

Adopted Levels, Gammas

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	E. Browne, J. K. Tuli	NDS 109,2657 (2008)	1-Jun-2008

Q(β^-)=-1313 7; S(n)=7097 6; S(p)=4163 4; Q(α)=5835 5 [2012Wa38](#)

Note: Current evaluation has used the following Q record \$ -1313 6 7098 5 4163.2 25 5835 4 [2003Au03](#).

Assignment: ²³⁰Th(d,3n) chem ([1949Hy01](#),[1958Hi78](#),[1987Ah05](#)); parent ²²⁵Ac ([1949Hy01](#)); Th(38-MeV p) chem ([1973Ag01](#)).

Theory, Calculations:

[2001Gr18](#),[2000Gr11](#),[2000Gr15](#),[1999Gr32](#): Parity nonconservation study with atomic radiation and helicity of ce for 0.22 γ .

Calculated M1 contribution in E1.

[1997Sp03](#),[1997Fi02](#),[1996Au06](#): Calculated electric nuclear moments.

²²⁹Pa Levels

Cross Reference (XREF) Flags

A	²³³ Np α decay	D	²³⁰ Th(p,2n γ)
B	²²⁹ U ϵ decay	E	²³¹ Pa(p,t γ)
C	²³¹ Pa(p,t)		

E(level) [†]	J ^π [‡]	T _{1/2}	XREF	Comments
0.0 ^f	(5/2 ⁺)	1.50 d 5	AB E	% ϵ =99.52 5; % α =0.48 5 β_2 =0.185 (2002De24) T _{1/2} : measurement of 1987Ah05 . Other measurement: 1.4 d 4 (1949Hy01). J ^π : log ft=5.6 for the ϵ branch to 5/2 ⁺ ²²⁹ Th g.s.; systematics of 5/2[642] Nilsson orbitals. β_2 =0.185, β_3 =0.0 or 0.08 from A ₂ =1.13 in $\alpha(\theta)$ (2002De24). % ϵ and % α were determined by 1987Ah05 from K x-ray and α particle intensities. Other measurements: % ϵ =99.75, % α =0.25 (1951Si94). $\alpha(\theta)$ from oriented nuclei in ²³² Th(p,4n): 5580 $\alpha(\theta)$: A ₂ =1.13 11; 5670 $\alpha(\theta)$: A ₂ =0.81 11 (1999Sc17 , 1997Sc26).
11.4 ^f 2	(7/2 ⁺)		B D	
11.6 [#] 3	3/2 ⁻		BCDE	Additional information 1. E(level): from (p,t γ).
26.7 [@] 4	1/2 ⁻		C	E(level): from (p,t).
59.1 ^f 5	(9/2 ⁺)		D	
68.1 [#] 3	7/2 ⁻		CD	
95.2 ^{?f}	(11/2 ⁺)		D	
99.3 [@] 4	5/2 ⁻		C	E(level): from (p,t).
134.10 10	(5/2 ⁻)		BCD	J ^π : Suggested configuration=5/2[523]+5/2[512] (1994Le22).
178.0 [#] 4	11/2 ⁻		CD	
220.0 [@] 4	9/2 ⁻		CD	
222.45 17	(3/2 ⁺)		B D	J ^π : Suggested configuration=3/2[651] (1994Le22).
251.9 ^{&} 6	1/2 ⁺		C	E(level): from (p,t).
253.34 14	(7/2 ⁺)		B D	J ^π : Suggested configuration=3/2[651] (1994Le22).
284.1 ^{&} 4	5/2 ⁺		C	E(level): from (p,t).
303.0 ^a 3	3/2 ⁺		C	E(level): from (p,t).
338.1 [#] 4	15/2 ⁻		CD	
377.3 ^{&} 4	9/2 ⁺		CD	
386.2 [@] 5	13/2 ⁻		CD	
392.4 ^a 5	7/2 ⁺		D	

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Adopted Levels, Gammas (continued) ^{229}Pa Levels (continued)

E(level) [†]	J ^π [‡]	XREF	Comments
470.26 16	(1/2,3/2,5/2)	B	J ^π : populated by ε decay from (3/2 ⁺) ^{229}U .
520.6 ^a 5	11/2 ⁺	D	
521.6 ^{&} 4	13/2 ⁺	CD	
545.3 [#] 5	19/2 ⁻	CD	
594.2 [@] 10	17/2 ⁻	CD	
689.2 ^a 5	15/2 ⁺	CD	
712.3 ^{&} 5	17/2 ⁺	CD	
714.4 ^b 8	(3/2 ⁻)	C	
738.7 ^b 9	(1/2 ⁻)	C	
767.4 ^b 7	(7/2 ⁻)	C	
788.4 8		C	
794.6 [#] 6	(23/2 ⁻)	CD	
812.1 ^b 7	(5/2 ⁻)	C	
840.8 [@] 10	(21/2 ⁻)	D	
842.1 ^c 7	3/2 ⁻	C	
858.2 ^c 9	(1/2 ⁻)	C	
876.6 ^c 8	(7/2 ⁻)	C	
902.9 ^c 9	(5/2 ⁻)	C	
942.1 ^c 10	(11/2 ⁻)	C	
978.0 10	3/2 ⁻	C	
991.2 9	3/2 ⁻	C	
1005.9 9	3/2 ⁻	C	
1024.2 15		C	
1033.6 10		C	
1068.5 10		C	
1075.5 13		C	
1085.0 10		C	
1116.4 10	(3/2 ⁻)	C	
1132.9 11		C	
1145.9 12		C	
1161.3 11		C	
1172.6 10		C	
1185.5 12		C	
1196.1 12		C	
1211.4 11		C	
1220.1 11		C	
1240.8 11		C	
1264.3 11		C	
1298.5 12		C	
1313.8 12		C	
1370.6 10	3/2 ⁻	C	
1412.5 11	3/2 ⁻	C	
1438.6 11	(3/2 ⁻)	C	
1468.8 12	(3/2 ⁻)	C	
1490.9 12		C	
1521.8 13	3/2 ⁻	C	
1535.3 ^d 13	3/2 ⁻	C	
1551.6 ^d 14	(1/2 ⁻)	C	
1581.4 ^d 13	(7/2 ⁻)	C	
1604.3 ^d 13	(5/2 ⁻)	C	
1610 ^e 5	(1/2 ⁺)	C	

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Adopted Levels, Gammas (continued)

²²⁹Pa Levels (continued)

E(level) [†]	J ^π [‡]	XREF	E(level) [†]	J ^π [‡]	XREF	E(level) [†]	XREF
1628.4 ^e 13	(5/2 ⁺)	C	1697.8 ^e 14	(9/2 ⁺)	C	1768.3 14	C
1648.0 ^e 13	(3/2 ⁺)	C	1720.5 ^d 14	(9/2 ⁻)	C	1784.8 14	C
1664.6 13		C	1742.9 14		C	1844.2 15	C
1678.3 ^d 14	(11/2 ⁻)	C	1753.7 14		C		

[†] Level energies are from least-squares fit to adopted γ -ray energies, readjusted to 11.6 keV 3 for the 3/2⁻ member of the 1/2⁻[530] rotational band (1998Le15).

[‡] J^π assignments are based on rotational structure, L-transfer values in the ²³¹Pa(p,t) reaction, γ -ray multiplicities from ²³⁰Th(p,2n γ) and ²²⁹U ϵ decay, and on the energy systematics of Nilsson single-particle orbitals in other neighboring odd-A protactinium isotopes.

Band(A): K^π=1/2⁻, s=-i band. Main configuration=1/2[530].

@ Band(B): K^π=1/2⁻, s=+i band. Main configuration=1/2[530].

& Band(C): K^π=1/2⁺, s=-i band. Main configuration=1/2[660].

^a Band(D): K^π=1/2⁺, s=+i band. Main configuration=1/2[660].

^b Band(E): K^π=1/2⁻ ²²⁸Th core-excited rotational band.

^c Band(F): K^π=1/2⁻ ²²⁸Th core-excited rotational band.

^d Band(G): K^π=1/2⁻ ²²⁸Th core-excited rotational band.

^e Band(H): K^π=1/2⁺ ²²⁸Th core-excited rotational band.

^f Band(I): 5/2[642].

γ (²²⁹Pa)

E _i (level)	J _i ^π	E _{γ} [†]	I _{γ}	E _f	J _f ^π	Mult.	Comments
11.4	(7/2 ⁺)	(11.2 7)		0.0	(5/2 ⁺)		
11.6	3/2 ⁻	11.6 3		0.0	(5/2 ⁺)	E1	E _{γ} : from (p,t γ).
59.1	(9/2 ⁺)	48 [#]		11.4	(7/2 ⁺)		
68.1	7/2 ⁻	56.4 3		11.6	3/2 ⁻	E2	
134.10	(5/2 ⁻)	122.51 [‡] 10	100	11.6	3/2 ⁻	M1	Mult.: from ϵ decay.
178.0	11/2 ⁻	82.6 [#]		95.2?	(11/2 ⁺)	(E1)	
		109.9 2		68.1	7/2 ⁻	E2	
		118.9 3		59.1	(9/2 ⁺)	E1	
220.0	9/2 ⁻	42.0 3		178.0	11/2 ⁻	(M1)	
		86.5 9		134.10	(5/2 ⁻)	(E2)	
222.45	(3/2 ⁺)	88.4 [‡] 5	100 10	134.10	(5/2 ⁻)	E1	Mult.: from ϵ decay.
		211.09 [‡] 10	20 2	11.4	(7/2 ⁺)	[E2]	
253.34	(7/2 ⁺)	119.24 [‡] 10	41 5	134.10	(5/2 ⁻)	E1	Mult.: from ϵ decay.
		241.92 [‡] 10	100 10	11.4	(7/2 ⁺)		
338.1	15/2 ⁻	160.1 2		178.0	11/2 ⁻	E2	
377.3	9/2 ⁺	199.3 2		178.0	11/2 ⁻	E1	
386.2	13/2 ⁻	48.1 3		338.1	15/2 ⁻	(M1)	
		208.2 5		178.0	11/2 ⁻	(M1)	
392.4	7/2 ⁺	172.4 3		220.0	9/2 ⁻	E1	
470.26	(1/2,3/2,5/2)	216.90 [‡] 10	42 4	253.34	(7/2 ⁺)		E _{γ} : from ϵ decay.
		247.84 [‡] 10	100 8	222.45	(3/2 ⁺)		E _{γ} ,Mult.: from ϵ decay.
520.6	11/2 ⁺	128.2 [#]		392.4	7/2 ⁺		
		134.4 5		386.2	13/2 ⁻	E1	
		300.6 2		220.0	9/2 ⁻	E1	
521.6	13/2 ⁺	143.3 [#]		377.3	9/2 ⁺		

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Adopted Levels, Gammas (continued) $\gamma(^{229}\text{Pa})$ (continued)

$E_i(\text{level})$	J_i^π	E_γ^\dagger	E_f	J_f^π	Mult.	$E_i(\text{level})$	J_i^π	E_γ^\dagger	E_f	J_f^π	Mult.
521.6	13/2 ⁺	183.5 4	338.1	15/2 ⁻	E1	712.3	17/2 ⁺	167.0 4	545.3	19/2 ⁻	E1
		343.6 2	178.0	11/2 ⁻	E1			190.7 [#] 6	521.6	13/2 ⁺	E2
545.3	19/2 ⁻	207.2 2	338.1	15/2 ⁻	E2			374.2 3	338.1	15/2 ⁻	E1
594.2	17/2 ⁻	256.1 9	338.1	15/2 ⁻	(M1)	794.6	(23/2 ⁻)	249.3 3	545.3	19/2 ⁻	(E2)
689.2	15/2 ⁺	168.6 [#]	520.6	11/2 ⁺		840.8	(21/2 ⁻)	295.5 9	545.3	19/2 ⁻	
		303.0 2	386.2	13/2 ⁻	E1						

† From $^{230}\text{Th}(p,2n\gamma)$, unless otherwise specified.

‡ From ^{229}U ε decay.

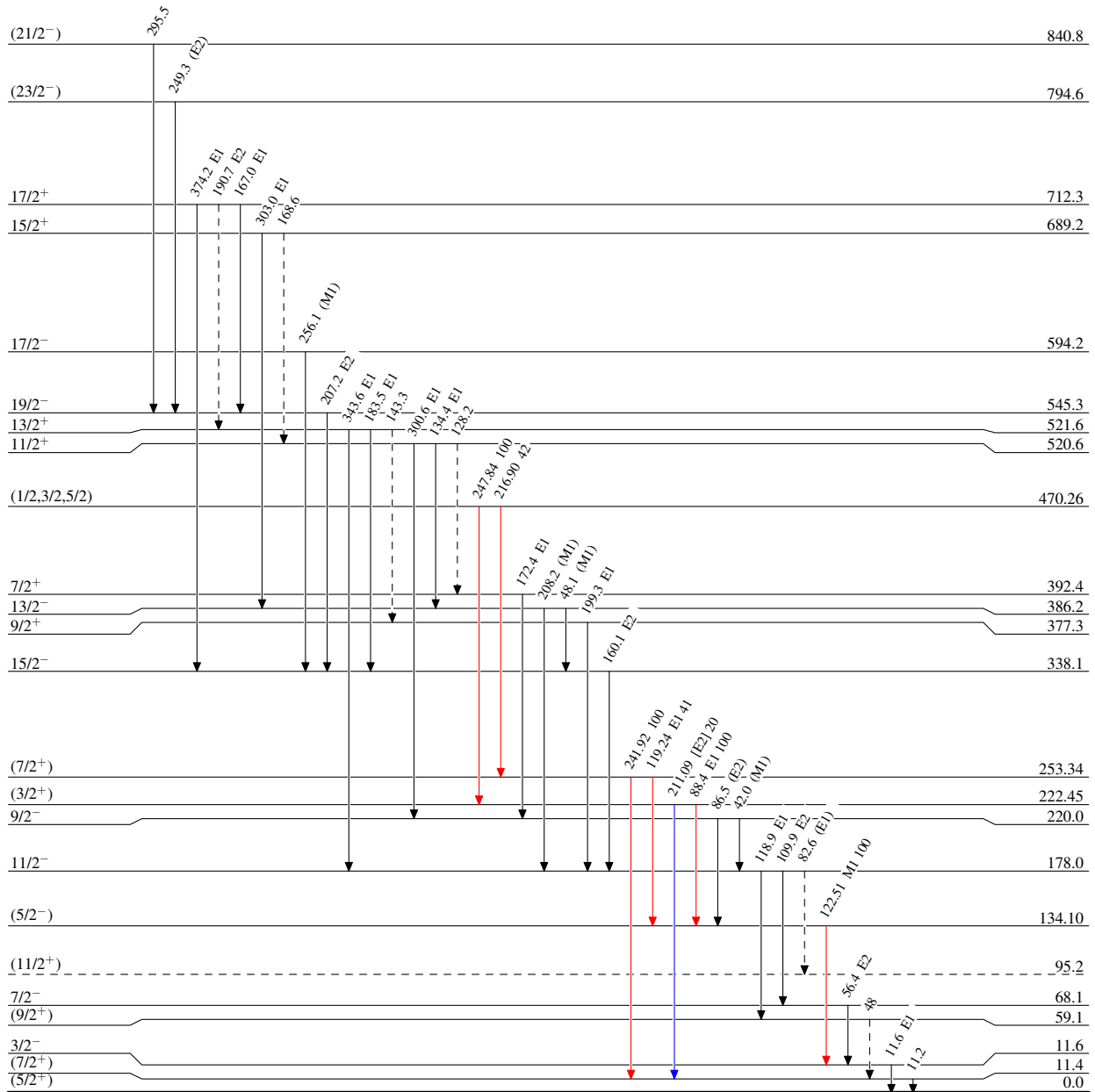
Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Legend

Level Scheme
 Intensities: Type not specified

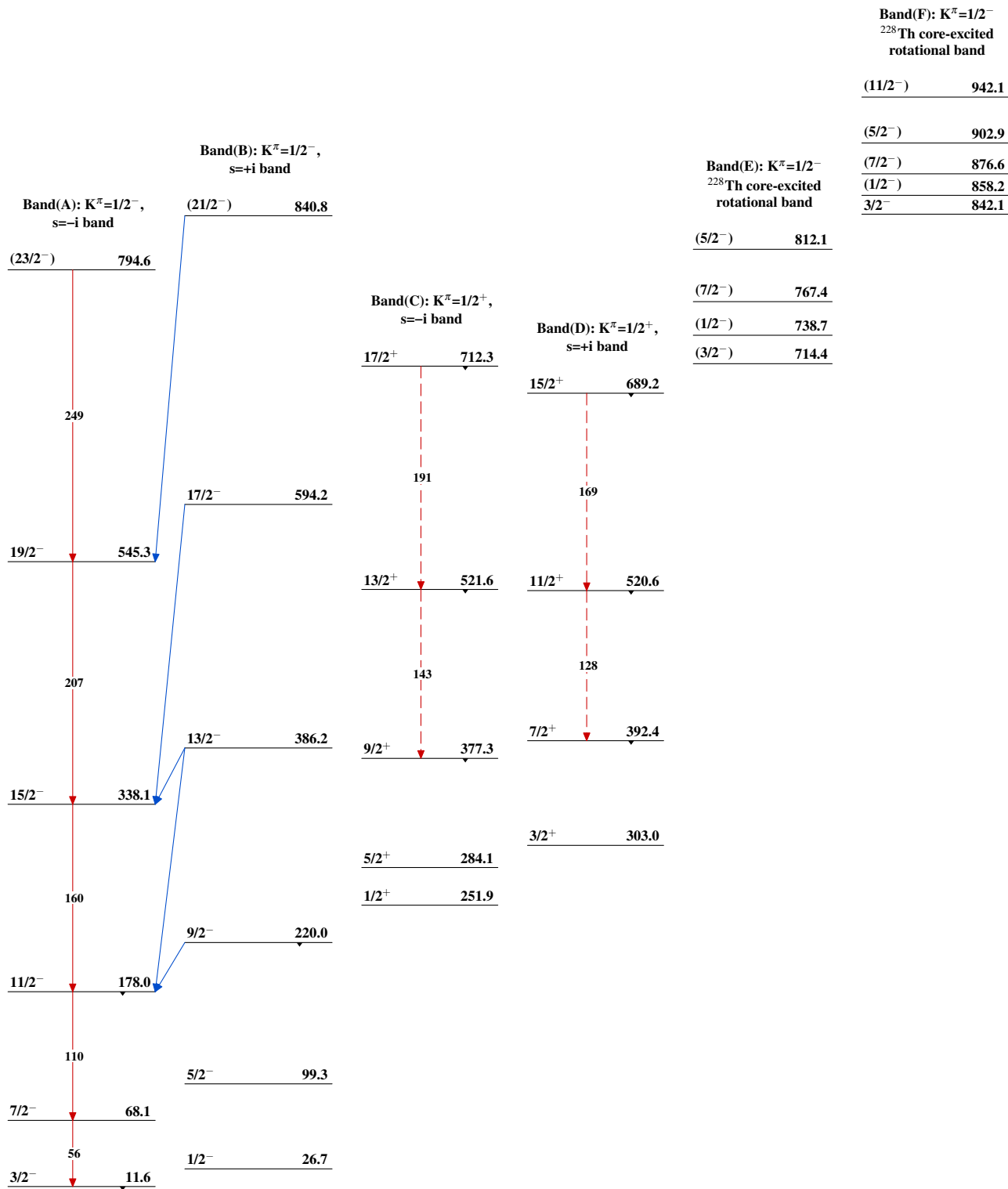
- ▶ $I_\gamma < 2\% \times I_\gamma^{max}$
- ▶ $I_\gamma < 10\% \times I_\gamma^{max}$
- ▶ $I_\gamma > 10\% \times I_\gamma^{max}$
- - -▶ γ Decay (Uncertain)



1.50 d 5

$^{229}_{91}\text{Pa}_{138}$

Adopted Levels, Gammas



Adopted Levels, Gammas (continued)

Band(G): $K^\pi=1/2^-$		Band(H): $K^\pi=1/2^+$	
^{228}Th core-excited		^{228}Th core-excited	
rotational band		rotational band	
<u>(9/2⁻)</u>	<u>1720.5</u>	<u>(9/2⁺)</u>	<u>1697.8</u>
<u>(11/2⁻)</u>	<u>1678.3</u>	<u>(3/2⁺)</u>	<u>1648.0</u>
		<u>(5/2⁺)</u>	<u>1628.4</u>
<u>(5/2⁻)</u>	<u>1604.3</u>	<u>(1/2⁺)</u>	<u>1610</u>
<u>(7/2⁻)</u>	<u>1581.4</u>		
<u>(1/2⁻)</u>	<u>1551.6</u>		
<u>3/2⁻</u>	<u>1535.3</u>		
		Band(I): 5/2[642]	
		<u>(11/2⁺)</u>	<u>95.2</u>
		<u>(9/2⁺)</u>	<u>59.1</u>
			↓ 48
		<u>(7/2⁺)</u>	<u>11.4</u>
			↓ 11
		<u>(5/2⁺)</u>	<u>0.0</u>