gamma(\theta)$ using NaI(Tl) detectors; deduced δ.

1967Ra20: measured half-lives of 91 and 5131 levels by $\beta\gamma$(t).

1967Ba06: measured ce, K/L ratios. Authors reported 135 ce lines to 66 γ transitions in ^{147}Pm from 77 keV to 763 keV, many of which have not been observed in other studies. For the well-known transitions, agreement is poor between their γ-ray energies and energies adopted here, based on more recent measurements. This work is not considered in the evaluation of this decay.

1966Be09: measured Eβ, $\beta\gamma(\theta)$, β(polarization), β shape factors.

1966Va06: measured Longitudinal polarization of 261β.

1966Be42: measured lifetime of the first excited state.

1966Go25: measured $\gamma\gamma(\theta)$ using NaI(Tl) detectors.

1965Ay03: measured β(91γ)(t); deduced $T_{1/2}$(91 level)=2.49 ns *12*.

1964Hu08: measured β, $\gamma\gamma$-coin.

1964Zu03: measured Eβ, Iβ.

1964Sa33: measured Eγ, Iγ, summed γ-γ.

1963Ph02: measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma\gamma(\theta)$ for 15 γ rays using NaI(Tl) detector.

1963Sp07: measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma\gamma(\theta)$ for four cascades; deduced five excited states defined by 15 γ rays.

1962Ri07: measured (321γ)(91γ)(t); deduced $T_{1/2}$(91 level)=2.50 ns *6*.

1962Be27: measured (β)(91 ceL)(t); deduced $T_{1/2}$(91 level)=2.59 ns *2*.

1962Sh08: measured β, $\beta\gamma$-coin, β shape factor.

1961Ew02 (also 1965Ew03,1957Ew38,1956Ew23,1956EwZZ): measured ce, deduced Eγ values for 11 γ rays.

1961Gu04: measured Eγ, Iγ, $\gamma\gamma$.

1961We07: measured $\gamma(\theta$,T,H) for six γ rays using aligned and polarized source at low temperatures; deduced mixing ratios.

1961Sa13: measured $\gamma\gamma(\theta)$ of five $\gamma\gamma$ cascades; deduced level spins and mixing ratios.

^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34 (continued)

1961Pe10: measured (365β)(531γ circ pol)(θ); deduced δ(531γ)=+1.75 *15* for Jπ(g.s. ^{147}Nd)=5/2$^-$ and 7/2$^+$ to 7/2$^+$ 531γ.
1961Ar09: measured γ spectrum, $\gamma\gamma$-coin, $\gamma\gamma(\theta)$ for 320-91 and 280-320 $\gamma\gamma$ cascades; deduced mixing ratios.
1960Wa11: measured Eγ of 91-keV transition using curved-crystal spectrometer.
1960Ma03: measured $\gamma\gamma(\theta)$.
1960Bo17: measured γ spectra, $\gamma\gamma$-coin, $\gamma\gamma(\theta)$ for six $\gamma\gamma$ cascades, $\gamma\gamma(\theta$,H); deduced half-life of 2.50 ns *6* and g factor=+1.42 *20* for the 91 level, $T_{1/2}\leq$0.5 ns for the 412 level, and mixing ratios for five γ rays.
1960We06: measured Eβ, Iβ, $\beta\gamma$-coin, F-K plot.
1958Be77: measured β, $\beta\gamma$-coin.
1958Co61: measured Eβ, Iβ, Eγ from external conversion.
1958Ev81: measured Eγ, Iγ for nine γ rays, Eβ, $\beta\gamma$-coin.
1958Mi88: measured Eβ.
1957Li40: measured $\gamma\gamma(\theta)$ for 320γ-91γ cascade.
1957Kn35 (thesis): deals with low-temperature angular correlation measurements.
1957Bi86: measured $\gamma(\theta)$ and polarization of oriented nuclei at low temperature; deduced mixing ratios of 531 and 91 gamma rays.
1953Gr07: measured β(91γ)(t), α(K) and K/L ratio; deduced half-life of 2.44 ns *8*, α(K)exp=1.8 and K/L=7.3 for 91γ.
1952Ko27: measured Eβ.
1951Em23: measured Eβ, Iβ.
1951MaZZ (also 1950Ma05,1947Ma28): measured Eγ, Iγ, Eβ, Iβ, x-rays, $T_{1/2}$ of ^{147}Nd decay, chemical identification.
1949Ma02 (also C.E. Mandeville and E. Shapiro, Phys. Rev. 79, 391 (1950)): measured β and γ activity.
1948Co09: measured Eβ and Eγ.
1947Ma28: firm isotopic assignment of 11-d activity to ^{147}Nd.
1946Bo25: identification of 11-d activity with possible assignment to ^{147}Nd activity.
1941La01: possible production of ^{147}Nd with 10-d half-life.

^{147}Pm Levels

Level at 649 keV with Jπ=11/2$^-$ in 1997Sa53 has been omitted as the 117.98 and 159.7 γ rays from this level have not been seen in two different in-beam reaction studies, where this level is populated quite strongly. Fairly intense 240γ from this level should have been detected by 1979Se05, but in their γ-ray spectrum, there is no evidence for such a line. Questionable level at 641 keV shown in level-scheme Fig. 3 of 1997Sa53 has also been omitted here, as there is no evidence for a 230.7 gamma emitted in the decay of ^{147}Nd.

E(level)[†]	J$^\pi$[‡]	$T_{1/2}$[‡]	Comments
0.0	7/2$^+$	2.6234 y *2*	
91.1052 *16*	5/2$^+$	2.51 ns *2*	Measured μ=+3.22 *16* (1980Ne07, DPAC method). Measured g factor=+1.52 *23* (IPAC), +1.37 *40* (DPAC) (1976Si08); 1.57 *29* (1972Si49, IPAC). $T_{1/2}$: unweighted average of values from $\beta\gamma$(t) data: 2.44 ns *8* (1953Gr07), 2.45 ns *20* (1960We06), 2.59 ns *2* (1962Be27), 2.49 ns *12* (1965Ay03), 2.34 ns *4* (1966Be42), 2.51 ns *5* (1967Ba22), 2.46 ns *7* (1967Ra20), 2.58 ns *2* (1971Si20), 2.48 ns *2* (1976Si08); and $\gamma\gamma$(t) data: 2.50 ns *6* (1960Bo17), 2.48 ns *4* (1962Ri07), 2.56 ns *3* (1971Si20), 2.51 ns *9* (1972Si49), 2.47 ns *5* (1976Si08), 2.6 ns *2* (1977Ko24, γ(t) in (p,2nγ), 2.66 ns *6* (1980Ne07). Weighted average is 2.53 ns *2*, but with reduced χ^2=3.7 as compared to critical χ^2=1.7. (804β)(91γ)(θ): 1973Su05, 1971Ya12, 1966Be09.
408.17 *7*	9/2$^+$		
410.516 *9*	3/2$^+$	0.139 ns *14*	J$^\pi$: combined analysis of $\gamma\gamma(\theta)$ and $\gamma(\theta$,H,T) for 276γ and 410γ data gives best possible choice of 3/2 for 410 level and 5/2 for 686 level. $T_{1/2}$: from (275γ)(319γ)(t) (1975Si01). Others: <0.7 ns (1960We06, $\beta\gamma$(t), <0.5 ns (1960Bo17, $\gamma\gamma$(t).
489.245 *14*	7/2$^+$		J$^\pi$: 7/2 is assigned by 1977Al34 based on combined analysis of $\gamma\gamma(\theta)$ and $\gamma(\theta$,H,T) data, which rule out 3/2 and 5/2. Others: 5/2 or 7/2 (1969Ba32,1961We07) based on $\gamma(\theta$,H), and δ(197γ,398γ) from α(K)exp and L-subshell ratios.
530.996 *9*	5/2$^+$	0.093 ns *20*	J$^\pi$: 5/2$^+$ assigned by 1977Al34 based on the analysis of 440$\gamma(\theta$,H,T) data.

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^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34 (continued)

^{147}Pm Levels (continued)

E(level)[†]	J$^\pi$[‡]	T$_{1/2}$[‡]	Comments
			T$_{1/2}$: from difference in centroids of delayed $\beta\gamma$ spectrum for ^{147}Nd and prompt $\beta\gamma$ spectrum from ^{60}Co source. Value is weighted average of 0.083 ns *15* (1967Ra20) and 0.133 ns *30* (1971Si20). Others: ≤0.10 ns (1976Si08, $\beta(531\gamma)$(t), <0.6 ns (1960We06, $\beta\gamma$(t)), ≤0.4 ns (1957Kn35, $\beta\gamma$(t)).
			(364β)(531γ)(θ) (1973Su05,1966Be09).
			(365β)(CP 531γ)(θ) (1961Pe10).
632.94 *5*	1/2$^+$		
680.435 *25*	7/2$^+$		
685.901 *11*	5/2$^+$	0.25 ns *10*	J$^\pi$: combined analysis of $\gamma\gamma(\theta)$ and $\gamma(\theta$,H,T) for 276γ and 410γ data gives best possible choice of 3/2 for 410 level and 5/2 for 686 level. T$_{1/2}$: from β(686γ)(t) (1971Si20). Other: <0.8 ns (1960We06, $\beta\gamma$(t)).

[†] From least-squares fit to Eγ data.
[‡] From Adopted Levels, unless otherwise stated.

β^- radiations

Eβ=720 *30*, Iβ=10% reported by 1960We06 is not observed by 1964Zu03 and 1967Ja05. Eβ=653 *11*, Iβ=5% reported by 1964Hu08 is unaccounted.

E(decay)	E(level)	Iβ^-[†‡]	Log *ft*	Comments
(209.6 *5*)	685.901	2.23 *8*	7.00 *2*	av Eβ=57.48 *15* E(decay): 215 *10* (1967Ja05), 209 (1967Ca18), 224 *10* (1964Zu03), 230 *30* (1964Hu08), 215 *9* (1960We06), 220 (1958Ev81), 230 *50* (1958Co61), 215 *15* (1958Be77), 214 *15* (1956Ew23). Iβ^-: 1.0 *5* (1967Ja05, $\beta\gamma$ coin), 1.8 (1967Ca18, F-K analysis), 12 (1964Zu03), 8 (1964Hu08), 12 (1960We06), 3 (1958Ev81), 16 (1958Co61).
(215.1 *5*)	680.435	0.090 *6*	8.43 *3*	av Eβ=59.11 *15*
(262.6[#] *5*)	632.94	<0.012	>9.3[1u]	av Eβ=85.82 *17*
(364.5 *5*)	530.996	15.2 *4*	6.96 *2*	av Eβ=105.96 *17* E(decay): 365 *8* (1979Vo09), 364 *8* (1971Na11), 369 *10* (1967Ja05), 365 (1967Ca18, F-K analysis), 364 *3* (1966Be09, F-K plot non-linear). 370 *30* (1964Zu03), 357 *18* (1964Zu03), F-K plot linear (1962Sh08), 370 *9* (1960We06, F-K plot linear), 362 (1958Ev81), 380 *50* (1958Co61), 363 *15* (1958Be77), 368 *10* (1956Ew23). β shape factors determined. Iβ^-: 15 *5* (1967Ja05), 14.3 (1967Ca18), 13 (1964Zu03), 20 (1964Hu08), 12 (1960We06), 20 (1958Ev81), 18 (1958Co61).
(406.3 *5*)	489.245	0.83 *4*	8.36 *2*	av Eβ=119.77 *17* E(decay): 410 *20* (1967Ja05, $\beta(489\gamma)$ coin, F-K plot). Iβ^-: 0.7 *5* (1967Ja05).
(485.0 *5*)	410.516	0.64 *6*	8.72 *5*	av Eβ=146.59 *18* E(decay): 500 *30* (1979Vo09), 490 *20* (1967Ja05, $\beta(319\gamma)$ coin, F-K plot), 530 *60* (1964Zu03), 500 *40* (1964Hu08), 480 *80* (1960We06), 529 *25* (1958Be77). Iβ^-: 0.4 *2* (1967Ja05), 7 (1964Zu03), 8 (1964Hu08), 0.5 (1960We06).
(487.3[#] *5*)	408.17	<0.002	>11.3[1u]	av Eβ=162.59 *18*
(804.4 *5*)	91.1052	80.9 *5*	7.394 *3*	av Eβ=263.91 *20* Iβ^-: from 100−(summed β feeding to other levels)=80.9 *5*. Other: 81 *4* from γ-transition intensity balance. E(decay): 808 *10* (1978Ma51), 806 *3* (1979Vo09, straight line shape for β spectrum), 803 *2* (1971Na11), 810 *10* (1967Ja05), 803.5 *10* (1967Ca18), 806 *2* (1966Be09), 806 *7* (1964Zu03), 817 *9* (1964Hu08), 809 *9* (1960We06, F-K plot linear), 801 (1958Mi88), 812 *30* (1958Co61), 815 *10* (1958Be77), 802

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^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34 (continued)

β^- radiations (continued)

E(decay)	E(level)	Iβ^-[†‡]	Log *ft*	Comments
				(1958Ev81), 818 *7* (1957Ew38), 780 *8* (1952Ko27), 825 (1952Ru10), 825 *15* (1951Em23); β shape factors determined. Non-linear F-K plot (1962Sh08). Non-unique first-forbidden transition in 1978Ma51 and 1984Wa23. Iβ^-: 83 *6* (1967Ja05), 83.9 (1967Ca18, F-K analysis), 68 (1964Zu03), 60 (1964Hu08), 65 (1960We06), 76 (1958Ev81), 66 (1958Co61), 60 (1951Em23).
(895.5[#] *5*)	0.0	<0.3	>9.8	av Eβ=299.37 *20* Iβ^-: from 0.22 *10* (1984Wa23, evaluator treats this value as upper limit), <1.1 *7* (1978Ma51, upper limit from priv. comm. with authors), <0.15% (1971Na11,1966Be09), <0.5% (1967Ja05), <0.25% (1962Sh08), <1% (1960We06), <10% (1957Ew38). E(decay): 896 *7* (1984Wa23), 910 *20* (1978Ma51). 1984Wa23 suggest first-forbidden unique shape for the β transition, which is unlikely in view of ΔJ=1 β transition.

† Based on (γ+ce) balance.
‡ Absolute intensity per 100 decays.
# Existence of this branch is questionable.

^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34 (continued)

$\gamma(^{147}Pm)$

Iγ normalization: Summed I(γ+ce)=100 to g.s., and Iβ=0.22 *10* (from a 1984 work by 1984Wa23 using magnetic spectrometer, treated here as upper limit). Others: ≤0.2% (based on β spectrum measurements by 1971Na11 and 1966Be09). Several other β studies measured upper limits, with no evidence for a definite β feeding to the ground state. Note that the γ-transition intensity balance in the present decay scheme gives Iβ<4% to the ground state, since the transition intensity for the 91-keV transition is not yet well known.

Eγ, Iγ data using Ge(Li) and HPGe detectors: 1997Sa53, 1995Go44, 1979Vo09, 1979Se05, 1974HeYW, 1974Ra30, 1971Si20, 1967Ja05, 1967Hi04, 1967Do07, 1967Ca18, 1967Ba21, 1967Ki08, 1966Ar16. Other: 1999Po32 has intensity data for four γ rays.

Eγ, Iγ data using crystal diffraction spectrometers: 1967Hi04 (data for eight γ rays), 1960Wa11 (Eγ for 91-keV γ). Other: 1957Ew38 (data for four γ rays, not so precise).

Eγ, Iγ, ce data by the detection of conversion electrons using magnetic spectrometers: 1967Ba21, 1966Ar16, 1966Ba46, 1961Ew02, 1958Mi88, 1957Ew38.

Eγ, Iγ data using scintillation detectors: 1967Ra19, 1966Ar16, 1966El02, 1964Hu08, 1964Sa33, 1963Ph02, 1963Sp07, 1961Gu04, 1958Mi88, 1958Co61, 1958Ev81, 1957Ew38, 1955Ha33, 1953Gr07, 1952Sm49, 1952Ru10, 1952Mi18, 1952Ko27.

Following γ rays reported by 1997Sa53, in singles γ-data only, are omitted: 6.8 keV from 641 level; 117.98 keV *5* (Iγ=0.12 *1*) and 159.7 keV *2* (Iγ=0.040 *3*), since both the γ rays are not observed in (p,2ng) in-beam γ-ray study, where the 649-keV level is strongly populated, also these γ rays are not seen in ^{208}Pb(^{136}Xe,X),E=85 MeV, multi-nucleon transfer reaction, where 649 level in ^{147}Pm is populated (2015Ba20, and priv. comm. from A.A. Sonzogni with reference to scanning of the γ spectra); 31.3 keV *2* (Iγ=0.34 *4*) from 680 level, and 36.75 keV *10* (Iγ=1.13 *10*) from 686 level, as both the γ rays imply unrealistically large transition intensities, thus creating severe intensity imbalances. 1958Co61 identified 31.4 and 36.9 lines as Auger α_1-L and α_1-M lines. In addition, 240.5 keV *2* (Iγ=0.32 *2*) and 649.04 keV *8* (Iγ=0.039 *3*), both from 649-keV level with Jπ=11/2$^-$ are omitted, as 240.5γ should have been detected by 1979Se05. With the omission of 240.5γ, existence of 649.04γ is also questionable, thus omitting the population of 649, 11/2$^-$ level in this decay.

Following γ rays, reported using Ge(Li) detector data are also omitted, as these are not confirmed in more recent studies: Eγ=77 , Iγ=5 (1967Ja05), this γ also reported by 1967Ar04 and 1963Ph02; Eγ=182, Iγ=0.1 (1967Ar04); Eγ=542 *5*, Iγ=0.2 (1966Ar16); Eγ=610 *5*, Iγ=0.2 (1966Ar16); Eγ=621 *5*, Iγ=0.1 (1966Ar16).

Measured Pm x-ray intensities (1995Go44), relative to 100 for 531γ: 144 *7* for K$_{\alpha 2}$, 253 *9* for K$_{\alpha 1}$, 49.5 *16* for K$_{\beta 1}$, and 12.9 *4* for K$_{\beta 2}$.

E$_\gamma$	I$_\gamma$[†][§]	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$	Mult.[‡]	α[&]	Comments
53.1 *2*	0.0057 *33*	685.901	5/2$^+$	632.94	1/2$^+$	[E2]	25.1 *6*	%Iγ=0.0007 *4* α(K)=4.40 *7*; α(L)=16.1 *4*; α(M)=3.73 *9* α(N)=0.808 *19*; α(O)=0.1003 *23*; α(P)=0.000221 *4* E$_\gamma$,I$_\gamma$: from 1979Se05 only, from $\gamma\gamma$-coin and singles spectra.
81.13 *8*	0.0055 *14*	489.245	7/2$^+$	408.17	9/2$^+$	[M1+E2]	3.8 *11*	%Iγ=0.00072 *18* α(K)=2.24 *16*; α(L)=1.25 *91*; α(M)=0.28 *22* α(N)=0.062 *46*; α(O)=0.0080 *56*; α(P)=1.21×10^{-4} *34* E$_\gamma$: weighted average: 81.15 *7* (1979Se05), 80.82 *27* (1997Sa53). I$_\gamma$: unweighted average of 0.0068 *9* (1997Sa53), 0.0041 *25* (1979Se05).

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
91.1050 *16*	217 *6*	91.1052	$5/2^+$	0.0	$7/2^+$	M1+E2	+0.089 *5*	2.03	%Iγ=28.2 *8* α(K)exp=1.73 *6*; α(L)exp=0.248 *9* (1997Sa53) L1/L3=26 *3*; L1/L2=9.6 *3*; K/L=6.8 *2* (1965Ew03) α(K)=1.714 *24*; α(L)=0.249 *4*; α(M)=0.0534 *8* α(N)=0.01202 *18*; α(O)=0.00180 *3*; α(P)=0.0001100 *16* GABS code gives %Iγ=28.21 *26*. Evaluator considers 0.9% uncertainty too low to be realistic, and has assigned an uncertainty of 2.8%, same as in relative Iγ. E_γ: from 1967Hi04, crystal diffraction spectrometer. Other precise Eγ=91.05 *4* (1960Wa11, crystal), 91.06 *5* (1961Ew02), 91.106 *20* (1974HeYW), 91.06 *3* (1979Se05), 91.109 *4* (1979Vo09), 91.004 *2* (1997Sa53, uncertainty seems underestimated). Other less precise Eγ using Ge(Li): 1957Ew38 (crystal), 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: weighted average of 210 *4* (1997Sa53, uncertainty of 2% is underestimated as the efficiency curve in this energy region is not well established, and this peak is situated on a high Compton continuum); 218 *2* (1995Go44, uncertainty of 1% is underestimated for the same reason as explained for 1997Sa53); 230 *25* (1979Se05); 239 *5* (1979Vo09); 213 (1974HeYW); 220 *14* (1974Ra30); 187 (1971Si20); 227 *35* (1967Hi04); 248 *13* (1967Do07); 211 *42* (1967Ca18); 213 *14* (1967Ba21); 300 *100* (1967Ja05); 275 *50* (1966Ar16). Minimum uncertainty of 5% is assumed by evaluator in the averaging procedure, as the efficiency response curve for the Ge detectors is not known well in this energy region. Other: 390 *20* (1967Ki08, is discrepant, not used in averaging). Ice(K)=27315 *518*, Ice(L)=3916 *101* (1997Sa53). 91$\gamma(\theta$,H,T): $B_2U_2A_2$=+0.023 *2*, $B_4U_4A_4$=+0.004 *2* (1977Al34). 91$\gamma(\theta$,H,T): $G_2U_2F_2$=+0.202 *14* (1969Ba32). (L1+L2):L3:M:N=330 *55*:10:78 *14*:20 *4* (1967Ba21). Probability for emission of two K-electrons in internal conversion of 91-keV γ (relative to one K-electron emission): 1.86×10^{-3} *9* (2003Vi13). δ: from $\gamma(\theta$,H,T) (1969Ba32, earlier value from this experimental group was +0.13 *2* reported in 1961We07). Others: 0.092 *5* (1965Ew03, L1/L3, L1/L2 and K/L; previous value was 0.089 *11* in 1961Ew02); +0.10 *9* (1957Bi86, $\gamma(\theta$,H,T)); 0.082 *10* (1967Ba21, ce data). Evaluator prefers to adopt value from $\gamma(\theta$,H,T) method, as the values deduced from internal conversion data may be dependent on penetration parameters. 1977Kr13 evaluation gives +0.099 *10*, based on data taken from 1969Ba32, 1961We07, 1961Ew02 and 1957Bi86. α(K)exp=1.63 *4*, with penetration parameter=3.2 *9* (2003Zh47); α(K)exp=1.737 from Ice(K)=173.7 (1961Ew02).

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
120.479 *9*	2.89 *12*	530.996	5/2$^+$	410.516	3/2$^+$	M1+E2	+0.048 *21*	0.911	%Iγ=0.376 *18* α(K)exp=0.79 *3*; α(L)exp=0.113 *5* (1997Sa53); α(K)exp=0.73 *10* (1967Ba21) α(L)exp=0.113 *5* (1997Sa53) α(K)=0.773 *11*; α(L)=0.1089 *17*; α(M)=0.0233 *4* α(N)=0.00524 *8*; α(O)=0.000790 *12*; α(P)=4.96×10^{-5} *7* E_γ: weighted average: 120.47 *5* (1961Ew02), 120.490 *9* (1967Hi04, crystal), 120.48 *5* (1974HeYW), 120.46 *2* (1979Se05), 120.453 *15* (1979Vo09), 120.488 *20* (1997Sa53, authors′ uncertainty of 0.005 increased by evaluator). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 2.81 *4* (1997Sa53); 3.57 *11* (1995Go44); 2.71 *25* (1979Se05); 3.05 *10* (1979Vo09); 3.03 *32* (1974HeYW); 3.3 *5* (1974Ra30); 2.65 *34* (1971Si20); 3.3 *5* (1967Hi04); 2.1 *2* (1967Do07); 2.5 *5* (1967Ca18); 3.0 *2* (1967Ba21); 2.6 *4* (1966Ar16). Others: 8 *1* (1967Ja05), 4.72 *24* (1967Ki08); both seem discrepant, these two values were not used in averaging. 120$\gamma(\theta$,H,T): $B_2U_2A_2$=+0.070 *25*, $B_4U_4A_4$=−0.017 *26* (1977Al34). (120γ)[319γ](91γ)(θ): A_2=+0.004 *22*, A_4=+0.020 *52* (1977Al34). (120γ)(410γ)(θ): A_2=−0.009 *78*, A_4=+0.05 *12* (1977Al34). (120γ)(319γ)(θ): A_2=−0.020 *12*, A_4=+0.001 *21* (1977Al34). (121γ)(319γ)(θ): A_2=−0.041 *8*, A_4=+0.006 *10* (1970Bl12, Ge(Li)-NaI(Tl) detectors). Ice(K)=166 *5*, Ice(L)=24 *1* (1997Sa53). Ice(K)=1.04 *10* (1967Ba21). δ: weighted average of 0.050 *21* from $\gamma\gamma(\theta)$ and +0.037 *56* from $\gamma(\theta$,H,T) (1977Al34). This value is consistent with ce data. Others: +0.04 *3* (1977Kr13 evaluation, based on $\gamma\gamma(\theta)$ data of 1970Bl12, 1966Go25, 1961Sa13 and 1960Bo17); ≈0.14 (1961Ew02, L-subshell ratios).
149.35 *20*	0.029 *3*	680.435	7/2$^+$	530.996	5/2$^+$	[M1+E2]		0.52 *3*	%Iγ=0.0038 *4* α(K)=0.39 *3*; α(L)=0.101 *42*; α(M)=0.0224 *99* α(N)=0.0050 *22*; α(O)=6.8×10^{-4} *25*; α(P)=2.2×10^{-5} *5* E_γ: average: 149.4 *2* (1979Se05), 149.3 *2* (1997Sa53). I_γ: from 1997Sa53. Other: 0.024 *12* (1979Se05).
154.91 *5*	0.043 *7*	685.901	5/2$^+$	530.996	5/2$^+$	[M1+E2]		0.466 *18*	%Iγ=0.0056 *9* α(K)=0.35 *3*; α(L)=0.088 *35*; α(M)=0.0195 *82* α(N)=0.0043 *18*; α(O)=5.9×10^{-4} *21*; α(P)=2.0×10^{-5} *5*

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
191.22 *9*	0.028 *3*	680.435	$7/2^+$	489.245	$7/2^+$	[M1+E2]		0.243 *9*	E_γ: weighted average: 154.92 *5* (1979Se05), 154.7 *2* (1997Sa53). Other: 154 *1* (1967Ja05). I_γ: unweighted average of 0.031 *3* (1997Sa53), 0.0545 *22* (1995Go44), 0.043 *7* (1979Se05). Other: <0.5 (1967Ja05). %Iγ=0.0036 *4* α(K)=0.191 *22*; α(L)=0.040 *11*; α(M)=0.0089 *26* α(N)=0.00197 *55*; α(O)=0.00028 *7*; α(P)=1.1×10^{-5} *3*
196.64 *3*	1.35 *5*	685.901	$5/2^+$	489.245	$7/2^+$	M1+E2	−0.22 *10*	0.231	E_γ: weighted average: 191.24 *9* (1979Se05), 191.0 *3* (1997Sa53). I_γ: from 1997Sa53. Other: 0.025 *13* (1979Se05). %Iγ=0.175 *8* α(K)exp=0.194 *9* (1997Sa53); α(K)exp=0.19 *2* (1967Ba21) α(K)=0.195 *4*; α(L)=0.0282 *10*; α(M)=0.00605 *23* α(N)=0.00136 *5*; α(O)=0.000204 *6*; α(P)=1.24×10^{-5} *3* E_γ: weighted average: 196.64 *7* (1961Ew02), 196.66 *3* (1967Hi04, crystal), 196.64 *4* (1974HeYW), 196.64 *3* (1979Se05), 196.616 *30* (1979Vo09). Eγ=196.448 *5* (1997Sa53, uncertainty seems underestimated, and discrepant in energy). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 1.42 *1* (1997Sa53); 1.329 *22* (1995Go44); 1.28 *10* (1979Se05); 1.38 *6* (1979Vo09); 1.56 *13* (1974HeYW); 1.4 *4* (1974Ra30); 1.36 *22* (1971Si20); 1.0 *1* (1967Do07); 1.30 *13* (1967Ca18); 1.53 *15* (1967Ba21); 1.3 *2* (1966Ar16). Others: 1.92 *16* (1967Ki08, seems discrepant), 2 *1* (1967Ja05), 1.5 *6* (1967Hi04). 196$\gamma(\theta$,H,T): $B_2U_2A_2$=−0.005 *45*, $B_4U_4A_4$=+0.033 *51* (1977Al34). (197γ)[398γ](91γ)(θ): A_2=−0.034 *34*, A_4=+0.026 *51* (1977Al34). Ice(K)=20.7 *8*, Ice(L)=2.6 *2* (1997Sa53). Ice(K)=0.138 *14* (1967Ba21). δ: from weighted average of −0.27 *10* form $\gamma\gamma(\theta)$ and −0.11 *15* from $\gamma(\theta$,H,T) (1977Al34). 1977Kr13 evaluation gives +0.50 *2* from 1974Bh02, 1961Sa13 and 1960Bo17; all from $\gamma\gamma(\theta)$ using NaI(Tl) detectors.
272.09 *22*	0.099 *7*	680.435	$7/2^+$	408.17	$9/2^+$	M1+E2	+0.10 *3*	0.0962	%Iγ=0.0129 *10* α(K)exp=0.091 *11* (1997Sa53) α(K)=0.0818 *12*; α(L)=0.01131 *16*; α(M)=0.00241 *4* α(N)=0.000544 *8*; α(O)=8.21×10^{-5} *12*; α(P)=5.21×10^{-6} *8* E_γ: unweighted average: 272.30 *4* (1979Se05), 271.87 *6* (1997Sa53). I_γ: from 1997Sa53). Other: 0.098 *25* (1979Se05). (272γ)(410γ)(θ): A_2=−0.283 *10*, A_4=+0.015 *18* (1979Se05, Ge(Li)-NaI(Tl) detectors).

^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34 (continued)

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
275.389 *13*	6.25 *18*	685.901	$5/2^+$	410.516	$3/2^+$	M1+E2	+0.109 *7*	0.0931	Ice(K)=0.68 *6* (1997Sa53). Mult.: from α(K)exp. δ: from $\gamma\gamma(\theta)$ (1979Se05). %Iγ=0.812 *31* α(N)=0.000526 *8*; α(O)=7.95×10^{-5} *12*; α(P)=5.04×10^{-6} *7* α(K)exp=0.081 *3*; α(L)exp=0.0109 *6* (1997Sa53) α(K)exp=0.080 *6*; α(L)exp=0.0077 *20* (1979Vo09); α(K)exp=0.10 *2* (1967Ba21) α(K)=0.0792 *11*; α(L)=0.01095 *16*; α(M)=0.00233 *4* E_γ: weighted average: 275.36 *8* (1961Ew02), 275.42 *2* (1967Hi04, crystal), 275.374 *15* (1974HeYW), 275.36 *2* (1979Se05), 275.419 *22* (1979Vo09, authors′ uncertainty of 0.011 increased by evaluator). Eγ=275.209 *5* (1997Sa53, uncertainty seems underestimated, and is discrepant in energy). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 6 *1* (1999Po32); 6.81 *6* (1997Sa53); 5.93 *7* (1995Go44); 5.5 *4* (1979Se05); 6.05 *10* (1979Vo09); 6.1 *4* (1974HeYW); 6.7 *7* (1974Ra30); 5.7 *4* (1971Si20); 6.8 *14* (1967Hi04); 6.1 *5* (1967Do07); 6.5 *7* (1967Ca18); 6.4 *4* (1967Ba21); 6.6 *7* (1966Ar16). Others: 7.9 *4* (1967Ki08, seems discrepant), *7 2* (1967Ja05). 275$\gamma(\theta$,H,T): $B_2U_2A_2$=+0.025 *12*, $B_4U_4A_4$=0.000 *13* (1977Al34). 91$\gamma(\theta$,H,T): $G_2U_2F_2$=+0.13 *6* (1969Ba32). (275γ)(320$\gamma)(\theta$): A_2=+0.006 *2*, A_4=+0.005 *5* (1979Se05, NaI(Tl) detectors). (275γ)(411$\gamma)(\theta$): A_2=−0.013 *17*, A_4=−0.008 *30* (1979Se05, Ge(Li)-NaI(Tl) detectors). (276γ)(319$\gamma)(\theta$): A_2=+0.008 *11*, A_4=+0.005 *19* (1977Al34). (276γ)(410$\gamma)(\theta$): A_2=−0.048 *78*, A_4=+0.10 *12* (1977Al34). (276γ)[319γ](91$\gamma)(\theta$): A_2=−0.030 *12*, A_4=+0.049 *26* (1977Al34). (276γ)(319$\gamma)(\theta$): A_2=+0.019 *10*, A_4=+0.011 *11* (1976Si08, NaI(Tl) detectors). (276γ)(319$\gamma)(\theta$): A_2=+0.079 *22*, A_4=−0.038 *29* (1970Bl12, Ge(Li)-NaI(Tl) detectors). Ice(K)=41.5 *15*, Ice(L)=5.6 *3* (1997Sa53). Ice(K)=37.5 *25*, Ice(L)=3.6 *9* (1979Vo09). Ice(K)=0.28 *6* (1967Ba21). δ: weighted average of +0.107 *7* (1979Se05, $\gamma\gamma(\theta)$); +0.14 *5* from $\gamma\gamma(\theta)$ and +0.14 *3* from $\gamma(\theta$,H,T) (1977Al34); +0.10 *4* (1969Ba32, $\gamma(\theta$,H,T), value as given in 1977Kr13, earlier value was 0.14 *2* in 1961We07). 1977Kr13 evaluation gives +0.14 *1* based on $\gamma\gamma(\theta)$ and $\gamma(\theta$,H,T) data in 1976Si08, 1974Bh02, 1970Bl12, 1969Ba32, 1966Go25, 1963Sp07, 1961We07, 1961Ar09 and 1960Bo17.

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
319.412 *12*	15.2 *3*	410.516	$3/2^+$	91.1052	$5/2^+$	M1+E2	−0.38 *2*	0.0607	%Iγ=1.98 *6* α(K)exp=0.052 *2*; α(L)exp=0.0079 *4* (1997Sa53) α(K)exp=0.045 *2*; α(L)exp=0.0065 *7* (1979Vo09); α(K)exp=0.052 (1961Ew02) α(K)=0.0514 *8*; α(L)=0.00734 *11*; α(M)=0.001572 *22* α(N)=0.000354 *5*; α(O)=5.30×10^{-5} *8*; α(P)=3.23×10^{-6} *5* E_γ: unweighted average: 319.39 *8* (1961Ew02), 319.41 *3* (1967Hi04, crystal), 319.411 *18* (1974HeYW), 319.39 *2* (1979Se05), 319.413 *12* (1979Vo09). Other: 319.542 *3* (1997Sa53, uncertainty seems underestimated; also a discrepant value). Others less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 15 *2* (1999Po32), 15.91 *11* (1997Sa53, uncertainty seems underestimated); 14.8 *2* (1995Go44); 13.8 *11* (1979Se05); 15.0 *3* (1979Vo09); 14.9 *9* (1974HeYW); 16.5 *10* (1974Ra30); 14.2 *13* (1971Si20); 17.0 *9* (1967Ki08), 16.3 *24* (1967Hi04); 15 *5* (1967Ja05); 15.8 *10* (1967Do07); 14.2 *14* (1967Ca18); 14.5 *11* (1967Ba21); 15.0 *15* (1966Ar16). 319$\gamma(\theta$,H,T): $B_2U_2A_2$=−0.062 *5*, $B_4U_4A_4$=+0.003 *6* (1977Al34). (319γ)(91γ)(θ): A_2=−0.092 *10*, A_4=+0.009 *14* (1977Al34). 319$\gamma(\theta$,H,T): $G_2U_2F_2$=−0.12 *2* (1969Ba32). (319γ)(91γ)(θ): A_2=−0.080 *6*, A_4=+0.0013 *60* (1979Vo09). (319γ)(91γ)(θ): A_2=−0.088 *8*, G_4A_4=−0.016 *14* (1976Si08, NaI(Tl) detectors). (319γ)(91γ)(θ): A_2=−0.085 *11*, A_4=−0.14 *15* (1970Bl12, Ge(Li)-NaI(Tl) detectors). Ice(K)=62.2 *18*, Ice(L)=9.5 *4* (1997Sa53). Ice(K)=53.0 *15*, Ice(L)=7.5 *8* (1979Vo09). δ: weighted average of −0.391 *16* (1979Se05, $\gamma\gamma(\theta)$); −0.41 *3* (1977Al34, $\gamma\gamma(\theta)$, authors′ other value is −0.32 to −1.7 from $\gamma(\theta$,H,T)); and the following values evaluated by 1977Kr13: −0.38 *2* (1976Si08, $\gamma\gamma(\theta)$); −0.37 *3* (1970Bl12, $\gamma\gamma(\theta)$); −0.31 *9* (1969Ba32, $\gamma(\theta$,H,T), authors′ value was +0.55 *5*); −0.34 *2* (1966Go25); −0.39 *4* (1963Sp07); −0.36 *2* (1961We07); −0.42 *8* (1961Ar09); −0.38 *2* (1960Bo17); −0.40 *2* (1957Li40). Others: -0.27 *1* (1960Ma03), ≈0.5 (1961Ew02, L-subshell ratios). 1977Kr13 evaluation gives −0.37 *1*.
398.124 *17*	6.63 *15*	489.245	$7/2^+$	91.1052	$5/2^+$	M1+E2	+0.30 *1*	0.0345 *5*	%Iγ=0.862 *29* α(K)=0.0293 *5*; α(L)=0.00406 *6*; α(M)=0.000866 *13* α(N)=0.000195 *3*; α(O)=2.94×10^{-5} *5*; α(P)=1.85×10^{-6} *3* α(K)exp=0.030 *4* (1997Sa53); α(K)exp=0.033 *3* (1979Vo09); α(K)exp=0.030 *4* (1967Ba21)

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
									α(N)=0.000195 *3*; α(O)=2.94×10^{-5} *5*; α(P)=1.85×10^{-6} *4* E_γ: weighted average: 398.22 *7* (1967Hi04, crystal), 398.155 *20* (1974HeYW), 398.13 *3* (1979Se05), 398.098 *16* (1979Vo09). Eγ=398.336 *2* (1997Sa53, uncertainty seems underestimated, and is discrepant in energy). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 6.82 *6* (1997Sa53); 6.64 *7* (1995Go44); 6.5 *5* (1979Se05); 6.59 *10* (1979Vo09); 6.7 *4* (1974HeYW); 6.5 *7* (1974Ra30); 6.3 *5* (1971Si20); 6.6 *3* (1967Ki08); 6.8 *11* (1967Hi04); 6.7 *5* (1967Do07); 6.4 *6* (1967Ca18); 6.6 *6* (1967Ba21); 7.0 *7* (1966Ar16). Other: 5 *2* (1967Ja05). 398$\gamma(\theta$,H,T): $B_2U_2A_2$=−0.052 *9*, $B_4U_4A_4$=+0.009 *10* (1977Al34). 397$\gamma(\theta$,H,T): $G_2U_2F_2$<0 (1969Ba32). (398γ)(91γ)(θ): A_2=−0.063 *10*, A_4=−0.015 *15* (1979Vo09). (398γ)(91γ)(θ): A_2=−0.092 *10*, A_4=+0.009 *14* (1977Al34). (398γ)(91γ)(θ): A_2=−0.074 *19*, A_4=−0.19 *23* (1970Bl12, Ge(Li)-NaI(Tl) detectors). Ice(K)=15.0 *5* (1997Sa53), 16.6 *10* (1979Vo09), 0.092 *9* (1967Ba21). δ: from Adopted Gammas, based on data in (p,2nγ). Value from β^- is +0.30 *4* from weighted average of +0.31 *5* from $\gamma\gamma(\theta)$ and +0.29 *4* from $\gamma(\theta$,H,T) (1977Al34). Others: +0.18 *6* (1974Bh02), +0.14 *6* (1970Bl12), +0.50 *7* (1966Go25), +0.31 *3* (1960Bo17), as evaluated by 1977Kr13 from respective $\gamma\gamma(\theta)$ data, and based on these data, 1977Kr13 give +0.24 *5*. The α(K)exp values are consistent with δ(E2/M1)=0.30 *4*.
408.34 *18*	0.128 *13*	408.17	9/2$^+$	0.0	7/2$^+$	M1+E2	+0.57 *3*	0.0304	%Iγ=0.0166 *17* α(K)=0.0257 *5*; α(L)=0.00369 *6*; α(M)=0.000790 *12* α(N)=0.000178 *3*; α(O)=2.65×10^{-5} *4*; α(P)=1.60×10^{-6} *3* E_γ: unweighted average: 408.16 *5* (1979Se05), 408.52 *6* (1997Sa53). I_γ: unweighted average of 0.14 *1* (1997Sa53), 0.115 *16* (1979Se05). Mult.,δ: from the Adopted Gammas.
410.53 *3*	1.10 *7*	410.516	3/2$^+$	0.0	7/2$^+$	E2		0.0212	%Iγ=0.143 *10* α(K)=0.01724 *25*; α(L)=0.00313 *5*; α(M)=0.000683 *10* α(K)exp=0.0171 *11* (1997Sa53); α(K)exp=0.027 *6* (1979Vo09); α(K)exp≈0.023 (1967Ba21) α(N)=0.0001520 *22*; α(O)=2.17×10^{-5} *3*; α(P)=9.80×10^{-7} *14* Eγ=410.48 *3* (1974HeYW), 410.51 *3* (1979Se05), 410.59 *7* (1979Vo09), 410.58 *3* (1997Sa53). Other less precise Eγ using Ge(Li): 1967Hi04, 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1971Si20, 1974Ra30. I_γ: unweighted average of 1.12 *1* (1997Sa53); 0.78 *4* (1995Go44); 0.79 *6* (1979Se05); 0.93 *5* (1979Vo09); 1.07 *6* (1974HeYW); 1.2 *3* (1974Ra30); 1.03 *28* (1971Si20); 1.2 *5* (1967Hi04); 1.0 *6* (1967Ja05); 0.9 *2*

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
439.872 *17*	9.28 *17*	530.996	$5/2^+$	91.1052	$5/2^+$	M1+E2	+0.62 *5*	0.0247 *5*	(1967Do07); 1.30 *13* (1967Ca18); 1.7 *2* (1967Ba21); 1.3 *1* (1966Ar16). Mult.: 410$\gamma(\theta$,H,T): $B_2U_2A_2$=−0.001 *58*, $B_4U_4A_4$=−0.068 *62*, consistent with pure E2 (1977Al34). The α(K)exp from 1997Sa53 is consistent with E2, but that from 1979Vo09 gives δ(E2/M1)<1.3. Ice(K)=1.44 *9* (1997Sa53), 2.0 *5* (1979Vo09). %Iγ=1.21 *4* α(K)exp=0.0212 *9*; α(L)exp=0.0028 *2* (1997Sa53); α(K)exp=0.016 *1* (1979Vo09) α(K)exp=0.022 (1961Ew02) α(K)=0.0209 *5*; α(L)=0.00299 *5*; α(M)=0.000640 *10* α(N)=0.0001440 *23*; α(O)=2.15×10^{-5} *4*; α(P)=1.30×10^{-6} *3* E_γ: weighted average: 439.82 *10* (1961Ew02), 439.85 *8* (1967Hi04, crystal), 439.895 *22* (1974HeYW), 439.92 *5* (1979Se05), 439.856 *17* (1979Vo09). Eγ=440.062 *2* (1997Sa53, uncertainty seems underestimated, and discrepant in energy). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 9.54 *7* (1997Sa53); 9.15 *17* (1995Go44); 9.1 *7* (1979Se05); 9.19 *14* (1979Vo09); 9.2 *6* (1974HeYW); 9.8 *2* (1974Ra30); 9.5 *6* (1971Si20); 9.3 *3* (1967Ki08); 9.3 *11* (1967Hi04); 9.7 *6* (1967Do07); 9.2 *9* (1967Ca18); 8.9 *6* (1967Ba21); 8.8 *9* (1966Ar16). Other: 8 *2* (1967Ja05). 440$\gamma(\theta$,H,T): $B_2U_2A_2$=−0.159 *10*, $B_4U_4A_4$=−0.001 *10* (1977Al34). 440$\gamma(\theta$,H,T): $G_2U_2F_2$=−0.485 *80* (1969Ba32). (440γ)(91γ)(θ): A_2=+0.073 *11*, A_4=−0.002 *15* (1977Al34). (440γ)(91γ)(θ): A_2=−0.067 *7*, A_4=+0.010 *8* (1979Vo09). (440γ)(91γ)(θ): A_2=+0.048 *9*, G_4A_4=+0.009 *6* (1976Si08, NaI(Tl) detectors). (440γ)(91γ)(θ): A_2=+0.054 *18*, A_4=+0.16 *24* (1970Bl12, Ge(Li)-NaI(Tl) detectors). Ice(K)=15.2 *5*, Ice(L)=2.0 *1* (1997Sa53). Ice(K)=10.9 *6* (1979Vo09). δ: weighted average of +0.77 *10* (1977Al34, $\gamma\gamma(\theta)$); and the following values evaluated by 1977Kr13: +0.59 *5* (1976Si08, $\gamma\gamma(\theta)$); +0.62 *7* (1974Bh02); +0.62 *+10−8* (1970Bl12, $\gamma\gamma(\theta)$); +0.70 *9* (1969Ba32, $\gamma(\theta$,H,T), previous value was +0.82 *65* in 1961We07); +0.62 *6* (1968Ra28); +0.56 *6* (1966Go25); +0.59 *7* (1963Sp07); +0.69 *+13−10* (1961Sa13); +0.63 *5* (1960Bo17). 1977Kr13 evaluation gives +0.62 *2*.

$^{147}_{61}Pm_{86}$-13

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
489.27 *3*	1.14 *9*	489.245	$7/2^+$	0.0	$7/2^+$	M1+E2	−0.79 *+23−45*	0.0179 *18*	%Iγ=0.148 *12* α(K)exp=0.018 *1* (1997Sa53); α(K)exp=0.023 *6* (1979Vo09) α(K)=0.0151 *16*; α(L)=0.00218 *14*; α(M)=0.00047 *3* α(N)=0.000105 *7*; α(O)=1.57×10^{-5} *12*; α(P)=9.4×10^{-7} *12* E_γ: weighted average: 489.240 *28* (1974HeYW), 489.30 *8* (1979Se05), 489.25 *3* (1979Vo09), 489.35 *4* (1997Sa53, authors′ uncertainty of 0.01 increased by evaluator). Other less precise Eγ using Ge(Li): 1967Hi04, 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 1.16 *1* (1997Sa53); 1.07 *24* (1995Go44); 1.07 *8* (1979Se05); 1.12 *6* (1979Vo09); 1.17 *6* (1974HeYW); 1.4 *4* (1974Ra30); 1.12 *19* (1971Si20); 0.8 *3* (1967Ki08); 1.1 *5* (1967Hi04); 1.0 *5* (1967Ja05); 1.2 *3* (1967Do07); 1.5 *8* (1967Ca18); 1.5 *2* (1967Ba21); 0.70 *8* (1966Ar16). 489$\gamma(\theta$,H,T): $B_2U_2A_2$=+0.048 *34*, $B_4U_4A_4$=−0.026 *37* (1977Al34). Ice(K)=1.57 *9* (1997Sa53), 2.0 *5* (1979Vo09). δ: from $\gamma(\theta$,H,T) (1977Al34). Other values of δ=>+4 and <−6 from $\gamma(\theta$,H,T) (1977Al34) are inconsistent with conversion data, which suggest dominant M1. δ=+1.2 *+28−8* from 1977Kr13 evaluation, based on $\gamma\gamma(\theta)$ data of 1961Sa13 is not in good agreement with either the value $\gamma(\theta$,H,T) or from ce data.
531.015 *18*	100.0 *10*	530.996	$5/2^+$	0.0	$7/2^+$	M1+E2	−0.40 *3*	0.0162 *3*	%Iγ=13.00 *34* α(K)exp=0.0133 *3* (1997Sa53); α(K)exp=0.0133 *12* (1967Ba21) α(L)exp=0.00204 *9* (1997Sa53); α(L)exp=0.0017 *2* (1979Vo09) α(K)=0.01376 *22*; α(L)=0.00189 *3*; α(M)=0.000402 *6* α(N)=9.06×10^{-5} *14*; α(O)=1.366×10^{-5} *21*; α(P)=8.62×10^{-7} *15* E_γ: weighted average: 530.95 *10* (1961Ew02), 531.01 *7* (1967Hi04, crystal), 531.016 *22* (1974HeYW), 531.05 *4* (1979Se05), 530.979 *18* (1979Vo09), 531.069 *24* (1997Sa53, authors′ uncertainty of 0.006 increased by evaluator). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: normalizing γ ray, 1% uncertainty assigned by evaluator. Iγ=100 (1999Po32), 100.0 *8* (1997Sa53); 100.0 *20* (1995Go44); 100 *7* (1979Se05); 100.0 *20* (1979Vo09); 100 *6* (1974HeYW); 100 (1974Ra30); 100.0 *28* (1971Si20); 100 (1967Ki08); 100 (1967Hi04); 100 (1967Ja05); 100 (1967Do07); 100 (1967Ca18); 100 *6* (1967Ba21); 100 (1966Ar16). 531$\gamma(\theta$,H,T): $B_2U_2A_2$=−0.074 *2*, $B_4U_4A_4$=−0.002 *2* (1977Al34).

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
									531$\gamma(\theta$,H,T): $G_2U_2F_2$=−0.300 *12* (1969Ba32). Ice(K)=100 *2*, Ice(L)=15.3 *5* (1997Sa53). Ice(K)=100 *5*, Ice(L)=13.1 *7* (1979Vo09). Ice(K)=0.63 *4* (1967Ba21). δ: from $\gamma(\theta$,H,T) (1977Al34). 1977Kr13 evaluation gives −0.54 *12* based on $\gamma(\theta$,H,T) data in 1969Ba32, 1961We07 and 1957Bi86.
541.84 *5*	0.146 *30*	632.94	1/2$^+$	91.1052	5/2$^+$	[E2]		0.00994	%Iγ=0.019 *4* α(N)=6.47×10^{-5} *9*; α(O)=9.39×10^{-6} *14*; α(P)=4.82×10^{-7} *7* α(K)=0.00824 *12*; α(L)=0.001338 *19*; α(M)=0.000290 *4* Eγ: weighted average: 541.85 *5* (1979Se05), 541.83 *7* (1997Sa53). Iγ: unweighted average of 0.14 *2* (1997Sa53); 0.098 *16* (1979Se05); 0.20 *5* (1966Ar16).
589.35 *3*	0.32 *2*	680.435	7/2$^+$	91.1052	5/2$^+$	(M1+E2)		0.011 *3*	%Iγ=0.0416 *28* α(K)=0.0090 *23*; α(L)=0.00128 *23*; α(M)=0.00027 *5* α(N)=6.2×10^{-5} *11*; α(O)=9.2×10^{-6} *18*; α(P)=5.5×10^{-7} *16* α(K)exp=0.013 *3* (1979Vo09) Eγ: weighted average: Eγ=589.35 *4* (1974HeYW), 589.35 *6* (1979Se05), 589.52 *13* (1979Vo09), 589.33 *4* (1997Sa53, authors′ uncertainty of 0.02 increased by evaluator). Other less precise Eγ using Ge(Li): 1967Hi04, 1967Do07, 1967Ba21, 1971Si20, 1974Ra30. Iγ: unweighted average of Iγ=0.29 *2* (1997Sa53); 0.344 *4* (1995Go44 uncertainty seems underestimated); 0.287 *25* (1979Se05); 0.30 *3* (1979Vo09); 0.350 *34* (1974HeYW); 0.29 *8* (1974Ra30); 0.37 *4* (1971Si20); 0.31 *14* (1967Hi04); 0.26 *6* (1967Do07); 0.28 *4* (1967Ba21); 0.40 *6* (1966Ar16). Ice(K)=0.29 *8* (1979Vo09).
594.792 *21*	1.98 *6*	685.901	5/2$^+$	91.1052	5/2$^+$	E2(+M1)	≥6	0.00790 *13*	%Iγ=0.257 *10* α(K)exp=0.0071 *5* (1997Sa53); α(K)exp=0.0049 *6* (1979Vo09) α(K)exp=0.0066 *40* (1967Ba21) α(K)=0.00658 *11*; α(L)=0.001033 *16*; α(M)=0.000223 *4* α(N)=4.98×10^{-5} *8*; α(O)=7.29×10^{-6} *12*; α(P)=3.88×10^{-7} *7* Eγ: weighted average: 594.74 *10* (1961Ew02), 594.80 *3* (1974HeYW), 594.84 *6* (1979Se05), 594.793 *24* (1979Vo09), 594.783 *21* (1997Sa53, authors′ uncertainty of 0.003 increased by evaluator). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Hi04, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. Iγ: unweighted average of 2.0 *3* (1999Po32); 2.12 *2* (1997Sa53); 1.852 *22* (1995Go44); 1.89 *16* (1979Se05); 1.92 *6* (1979Vo09); 2.03 *13* (1974HeYW); 2.0 *3* (1974Ra30); 2.06 *19* (1971Si20); 2.08 *24* (1967Ki08); 1.9 *4* (1967Hi04); 1.6 *2* (1967Do07); 2.2 *2* (1967Ca18); 1.9 *2* (1967Ba21); 2.2 *2* (1966Ar16). Other: 2 *1*

$\gamma(^{147}Pm)$ (continued)

E_γ	I_γ[†][§]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[‡]	δ	α[&]	Comments
									(1967Ja05). 595$\gamma(\theta$,H,T): $B_2U_2A_2$=+0.047 *36*, $B_4U_4A_4$=+0.001 *37* (1977Al34). (595γ)(91γ)(θ): A_2=+0.043 *38*, A_4=−0.044 *54* (1977Al34). Ice(K)=1.13 *7* (1997Sa53), 0.78 *8* (1979Vo09), ≈0.0063 (1967Ba21). β(595γ) coin from 1960We06. δ: $\delta\geq6$ from $\gamma\gamma(\theta)$ and ≥7 from $\gamma(\theta$,H,T) (1977Al34). This value is consistent with ce data which give dominant E2 1977Kr13 evaluation gives δ=+0.55 *5* from 1974Bh02, 1968Ra28, 1963Sp07 and 1961Sa13; all from $\gamma\gamma(\theta)$ data using NaI(Tl) detectors. But this value is inconsistent with $\gamma\gamma(\theta)$ and $\gamma(\theta$,H,T) data from 1977Al34, as well as with ce data from 1997Sa53 and 1979Vo09.
680.38 *5*	0.18 *3*	680.435	7/2$^+$	0.0	7/2$^+$	[M1+E2]		0.0074 *18*	%Iγ=0.023 *4* α(K)=0.0063 *16*; α(L)=0.00088 *17*; α(M)=0.00019 *4* α(N)=4.2×10^{-5} *8*; α(O)=6.4×10^{-6} *13*; α(P)=3.9×10^{-7} *11* E_γ: weighted average: 680.52 *15* (1974HeYW), 680.39 *5* (1979Se05), 680.36 *5* (1997Sa53). Eγ=681.05 *22* (1979Vo09) seems discrepant. Other less precise Eγ using Ge(Li): 1967Hi04, 1971Si20, 1974Ra30. I_γ: unweighted average of 0.22 *1* (1997Sa53); 0.122 *7* (1995Go44); 0.123 *6* (1979Se05); 0.30 *5* (1979Vo09); 0.149 *32* (1974HeYW). Others: 0.06 (1974Ra30), 0.32 *15* (1971Si20), 0.23 *16* (1967Hi04), <0.05 (1967Do07).
685.890 *28*	6.41 *15*	685.901	5/2$^+$	0.0	7/2$^+$	M1+E2	−0.97 *30*	0.0073 *7*	%Iγ=0.833 *28* α(K)=0.0062 *6*; α(L)=0.00087 *6*; α(M)=0.000186 *13* α(N)=4.2×10^{-5} *3*; α(O)=6.3×10^{-6} *5*; α(P)=3.8×10^{-7} *4* E_γ: weighted average: 685.80 *10* (1961Ew02), 685.902 *35* (1974HeYW), 685.89 *4* (1979Se05), 685.889 *28* (1979Vo09). Eγ=685.792 *8* (1997Sa53, uncertainty seems underestimated, and is also somewhat discrepant in energy). Other less precise Eγ using Ge(Li): 1967Do07, 1967Ca18, 1967Hi04, 1967Ja05, 1967Ba21, 1967Ki08, 1971Si20, 1974Ra30. I_γ: unweighted average of 6.63 *5* (1997Sa53); 6.21 *7* (1995Go44); 6.6 *5* (1979Se05); 6.1 *2* (1979Vo09); 6.2 *4* (1974HeYW); 6.7 *6* (1974Ra30); 6.5 *4* (1971Si20); 6.4 *4* (1967Ki08); 5.9 *10* (1967Hi04); 6 *1* (1967Ja05); 5.9 *4* (1967Do07); 6.6 *7* (1967Ca18); 7.0 *4* (1967Ba21); 7.0 *7* (1966Ar16). 686$\gamma(\theta$,H,T): $B_2U_2A_2$=−0.116 *9*, $B_4U_4A_4$=+0.002 *10* (1977Al34). 686$\gamma(\theta$,H,T): $G_2U_2F_2$=−0.329 *6* (1969Ba32). Ice(K)=3.4 *2* (1997Sa53), 3.1 *6* (1979Vo09), 0.021 *3* (1967Ba21). α(K)exp=0.0068 *4* (1997Sa53), 0.0066 *13* (1979Vo09), 0.0073 *12* (1967Ba21). δ: from $\gamma(\theta$,H,T); weighted average of −0.95 *30* (1977Al34); and -1.05 *65* (1969Ba32; previous value was −0.95 *33* in 1961We07). 1977Kr13 evaluation gives −0.97 *27* from $\gamma(\theta$,H,T) date of 1969Ba32 and 1961We07.

^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34 (continued)

$\gamma(^{147}Pm)$ (continued)

E_i(level) Comments

† From averages of values from various studies as specified with each γ ray. Relative intensities in 1995Go44, 1979Se05, 1974HeYW, 1971Si20 and 1967Ba21 were normalized to 100 for the 91-keV γ ray. Evaluator has renormalized intensity data in references to 100 for the 531-keV γ ray. Except for the 91-keV γ ray, unweighted averages are taken, as 1997Sa53 and 1995Go44 seem to report intensities with very low (probably underestimated) uncertainties, as compared to those reported in other studies using nearly similar type of apparatus.

‡ Based on α(K)exp, except as noted. The α(K)exp and α(L)exp (1997Sa53) normalized to α(K)exp(531γ)=0.0133 *3*, δ=−0.41 *2*; α(K)exp=ce(K)(1967Ba21)/Iγ normalized to α(L1)+α(L2)(91γ)=0.2458 (M1+E2 theory). ce(K)(1961Ew02) data are normalized to ce(K)(531γ)=0.626 in accord with 1967Ba21.

§ For absolute intensity per 100 decays, multiply by 0.1300 *33*.

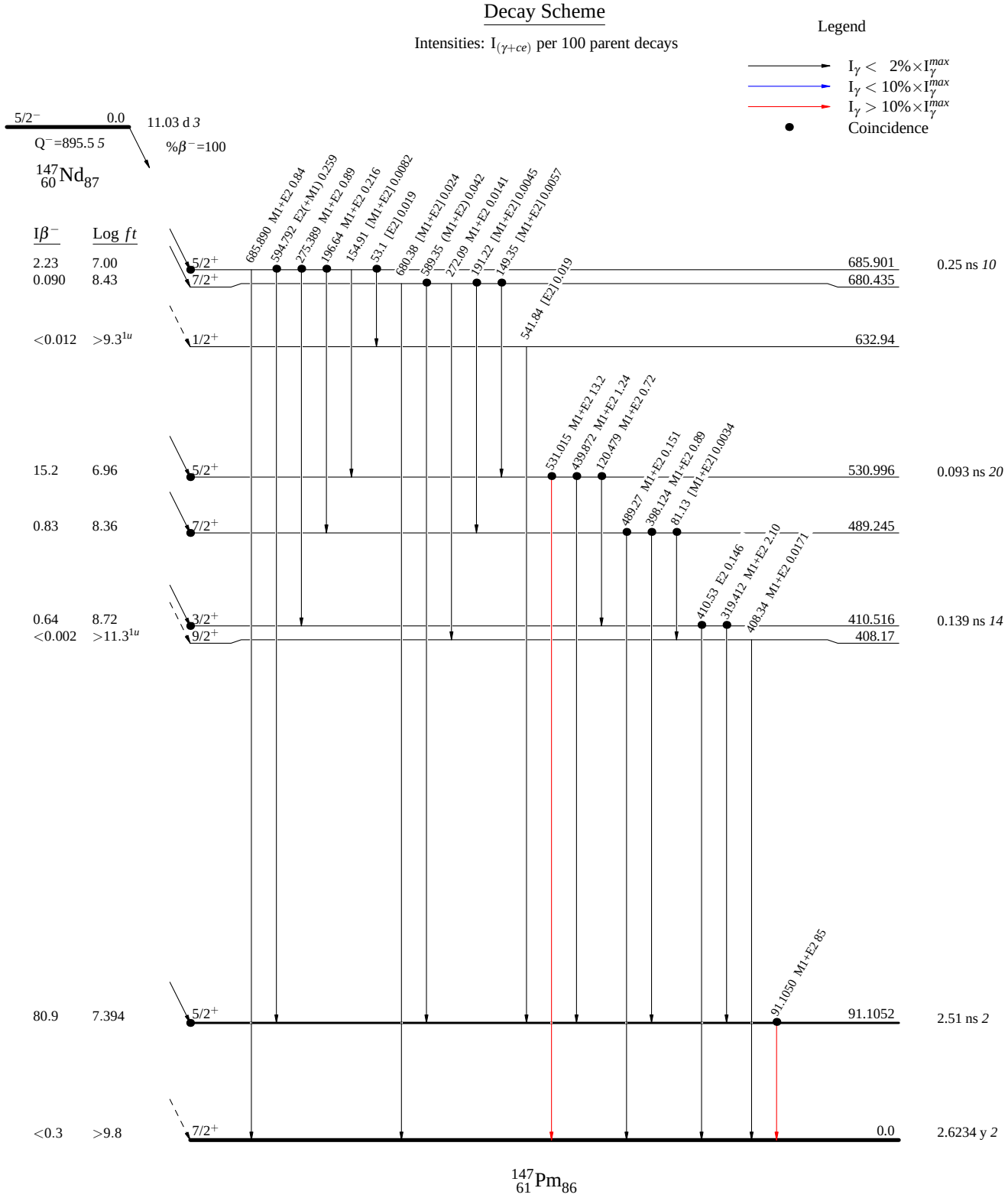
& Total theoretical internal conversion coefficients, calculated using the BrIcc code (2008Ki07) with Frozen orbital approximation based on γ-ray energies, assigned multipolarities, and mixing ratios, unless otherwise specified.

$^{147}_{61}Pm_{86}$-17

^{147}Nd β^- decay (11.03 d) 1997Sa53,1979Se05,1977Al34

Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays



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