^{138}Pr ε decay (2.03 h) 1974Bu03

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Jun Chen	NDS 146, 1 (2017)	30-Sep-2017

Parent: ^{138}Pr: E=364 *23*; $J^{\pi}=7^-$; $T_{1/2}$=2.03 h *4*; Q(ε)=4437 *10*; %ε+%β^+ decay=100.0

^{138}Pr-J^{π},$T_{1/2}$: From Adopted Levels of ^{138}Pr.

^{138}Pr-Q(ε): From 2017Wa10.

1974Bu03: Source of ^{138}Pr was prepared at JINR. Ions were separated and selected with an electromagnetic separator and implanted into aluminum foil. γ rays were detected with Ge(Li) detectors (FWHM=0.7 keV at Eγ=40 keV, 2.3 and 2.9 keV at Eγ=1 MeV); conversion electrons were detected with a β-ray spectrometer incorporating Si(Li) detectors (FWHM=2.5-3.0 keV at K788.7 line of ^{138}Pr). Measured Eγ, Iγ, E(ce), I(ce), $\beta\gamma$-coin. Deduced levels, J, π, γ and β branching ratios, conversion coefficients, γ-ray multipolarities. See also 1971Af05 from the same group.

1972Lu01: Source of ^{138}Pr was produced by bombarding natural lantanium oxide with E=35 MeV ^{3}He ions. γ rays were detected with Ge(Li) detectors (FWHM=2.4-3.0 keV at Eγ=1.33 MeV). Measured Eγ, Iγ, $\gamma\gamma$-coin, $\gamma\gamma$(t). Deduced levels.

1971Ju01: Source of ^{138}Pr was prepared by the (p,n) reaction on enriched ^{138}Ce target in the form of cerium oxide or cerium chloride, bombarded with E=10 MeV protons. γ rays were detected with a Ge(Li) detector (FWHM=5 keV at Eγ=1 MeV). Measured Eγ, Iγ. Deduced levels.

1970Ho28: ^{138}Pr source was prepared by (p,p3n) reaction with 99.999% pure praseodymium dioxide target bombarded with 48-MeV protons from the McGill University Synchrocyclotron. γ rays were detected with a Ge(Li) detector. Measured Eγ, Iγ. Deduced levels.

Others: 1964Fu08, 1965Gr38, 1965Ba45, 1967Ba66, 1968Na04.

The total average radiation energy released by ^{138}Pr ε decay is 4885 keV *155* (calculated by evaluator using the computer program RADLST). This value agrees well with Q(ε)=4437 keV *10* (2017Wa10) plus parent E(level)=364 *23* and shows the completeness of the decay scheme.

Decay scheme is that of 1974Bu03. Additional levels at 4026, 4145, and tentative levels at 1729, 1985 or 2058, 2011 or 2033, 2318, 3501 and 4107 proposed by 1972Lu01, levels at 2483, 2372, proposed by 1967Ba66, have not been confirmed by 1974Bu03.

^{138}Ce Levels

E(level)[†]	J^{π}[‡]	$T_{1/2}$[‡#]	Comments
0.0	0^+		
788.90 *10*	2^+	1.98 ps *4*	
1826.87 *14*	4^+	<40 ps	
2129.55 *17*	7^-	8.73 ms *20*	
2137.2 *3*	4^+		
2217.75 *17*	5^-	450 ps *30*	$T_{1/2}$: <0.3 ns from $\gamma\gamma$(t) (1972Lu01).
2765.24 *18*	6^-		
2899.4 *4*	6^-		
3368.3 *5*			
3670.9 *3*	$(6,7^-)$		
3800.9 *4*	$(6,7^-)$		
3927.0 *6*	$(6,7^-)$		
4157.3 *5*	6,7,8		
4248.4 *7*	$(6,7^-)$		

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

[‡] From Adopted Levels.

[#] $T_{1/2}$<0.3 ns for (547γ)(390γ) (1972Lu01).

^{138}Pr ε decay (2.03 h) 1974Bu03 (continued)

ε,β+ radiations

No (β^+)(303γ,789γ,1038γ) (1965Ba45,1964Fu08).

E(decay)	E(level)	Iβ+ ‡	Iε‡	Log *ft*	I(ε+β+)†‡	Comments
553 *20*	4248.4		0.10 *4*	7.1 *2*	0.10 *4*	εK=0.8345 *10*; εL=0.1287 *7*; εM+=0.03682 *23*
644 *20*	4157.3		0.314 *20*	6.7 *1*	0.314 *20*	εK=0.8371 *7*; εL=0.1267 *5*; εM+=0.03615 *17*
875 *20*	3927.0		0.184 *15*	7.2 *1*	0.184 *15*	εK=0.8412 *4*; εL=0.1236 *3*; εM+=0.03512 *9*
1001 *20*	3800.9		0.235 *17*	7.23 *4*	0.235 *17*	εK=0.8427 *3*; εL=0.12257 *19*; εM+=0.03477 *7*
1131 *20*	3670.9		0.42 *15*	7.1 *2*	0.42 *15*	εK=0.8438 *2*; εL=0.12174 *15*; εM+=0.03449 *5*
1433 *20*	3368.3	0.00027 *9*	0.120 *20*	7.8 *1*	0.120 *20*	av Eβ=195 *12*; εK=0.8436 *5*; εL=0.12013 *16*; εM+=0.03397 *5*
1902 *20*	2899.4	0.05 *3*	1.2 *7*	7.1 *3*	1.2 *7*	av Eβ=401 *11*; εK=0.814 *4*; εL=0.1145 *6*; εM+=0.03231 *15*
2036 *20*	2765.24	0.44 *4*	6.6 *3*	6.41 *3*	7.0 *3*	av Eβ=460 *11*; εK=0.794 *5*; εL=0.1114 *7*; εM+=0.03143 *19*
2672 *20*	2129.55	23 *2*	68 *5*	5.64 *4*	91 *6*	av Eβ=742 *12*; εK=0.633 *8*; εL=0.0881 *12*; εM+=0.0248 *4*
						E(decay): from E(β^+)=1650 *20* in 1964Fu08.
						I(1650β^+)/I(789γ)=0.23 *6* (1964Fu08).

† From γ+ce intensity balance at each level.
‡ Absolute intensity per 100 decays.

$\gamma(^{138}Ce)$

Iγ normalization: from I(789γ)=100%. No other transitions feed the ground state.

E_γ ‡	I_γ &d	E_i(level)	J_i^π	E_f	J_f^π	Mult. c	α †	Comments
x75.5 f 7	0.11 a 5							
79.4 6	0.14 6	2217.75	5−	2137.2	4+	[E1]	0.458 12	α(K)=0.388 10; α(L)=0.0556 15; α(M)=0.0116 3 α(N)=0.00252 7; α(O)=0.000388 10; α(P)=2.26×10^{-5} 6 I_γ: weighted average of 0.12 4 (1972Lu01) and 0.28 10 (1974Bu03). Additional information 3.
x158.0 b 10	0.11 b 5							
x170.0 f 7	0.14 a 7							
x177.5 @ 10	0.064 @ 14							
x184.0 @ 10	0.053 @ 16							
x196.0 @ 10	0.083 @ 17							
x206.0 b 10	0.16 b 7							
x231.0 b 10	0.12 b 6							
302.7 # 1	80 5	2129.55	7−	1826.87	4+	E3	0.183	α(K)=0.1237 18; α(L)=0.0463 7; α(M)=0.01035 15 α(N)=0.00224 4; α(O)=0.000325 5; α(P)=8.32×10^{-6} 12 Additional information 2. I_γ: weighted average of 80 5 (1972Lu01) and 80 8 (1974Bu03). Mult.: α(K)exp=0.129 10 (1964Fu08), 0.14 2 (1965Ba45), K/L+M=2.12 8 (1964Fu08), 2.5 3 (1965Ba45), K:L1:L2:L3=100:6.0 12:11.0 22:5.6 11 (1967Ba66), α(total)exp=0.190 11 (1964Fu08). for 303-1038 cascade, A_2=+0.198 12, A_4=+0.019 16 (1964Fu08), A_2=+0.22 3, A_4=−0.03 4 (1965Gr38); for 303-789 cascade A_2=+0.173 18, A_4=−0.028 25 (1964Fu08).
x351.0 @ 10	0.105 @ 21							
x354.2 f 3	4.0 4							E_γ,I_γ: from 1967Ba66 only. Placed from a level at 2483, which is not confirmed by 1974Bu03.
x359.4 # 1	0.24 a 20							
390.9 # 1	5.9 3	2217.75	5−	1826.87	4+	E1	0.00642	α(K)=0.00552 8; α(L)=0.000713 10; α(M)=0.0001482 21 α(N)=3.27×10^{-5} 5; α(O)=5.25×10^{-6} 8; α(P)=3.81×10^{-7} 6 Additional information 4. I_γ: weighted average of 6.06 30 (1972Lu01) and 5.8 3 (1974Bu03). Mult.: α(K)exp=0.0048 15 (1971Af05).
x457.9 # 4	0.5 a 4							
547.5 # 1	5.19 26	2765.24	6−	2217.75	5−	M1	0.01239	α(K)=0.01064 15; α(L)=0.001389 20; α(M)=0.000290 4 α(N)=6.43×10^{-5} 9; α(O)=1.045×10^{-5} 15; α(P)=8.07×10^{-7} 12 Additional information 5.

$^{138}_{58}Ce_{80}$-3

^{138}Pr ε decay (2.03 h) 1974Bu03 (continued)

γ(^{138}Ce) (continued)

E_γ ‡	I_γ &d	E_i(level)	J_i^π	E_f	J_f^π	Mult.[c]	δ	α†	Comments
									E_γ: 1967Ba66 placed a γ ray at 546.2 *5* from a level at 2372. I_γ: weighted average of 5.23 *26* (1972Lu01) and 5.1 *4* (1974Bu03). Mult.: α(K)exp=0.009 *3* (1971Af05).
635.7# *1*	1.83 *16*	2765.24	6⁻	2129.55	7⁻	M1		0.00858	α(K)=0.00737 *11*; α(L)=0.000958 *14*; α(M)=0.000200 *3* α(N)=4.43×10^{-5} *7*; α(O)=7.21×10^{-6} *10*; α(P)=5.58×10^{-7} *8* Additional information 6. I_γ: weighted average of 1.78 *10* (1972Lu01) and 2.3 *3* (1974Bu03). Mult.: α(K)exp=0.0048 *24* (1971Af05).
680.8 *5*	0.21 *4*	2899.4	6⁻	2217.75	5⁻	M1+E2	−2.5 *3*	0.00519 *11*	α(K)=0.00440 *10*; α(L)=0.000622 *12*; α(M)=0.0001306 *24* α(N)=2.88×10^{-5} *6*; α(O)=4.60×10^{-6} *9*; α(P)=3.19×10^{-7} *8* Additional information 7. I_γ: weighted average of 0.21 *4* (1972Lu01) and 0.21 *5* (1974Bu03).
770.4 *4*	0.60 *8*	2899.4	6⁻	2129.55	7⁻	M1		0.00539	α(K)=0.00463 *7*; α(L)=0.000598 *9*; α(M)=0.0001246 *18* α(N)=2.77×10^{-5} *4*; α(O)=4.50×10^{-6} *7*; α(P)=3.50×10^{-7} *5* Additional information 8. I_γ: weighted average of 0.66 *8* (1972Lu01) and 0.5 *1* (1974Bu03).
788.9# *1*	100 *5*	788.90	2⁺	0.0	0⁺	E2		0.00342	α(K)=0.00291 *4*; α(L)=0.000406 *6*; α(M)=8.52×10^{-5} *12* α(N)=1.88×10^{-5} *3*; α(O)=3.01×10^{-6} *5*; α(P)=2.10×10^{-7} *3* Additional information 1. E_γ: weighted average of 789.0 *1* (1972Lu01) and 788.7 *1* (1971Af05). Mult.: α(K)exp=0.0034 (1965Ba45), 0.0036 *7* (1971Af05), K/L=6.7 *8* (1964Fu08).
x940.0[b] *15*	0.50[b] *15*								
1038.0 *1*	101 *5*	1826.87	4⁺	788.90	2⁺	E2		0.00186	α(K)=0.001594 *23*; α(L)=0.000213 *3*; α(M)=4.44×10^{-5} *7* α(N)=9.83×10^{-6} *14*; α(O)=1.582×10^{-6} *23*; α(P)=1.156×10^{-7} *17* E_γ: weighted average of 1038.2 *1* (1972Lu01) and 1037.8 *1* (1971Af05). I_γ: weighted average of 101 *5* (1972Lu01) and 100 *5* (1974Bu03). Mult.: α(K)exp=0.00162 *9*, K/L+M=5.3 *6* (1964Fu08). A_2=+0.092 *10*, A_4=+0.017 *23* (1964Fu08); A_2=+0.055, A_4=−0.01 *5* (1965Gr38).
x1083.1[f] *10*	0.20[a] *5*								
x1202.4[f] *6*	≈0.06								
1239.6 *6*	1.08 *6*	3368.3		2129.55	7⁻				E_γ: unweighted average of 1240.1 *5* (1972Lu01) and 1239.0 *2* (1974Bu03). I_γ: weighted average of 1.06 *6* (1972Lu01) and 1.20 *15* (1974Bu03).
x1257.5 *10*	0.066 *14*								E_γ,I_γ: from 1972Lu01. Other: Iγ≤0.03 (1974Bu03).
x1279.7 *10*	0.080 *25*								E_γ,I_γ: from 1974Bu03.
x1282.5 *10*	0.090 *14*								E_γ,I_γ: from 1972Lu01.

$^{138}_{58}Ce_{80}$-4

γ(^{138}Ce) (continued)

E_γ[‡]	I_γ[&d]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[c]	α[†]	Comments
1348.0 *3*	0.37 *5*	2137.2	4^+	788.90	2^+	E2	1.12×10^{-3}	α(K)=0.000937 *14*; α(L)=0.0001213 *17*; α(M)=2.52×10^{-5} *4* α(N)=5.59×10^{-6} *8*; α(O)=9.05×10^{-7} *13*; α(P)=6.81×10^{-8} *10*; α(IPF)=3.17×10^{-5} *5* I_γ: weighted average of 0.33 *4* (1972Lu01) and 0.42 *5* (1974Bu03).
1392.6 *5*	0.127 *14*	4157.3	6,7,8	2765.24	6^-			E_γ: weighted average of 1392.1 *5* (1972Lu01) and 1393.0 *5* (1974Bu03). I_γ: weighted average of 0.120 *14* (1972Lu01) and 0.14 *2* (1974Bu03).
[x]1416.5 *10*	0.044 *12*							E_γ,I_γ: from 1972Lu01. Other: Iγ≤0.02 (1974Bu03).
1453.3 *3*	0.263 *19*	3670.9	(6,7$^-$)	2217.75	5^-			E_γ: 1455.2 *5* from 1972Lu01. I_γ: weighted average of 0.260 *19* (1972Lu01) and 0.28 *4* (1974Bu03).
[x]1509.3 *7*	0.054 *12*							E_γ: 1511.6 *10* in 1972Lu01. I_γ: weighted average of 0.056 *12* (1972Lu01) and 0.05 *2* (1974Bu03).
[x]1527.6 *4*	0.166 *17*							E_γ: 1529.4 *5* in 1972Lu01. I_γ: weighted average of 0.170 *17* (1972Lu01) and 0.16 *2* (1974Bu03).
1540.9[e] *5*	0.153[e] *14*	3368.3		1826.87	4^+			E_γ: 1542.6 *5* in 1972Lu01. I_γ: weighted average of 0.160 *14* (1972Lu01) and 0.14 *2* (1974Bu03).
1540.9[e] *5*	0.153[e] *14*	3670.9	(6,7$^-$)	2129.55	7^-			E_γ: 1542.6 *5* in 1972Lu01. I_γ: weighted average of 0.160 *14* (1972Lu01) and 0.14 *2* (1974Bu03).
1583.2 *5*	0.127 *13*	3800.9	(6,7$^-$)	2217.75	5^-			E_γ: 1585.2 *5* in 1972Lu01. I_γ: weighted average of 0.121 *13* (1972Lu01) and 0.14 *2* (1974Bu03).
[x]1631.5 *7*	0.04[a] *2*							
1671.2 *5*	0.108 *10*	3800.9	(6,7$^-$)	2129.55	7^-			E_γ: 1673.6 *5* in 1972Lu01. I_γ: weighted average of 0.102 *10* (1972Lu01) and 0.13 *2* (1974Bu03).
1709.2 *7*	0.088 *11*	3927.0	(6,7$^-$)	2217.75	5^-			E_γ: 1711.0 *5* in 1972Lu01. I_γ: weighted average of 0.088 *11* (1972Lu01) and 0.09 *2* (1974Bu03).
[x]1726.5 *7*	0.025 *8*							E_γ: 1727.0 *10* in 1972Lu01. I_γ: weighted average of 0.023 *8* (1972Lu01) and 0.04 *2* (1974Bu03).
1797.5 *7*	0.096 *10*	3927.0	(6,7$^-$)	2129.55	7^-			E_γ: 1800.3 *5* in 1972Lu01. I_γ: weighted average of 0.100 *10* (1972Lu01) and 0.08 *2* (1974Bu03).
[x]1808.1 *5*	0.248 *18*							E_γ: 1808.7 *5* in 1972Lu01. I_γ: weighted average of 0.251 *18* (1972Lu01) and 0.24 *3* (1974Bu03).
[x]1851.0 *9*	0.030 *7*							E_γ: 1855.1 *10* in 1972Lu01. I_γ: weighted average of 0.028 *7* (1972Lu01) and 0.05 *2* (1974Bu03).
[x]1864.4 *5*	0.215 *14*							E_γ: 1867.7 *5* in 1972Lu01. I_γ: weighted average of 0.214 *14* (1972Lu01) and 0.22 *3* (1974Bu03).
[x]1884.1 *5*	0.080 *8*							E_γ: 1889.0 *5* in 1972Lu01. I_γ: weighted average of 0.080 *8* (1972Lu01) and 0.08 *2* (1974Bu03).
[x]1914.0 *10*	0.016 *5*							E_γ,I_γ: from 1972Lu01. Other: Iγ≤0.01 (1974Bu03).
[x]1927.8 *10*	0.014 *5*							E_γ,I_γ: from 1972Lu01. Other: Iγ≤0.01 (1974Bu03).
[x]1947.0 *10*	0.023 *5*							E_γ,I_γ: from 1972Lu01. Other: Iγ≤0.01 (1974Bu03).
[x]1956.5 *10*	0.026 *5*							E_γ,I_γ: from 1972Lu01. Other: Iγ≤0.01 (1974Bu03).
[x]1957.0 *6*	0.095 *9*							E_γ: 1961.7 *5* in 1972Lu01. I_γ: weighted average of 0.094 *9* (1972Lu01) and 0.10 *2* (1974Bu03).
[x]1969	0.028 *7*							I_γ: from 1972Lu01. Other: ≤0.01 (1974Bu03).
[x]1979	0.014 *5*							I_γ: from 1972Lu01. Other: ≤0.01 (1974Bu03).

^{138}Pr ε decay (2.03 h) 1974Bu03 (continued)

γ(^{138}Ce) (continued)

E_γ ‡	I_γ &d	E_i(level)	J_i^π	E_f	J_f^π	Comments
x2010.2 *10*	0.032 *6*					E_γ: 2015.7 *10* in 1972Lu01. I_γ: weighted average of 0.034 *6* (1972Lu01) and 0.023 *13* (1974Bu03).
2026.6 *7*	0.187 *14*	4157.3	6,7,8	2129.55	7^-	E_γ: 2031.4 *5* in 1972Lu01. I_γ: weighted average of 0.190 *14* (1972Lu01) and 0.15 *5* (1974Bu03).
2030.2 *9*	0.06 *4*	4248.4	(6,7^-)	2217.75	5^-	
x2066.1 f *10*	0.02 a *1*					
x2111.7 *10*	0.03 a *1*					
2119.3 *9*	0.038 *7*	4248.4	(6,7^-)	2129.55	7^-	E_γ: 2120.2 *10* in 1972Lu01. I_γ: weighted average of 0.038 *7* (1972Lu01) and 0.040 *15* (1974Bu03).
x2198.5 @ *10*	0.012 @ *4*					
x2222.5 *10*	0.06 a *2*					
x2236.4 *10*	0.03 a *1*					

† Additional information 9.
‡ From 1974Bu03, unless otherwise noted.
# From 1971Af05.
@ Seen only by 1972Lu01.
& Weighted average of values from 1972Lu01 and 1974Bu03, unless otherwise noted.
a From 1974Bu03, not seen in 1972Lu01.
b Seen only in coincidence by 1972Lu01.
c From Adopted Gammas. Arguments from this dataset are ce data given as comments.
d Absolute intensity per 100 decays.
e Multiply placed with undivided intensity.
f Placement of transition in the level scheme is uncertain.
x γ ray not placed in level scheme.

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Decay Scheme

Intensities: $I_{(\gamma+ce)}$ per 100 parent decays
& Multiply placed: undivided intensity given