^{178}Hf(d,p), ^{180}Hf(d,t) 1989Ri03,1963Ve09,1968Ri07

History			
Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Coral M. Baglin	NDS 110, 265 (2009)	15-Nov-2008

1989Ri03: E=15 MeV for (d,t); E=15, 23 MeV for (d,p). Measured proton and triton spectra at θ(lab)=45°. Detector: magnetic spectrograph + 576-wire detector. See also 1985Ri09.

1968Ri07: (d,p), ED=12 MeV. 96.0% ^{178}Hf target; measured proton spectra (short exposures only, to obtain normalization to data of 1963Ve09) at θ=65° and 90°; magnetic spectrograph. Measured triton spectra at θ(lab)=50°, 65°, and 90°; 99.0% ^{180}Hf target; magnetic spectrograph + nuclear emulsions.

1963Ve09: (d,p), ED=12 MeV. 95.5% enriched ^{178}Hf target. Measured unnormalized proton spectra at θ(lab)=25°, 35°, 45°, 55°, 65°, 77°, and 90°; magnetic spectrograph + nuclear emulsions, FWHM≈15 keV for similar target and geometry.

^{179}Hf Levels

E(level)[#]	J$^\pi$[‡]	L[@]	C^{2}S[†]	Comments
0.0[c] *1*	9/2$^+$		0.078	σ(E=23 MeV)/σ(E=15 MeV)=2.1 *5*, L=2-5 (1989Ri03).
123.4[c] *4*	11/2$^+$		0.023	σ(E=23 MeV)/σ(E=15 MeV)=2.4 *10*, L=0-6 (1989Ri03).
214.1[d] *13*	7/2$^-$		0.016	
269.1[c] *1*	13/2$^+$	6		σ(E=23 MeV)/σ(E=15 MeV)=4.4 *5* (1989Ri03). J$^\pi$: from L(d,p)=6 and band assignment (1989Ri03).
337.7[d] *1*	9/2$^-$		0.58	σ(E=23 MeV)/σ(E=15 MeV)=1.7 *3* (1989Ri03).
375.2[e] *2*	1/2$^-$	0,1	0.019	σ(E=23 MeV)/σ(E=15 MeV)=0.95 *13* (1989Ri03).
420.9[e] *1*	3/2$^-$	0,1	0.62	σ(E=23 MeV)/σ(E=15 MeV)=1.00 *8* (1989Ri03).
440.1[c] *7*	15/2$^+$			
476.4[e] *1*	5/2$^-$	2,3,5	0.76	σ(E=23 MeV)/σ(E=15 MeV)=1.49 *15* (1989Ri03).
486.9[d] *4*	11/2$^-$		0.93	
518.3[f] *1*	5/2$^-$		0.014	σ(E=23 MeV)/σ(E=15 MeV)=2.1 *7*, L=0-5 (1989Ri03).
582.1[e] *3*	7/2$^-$		0.24	σ(E=23 MeV)/σ(E=15 MeV)=1.49 *16*, L=2-5 (1989Ri03).
615.4 *1*				Probably a doublet comprised of the J$^\pi$=1/2$^-$ and J$^\pi$=7/2$^-$ members of the 1/2[521] and 5/2[512] rotational bands, respectively, with C^{2}S≈0.079 and≈0.22. σ(E=23 MeV)/σ(E=15 MeV)=1.34 *12* (1989Ri03) for doublet.
632.3[&c] *6*	17/2$^+$			σ(E=23 MeV)/σ(E=15 MeV)=2.6 *9* (1989Ri03).
665.0[ad] *14*	(13/2$^-$)			
679.5[g] *1*	3/2$^-$		0.014	σ(E=23 MeV)/σ(E=15 MeV)=1.12 *11* (1989Ri03).
701.0[g] *1*	5/2$^-$		0.081	σ(E=23 MeV)/σ(E=15 MeV)=1.47 *15*, L=2-5 (1989Ri03).
720.5[h] *5*	3/2$^-$	0,1	0.13	σ(E=23 MeV)/σ(E=15 MeV)=0.83 *8* (1989Ri03).
732.2 *4*				σ(E=23 MeV)/σ(E=15 MeV)=1.1 *4*, L=0-3,5 (1989Ri03).
742.5[f] *3*	9/2$^-$			
788.0[h] *3*	5/2$^-$	2,3,5	0.59	σ(E=23 MeV)/σ(E=15 MeV)=1.39 *11* (1989Ri03).
849.2[g] *1*	7/2$^-$	2,3,5	0.057	σ(E=23 MeV)/σ(E=15 MeV)=1.26 *12* (1989Ri03).
860.3[ad] *7*	(15/2$^-$)			
870.3[i] *1*	7/2$^-$		1.34	σ(E=23 MeV)/σ(E=15 MeV)=1.55 *12*, L=2-5 (1989Ri03).
889.1[&] *9*				
896.4 *2*				σ(E=23 MeV)/σ(E=15 MeV)=1.9 *6*, L=1-5 (1989Ri03).
912.5 *3*				σ(E=23 MeV)/σ(E=15 MeV)=1.8 *5*, L=1-5 (1989Ri03).
935.6[h] *1*	7/2$^-$			σ(E=23 MeV)/σ(E=15 MeV)=1.06 *14*, L=0,1,3,5 (1989Ri03).
958.6 *13*				
992.0[i] *14*	(9/2$^-$)			σ(E=23 MeV)/σ(E=15 MeV)=1.5 *4*, L=0-5 (1989Ri03).
1004.1[j] *3*	5/2$^+$			σ(E=23 MeV)/σ(E=15 MeV)=1.6 *3*, L=2-5 (1989Ri03).
1024.0[a] *16*				
1030.8[&h] *3*	9/2$^-$			σ(E=23 MeV)/σ(E=15 MeV)=1.7 *4*, L=2-5 (1989Ri03).
1074.8[&] *7*				

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^{178}Hf(d,p), ^{180}Hf(d,t) 1989Ri03,1963Ve09,1968Ri07 (continued)

^{179}Hf Levels (continued)

E(level)[#]	Jπ[‡]	L[@]	Comments
1078.6[&j] *13*	7/2+		
1080.4[a] *13*			
1087.8[a] *6*			
1096.8[&] *11*			
1122.0[a] *16*			
1138.8 *3*			σ(E=23 MeV)/σ(E=15 MeV)=2.2 *5*, L=2-5 (1989Ri03).
1150.4[l] *2*	1/2+	0,1	σ(E=23 MeV)/σ(E=15 MeV)=0.70 *22* (1989Ri03).
1162.4[&] *5*			Doublet (1989Ri03).
1168.6[k] *1*	9/2+		σ(E=23 MeV)/σ(E=15 MeV)=2.1 *4*, L=2-5 (1989Ri03).
1176.2[&j] *7*	(9/2+)		σ(E=23 MeV)/σ(E=15 MeV)=3.4 *12*, L=2-6 (1989Ri03).
1183.1[l] *14*	3/2+		
1199.9 *1*			σ(E=23 MeV)/σ(E=15 MeV)=2.6 *9*, L=1-6 (1989Ri03).
1235.6[&l] *4*	5/2+		σ(E=23 MeV)/σ(E=15 MeV)=1.6 *5*, L=0-5 (1989Ri03).
1249.6[m] *1*	3/2−		σ(E=23 MeV)/σ(E=15 MeV)=1.5 *4*, L=0-5 (1989Ri03).
1269.4[n] *1*	3/2−		σ(E=23 MeV)/σ(E=15 MeV)=1.6 *6*, L=0-5 (1989Ri03).
1282.5[k] *7*	11/2+		
1313.4[m] *4*	5/2−		σ(E=23 MeV)/σ(E=15 MeV)=1.2 *3*, L=0-5 (1989Ri03).
1344.6[&] *4*		4,6	σ(E=23 MeV)/σ(E=15 MeV)=3.7 *9* (1989Ri03).
1359.0[k] *2*	13/2+		σ(E=23 MeV)/σ(E=15 MeV)=2.1 *6* (1989Ri03). L=2-5 in table 1 of 1989Ri03 but L=6 indicated in fig. 1.
1386.5 *4*			σ(E=23 MeV)/σ(E=15 MeV)=2.9 *7*, L=2-6 (1989Ri03).
1405.2[m] *3*	7/2−		
1428.6[n] *1*	(7/2−)		σ(E=23 MeV)/σ(E=15 MeV)=1.0 *8*, L=0-5 (1989Ri03).
1436.0 *4*			σ(E=23 MeV)/σ(E=15 MeV)=1.5 *7*, L=0-5 (1989Ri03).
1453.1[a] *5*			
1459.0[o] *3*	3/2−	0,1	σ(E=23 MeV)/σ(E=15 MeV)=0.76 *11* (1989Ri03).
1482.2[ap] *5*	3/2+		
1509.2[a] *6*			
1530.2[&] *1*	1/2+	0	Jπ: from L=0. σ(E=23 MeV)/σ(E=15 MeV)=0.33 *6* (1989Ri03).
1531.6[p] *2*	5/2+		From (d,t) only; doublet (1989Ri03).
1534.6[&o] *2*	(5/2−)		σ(E=23 MeV)/σ(E=15 MeV)=1.29 *22*, L=2-5 (1989Ri03).
1557.4 *2*		0,1	σ(E=23 MeV)/σ(E=15 MeV)=0.75 *13* (1989Ri03).
1570.1[&] *5*			σ(E=23 MeV)/σ(E=15 MeV)=1.7 *6*, L=0-5 (1989Ri03).
1580.5[&] *1*			
1582.4 *2*			Doublet (1989Ri03). σ(E=23 MeV)/σ(E=15 MeV)=1.55 *17* (1989Ri03).
1586.0[&] *3*			
1598.4[&] *4*			σ(E=23 MeV)/σ(E=15 MeV)=1.5 *4*, L=0-5 (1989Ri03).
1602.3[a] *8*			
1614.9 *4*			σ(E=23 MeV)/σ(E=15 MeV)=1.0 *3*, L=0-3,5 (1989Ri03).
1638.7 *4*			σ(E=23 MeV)/σ(E=15 MeV)=0.99 *21*, L=0-3 (1989Ri03).
1658.4[q] *1*	(1/2−)	0,1,2	σ(E=23 MeV)/σ(E=15 MeV)=0.93 *14* (1989Ri03).
1665.7 *2*	1/2+	0	Jπ: from L=0. σ(E=23 MeV)/σ(E=15 MeV)=0.58 *10* (1989Ri03).
1687.0 *3*			σ(E=23 MeV)/σ(E=15 MeV)=1.02 *21*, L=0-3,5 (1989Ri03).
1698.6 *3*			
1705.8[q] *3*	(3/2−)		
1715.2 *18*			
1726.4 *8*			
1752.8 *2*			

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^{178}Hf(d,p), ^{180}Hf(d,t) 1989Ri03,1963Ve09,1968Ri07 (continued)

^{179}Hf Levels (continued)

E(level)[#]	E(level)[#]	E(level)[#]	E(level)[#]
1760.9 *3*	1926.3 *5*	2182	2606
1770.8 *5*	1964.7 *4*	2220 *3*	2665
1784.7 *4*	1977.0 *1*	2251 *3*	2700[b]
1799.7 *4*	1987.1 *5*	2282 *3*	2727
1811.0 *1*	2008.7 *15*	2297 *3*	2742 *3*
1838.7 *4*	2020.5 *7*	2354 *3*	2788 *3*
1847.6 *4*	2031.9 *8*	2392 *3*	2857
1857.0 *5*	2039.8 *3*	2419	2921 *3*
1877.0 *10*	2049.6 *8*	2455	2950 *3*
1884.0 *5*	2067	2497 *3*	2969
1895.3 *5*	2089	2521	2986
1903.8 *5*	2144	2556 *3*	
1915.1 *2*	2161	2590	

† Spectroscopic factors are for the (d,p) reaction; they are σ(exp)/ σ(DWBA)=2C(j,l)^{2}U^2 as implied in table X of 1968Ri07.

‡ Probable values based on L (from 1989Ri03), C^{2}S (from 1968Ri07), and/or deduced rotational structure, except As noted. Nilsson orbital assignments are from 1989Ri03.

Level energies are from 1989Ri03 for E≤2050 keV, from 1963Ve09 for E>2050 keV (ΔE≤3 keV, except as noted). Statistical uncertainties only are given here for data from 1989Ri03; additional systematic uncertainties of <0.5 keV for E≤1700, <3 keV for E=1700-2050 apply to these data. Levels with E>1650 are observed only in (d,p); ΔE>3 keV for these levels, if not noted otherwise.

@ Based on [σ(exp);E=23 MeV]/[σ(exp);E=15 MeV] in (d,p) (1989Ri03). See comments on individual levels for ranges of L based on this criterion for several additional levels.

& Observed in (d,p) only.

a Observed in (d,t) only.

b ΔE>10 keV.

c Band(A): 9/2[624] band.

d Band(B): 7/2[514] band.

e Band(C): 1/2[510] band. Assignment supported by level energies and cross section fingerprint.

f Band(D): 5/2[512] band.

g Band(E): 1/2[521] band. Assignment supported by level energies and cross section fingerprint (1968Ri07).

h Band(F): 3/2[512] band.

i Band(G): 7/2[503] band.

j Band(H): K$^\pi$=5/2$^+$ g.s. γ-vibrational band.

k Band(I): 7/2[633] band.

l Band(J): K$^\pi$=1/2+(1/2[510] + 1$^-$) band.

m Band(K): K$^\pi$=3/2−(7/2[514] + 2$^+$) band.

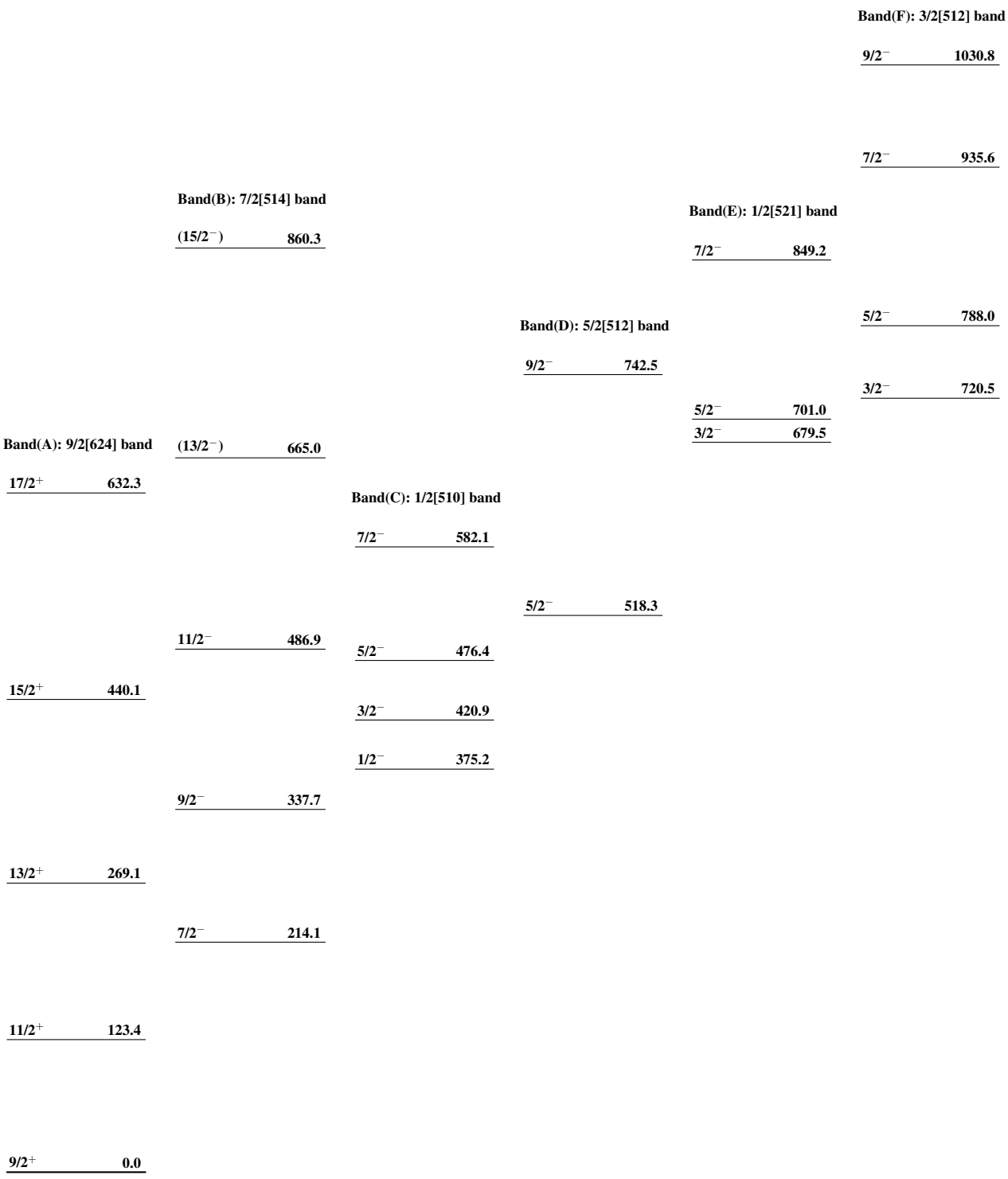
n Band(L): 3/2[521] band.

o Band(M): 3/2[501] band.

p Band(N): K$^\pi$=3/2+(1/2[521] + 1$^-$) band.

q Band(O): 1/2[501] band.

^{178}Hf(d,p), ^{180}Hf(d,t) 1989Ri03,1963Ve09,1968Ri07



$^{179}_{72}Hf_{107}$

^{178}Hf(d,p), ^{180}Hf(d,t) 1989Ri03,1963Ve09,1968Ri07 (continued)

Band(L): 3/2[521] band

(7/2$^-$) 1428.6

Band(K): K$^\pi$=3/2−(7/2[514] + 2$^+$) band

7/2$^-$ 1405.2

Band(I): 7/2[633] band

13/2$^+$ 1359.0

5/2$^-$ 1313.4

11/2$^+$ 1282.5

3/2$^-$ 1269.4

Band(J): K$^\pi$=1/2+(1/2[510] + 1$^-$) band

3/2$^-$ 1249.6

5/2$^+$ 1235.6

Band(H): K$^\pi$=5/2$^+$ g.s. γ-vibrational band

3/2$^+$ 1183.1

(9/2$^+$) 1176.2

9/2$^+$ 1168.6

1/2$^+$ 1150.4

7/2$^+$ 1078.6

Band(G): 7/2[503] band

5/2$^+$ 1004.1

(9/2$^-$) 992.0

7/2$^-$ 870.3

$^{179}_{72}Hf_{107}$

^{178}Hf(d,p), ^{180}Hf(d,t) 1989Ri03,1963Ve09,1968Ri07 (continued)

Band(O): 1/2[501] band

$(3/2^-)$ 1705.8

$(1/2^-)$ 1658.4

Band(M): 3/2[501] band

$(5/2^-)$ 1534.6

Band(N): K^π=3/2+(1/2[521] + 1^-) band

$5/2^+$ 1531.6

$3/2^+$ 1482.2

$3/2^-$ 1459.0

$^{179}_{72}Hf_{107}$