^{238}Pa β^- decay

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	E. Browne, J. K. Tuli	NDS 127, 191 (2015)	1-Jun-2014

Parent: ^{238}Pa: E=0.0; $J^\pi=(3^-)$; $T_{1/2}$=2.28 min *10*; Q(β^-)=3585 *16*; %β^- decay=100.0

Additional information 1.

The Gamow-Teller β-decay strength function has been calculated in 1978Iz04 and 1979KlZT.

The decay scheme is that given in 1970HeZX. It is the same as that given in 1969KaZP except that 1969KaZP show a level at 1160, not adopted here, and 1970HeZX show a level at 1243.

Delayed fission activity observed ($T_{1/2}$=2.3 min *1*) from ^{238}Pa source was interpreted in 1978Ga07 as due to a spontaneously fissioning level in the second minimum of ^{238}U nuclear potential, populated in ^{238}Pa β^- decay. Delayed fission probability was determined to be $\approx 1\times10^{-8}$. Delayed fission probability more than 5×10^{-7} from 1977BoZO. Delayed fission probability less than 2.6×10^{-8} obtained by 1985Ba57. This result rules out positive evidence for this decay mode of ^{238}Pa reported in 1977BoZO and 1978Ga07.

^{238}U Levels

E(level)	J^π†	$T_{1/2}$	E(level)	J^π†	E(level)	J^π†
0.0‡	0^+	4.468×10^9 y *6*	1037@	2^+	1412.95?@ *12*	2^+
45.0‡	2^+		1059.5[b]	(3^+)	1561.4	
148.6‡	4^+		1060.0[c]	2^+	1617.2	
307.3‡	6^+		1105.7[d]	(3^+)	1645.1	
680.0#	1^-		1128.2[e]	(2^-)	1675.5	(3^-)
732.0#	3^-		1167.8	(4^+)	1774.6	
826.6#	5^-		1168.9[e]	3^-	1934.2	(3^-)
930.5&	(1^-)		1223.9@	2^+	1992.1	(3^-)
949.9[a]	2^-		1243.1[e]	(4^-)	2063.9	(2^-)
997.6&	3^-		1381.1?			

† From Adopted Levels.
‡ Band(A): $K^\pi=0^+$ ground-state band.
# Band(B): $K^\pi=0^-$ octupole-vibrational band.
@ Level proposed by evaluators based on data in Coulomb excitation and (n,n′γ).
& Band(C): $K^\pi=1^-$. α=1.
[a] Band(D): $K^\pi=1^-$. α=0.
[b] Band(E): $K^\pi=3\ \nu\ 1/2(631)+\nu\ 5/2(622)$.
[c] Band(F): $K^\pi=2^+$ γ-vibrational band. α=0.
[d] Band(G): $K^\pi=2^+$ γ-vibrational band. α=1.
[e] Band(H): $K^\pi=2^-$.

β^- radiations

E(decay)†	E(level)	Iβ^-‡#
1200		35
1700		40
2200		20
2900		5

† From 1968Tr07 (scin).

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^{238}Pa β^- decay (continued)

β^- radiations (continued)

‡ From 1968Tr07. Intensities are per 100 β^- decays.
# Absolute intensity per 100 decays.

$\gamma(^{238}U)$

$\gamma\gamma$: see 1969KaZP, 1970TrZZ.

x-rays (relative to Iγ(1015γ)=100 (1969KaZP,1968Tr07)):

Eγ	Iγ		
13.53		Lα_1	x ray+Lα_2 x ray
17.17		Lβ_1	x ray
16.44		Lβ_2	x ray
20.13		Lγ_1	x ray
94.67	60	Kα_2	x ray
98.42	83	Kα_1	x ray
110.42		Kβ_3	x ray
111.28	33	Kβ_1	x ray
114.39	11	Kβ_2	x ray

the intensity given for Kβ_1 x ray includes Kβ_3 x ray

E$_\gamma$[†]	I$_\gamma$[‡#]	E$_i$(level)	J$_i^\pi$	E$_f$	J$_f^\pi$	Comments
(41.4)		1168.9	3$^-$	1128.2	(2$^-$)	E$_\gamma$: from Coulomb excitation. Not seen in β^- decay.
45.02[d]		45.0	2$^+$	0.0	0$^+$	
68.1[&]		1128.2	(2$^-$)	1060.0	2$^+$	
68.8	7	1128.2	(2$^-$)	1059.5	(3$^+$)	
103.4	12	148.6	4$^+$	45.0	2$^+$	
109.4[&]		1168.9	3$^-$	1059.5	(3$^+$)	
[x]114.8[d]						
[x]115.23[d]						
[x]115.55[d]						
130.7		1128.2	(2$^-$)	997.6	3$^-$	
[x]142.64[d]						
[x]154.4	3					
158.7	4	307.3	6$^+$	148.6	4$^+$	
[x]164.5						
171.1		1168.9	3$^-$	997.6	3$^-$	
178.2	11	1128.2	(2$^-$)	949.9	2$^-$	
[x]189.4	≤2[h]					
[x]193.3	≤2[h]					
197.8	9	1128.2	(2$^-$)	930.5	(1$^-$)	
[x]212.9						
217.9	14	949.9	2$^-$	732.0	3$^-$	
[x]221.9	4					
[x]228.8						
[x]238.3						E$_\gamma$: placed by 1970HeZX from the 1169 *3-* level; however, this transition is not reported in Coulomb excitation or in (n,n′γ).
250.6	7	930.5	(1$^-$)	680.0	1$^-$	
[x]258.5	8					
[x]265.5						E$_\gamma$: placed by 1970HeZX from the 998 *3-* level; however, this transition is not reported in Coulomb excitation or in (n,n′γ).
269.8	12	949.9	2$^-$	680.0	1$^-$	

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^{238}Pa β^- decay (continued)

$\gamma(^{238}U)$ (continued)

E_γ [†]	I_γ [‡#]	E_i(level)	J_i^π	E_f	J_f^π	Comments
[x]276						
289.1	4	1934.2	(3$^-$)	1645.1		
[x]293.0	12					
[x]301.8	2					
317.0	7	1934.2	(3$^-$)	1617.2		
[x]322.0						
[x]329.5						
[x]347.3						
[x]353.3						
373	≤6[@]	1934.2	(3$^-$)	1561.4		
375	≤6[@]	1992.1	(3$^-$)	1617.2		
[x]377	≤6[@]					
396.5	18	1128.2	(2$^-$)	732.0	3$^-$	
[x]407.5	9					
[x]422.2	6					
[x]433.0						
437.0	16	1168.9	3$^-$	732.0	3$^-$	
[x]442.9						
448.3	69[p]	1128.2	(2$^-$)	680.0	1$^-$	
448.3	≈7[p]	1617.2		1168.9	3$^-$	E_γ: taken from author's spectrum. The value given on the decay scheme is 448.4.
[x]456.2	7					
[x]459.6						
[x]465.6	2					
476.2	19	1645.1		1168.9	3$^-$	
489.0	4[q]	1168.9	3$^-$	680.0	1$^-$	
489.0	16[q]	1617.2		1128.2	(2$^-$)	
501.9	26	1561.4		1059.5	(3$^+$)	
[x]508.4						
[x]511						
519.3	≈1.5[n]	826.6	5$^-$	307.3	6$^+$	
547.2	40	1675.5	(3$^-$)	1128.2	(2$^-$)	
557.9	≤4[a]	1617.2		1059.5	(3$^+$)	557.9γ may feed the 1059.5- or 1060.0-keV level.
[x]569.6	≤6[l]					
[x]572.1	≤6[l]					
583.5	41	732.0	3$^-$	148.6	4$^+$	
605.7	10	1774.6		1168.9	3$^-$	
[x]615.2	8					
[x]623.6	19					
635.0	88	680.0	1$^-$	45.0	2$^+$	
646.4	9	1774.6		1128.2	(2$^-$)	
[x]659.8						
[x]667.7						
678[f]	≈3[n]	826.6	5$^-$	148.6	4$^+$	
679.9	70[n]	680.0	1$^-$	0.0	0$^+$	
686.8	54	732.0	3$^-$	45.0	2$^+$	
[x]744						
[x]749						
765.3	4	1934.2	(3$^-$)	1168.9	3$^-$	
[x]769						
[x]797.5						
805.7	44	1934.2	(3$^-$)	1128.2	(2$^-$)	
[x]818.1						
823.2	9	1992.1	(3$^-$)	1168.9	3$^-$	

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^{238}Pa β^- decay (continued)

$\gamma(^{238}U)$ (continued)

E_γ[†]	I_γ[‡#]	E_i(level)	J_i^π	E_f	J_f^π	Comments
[x]836.7						
[x]839.6						
849.1	20	997.6	3^-	148.6	4^+	I_γ: 1968Tr07 assign Iγ=14 and Iγ=6 to peaks at 849.3 and 851.9, respectively. Only a single peak is shown in 1970HeZX.
863.6	54	1992.1	(3^-)	1128.2	(2^-)	
874.4	9	1934.2	(3^-)	1059.5	(3^+)	
885.5	45	930.5	(1^-)	45.0	2^+	
905.0	23	949.9	2^-	45.0	2^+	
911.1	17[m] 3	1059.5	(3^+)	148.6	4^+	
911.1	2[m] 2	1060.0	2^+	148.6	4^+	
930.5	≤6[b]	930.5	(1^-)	0.0	0^+	
932.5	≤6[b]	1992.1	(3^-)	1059.5	(3^+)	
943.5	7	1675.5	(3^-)	732.0	3^-	
952.4	21	997.6	3^-	45.0	2^+	
957.2	18	1105.7	(3^+)	148.6	4^+	
[x]961						
[x]967	≤4[c]					
[x]969	≤4[c]					
[x]979.6						
984.6	7	1934.2	(3^-)	949.9	2^-	
[x]991.1						
991.1[e]		1037	2^+	45.0	2^+	
995.4	10	1675.5	(3^-)	680.0	1^-	
1003.6		1934.2	(3^-)	930.5	(1^-)	
1014.5	≤100[s]	1059.5	(3^+)	45.0	2^+	
1015.2	≤100[s]	1060.0	2^+	45.0	2^+	
1019	≈2[r]	1167.8	(4^+)	148.6	4^+	
1020	8[r]	1168.9	3^-	148.6	4^+	
[x]1032.9						
[x]1036.1						
1036.1[e]		1037	2^+	0.0	0^+	
1042.4	8	1774.6		732.0	3^-	
1060.1	≤45[t]	1060.0	2^+	0.0	0^+	
1060.6	≤45[t]	1105.7	(3^+)	45.0	2^+	
[x]1071						
[x]1074						
1083.4	50	1128.2	(2^-)	45.0	2^+	
[x]1090.2						
1094.5[u]	≤5[u]	1243.1	(4^-)	148.6	4^+	
1094.5[u]	≤5[u]	1774.6		680.0	1^-	
[x]1112	≤6[j]					
[x]1113	≤6[j]					
1123	≈1[o]	1167.8	(4^+)	45.0	2^+	
1124	4[o]	1168.9	3^-	45.0	2^+	
[x]1159.5	≤5[k]					
[x]1161.5	≤5[k]					
[x]1178.8	6					
1178.8[e]	6	1223.9	2^+	45.0	2^+	
[x]1214.8	6					
[x]1224.0	6					
1224.0[e]	6	1223.9	2^+	0.0	0^+	
[x]1233.5						
[x]1306.4						

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^{238}Pa β^- decay (continued)

$\gamma(^{238}U)$ (continued)

E_γ[†]	I_γ[‡#]	E_i(level)	J_i^π	E_f	J_f^π	Comments
[x]1311.7						
[x]1325.2						
1332.0	5	2063.9	(2$^-$)	732.0	3$^-$	
[x]1336.7						
1336.7[iv]	≈1	1381.1?		45.0	2$^+$	
[x]1359.3						
[x]1364						
[x]1368.8	5					
1368.8[iv]	5	1412.95?	2$^+$	45.0	2$^+$	
[x]1377.1	4					
1383.9	7	2063.9	(2$^-$)	680.0	1$^-$	
[x]1394						
[x]1410	≤3[g]					
1413[iv]	3	1412.95?	2$^+$	0.0	0$^+$	
1413	≤3[g]	1561.4		148.6	4$^+$	
[x]1420						
1496.6	8	1645.1		148.6	4$^+$	
[x]1507.1						
1516.5		1561.4		45.0	2$^+$	
1527.1	4	1675.5	(3$^-$)	148.6	4$^+$	
1600	3[a]	1645.1		45.0	2$^+$	
[x]1611	3					
[x]1620						
1626	3[a]	1774.6		148.6	4$^+$	
1630.5	3[a]	1675.5	(3$^-$)	45.0	2$^+$	
[x]1647.5						
1730	3[a]	1774.6		45.0	2$^+$	
[x]1737						
[x]1752						
1785.7		1934.2	(3$^-$)	148.6	4$^+$	
[x]1804						
[x]1841						
[x]1872.5						
1889.1	17	1934.2	(3$^-$)	45.0	2$^+$	
[x]1907.0						
[x]1976						
[x]1985.5						
[x]1997	4					
[x]2013	3					
2019	7	2063.9	(2$^-$)	45.0	2$^+$	
[x]2048						
[x]2081						
[x]2089						
[x]2126						
[x]2529 2						E_γ: reported only by 1968Tr07.

[†] From 1970HeZX, except where noted otherwise. Others: 1968Tr07 and 1969KaZP. These three references refer to work by the same group, but the spectrum of 1970HeZX is a sum of more runs than the others, and more transitions are reported. All spectra were recorded with a 60 α Ge(Li) detector. In addition, 1969KaZP show a low-energy spectrum, 5-170 keV, taken with a 0.5 α Ge(Li) detector. Only 1968Tr07 report intensities.

[‡] From 1968Tr07. No uncertainties are given.

[#] From 1968Tr07. No uncertainties are given. The decay scheme cannot be normalized since the schemes given in the papers

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^{238}Pa β^- decay (continued)

$\gamma(^{238}U)$ (continued)

1970HeZX, 1969KaZP, 1968Tr07 are not complete. In particular, the intensities of several of the transitions among the low-lying levels are not known, and a comparison of the measured E(β^-) of 1968Tr07 with the Q(β^-) value of 1985Ba57 and known level energies does not allow one to determine to which levels the measured I(β^-) correspond.

@ I(373γ+375γ+377γ)=6.

& Peak not labeled in spectrum of 1970HeZX, but placed in decay scheme. Peak is present in low-energy spectrum of 1969KaZP.

a Estimated by evaluators from authors' spectrum.

b I(930.5γ+932.5γ)=6.

c I(967γ+969γ)=4.

d Reported only in 1969KaZP in their low-energy spectrum.

e Unplaced by 1970HeZX, but energy agrees with transition seen in Coulomb excitation and in (n,n'γ).

f Peak not labeled in spectrum of 1970HeZX, but placed in decay scheme. This weak transition would not be resolved in singles from a strong close-lying peak.

g I(1410γ+1413γ)=3.

h Iγ(189.4γ+193.3γ)=2.

i Unplaced by authors. Placement suggested by evaluators on the basis of data in Coulomb excitation or (n,n'γ).

j Iγ(1112+1113γ)=6.

k Iγ(1159.5γ+1161.5γ)=5.

l Iγ(569.6γ+572.1γ)=6.

m 1968Tr07 report Iγ=19 for the 911γ, deexciting the 1060 doublet. From branching in Coulomb excitation, one obtains I$\gamma\leq$4 for placement from the 1060 *2+*. If one assigns an uncertainty of 10% to Iγ(911γ), then, with the component from the 1060 *2+* taken as 2 *2*, one obtains Iγ=17 *3* for the component from the 1060 *3+*.

n Iγ(678γ+679.9γ)=73. The 678γ is placed from the 827 level, and the 679.9γ from the 680 level. From Iγ/Iγ(635γ)=0.79 *4* for the 680 level in Coulomb excitation, one obtains Iγ(679.9γ)=70. Leaving Iγ(678γ)$\approx$3. From Iγ(519γ)/Iγ(678γ)=0.50 *5* for the 827 level in Coulomb excitation, one can deduce Iγ(519γ)$\approx$1.5 in β decay. 1968Tr07 do not report an intensity for this transition.

o 1968Tr07 report Iγ=5 for the 1123+1124 doublet. From Coulomb excitation, Iγ(1124γ)/Iγ(437γ)=0.27 *3* for the 1169 *3-* level, giving Iγ(1124γ)=4, thus leaving Iγ(1123)$\approx$1 for the 1168 *4+* level.

p 1968Tr07 report Iγ=76 for the 448.3γ placed by them from the 1129 *2-* and 1617 levels. From Coulomb excitation, Iγ/Iγ(396γ)=3.84 *25* for placement from the 1129 level, giving Iγ(448.3γ)=69 for this placement, leaving I$\gamma\approx$7 for placement from the 1617 level. No uncertainties are given in 1970HeZX, but if the uncertainties were greater than about 5%, the data would be consistent with placing the 448γ entirely from the 1129 level.

q 1970HeZX report a 489.0 transition with Iγ=20 (1967Tr07) which they place from the 1169 *3-* and 1617 levels. From branching in Coulomb excitation, Iγ/Iγ(437γ)=0.234 *19* for placement from the 1169 level which gives Iγ(489γ)=4 for this placement, leaving Iγ=26 for placement from the 1617 level.

r 1968Tr07 report Iγ=10 for the 1019+1020 transitions. From Coulomb excitation, Iγ(1020γ)/Iγ(437γ)=0.50 *6* for the 1169 *3-* level, giving Iγ(1020γ)=8, thus leaving Iγ(1019γ)$\approx$2 for the 1168 *4+* level.

s Iγ(1014.5γ+1015.2γ)=100.

t Iγ(1060.1γ+1060.6γ)=45.

u Multiply placed with undivided intensity.

v Placement of transition in the level scheme is uncertain.

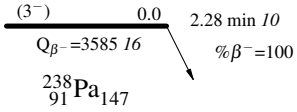
x γ ray not placed in level scheme.

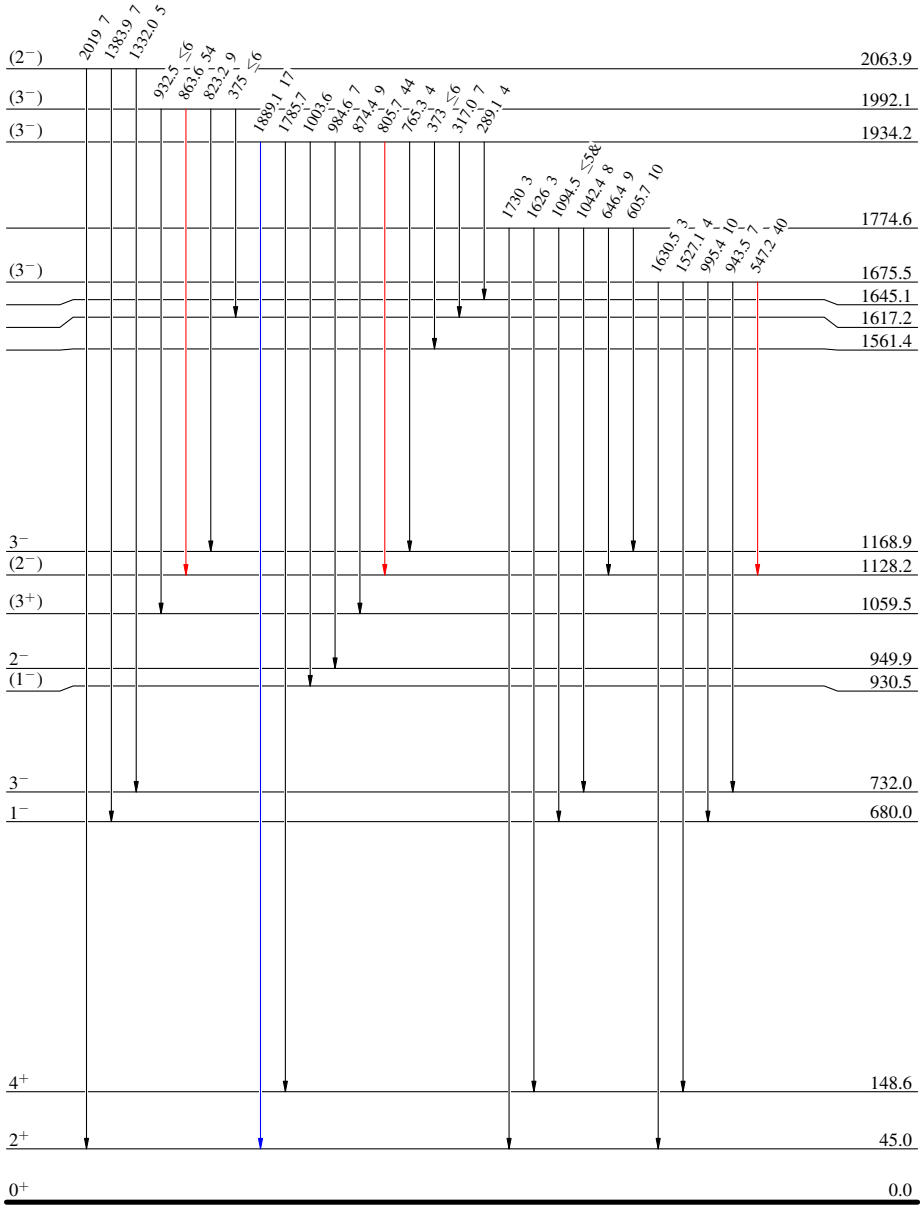
^{238}Pa β^- decay

Decay Scheme

Intensities: Type not specified
& Multiply placed: undivided intensity given

Legend
$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$





4.468×10⁹ y 6

$^{238}_{92}U_{146}$

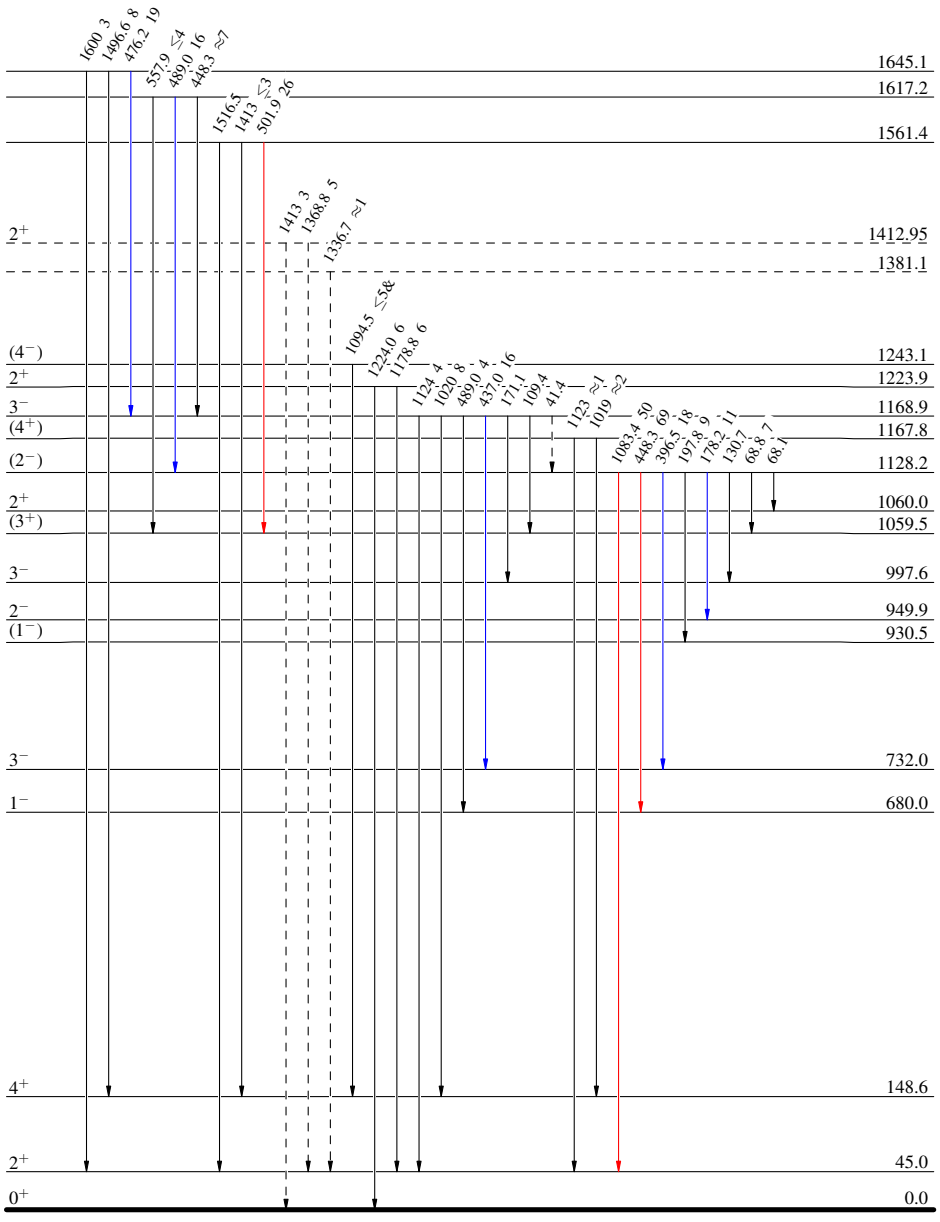
^{238}Pa β^- decay

Decay Scheme (continued)

Intensities: Type not specified
& Multiply placed: undivided intensity given

Legend
$I_\gamma < 2\% \times I_\gamma^{max}$
$I_\gamma < 10\% \times I_\gamma^{max}$
$I_\gamma > 10\% \times I_\gamma^{max}$
γ Decay (Uncertain)

(3^-) 0.0 2.28 min *10*
Q_{β^-}=3585 *16* $\%\beta^-$=100
$^{238}_{91}Pa_{147}$



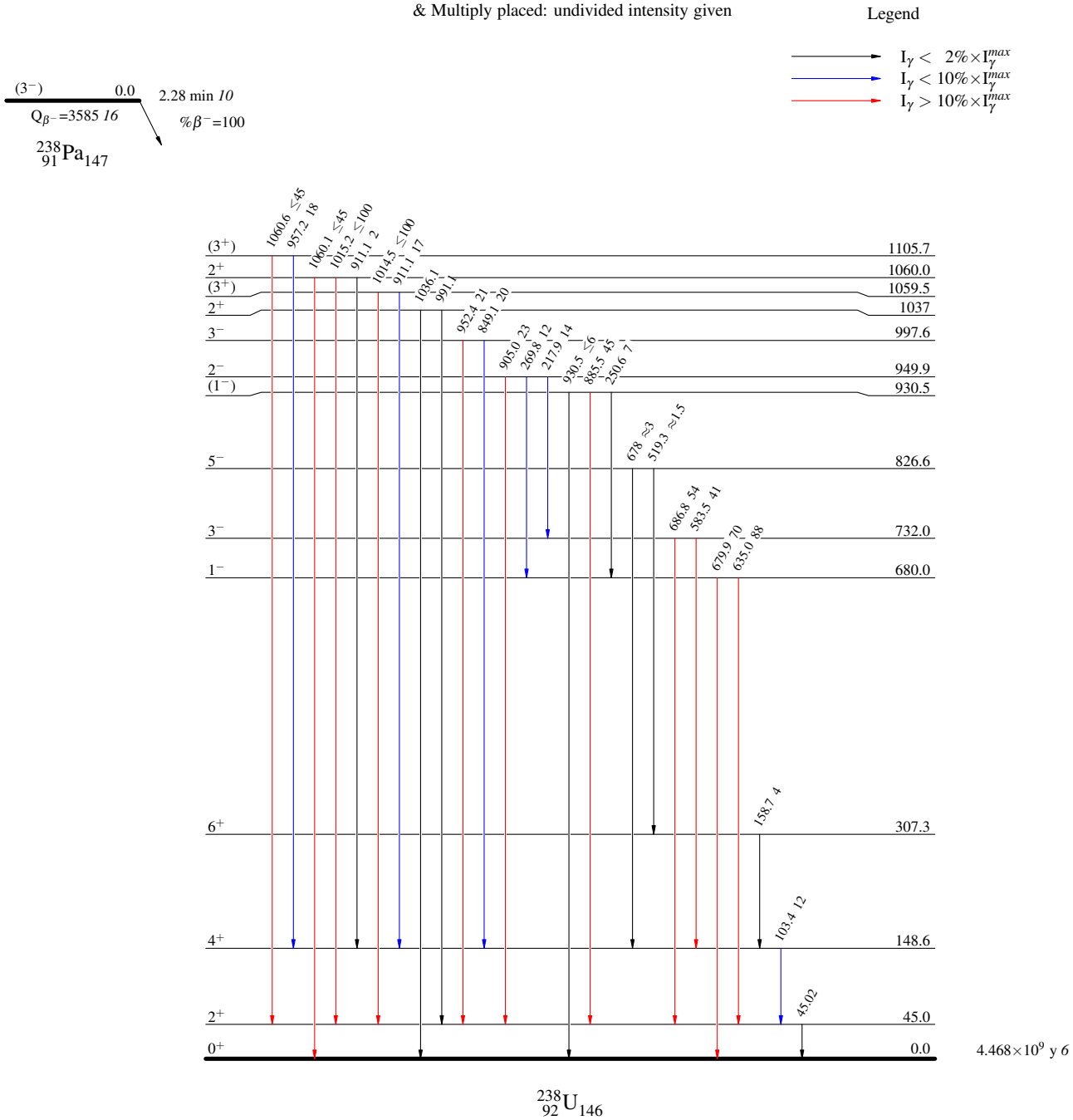
4.468×10^9 y *6*

$^{238}_{92}U_{146}$

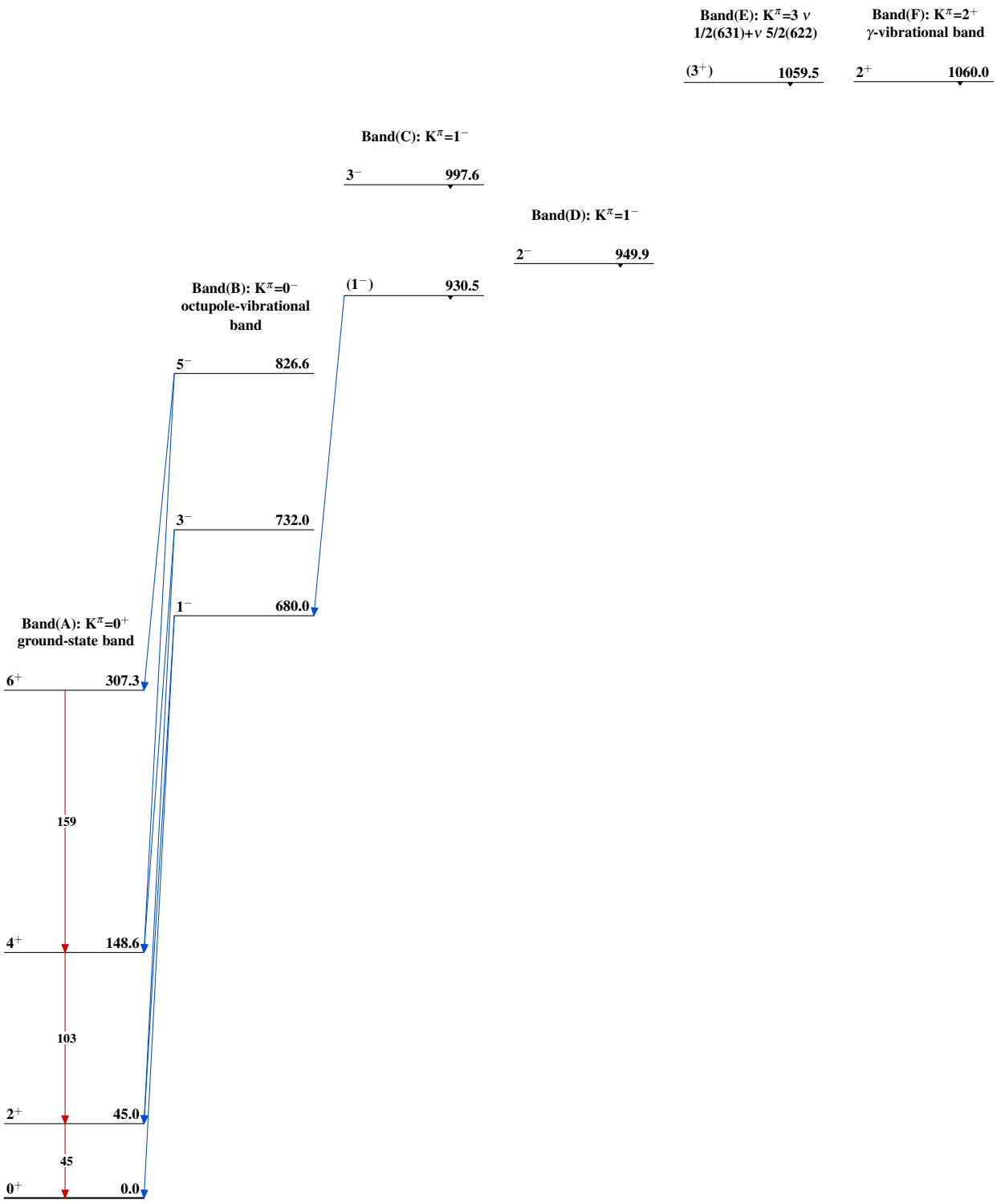
^{238}Pa β^- decay

Decay Scheme (continued)

Intensities: Type not specified
& Multiply placed: undivided intensity given

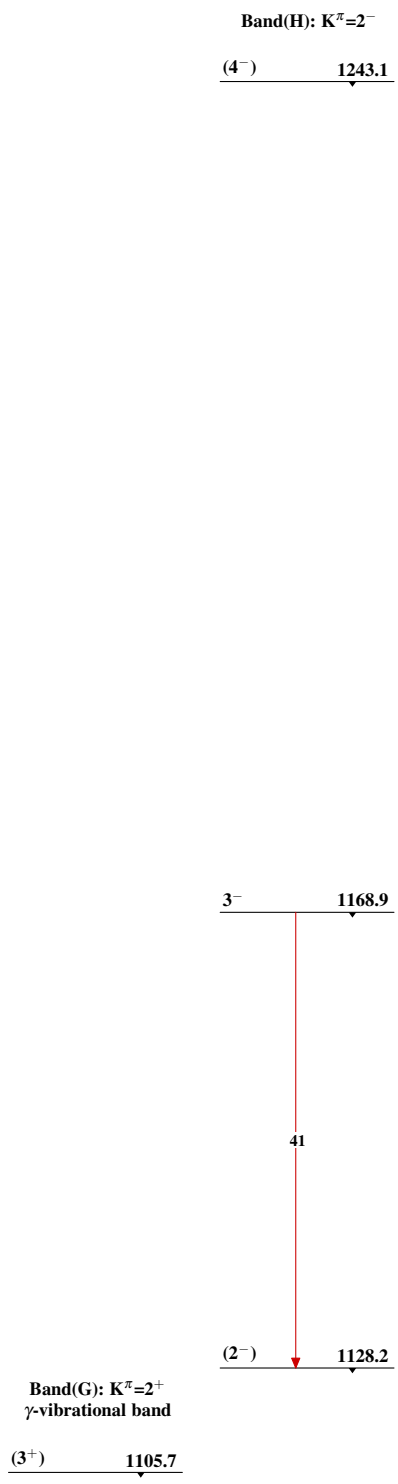


^{238}Pa β^- decay



$^{238}_{92}U_{146}$

^{238}Pa β^- decay (continued)



$^{238}_{92}U_{146}$