^{226}Th α decay (30.72 min) 1976Ku08,1995Ko54,2012Ma30

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh, M. S. Basunia, Jun Chen et al. ,	NDS 192,315 (2023)	25-Sep-2023

Parent: ^{226}Th: E=0.0; $J^\pi=0^+$; $T_{1/2}$=30.72 min *5*; Q(α)=6452.5 *10*; %α decay=100

^{226}Th-$T_{1/2}$: NRM-weighted average with reduced χ^2=3.06 of 30.70 min *3* (2012Po13, analysis of seven α-decay curves), 30.83 min *1* (1995Ko54, γ-decay curves for four sources, each counted for five half-lives, uncertainty of 0.01 min gets inflated to 0.06 min in the NRM procedure), 30.57 min *10* (1987Mi10, α-decay curves, weighted average of 39 measurements). Weighted average is 30.82 *3*, with reduced χ^2=11.5. LWM-weighted average is 30.76 *5*, with reduced χ^2=6.8. Unweighted average is 30.70 *8* min. Other: 30.9 min (1948St42).

^{226}Th-Q(α): From 2021Wa16.

^{226}Th-%α decay: %α=100 for ^{226}Th decay. 2001Bo11 measured %^{18}O cluster decay of $<3.2\times10^{-14}$.

Dataset by Balraj Singh, Jun Chen, and IAEA-ICTP-workshop participants: A. Rathi and P.S. Rawat.

1976Ku08: ^{230}U activity was from decay of ^{230}Pa produced by natural Thorium target with 100 MeV proton beam at Dubna. Measured Eγ, Iγ, $\gamma\gamma$-coin, γ(x ray)-coin, ce using two Ge(Li) detectors with volumes of 0.17cm^3 and 32cm^3 for low and high energy γ-rays and Si(Li) detector for ce measurement. Deduced levels, J, π, α-decay branching ratios, hindrance factors.

1995Ko54: ^{230}U activity was from decay of ^{230}Pa produced via ^{232}Th(p,3n)^{230}Pa reaction at 30 MeV. Measured Eγ, Iγ using HPGe coaxial detector and LEPS detector. Deduced levels, J, π, $T_{1/2}$ of ^{226}Th and ^{222}Ra decay, α-decay branching ratios, hindrance factors.

2012Ma30: source of 18.6 mm diameter prepared from electro-deposition of ^{230}U solution with activity at starting of order of 1kBq. α-particles were detected using ion-implanted planar silicon detector. Measured Eα, Iα.

Other measurements or analyses:

2012Po13: source prepared by capturing recoil atoms from open ^{230}U; measured $T_{1/2}$ of ^{226}Th and ^{222}Ra decays; α detection by ion-implanted silicon detector.

2009Mo37: Measured cross sections and thick-target yields; Deuteron irradiations of ^{231}Pa targets ; comparison with EMPIRE 3 code; No Eα, Iα data for ^{226}Th decay.

1991Ry01: Evaluated Eα and Iα for the two most intense α lines of 6338- and 6229-keV.

1991Ga28: α spectrum contained peaks assigned to ^{226}Th decay; no Eα, Iα data; ON-Line Gas chemistry apparatus used.

1988Hu08: α spectrum contained peaks assigned to ^{226}Th decay; no Eα, Iα data; measured mass-separated yields using ion-guide separation technique; used natural ^{232}Th and radioactive ^{230}Th targets with 55 MeV proton beam.

1987Mi10: $T_{1/2}$ of ^{226}Th decay; ^{232}Th irradiated with bremsstrahlung beams; solid state detector used for α detection.

1975VaZD: Measured Eα, Iα; deduced hindrance factors; JINR magnetic α spectrograph; sources mass-separated from Th.

1974Va28: Measured Eγ, Iγ.

1971He19: ^{226}Th source prepared by capturing recoil atoms from ^{230}U on Al foil; $\alpha\gamma(\theta)$, geometrical factor corrections; Ge(Li) and surface barrier detector.

1969Br10: Measured Eγ, Iγ, ce, $\alpha\gamma$-, α(ce)-coin, Ge(Li) Detector.

1969Pe17: ^{226}Th source from successive disintegration of ^{230}U extracted chemically from Th(p,3n)^{230}Pa reaction; measured $\alpha\gamma$-coin, Iγ for 111γ, Iα for 6229α, ce; Si detector.

1967LoZZ (thesis): Source produced by proton irradiation of natural Th; measured ce for ^{222}Ra using double focusing spectrometer; Eγ, Iγ using Ge(Li) detector.

1963Le17 (thesis): Sources are produced by irradiation method; Eα, Iα, Eγ, Iγ, ce, I_{ce}, $\alpha\gamma$-, α(ce)-, γ-γ coin; silicon detectors, anthracene and NaI scintillators.

1961Ru06 (thesis): Source by bombarding He ion beam at ^{232}Th; Eα, Iα, Iγ, $\alpha\gamma$-, γ-γ coin; ionization chamber and scintillator.

1956As38: Source by collecting recoils from ^{230}U α-decay; Eα, Iα, Eγ, Iγ, $\gamma\gamma$-coin; electromagnetic spectrograph and NaI scintillator.

1956Sm88: ^{230}U separated from Th(p,3n)^{230}Pa reaction, measured Eγ using ce for ^{230}U decay series; beta-ray spectrographs.

1954St02: Eα, $\gamma\gamma$-coin, $\alpha\gamma(\theta)$, NaI(Tl) detector for γ and thin NaI crystal for α.

1948St42: Deuteron and He ion bombardment of Th; $T_{1/2}$ of ^{226}Th using α-activity from recoils of parent; Eα using pulse analyzer.

^{226}Th α decay (30.72 min) 1976Ku08,1995Ko54,2012Ma30 (continued)

^{222}Ra Levels

E(level)[†]	J^{π}[‡]	$T_{1/2}$[‡]	Comments
0.0[#]	0^+	33.6 s *4*	
111.134[#] *9*	2^+	0.52 ns *4*	$T_{1/2}$: adopted value from (6234α)(ce 111γ)(t) (1960Be25).
242.157[@] *9*	1^-	9.5 ps *+21−16*	$T_{1/2}$: other: <1.2 ns ((α)(240γ)(t)) (1956St23).
301.445[#] *13*	4^+	135 ps *+17−14*	$T_{1/2}$: other: <1.4 ns (α(190γ)(t)) (1956St23).
317.385[@] *13*	$(3)^-$	4.7 ps *+26−14*	
473.74[@] *20*	(5^-)	24 ps *+5−9*	
914.174[&] *22*	(0^+)		
1024.96[&] *6*	(2^+)		J^{π}: gammas to 0^+ and 4^+ levels; possible member of band based on (0^+).

[†] From a least-squares fit to Eγ data. Reduced χ^2=2.1 is within the 95% confidence limit.
[‡] From the Adopted Levels.
[#] Band(A): g.s. band.
[@] Band(B): Octupole band, based on 1^-.
[&] Band(C): Possible band based on (0^+).

α radiations

Additional information 1.

Eα[†]	E(level)	Iα[†@]	HF[‡]	Comments
(5331.4[#] *10*)	1024.96	1.50×10^{-4}[#] *23*	4.6 *8*	
(5440.2[#] *10*)	914.174	3.3×10^{-4}[#] *4*	8.5 *9*	
(5872.8[#] *10*)	473.74	2.28×10^{-4}[#] *23*	2.26×10^3 *23*	
6027.1 *10*	317.385	0.230 *5*	12.42 *31*	Eα: 2012Ma30 give 0.9 keV lower than 6028 *5* quoted as from 1991Ry01, which however does have this Eα. Other: 6024.5 *50* (1975VaZD), 6029 (1956As38); 6026.6 *10* from Q(α)-level energy, de-corrected for recoil. Iα: others: 0.22 *2* (1975VaZD); 0.207 *7* from γ+ce intensity balance.
6042.5 *10*	301.445	0.181 *4*	18.7 *5*	Eα: 2012Ma30 give 2.5 keV higher than 6040 *5* in 1975VaZD. Other: 6042.2 *10* from Q(α)-level energy, de-corrected for recoil. Iα: others: 0.20 *2* (1975VaZD); 0.189 *7* from γ+ce intensity balance.
6100.2 *10*	242.157	1.266 *7*	5.02 *7*	Eα: 2012Ma30 give 1.2 keV higher than 6099 *5* quoted as from 1991Ry01, which however does have this Eα. Others: 6099.5 *50* (1975VaZD), 6095 (1956As38); 6100.5 *10* from Q(α)-level energy, de-corrected for recoil. Iα: other: 1.70 *15* (1956As38), 1.2 *4* (1963Le17), 1.3 *2* (1975VaZD); 1.25 *4* from γ+ce intensity balance.
6229.1 *10*	111.134	22.93 *9*	1.076 *13*	Eα: 2012Ma30 give 4.9 keV lower than 6234 *5* quoted in 2012Ma30 as from 1991Ry01 based on measured values of 6234 *5* (1975VaZD), 6220 *3* (1956As38), but the actual value from 1991Ry01 is 6230.7 *30*. Other: 6229.2 *10* from Q(α)-level energy, de-corrected for recoil. Iα: others: 22.8 *2* (1969Pe17), 19.0 *15* (1956As38), 20 (1961Ru06), 23.0 *23* (1975VaZD); 21.4 *12* from γ+ce intensity balance.
6338.2 *10*	0.0	75.39 *10*	1.0	Eα: 2012Ma30 give 1.4 keV higher than 6336.8 *10* recommended by 1991Ry01, based on measured values of 6337.5 *50* (1975VaZD) and 6330 *10* (1956As38). Other: 6338.3 *10* from Q(α), de-corrected for recoil; 6300 (1948St42, also mentioned Eα=6300 *25* from re-analysis by A. H. Joffey). Iα: others: 79 (1956As38), 78 (1961Ru06), 75 *8* (1975VaZD); 76.9 *12* from 100−ΣI(γ+ce to g.s.).

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^{226}Th α decay (30.72 min) 1976Ku08,1995Ko54,2012Ma30 (continued)

α radiations (continued)

† From 2012Ma30, unless otherwise noted. Uncertainty for Eα is not given in 2012Ma30, but estimated as 1 keV in priv. comm. by the evaluator (B. Singh) with S. Pomme in March 2021.
‡ The nuclear radius parameter $r_0(^{222}Ra)$=1.53762 *45* is deduced from assumed HF=1.0 for the ground-state to ground-state alpha decay branch.
# α not observed; Eα from Q(α)-level energy, de-corrected for recoil; Iα from γ+ce intensity balance at each level.
@ Absolute intensity per 100 decays.

$\gamma(^{222}Ra)$

E_γ†	I_γ†‡	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α#	Comments
(75.13 2)	0.000033 *9*	317.385	(3)$^-$	242.157	1$^-$	[E2]	36.8 *5*	%Iγ=0.000033 *9* α(L)=27.0 *4*; α(M)=7.35 *10* α(N)=1.940 *27*; α(O)=0.412 *6*; α(P)=0.0593 *8*; α(Q)=0.0001583 *22* E_γ: from 1992Ru01 in ^{222}Fr β^-. The Eγ value not used in the least-squares fitting procedure. Fitted Eγ=75.228 *13*. I_γ: from Iγ(75γ)/Iγ(206γ)=0.017 *4*/100 *10* (1992Ru01,^{222}Fr β^- decay).
111.15 *1*	3.11 *15*	111.134	2$^+$	0.0	0$^+$	E2	6.12 *9*	%Iγ=3.11 *15* α(K)=0.293 *4*; α(L)=4.28 *6*; α(M)=1.166 *16* α(N)=0.308 *4*; α(O)=0.0655 *9*; α(P)=0.00951 *13*; α(Q)=3.90×10^{-5} *5* E_γ: weighted average of 111.15 *1* (1995Ko54), 111.12 *3* (1976Ku08). Others: 111.1 *3* (1956Sm88, from L2, L3, M2, M3, N and O conversion lines using β-ray spectrometer), 112 *3* (1956As38), 111 *2* (1967LoZZ), 111.3 (1969Pe17), 111 (1969Br10). E_γ: uncertainty multiplied by a factor of 2 in the fitting; level-energy difference=111.135. I_γ: weighted average of 2.908 *145* (1995Ko54), 3.290 *200* (1976Ku08), 3.3 *2* (1969Pe17). Others: 3.8 *4* (1961Ru06, author mentioned that intensities are not determined experimentally so limits on error are to be used from previous work 1956As38), 4.8 *4* (1956As38). Relative Iγ=100 (1969Br10). Mult.: L12:L3:M23:N=17.0 *22*:11.6 *19*:9.5 *17*:3.2 *7* (1967LoZZ), α(L2)=2.4 *4*, α(L)=4.1 *5* (1974Va28). I(ce) values given here were normalized to Ice(K)(230γ of ^{226}Ac decay)=5.45. For absolute I(ce) values per 100α decays, multiply by 0.269 *18*. Value of α(exp)=6.24 *25* was deduced by 1969Pe17 from αγ−coin data. Other: L/M+N+=3.12 (1969Br10).
131.04 *1*	0.270 *13*	242.157	1$^-$	111.134	2$^+$	(E1)	0.2499 *35*	%Iγ=0.270 *13* α(K)=0.1957 *27*; α(L)=0.0411 *6*; α(M)=0.00988 *14* α(N)=0.00257 *4*; α(O)=0.000565 *8*; α(P)=9.02×10^{-5} *13*; α(Q)=4.85×10^{-6} *7* E_γ: weighted average: 131.04 *1* (1995Ko54),

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^{226}Th α decay (30.72 min) 1976Ku08,1995Ko54,2012Ma30 (continued)

$\gamma(^{222}Ra)$ (continued)

E_γ [†]	I_γ [†‡]	E_i(level)	J_i^π	E_f	J_f^π	Mult.	α [#]	Comments
								131.02 *5* (1976Ku08). Other: 131 *5* (1956As38), 131 (1969Br10). E_γ: uncertainty multiplied by a factor of 2 in the fitting; level-energy difference=131.021. I_γ: weighted average: 0.262 *13* (1995Ko54), 0.278 *13* (1976Ku08). Others: 0.4 *1* (1956As38), 0.3 *1* (1961Ru06, author mentioned that intensities are not determined experimentally so limits on error are to be used from previous work 1956As38). Relative Iγ=11 (1969Br10). Mult.: from intensity balance. No ce lines were observed (1969Br10).
172.3 *2*	2.02×10^{-4} *20*	473.74	(5$^-$)	301.445	4$^+$	[E1]	0.1289 *18*	%Iγ=0.000202 *20* α(K)=0.1022 *15*; α(L)=0.02028 *29*; α(M)=0.00486 *7* α(N)=0.001268 *18*; α(O)=0.000280 *4*; α(P)=4.55×10^{-5} *7*; α(Q)=2.62×10^{-6} *4* E_γ: weighted average: 172.3 *2* (1995Ko54), 172.3 *3* (1976Ku08). I_γ: weighted average: 0.00030 *15* (1995Ko54), 0.00020 *2* (1976Ku08, γ observed only in γγ-coin in this work).
190.31 *1*	0.111 *4*	301.445	4$^+$	111.134	2$^+$	E2	0.701 *10*	%Iγ=0.111 *4* α(K)=0.1776 *25*; α(L)=0.385 *5*; α(M)=0.1041 *15* α(N)=0.0275 *4*; α(O)=0.00589 *8*; α(P)=0.000871 *12*; α(Q)=8.45×10^{-6} *12* E_γ: weighted average: 190.31 *1* (1995Ko54), 190.30 *5* (1976Ku08). Other: 197 *10* (1956As38), 188 (1969Br10). I_γ: weighted average: 0.112 *4* (1995Ko54), 0.109 *6* (1976Ku08). Others: 0.40 *5* (1956As38), 0.30 *5* (1961Ru06, author mentioned that Iγ are not determined experimentally so limits on error are to be used from previous work 1956As38). Relative Iγ=3.3 (1969Br10). Mult.: from ce data of 1976Ku08 (measured ce intensities were not given). Only E2 multipolarity yields an intensity balance at the 301.42−keV level. Other: L/M+N+=1.8 (1969Br10), I(ce)=0.4 (1956As38).
206.25 *1*	0.191 *6*	317.385	(3)$^-$	111.134	2$^+$	E1	0.0838 *12*	%Iγ=0.191 *6* α(K)=0.0669 *9*; α(L)=0.01288 *18*; α(M)=0.00308 *4* α(N)=0.000804 *11*; α(O)=0.0001786 *25*; α(P)=2.93×10^{-5} *4*; α(Q)=1.757×10^{-6} *25* E_γ: weighted average: 206.25 *1* (1995Ko54), 206.23 *5* (1976Ku08). Other: 207 (1969Br10). I_γ: weighted average: 0.192 *6* (1995Ko54), 0.189 *8* (1976Ku08). Relative Iγ=5.5 (1969Br10). Mult.: from ce data of 1976Ku08 (measured ce intensities were not given). Only E1

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^{226}Th α decay (30.72 min) 1976Ku08,1995Ko54,2012Ma30 (continued)

γ(^{222}Ra) (continued)

E_γ [†]	I_γ [†‡]	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α [#]	Comments
								multipolarity is consistent with the intensity balance at the 317.35 level. Other: I(ce)/Iγ≤0.04 (1969Br10).
242.14 *1*	0.866 *26*	242.157	1$^-$	0.0	0$^+$	E1	0.0575 *8*	%Iγ=0.866 *26* α(K)=0.0461 *6*; α(L)=0.00866 *12*; α(M)=0.002068 *29* α(N)=0.000541 *8*; α(O)=0.0001204 *17*; α(P)=1.990×10^{-5} *28*; α(Q)=1.236×10^{-6} *17* E_γ: weighted average: 242.14 *1* (1995Ko54), 242.12 *5* (1976Ku08). Other: 242 *3* (1956As38), 242 (1969Br10). I_γ: weighted average: 0.866 *26* (1995Ko54), 0.866 *40* (1976Ku08). Others: 1.2 *1* (1956As38), 1.2 *4* (1963Le17), 0.9 *1* (1961Ru06, author mentioned that intensities are not determined experimentally so limits on error are to be used from previous work 1956As38). Relative Iγ=29 (1969Br10), Mult.: from α(K)exp≈0.06 (estimated by the evaluator from the (α)(ce) spectrum shown by 1969Br10).
672.02 *2*	0.00029 *2*	914.174	(0$^+$)	242.157	1$^-$	[E1]	0.00661 *9*	%Iγ=0.00029 *2* α(K)=0.00542 *8*; α(L)=0.000904 *13*; α(M)=0.0002132 *30* α(N)=5.59×10^{-5} *8*; α(O)=1.264×10^{-5} *18*; α(P)=2.166×10^{-6} *30*; α(Q)=1.588×10^{-7} *22* E_γ: weighted average: 672.02 *2* (1995Ko54), 671.9 *3* (1976Ku08). I_γ: weighted average: 0.00029 *2* (1995Ko54), 0.00028 *3* (1976Ku08).
707.52 *9*	0.00005 *1*	1024.96	(2$^+$)	317.385	(3)$^-$	[E1]	0.00600 *8*	%Iγ=0.00005 *1* α(K)=0.00492 *7*; α(L)=0.000817 *11*; α(M)=0.0001926 *27* α(N)=5.05×10^{-5} *7*; α(O)=1.143×10^{-5} *16*; α(P)=1.960×10^{-6} *27*; α(Q)=1.446×10^{-7} *20* E_γ: weighted average: 707.52 *9* (1995Ko54), 707.5 *5* (1976Ku08). I_γ: weighted average: 0.00005 *1* (1995Ko54), 0.00006 *2* (1976Ku08).
722.9 *4*	7×10^{-6} *3*	1024.96	(2$^+$)	301.445	4$^+$	[E2]	0.01714 *24*	%Iγ=0.000007 *3* α(K)=0.01255 *18*; α(L)=0.00345 *5*; α(M)=0.000861 *12* α(N)=0.0002271 *32*; α(O)=5.05×10^{-5} *7*; α(P)=8.31×10^{-6} *12*; α(Q)=4.40×10^{-7} *6* E_γ,I_γ: from 1995Ko54.
783.0 *5*	5.6×10^{-5} *12*	1024.96	(2$^+$)	242.157	1$^-$	[E1]	0.00496 *7*	%Iγ=0.000056 *12* α(K)=0.00408 *6*; α(L)=0.000672 *9*; α(M)=0.0001582 *22* α(N)=4.15×10^{-5} *6*; α(O)=9.40×10^{-6} *13*;

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^{226}Th α decay (30.72 min) 1976Ku08,1995Ko54,2012Ma30 (continued)

γ(^{222}Ra) (continued)

E_γ [†]	I_γ [†‡]	E_i(level)	J^π_i	E_f	J^π_f	Mult.	α [#]	Comments
								α(P)=1.615×10^{-6} *23*; α(Q)=1.205×10^{-7} *17* E_γ: weighted average: 782.9 *5* (1995Ko54), 783.0 *5* (1976Ku08). I_γ: weighted average: 0.000052 *10* (1995Ko54), 0.00009 *3* (1976Ku08).
802.7 *1*	3.7×10^{-5} *24*	914.174	(0$^+$)	111.134	2$^+$	[E2]	0.01385 *19*	%Iγ=0.000037 *24* α(K)=0.01035 *14*; α(L)=0.00263 *4*; α(M)=0.000651 *9* α(N)=0.0001717 *24*; α(O)=3.83×10^{-5} *5*; α(P)=6.35×10^{-6} *9*; α(Q)=3.59×10^{-7} *5* E_γ: poor fit in the level scheme, level-energy difference=803.036; uncertainty multiplied by a factor of 2 in the fitting procedure. E_γ: weighted average: 802.7 *1* (1995Ko54), 802.7 *5* (1976Ku08). E_γ: uncertainty multiplied by a factor of 2 in the fitting; level-energy difference=803.037. I_γ: unweighted average: 0.000013 *4* (1995Ko54), 0.00006 *2* (1976Ku08).
913.9 *4*	3.3×10^{-5} *16*	1024.96	(2$^+$)	111.134	2$^+$			%Iγ=0.000033 *16* E_γ,I_γ: from 1995Ko54.
^{x}929.5 *2*	0.020 *6*							%Iγ=0.020 *6* E_γ,I_γ: from 1995Ko54. In ^{222}Fr β^- decay, Eγ=929.47 *8* is reported in 1992Ru01 from an 1171.6 level, but there are several other γ rays of comparable intensities in 1992Ru01, which are not reported in 1995Ko54.
(1025.02 *8*)	3.6×10^{-6} *8*	1024.96	(2$^+$)	0.0	0$^+$	[E2]	0.00859 *12*	%Iγ=0.0000036 *8* α(K)=0.00666 *9*; α(L)=0.001456 *20*; α(M)=0.000356 *5* α(N)=9.36×10^{-5} *13*; α(O)=2.104×10^{-5} *29*; α(P)=3.55×10^{-6} *5*; α(Q)=2.256×10^{-7} *32* E_γ: from 1992Ru01 in ^{222}Fr β^- decay. I_γ: Iγ(1025γ)/Iγ(707γ+783γ)=0.060 *10*/1.76 *9* (1992Ru01,^{222}Fr β^-) gives Iγ(1025γ)=0.0000036 *8*, which is adopted here.

† Weighted or unweighted average of the listed values, as specified in comments. Measured values are mainly from 1995Ko54 and 1976Ku08.
‡ Absolute intensity per 100 decays.
\# 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.
^{x} γ ray not placed in level scheme.

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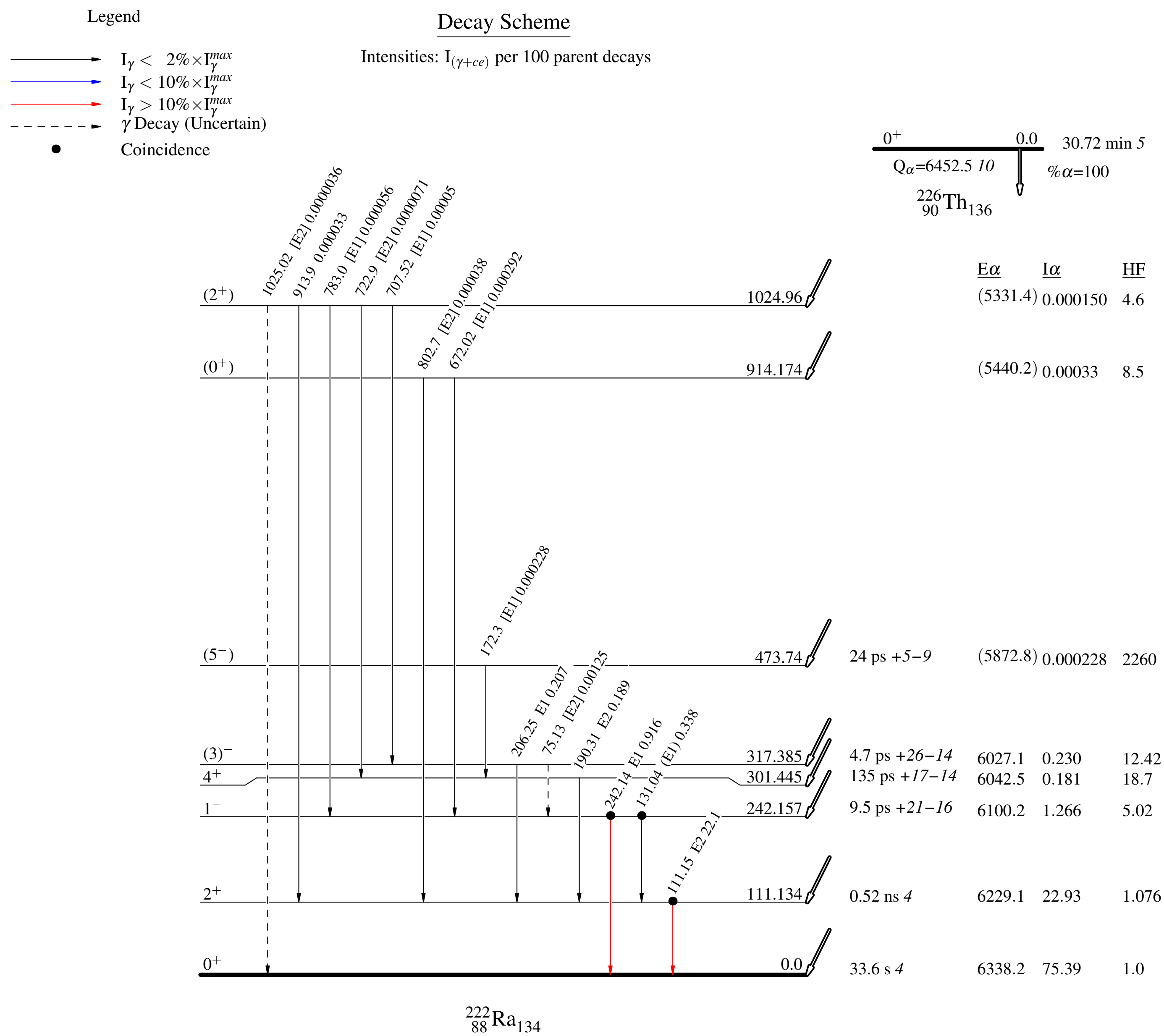
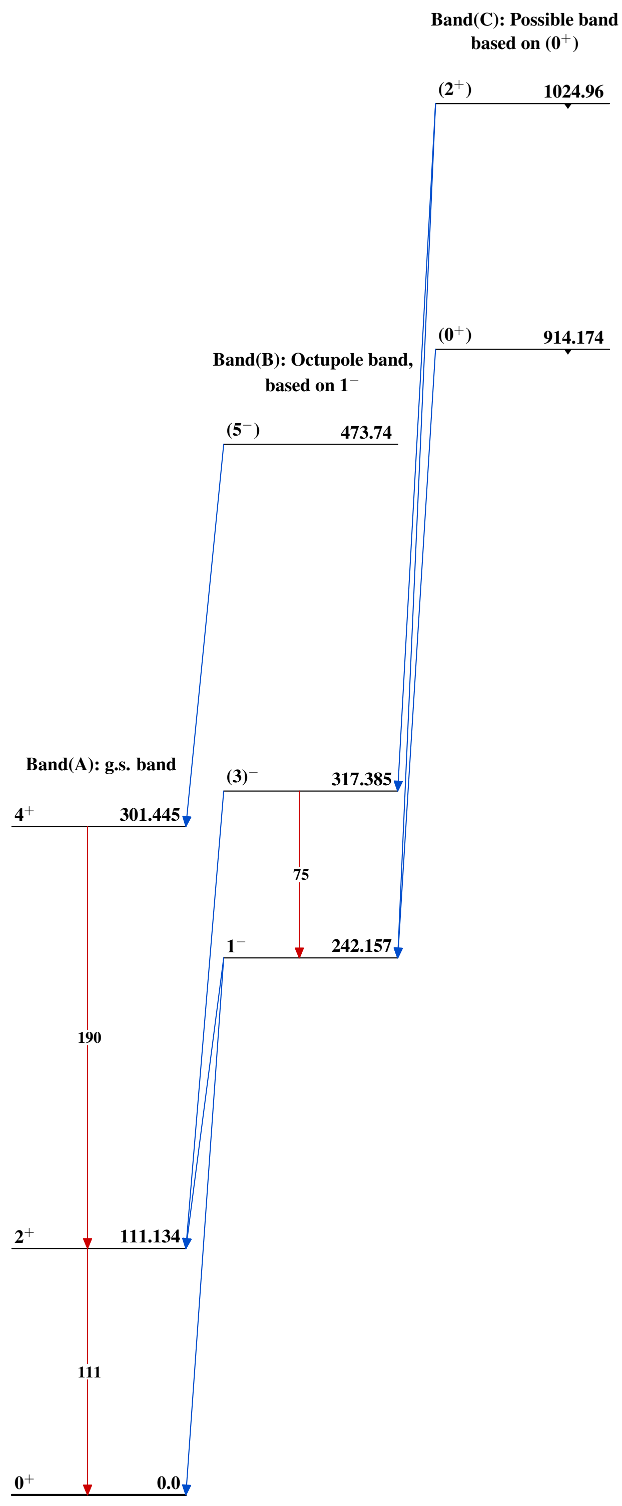


^{226}Th α decay (30.72 min) 1976Ku08,1995Ko54,2012Ma30



$^{222}_{88}Ra_{134}$