Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

Q(β^-)=13436.9 *10*; S(n)=4878.8 *17*; S(p)=15804.8 *22*; Q(α)=−10817.9 *10* 2021Wa16
S_{2n}=8248.4 *17*; S_{2p}=38744 *1*; Q(β-n)=8490.6 *10* (2021Wa16).

General theory:
1973Sa25, 1973Sa30, 1974Ch46, 1981Av02, 1981Se06, 1983Va08, 1984Va06, 1990Wo10, 1991Po11, 1994Ho21, 1995Ka23, 1997Ba54, 1997Re07, 1999Gu14, 1999Kn04, 1999Ta09, 2001Ka66, 2001Ta04, 2003Is17, 2003Jh01, 2003Sm02, 2003Su04, 2004Um01, 2005Ar12, 2007Gu03, 2008Ka24, 2008Ka36, 2008Sh16, 2011Al11, 2011SuZU, 2012Yu07, 2013Ma60, 2014Me02, 2015Fo06, 2015Ka02, 2015Sh21, 2020Ch40, 2021Ca23, 2021Ma32, 2022Mo36, 2023Me02.

Calculations related to dipole and quadrupole moments:
1972Gu05, 1984Ku07, 1984Va06, 1988Va03, 1991Bo02, 1998Hu08, 1999Ki27, 1999Ki28, 2001Sa24, 2002Sa12, 2003Is17, 2003Jh01, 2003Sm02, 2003Su04, 2003Su28, 2003Um02, 2014Ra17, 2021Ca23.

Mirror nuclear decay and fundamental symmetry effect studies:
1970Wi02, 1971Bl12, 1973Sa25, 1973Wi11, 1977Az02, 1977Ri08, 1993Ch06, 1999Ba21, 2023Se01.

Other relevant results:
1973Sa25: General review of the A=13 isobars and discussion on the isobaric multiplet mass equation. See also (1983An15).
2010Ma44: Measured G-parity conservation via correlations of nuclear spins and β-ray angular distribution. Found $\alpha_{-}(^{13}B)$=+0.05% *2* MeV^{-1} and g_{II}/g_a=−0.8 *5*.

^{13}B Levels

Cross Reference (XREF) Flags

A	^{14}Be β^-n decay	P	^{12}C(^{9}Be,^{8}B)	AD	^{14}C(γ,p)
B	^{1}H(^{12}Be,^{13}Be)	Q	^{12}C(^{12}Be,^{13}B)	AE	^{14}C(d,^{3}He)
C	^{1}H(^{13}B,X)	R	^{12}C(^{13}C,^{12}N)	AF	^{14}C(t,^{4}He)
D	^{2}H(^{12}B,p)	S	^{12}C(^{14}C,^{13}N)	AG	^{14}C(^{11}B,^{12}C)
E	^{2}H(^{13}B,^{13}B)	T	^{12}C(^{15}N,^{14}O)	AH	^{15}N(p,3p)
F	^{2}H(^{15}C,α)	U	^{12}C(^{16}O,^{13}B),(^{18}O,^{13}B)	AI	^{16}O(^{14}C,^{17}F)
G	^{4}He(^{9}Li,α)	V	^{13}C(γ,π^+)	AJ	^{48}Ca(^{11}B,^{13}B)
H	^{4}He(^{12}Be,^{13}Bγ)	W	^{13}C(μ^-,ν)	AK	^{136}Xe(p,^{13}B)
I	^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,pγ)	X	^{13}C(π^-,γ)	AL	^{181}Ta(^{22}Ne,^{13}B),(^{20}Ne,^{13}B)
J	^{9}Be(^{13}B,X)	Y	^{13}C(π^-,π^0)	AM	^{197}Au(^{15}N,^{13}B)
K	^{9}Be(^{14}B,^{13}Bγ),^{197}Au(^{14}B,^{13}Bγ)	Z	^{13}C(n,p)	AN	^{208}Pb(^{13}B,^{13}B)
L	^{9}Be(^{15}N,^{13}B)	Others:		AO	^{232}Th(^{18}O,^{13}B),^{232}Th(^{22}Ne,^{13}B)
M	^{9}Be(^{40}Ar,^{13}B)	AA	^{13}C(d,^{2}He)	AP	^{238}U(^{18}O,^{13}B)
N	^{11}B(t,p)	AB	^{13}C(t,^{3}He)	AQ	U(p,^{13}B),^{232}Th(p,^{13}B)
O	^{11}B(^{18}O,^{16}O)	AC	^{13}C(^{7}Li,^{7}Be)		

E(level)	J^π	$T_{1/2}$ or Γ	XREF	Comments
0.0	3/2⁻	17.30 ms *17*	A CDEF HIJKLMNOP RSTUVWX Z	XREF: Others: AA, AB, AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, AM, AN, AO, AP, AQ %β^-=100 %β^-n=0.276 *37* (1974Al12) T=3/2 μ=+3.1778 *5* (2004Na38,2019StZV) Q=0.0365 *8* (2021StZZ) μ: See previous value +3.17712 *51* (1971Wi09,1989Ra17).

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J$^{\pi}$	$T_{1/2}$ or Γ	XREF	Comments
				Q: From β−NMR in (2004Na38,2004Na46), sign=(+). See previous values Q=0.0374 *14* (1973HaVZ,1989Ra17) and Q=0.0369 *10* in (2003Og03). %β^-n: See also (1962Ma19,1969Jo21). The preliminary work of found %β-n=0.254 *36* in an experiment that didn′t resolve discrete neutron decay groups; the work of (1974Al12) was carried out by the same group, but with significantly improved experimental sensitivity and neutron group resolution. See theoretical discussion in (2003Fo11). $T_{1/2}$: From the weighted average of 17.39 ms *41* (1962Ma19), 17.33 ms *17* (1971Wi07), 17.6 ms *12* (1988Sa04), 16.7 ms *6* (1994ReZZ). $T_{1/2}$: Excluded values are 16.59 ms *2* (2006Ge21), ≈17.36 (2002GeZT, 2005GeZY), 17.0 ms *4* (1997So34) and 16 ms 1 (1968Ch28), 11 ms 9 (1991Re02) and 16.7 ms *3* (1995ReZZ, 2008ReZZ). See also the evaluated value $T_{1/2}$=17.16 ms *18* in (2015Bi05). J$^{\pi}$: (2000Gu23) ^{9}Be(^{14}B,^{13}Bγ): L=0 proton removal from ^{14}B, and allowed β^- decay to ^{13}C J$^{\pi}$=1/2$^-$, 3/2$^-$ and 5/2$^-$ states.
3483 *5*	1/2$^+$		D H K N p v x z	%IT=100 XREF: p(3600)v(3.5E3)x(3.5E3)z(3.5E3). E(level): From average of 3483 keV *5* (1964Mi04) and 3482 keV *10* (1978Aj02). J$^{\pi}$: From (2010Ba06) where L=0 is dominant in ^{12}B(d,p), arguments from spectroscopic factor analysis and shell model expectation of pure L=0 strength from a 1/2$^+$ state support this assignment. In (2000Gu23) ^{9}Be(^{14}B,^{13}Bγ): L=1 proton removal from ^{14}B is reported; arguments based on cross section values led to an assignment of 3/2$^+$. See also π=+ (1978Aj02) ^{11}B(t,p).
3536.4 *17*	3/2$^-$	0.90 ps *21*	A HI N p v x z	XREF: Others: AB, AC %IT=100 XREF: p(3600)v(3.5E3)x(3.5E3)z(3.5E3)AB(3.6E3)AC (3.5E3). E(level): From average of 3537 keV *2* (2002Ao03:Eγ=3536 keV *2*) ^{14}Be β-n, 3536.8 keV *42* (1969Th01) ^{7}Li(^{7}Li,pγ), 3533 keV *5* (1964Mi04) ^{11}B(t,p) and 3531 keV *10* (1978Aj02) ^{11}B(t,p). $T_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J$^{\pi}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ) based on lifetime and M1+E2 decay to $^{13}B_{g.s.}$. See also 3/2$^-$ from (2009Gu23) ^{13}C(t,^{3}He) and see π=− (1978Aj02) ^{11}B(t,p).
3681 *5*	(5/2$^+$,3/2$^+$)	38 fs *14*	D F HI K NOp rst	XREF: Others: AA %IT=100 XREF: p(3600)r(3690)s(3680)t(3720)aa(3.8E3). E(level): From average of 3681 keV *5* (1964Mi04) ^{11}B(t,p) and 3681 keV *10* (1978Aj02) ^{11}B(t,p).

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J$^\pi$	T$_{1/2}$ or Γ	XREF	Comments
				T$_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J$^\pi$: From (2010Ba06) where L=2 is dominant in ^{12}B(d,p); arguments from spectroscopic factor analysis and shell model expectation of dominant L=2 strength from a 5/2$^+$ state support this assignment. A 3/2$^+$ state, with equal admixtures of L=0 and 2, is expected within 60 keV of the 5/2$^+$ state. (2000Gu23) ^{9}Be(^{14}B,^{13}Bγ) had suggested J^π=3/2$^+$ and 5/2$^+$ for ^{13}B*(3.48,3.61 MeV), respectively, based in L=1 proton removal from ^{14}B and cross section arguments. See also π=+ (1978Aj02) ^{11}B(t,p).
3713 *5*	1/2$^-$	≤0.21 fs	HI N p rst	XREF: Others: AA, AE %IT=100 XREF: p(3600)r(3690)s(3680)t(3720)aa(3.8E3). E(level): From average of 3712 keV *5* (1964Mi04) ^{11}B(t,p) and 3715 keV *10* (1978Aj02) ^{11}B(t,p). T$_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J$^\pi$: From (1975Ma41, 2016Be08) ^{14}C(d,^{3}He) based on L=1 and the spectroscopic factor magnitude. See also π=− (1978Aj02) ^{11}B(t,p) and (5/2$^-$) from analysis of various 1p plus 2n transfer reactions on ^{12}C in (2000Ka21) where the E$_x$=3.6 and 3.7 MeV states are unresolved.
4131 *5*	$^-$	≤0.21 fs	HI K NO RST	XREF: Others: AC %IT=100 XREF: AC(4.0E3). E(level): From average of 4134.1 keV *78* (1969Th01) ^{7}Li(^{7}Li,pγ), 4130 keV *10* (1964Mi04) ^{11}B(t,p) and 4128 keV *10* (1978Aj02) ^{11}B(t,p). T$_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J$^\pi$: See π=− (1978Aj02) ^{11}B(t,p).
4829 *6*	1/2$^+$	≤0.21 fs	HI N S	XREF: Others: AE, AI %IT=100 XREF: S(4910). E(level): From average of 4833 keV *10* (1972Wy01) ^{7}Li(^{7}Li,p), 4820 keV *10* (1964Mi04) ^{11}B(t,p) and 4834 keV *10* (1978Aj02) ^{11}B(t,p). T$_{1/2}$: From (2009Iw03) ^{7}Li(^{7}Li,pγ). J$^\pi$: From L(p)=0: (2008Ot05) ^{4}He(^{12}Be,^{13}B). See also (1/2$^+$) (2016Be08) ^{14}C(d,^{3}He) where L=0 is deduced. In (2000Ka21) ^{16}O(^{14}C,^{17}F), ^{13}B*(4.8,6.9 MeV) are reported; the authors suggest a mechanism with one 1$p_{1/2}$ and two 1$p_{3/2}$ proton transfers from ^{16}O; leaving remaining protons to couple to 0$^+$ for the lower state and 2$^+$ for the higher state, resulting in J^π=1/2$^-$ and (3/2,5/2)$^-$, respectively.
5024† *6*			I N R T	E(level): From average of 5033 keV *8* (1972Wy01) ^{7}Li(^{7}Li,p), 5010 keV *10* (1964Mi04) ^{11}B(t,p) and 5023 keV *10* (1978Aj02) ^{11}B(t,p).
5106† *10*		60 keV *10*	D N p	XREF: Others: AA, AB XREF: p(5200). E(level),Γ: From (1978Aj02).

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J$^{\pi}$	T$_{1/2}$ or Γ	XREF	Comments
5388[†] *6*	(1/2,3/2)$^-$	14 keV *5*	D I NOp RST	XREF: Others: AE XREF: p(5200). E(level): From average of 5391 keV *8* (1972Wy01) ^{7}Li(^{7}Li,p), 5380 keV *10* (1964Mi04) ^{11}B(t,p), and 5393 keV *10* (1978Aj02) ^{11}B(t,p). Γ: From average of 15 keV *5* (1964Mi04) and 10 keV *10* (1978Aj02). J$^{\pi}$: From L(p)=1 in ^{14}C(d,^{3}He) (2016Be08).
5557?[†] *7*			I	E(level): From (1972Wy01) ^{7}Li(^{7}Li,p).
6167[†] *6*		<20 keV	I NOP T	XREF: Others: AE XREF: AE(6.3E3). E(level): From average of 6169 keV *8* (1972Wy01) ^{7}Li(^{7}Li,p), 6170 keV *20* (1964Mi04) ^{11}B(t,p) and 6164 keV *10* (1978Aj02) ^{11}B(t,p). Γ: In Fig. 10 of (1978Aj02) this state is narrower than the E$_x$=5.39 MeV state. It's width is assigned Γ<20 keV. See also Γ≈60 keV (2000Ka21) ^{12}C(^{15}N,^{14}O).
6425[†] *7*		36 keV *5*	I NOP RST V X ZA	XREF: Others: AE XREF: S(6370)AE(6.3E3). E(level): From average of 6419 keV *8* (1972Wy01) ^{7}Li(^{7}Li,p) and 6434 keV *10* (1978Aj02) ^{11}B(t,p). Γ: From (1978Aj02). J$^{\pi}$: In (2000Ka21) analysis of ^{12}C(^{13}C,^{12}N),(^{14}C,^{13}N) and (^{15}N,^{14}O) multi-nucleon transfer reactions suggest J^{π}=(9/2$^+$).
6934[†] *9*		55 keV *15*	I N ST	XREF: Others: AB, AI XREF: AI(6900). E(level): From average of 6939 keV *15* from (1972Wy01) ^{7}Li(^{7}Li,p) and 6932 keV *10* (1978Aj02) ^{11}B(t,p) See also (2000Ka21) where E$_x$≈6930 keV and Γ≈150 keV are reported. J$^{\pi}$: In (2000Ka21) ^{16}O(^{14}C,^{17}F), ^{13}B*(4.8,6.9 MeV) are reported; the authors suggest a mechanism with one 1$p_{1/2}$ and two 1$p_{3/2}$ proton transfers from ^{16}O; leaving remaining protons to couple to 0$^+$ for the lower state and 2$^+$ for the higher state, resulting in J^{π}=1/2$^-$ and (3/2,5/2)$^-$, respectively. Γ: From (1978Aj02).
7516?[†] *8*			I st X Z	XREF: s(7580)t(7760). E(level): From (1972Wy01). E(level): A low-energy shoulder is reported on the 8133 keV peak reported in (2000Ka21) ^{12}C(^{14}C,^{13}N) and ^{12}C(^{15}N,^{13}O); the authors suggest this group may correspond to unresolved groups that include ^{13}B*(7516,7859).
7859?[†] *20*			I st	XREF: s(7580)t(7760). E(level): From (1972Wy01). E(level): A low-energy shoulder is reported on the 8133 keV peak reported in (2000Ka21) ^{12}C(^{14}C,^{13}N) and ^{12}C(^{15}N,^{13}O); the authors suggest this group may correspond to unresolved

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	J$^{\pi}$	$T_{1/2}$ or Γ	XREF	Comments
				groups that include ^{13}B*(7516,7859).
8134† *7*		100 keV *15*	I NO RST	XREF: O(8.32E3). E(level): From average of 8129 keV *10* (1972Wy01) and 8138 keV *10* (1978Aj02). Γ: From (1978Aj02).
8683‡ *7*		89 keV *20*	I N RST	E(level): From average of 8682 keV *9* (1972Wy01) and 8684 keV *10* (1978Aj02). Γ: From (1978Aj02).
9.0×10^{3}		≈8.1 MeV	Y	T=3/2 (1994Ha41) E(level),Γ: From (1994Ha41). Represents the T=3/2 giant resonance built on ^{13}C$_{g.s.}$
9440‡ *30*		81 keV *25*	N RST	XREF: R(9310). E(level),Γ: From (1978Aj02).
9.5×10^{3}?‡ *3*				XREF: Others: AC Γ: Γ=broad. E(level),Γ: From (1990Na03) ^{13}C(^{7}Li,^{7}Be).
10220‡ *20*		210 keV *20*	F N RST X Z	XREF: Others: AB E(level),Γ: From (1978Aj02). J$^{\pi}$: In (2000Ka21) analysis of ^{12}C(^{13}C,^{12}N),(^{14}C,^{13}N) and (^{15}N,^{14}O) multi-nucleon transfer reactions suggest J^{π}=(11/2^{-}).
10890# *20*			N	E(level): From (1978Aj02).
11050#		1.8 MeV	RST	XREF: R(11180)S(10980). Γ: Broad, possibly many states. E(level),Γ: From (2000Ka21) ^{12}C(^{15}N,^{14}O).
11.7×10^{3}#	(5/2^{+},7/2^{+})		F N	E(level),J$^{\pi}$: From (2014Wu10) ^{2}H(^{15}C,α). See also (11.8 MeV) (1978Aj02) ^{11}B(t,p). J$^{\pi}$: For 11.7- and 12.2-MeV doublet. Comparison of the angular distribution of the E$_{x}$≈12 MeV group with the ^{2}H(^{14}C,α)^{12}B*(5.61, J^{π}=3^{+}) suggests this doublet results from the coupling of a 1s$_{1/2}$ neutron to an aligned [(0p$_{3/2}$)$^{-2}$]$_{3+}$ configuration in ^{12}B (2014Wu10).
12.2×10^{3}#	(5/2^{+},7/2^{+})		F	E(level): From (2014Wu10) ^{2}H(^{15}C,α). J$^{\pi}$: See comment on E$_{x}$=11.7 MeV.
13.6×10^{3} *1*		≤320 keV	I Q T	%α≤100 E(level),Γ: From (2008Ch28) ^{12}C(^{12}Be,^{13}Be), see also E$_{x}$=13.65 MeV *23* and Γ≈300 keV (2000Ka21) ^{12}C(^{15}N,^{14}O).
14390#		≈400 keV	T	E(level),Γ: From (2000Ka21) ^{12}C(^{15}N,^{14}O).
16.3×10^{3}			G	E(level): From (2022Di05) ^{4}He(^{9}Li,α). %α: Observed in ^{4}He(^{9}Li,α).

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Adopted Levels, Gammas (continued)

^{13}B Levels (continued)

E(level)	Jπ	$T_{1/2}$ or Γ	S	XREF	Comments
18.25×10^3 *10*	1/2+	0.7 MeV *+4−3*		B G	T=(5/2) (2023Hu20) XREF: G(18.4E3). Γ: T=0.66 MeV $^{+40}_{-25}$. E(level),Jπ,Γ: From R-matrix analysis in (2023Hu20). See also 18.4 MeV from (2022Di05) ^{4}He(^{9}Li,α). %p,%α: Observed in ^{1}H(^{12}Be,^{13}Be) and ^{4}He(^{9}Li,α).
19.95×10^3 *6*	5/2+	0.60 MeV *10*	0.49 *8*	B G	T=(5/2) (2023Hu20) XREF: G(19.5E3). E(level),Jπ,Γ: From R-matrix analysis in (2023Hu20). See also 19.5 MeV from (2022Di05) ^{4}He(^{9}Li,α). %p,%α: Observed in ^{1}H(^{12}Be,^{13}Be) and ^{4}He(^{9}Li,α).

† Decay mode not reported; only IT and neutron emission are possible.
‡ Decay mode not reported; IT, 1n and 2n emission are possible.
# Decay mode not reported; IT, 1n, 2n and α emission are possible.

γ(^{13}B)

Additional information 1.

E_i(level)	J^π_i	E_γ	I_γ	E_f	J^π_f	Mult.	α†	Comments
3483	1/2+	3482	100	0.0	3/2−			E_γ: 3482 keV *6* from Level Energy Difference.
3536.4	3/2−	3536 *2*	100	0.0	3/2−	[M1,E2]	0.00093 *8*	α(K)=1.221×10^{-7} *23*; α(L)=4.98×10^{-9} *10* α(IPF)=0.00093 *8* B(M1)(W.u.)<7.2×10^{-4} (2009Iw03); B(E2)(W.u.)<0.81 (2009Iw03) E_γ,I_γ: From (2002Ao03) ^{14}Be β-n.
3681	(5/2+,3/2+)	3680	100	0.0	3/2−	[E1]	1.55×10^{-3} *2*	α(K)=9.05×10^{-8} *13*; α(L)=3.69×10^{-9} *5* α(IPF)=0.001552 *22* B(E1)(W.u.)=7.7×10^{-4} *28* E_γ,I_γ: See (2000Gu23,2009Iw03). B(E1)(W.u.): See also 6.4E-4 23 in (2009Iw03).
3713	1/2−	178	<10‡	3536.4	3/2−			E_γ: 178 keV *6* from Level Energy Difference.
		3713 *5*	100‡	0.0	3/2−			E_γ: 3713 keV *5* from Level Energy Difference.
4131	−	418 *8*	<14‡	3713	1/2−			E_γ: 418 keV *8* from Level Energy Difference.
		596 *8*	33‡ *14*	3536.4	3/2−			E_γ: 596 keV *8* from Level Energy Difference.
		4131 *6*	100‡ *14*	0.0	3/2−			E_γ: 4131 keV *8* from Level Energy Difference.

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Adopted Levels, Gammas (continued)

$\gamma(^{13}B)$ (continued)

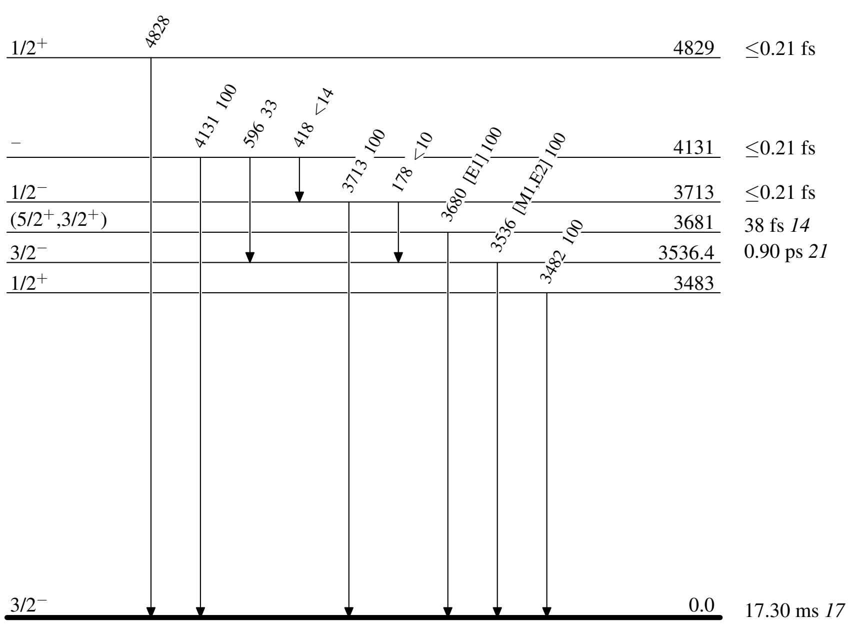
E_i(level)	J_i^π	E_γ	E_f	J_f^π	Comments
4829	1/2+	4828	0.0	3/2−	E_γ: 4828 keV *6* from Level Energy Difference.

† Additional information 2.
‡ From (1963Ca09).

Adopted Levels, Gammas

Level Scheme

Intensities: Relative photon branching from each level



$^{13}_{5}B_{8}$

^{14}Be β^-n decay 1999Be53,2002Ao03

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

Parent: ^{14}Be: E=0; $J^\pi=0^+$; $T_{1/2}$=4.65 ms *10*; Q(β^-n)=1.532×10^4 *13*; %β^-n decay>97.8

^{14}Be-Q(β^-n): From 2021Wa16.

^{14}Be-%β-1n from discussion below: %β-0n<0.6% (2002Ao03): %β-2n<1.6 and %β-3n<0.5 from (1999Be53) where $P_{2n}+3P_{3n}$<1.6% was deduced.

^{14}Be-The reported ^{14}Be lifetime values are discrepant: $T_{1/2}$=4.2 ms *7* (1986Cu01), 4.35 ms *17* (1988Du09), 4.78 ms *19* (1995ReZZ,2008ReZZ), 4.8 ms *2*(stat.) *4*(sys.) and 4.0 ms *12* (1995Be25), 4.29 ms *12* (1997Be66), and 4.84 ms *10* (2002Ao03). The value $T_{1/2}$=4.65 ms *10* is accepted; this value is the weighted average of measurements.

^{14}Be-%β^-n decay: Studies of ^{14}Be β^-n decay aimed to locate the position of the ^{14}B $J^\pi=1^+$ excited state, which was suggested to be the only allowed low-lying ^{14}B state populated in ^{14}Be β decay. In (1986Cu01) and the associated thesis, the level was predicted to lay close to the ^{14}B neutron binding energy. Numerous experimental failures perpetuated ambiguity in the state's position before the issue was finally settled in (2002Ao03). The ^{14}B $J^\pi=1^+$ state was found at 1.38 MeV, which is well above the 970 keV neutron binding energy. In this case, with no decay to β allowed bound states, ^{14}Be decay must be dominated by β-delayed neutron emission. This point seems to have been overlooked in (2015Bi05), where a sizeable (9%) component to ^{14}B bound states is suggested.

^{14}Be-%β^-n decay: With the exception of (1988Du09), all experiments find only upper limits on the population of the $\pi=-$ bound levels in ^{14}B*(0,740); stringent limits of P(0n)<4% (1999Be53) and <0.6% (2002Ao03) are determined. P(0n)<0.6%, which is based on the search for ^{14}B decay radiations is accepted. P(0n)<0.6% is compatible with expectations for the forbidden decay to $\Delta\pi$=yes states and incompatible with, for example, the unexpected P_{0n}=14% *3* findings of (1988Du09).

^{14}Be-%β^-n decay: Evidence for β-delayed one neutron decay is significant. In (1988Du09) P(1n)=81% *4* is reported, but these results were found as unreliable. In (2002Ao03), analysis of the ^{13}B radiations implies P(1n)=94% *5*, while data from a moderated ^{3}He counter gives P(1n)>96% (1999Be53). The data offer some ambiguity in the analysis, since (2002Ao03) assign only 91% *9* of the intensity to neutron decay from ^{14}B*(1.28 MeV *1*) to $^{13}B_{g.s.}$; no γ-rays are observed in coincidence, so ^{14}Be β-decay is assumed to populate ^{14}B*(1.28 MeV) directly. There are no other known allowed states, so single- or multi-neutron emission must dominate any expectation. The decay path is not fully understood for all the β^-1n intensity. Two additional decay radiations appear relevant to β^-1n decay; first is the 3536 keV transition to ^{13}B ground state observed by (1995Be25) and (2002Ao03), and second is the E_n=3.02 MeV group observed by (1995Be25). The intensity I(γ:3536)=0.9% *3* was measured by (2002Ao03), though no neutron group was observed in a coincidence spectrum. Also a very weak population of an E_n=3.02 MeV group was observed by (1995Be25); while no γ-rays are observed in a coincidence, the neutron group cannot be definitively associated with decay to $^{13}B_{g.s.}$. P(1n)=94% *5* could be suggested (2002Ao03), but this value is not favored.

^{14}Be-%β^-n decay: The 2n and 3n decay modes are not clearly identifiable, most reported values are given as upper limits. Two relevant results are given in (2002Ao03), where P(2n)=6% *5* is deduced from their P(0n)<0.6% and P(1n)=94% *6* values, and in (1999Be53) where analysis of the n-n and n-n-n correlations in their moderated ^{3}He counter set the limit (P(2n)+3P(3n))<1.6% (1σ value) (based on the 95% confidence limit $P_{2n}+3P_{3n}$<2.4% *8*).

^{14}Be-%β^-n decay: Further studies on the open charged particle decay channels have found the $\beta^-\alpha$ intensity of P(α)<0.004% (2002Je14) and the β^-t intensity of P(t)=0.02% *1* (2002Je14); the parent levels are not identified. See also P(α)<0.002% (2002Je11) and the β^-t intensity of P(t)=0.021% *8* (2002Je11).

^{14}Be-%β^-n decay: In the above discussion, the evaluator finds reason to recommend: P(0n)<0.6%; (P(2n)+3P(3n))<1.6%; P(α)<0.004%; P(t)=0.02% *1*. Using these, the remainder is P(1n)>97.8%.

1986Cu01: A beam of ^{14}Be ions was produced by fragmenting a 540 MeV ^{18}O beam on Be and Ta targets. The secondary fragments were filtered using the RPMS Wein Filter at NSCL and were focused on a ΔE-E stopping detector telescope. When a particle was measured in the telescope the rf was scrambled until a decay was measured in the telescope. Analysis of the implantation to decay period, gated on nuclear species, provided the lifetime measurement. $T_{1/2}$=4.2 ms *7* was measured.

1988Du09: ^{14}Be was produced by fragmenting a 60 MeV/nucleon ^{22}Ne beam on either a tantalum or a carbon target; ^{14}Be was selected using the LISE spectrometer. The β-particles were detected using a plastic scintillator while the delayed neutrons were detected through the Gd(n,γ) reaction. $T_{1/2}$=4.35 ms *17*, P_{0n}=0.14 *3*, P_{1n}=0.81 *4* and P_{2n}=0.05 *2* were measured. See also (1988DuZT,1988DuZZ). *Evaluator's comment:* ^{14}B has two bound states with $\pi=-$ (2013Be25); any combination of intensities adding to 14% *3* feeding these forbidden transitions is unreasonable. An upper limit of %Iβ≤0.6 is expected. The later work of (2002Ao03), which searched for radiations from the ^{14}B daughter, convincingly verified this upper limit. A systematic error appears to be present in the work of (1988Du09).

^{14}Be β^-n decay 1999Be53,2002Ao03 (continued)

1995Be25: ^{14}Be ions were produced by fragmenting an 80 MeV/nucleon ^{18}O beam on a Be target and filtering in the A1200 separator. The beam was implanted in a thick BC412 scintillator during a 10.3 ms accumulation period, followed by either a 10.3 ms or 40 ms beam-off counting period. Beta particles from the decay were detected by the implantation detector, while delayed neutrons were detected using an array of 15 curved scintillator bars that were placed 1 meter from the implantation scintillator. Neutron energies were deduced from the time-of-flight (tof) between the β-detector and the neutron array. In addition a HPGe detector was placed 83 mm from the implantation target.

Analysis of the data indicated 3-4% contamination from ^{11}Li, a correction was possible since the ^{11}Li decay had been studied in the same configuration. A neutron detector threshold of 0.77 MeV was unfortunately used in the measurements, which led to a significantly low number of β-n events. The data showed evidence for delayed neutron groups at E_n= 3.02 MeV *3* and 3.52 MeV *7* with intensities of 0.11% *2*(stat) *4*(sys) and 0.30% *3*(stat) *5*(sys); the peaks from these weak branches lay on top of a broad peak that was associated with 2n and 3n decay. The multi-neutron branching ratio associated with the broad peak is 5% *1*(stat) *2*(sys). Furthermore, it is plausible that, for example, the E_n=3.52 MeV neutron group may correspond to sequential 2n decay.

Data from the HPGe detector indicated small participation from two transitions related to ^{13}B with E_γ=3528 keV *1* and 3680 keV *1*, however low statistics prevented analysis of the neutron groups that feed these transitions. No 740 keV γ-ray was observed for the transition between the ^{14}B first excited state and ground state. Note: the 3680 keV *1* energy for the $^{13}C^*$(3684.507)→g.s. transition is lower than expected.

A critical issue in the data collection is the relatively low rate of delayed neutron emission. While more than 85% of the decays were expected to be accompanied with neutrons, only about 7% of that intensity is presently observed. It is then suggested that a state in ^{14}B, neutron unbound by <800 keV, is strongly populated. Lifetimes were deduced by two techniques, though high backgrounds significantly complicated the determinations; 4.8 ms *2*(stat) *4*(sys) was deduced from the raw decay curve while 4.0 ms *12* was deduced from the β-n coincidence data.

1997Be66: The authors of (1995Be25) carried out a new measurement at RIKEN, aimed at identifying the low-energy neutron group that participates in the decay. A ^{14}Be beam was produced by fragmenting a 100 MeV/nucleon ^{18}O beam on a Be target; the beam was implanted in the center of a Si detector telescope comprised of 5 detectors. The telescope was sandwiched between two sets of plastic scintillators that detected beta particles. Neutrons were detected in an array of BC408 scintillator walls that were positioned ≈ 200 cm from the implantation detector. In addition a HPGe detector was positioned 131 mm from the implantation detector.

Analysis of the decay curve indicates $T_{1/2}$=4.29 ms *18*. Attention was focused on the neutron energy region below E_n=800 keV, where a sharp peak with E_n=287 keV *3* and width=60 keV *5* is observed. The peak falls at the edge of the neutron detectors′ thresholds and hence yields significant uncertainty in the branching ratio; I(n:287)=39 to 100%. No γ-rays are observed in coincidence with the neutron group, strongly (but inconclusively) suggesting decay to ^{13}B ground state. Decay to $^{13}B_{g.s.}$ would imply decay from a ^{14}B*(1.28 MeV *2*). The 740 keV γ-ray is not found in the spectrum, and no comment is given on the 3528 and 3680 keV gamma rays.

1998KoZP, 1999Be53, 2002Be53: An uranium carbide target was bombarded by a 1-GeV proton beam to produce a ^{14}Be beam that was implanted in a kapton foil located at the center of a moderated ^{3}He cylindrical neutron counter array. The β-particles from ^{14}Be decay were detected by a plastic scintillator located directly behind the implantation foil. The P_n value was determined from the rate of neutrons detected in the ^{3}He counter. The total neutron-emission probability P_n=101% *4* was measured along with an upper limit of $P_{2n}+3P_{3n}$ < 2.4% (95% confidence limit). Combining P_n with the $P_{2n}+3P_{3n}$ limit P_{1n}≈100%(> 96%), P_{0n}<4%, and $P_{2n}+3P_{3n}$=0.8% *8* were deduced. See additional discussion suggesting an error in %β-2n value of (1988Du09).

1997Ao01, 1997Ao04, 2002Ao03: A thick Be target was bombarded by a 100 MeV/nucleon ^{18}O beam to produce a ^{14}Be beam that was selected by the RIPS separator. The beam was implanted in a Si detector.

The β-rays were detected using a set of ΔE-ΔE-E plastic scintillator detectors that were positioned above and below the implantation detector, and a ΔE-ΔE coincidence requirement was implemented to reduce background. Neutrons were detected either in a low-energy array located 50 cm away from the stopper or in a high-energy array located 1.5 m from the stopper. In addition a HPGe clover detector was placed 149 mm from the target.

$T_{1/2}$=4.84 ms *10* was deduced by analyzing the decay curve associated with the E_n=288−keV group; there is no understanding of the discrepancy between this and prior values. The neutron tof spectrum was dominated by the E_n=288 keV *1* peak, I(n:288)=91% *9*, that was not found in coincidence with any γ-ray. The intensity of an additional neutron group at E_n=3.51 MeV *6* is found to be in agreement with the expectation from β-delayed neutron decay of the ^{13}B daughter nucleus. The present analysis was insensitive to the 3.02 MeV group reported by (1995Be25). The γ-ray spectrum indicated peaks at E_γ=3536 keV *2* and 3685 keV *1*; the 3536 keV transition with I(γ)=0.9% *3* is ascribed to a transition fed following delayed neutron decay to states in ^{13}B, while the 3685 keV transition is fed in ^{13}B decay to ^{13}C states.

Analysis of the data provides a measure on the 0n, 1n and 2n decay branches. While the 740 keV transition between ^{14}B first

^{14}Be β^-n decay 1999Be53,2002Ao03 (continued)

excited state and $^{14}B_{g.s.}$ is not observed, a limit on decay to either of these states is found as I(0n)<0.6% by searching for the 6.09 MeV γ-ray that is fed in 81% of ^{14}B decays to ^{14}C. Similarly, the intensity of the 3685 keV transition, which is fed by 7.6% of ^{13}B decays to ^{13}C, implies I(1n)=94% *5*. No γ rays from ^{12}B decay were observed so I(2n)=6% *5* is deduced from $1=P_{0n}+P_{1n}+P_{2n}$.

See theoretical analyses in (1996Ti05).

Summarizing again, in the above discussion, the evaluator finds reason to recommend: P(0n)<0.6% (2002Ao03) ; (P(2n)+3P(3n))<1.6% (1999Be53); P(α)<0.004% and P(t)=0.02% *1* (2002Je14). Using these, the remainder is P(1n)>97.8%.

^{13}B Levels

E(level)†	J$^\pi$†	$T_{1/2}$†
0.0	3/2$^-$	17.30 ms *17*
3536.4 *17*	3/2$^-$	0.90 ps *21*

† From Adopted Levels.

γ(^{13}B)

E_γ	I_γ†	E_i(level)	J_i^π	E_f	J_f^π	Comments
3536 *2*	0.9 *3*	3536.4	3/2$^-$	0.0	3/2$^-$	E_γ: From (2002Ao03); see also 3528 keV *1* (1995Be25). I_γ: From (1995Be25).

† Absolute intensity per 100 decays.

Delayed Neutrons (^{13}B)

E(n)	E(^{13}B)	I(n)†	E(^{14}B)	Comments
3.02×10^3 *3*		0.11 *5*		E(n),I(n): From (1995Be25).
288 *1*	0.0	91 *9*	1280	The decay is from ^{14}B*(1280 keV *10*). E(n),I(n): From (2002Ao03).

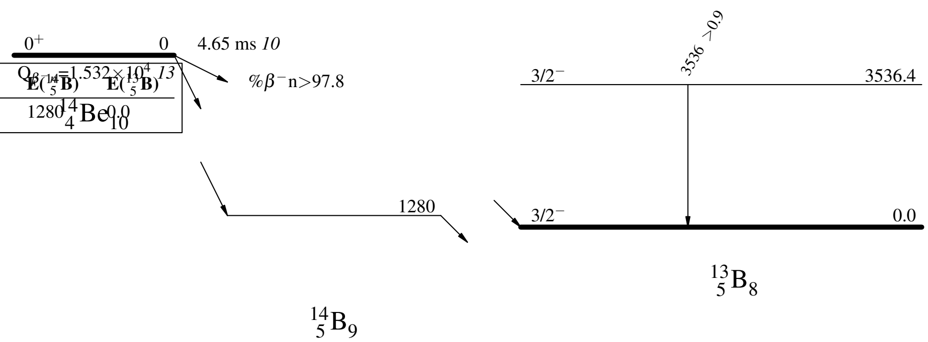
† Absolute intensity per 100 decays.

^{14}Be β^-n decay 1999Be53,2002Ao03

Decay Scheme

γ Intensities: $I_{(\gamma+ce)}$ per 100 parent decays
I(n) Intensities: I(n) per 100 parent decays

E(n)	I(n)	E($^{14}_{5}$B)	E($^{13}_{5}$B)
288	91	1280	0.0



$^{1}H(^{13}B,X)$ 2021Li64

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2021Li64: XUNDL dataset compiled by TUNL (2022).

The authors determined the spectroscopic factors for $^{1}H(^{13}B,d)$ *s*-, *p*- and *d*-wave neutron transfer to low-lying ^{12}B states. Using these spectroscopic factors, they analyzed the intruder *s*- and *d*-wave strengths that comprise the ^{13}B ground state.

A beam of 23 MeV/nucleon ^{13}B ions from the RCNP/Osaka electromagnetic isotope separator impinged on a 6.76 mg/cm^2 polyethylene target that was rotated slightly by 20° with respect to the incident beam. The ^{12}B $+d$ reaction products were momentum analyzed using a set of three 5 cm × 5 cm position sensitive ΔE-ΔE-E telescopes. The ^{12}B ejectiles were detected using the T0 telescope, which was centered along θ=0°; deuterons were detected by the T1 and T2 telescopes, which were centered on the horizontal plane at θ=−31° and θ=−70°, respectively. Lastly, a position sensitive Si annular detector was positioned at backward angles to detect protons from any $^{2}H(^{13}B,p)$ reactions.

Differential cross sections for $^{1}H(^{13}B,p)$ elastic scattering were obtained and evaluated via optical model analysis, while $^{1}H(^{13}B,d)$ reactions to ^{12}B states up to E_x=6.0 MeV were evaluated via DWBA using FRESCO to obtain the relative spectroscopic factors. For some higher-lying states, the ^{12}B ejectile neutron decayed to ^{11}B, which was detected and identified via ΔE-E in the T0 telescope. The dominant neutron transfer orbital from each state was analyzed to obtain the $^{13}B_{g.s.}$ *s*-, *p*- and *d*-wave neutron strengths. The relevant contributions are given below. Values of 83% *6* *p*-wave, 5% *2* *s*-wave and 12% *2* *d*-wave were determined for $^{13}B_{g.s.}$. Using these observations, the authors find consistency with shell model predictions and N=8 magicity in the ^{13}B nucleus.

See also (2013Ti05).

Levels in ^{12}B

Level Energy (keV)	L	neutron orbital	J^π	S_{rel}
0	1	$1p_{1/2}$	1^+	0.54 *5*
953	1	$1p_{1/2}$	2^+	1.11 *7*
1674	0	$2s_{1/2}$	2^-	0.06 *2*
2621	0	$2s_{1/2}$	1^-	0.04 *1*
3389	2	$1d_{5/2}$	3^-	0.13 *2*
4460&4523	2	$1d_{5/2}$	2^-&4^-	(Sum)=0.11 *2*
6000	2	$1d_{5/2}$	1^-	≤0.01

^{13}B Levels

E(level)	J^π	Comments
0	$3/2^-$	J^π: 83% *6* *p*-wave, 5% *2* *s*-wave and 12% *2* *d*-wave neutron strengths were deduced for $^{13}B_{g.s.}$, which are consistent with shell model predictions and N=8 magicity in ^{13}B.

$^{1}H(^{12}Be,^{13}Be)$ 2023Hu20

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

XUNDL dataset compiled by TUNL (2023).

T=5/2 states in ^{13}B were populated using thick-target inverse kinematics scattering techniques. An R-matrix analysis of the excitation function determined the J^{π} values for the near-threshold resonances. Using these results, the J^{π} values for near threshold n+^{12}Be analog resonances in ^{13}Be were deduced using isospin symmetry arguments.

A beam of 6.0 MeV/nucleon ^{12}Be ions from the TRIUMF ISAC-II facility entered the TexAT active target time-projection chamber, and backscattered protons were detected using a set of six ΔE-E detector telescopes at the downstream wall of the TexAT chamber. The reaction kinematics were determined from analysis of the incident ^{12}Be and recoiling ^{12}Be and proton tracks. Excitation functions for elastic scattering were obtained by analyzing events in the different ΔE-E telescopes separately.

Evidence for a $J^{\pi}=1/2^{+}$ resonance at $E_{c.m.}$=2.45 MeV and a $J^{\pi}=5/2^{+}$ resonance at $E_{c.m.}$=4.15 MeV was found using the MINRMATRIX code. The authors explored any improvement of the fit by adding $J^{\pi}=1/2^{-}$ and or $3/2^{-}$ states, but found their experimental data were not sensitive to negative parity states. Expanding on this point, the *conclusion* discussion indicates participation of negative parity states cannot be excluded. The p+^{12}Be reaction can populate T=3/2 and 5/2 states, but an argument is made for preferential population of T=5/2 resonances; in this case, the observed resonances may be related to expected ^{13}Be resonances by isospin symmetry arguments. As a result, $J^{\pi}=1/2^{+}$ and $5/2^{+}$ neutron unbound states in ^{13}Be are expected at $E_{c.m.}$=0.6 MeV *1* and 2.34 MeV *6*, respectively. These agree well with known states in ^{13}Be, and the authors claim this is the first definitive determination of J^{π} values in ^{13}B.

^{13}B Levels

E(level)†	J^{π}†	Γ†	S	Comments
18.25×10^{3} *10*	$1/2^{+}$	0.7 MeV *+4−3*	0.16 *+9−6*	T=(5/2) Γ: Γ=0.66 MeV *+40−25*. E(level): From $E_{c.m.}$(p+^{12}Be)=2.45 MeV *10*.
19.95×10^{3} *6*	$5/2^{+}$	0.60 MeV *10*	0.49 *8*	T=(5/2) E(level): From $E_{c.m.}$(p+^{12}Be)=4.15 MeV *6*.

† From R-matrix analysis in (2023Hu20).

^{2}H(^{15}C,α) 2014Wu10

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2014Wu10: XUNDL dataset compiled by TUNL, 2015.

The authors used the highly spin selective (d,α) deuteron transfer reaction to study states with "stretched" nuclear configurations.

A beam of 15.7 MeV/nucleon ^{15}C ions was produced using the ^{2}H(^{14}C,^{15}C) reaction at the ANL/ATLAS In-Flight production facility. The beam impinged on 145 μg/cm^{2} $(Cd_2)_n$ polyethylene foils located at the HELIcal Orbit Spectrometer (HELIOS) target position. The kinematics of α particles from (d,α) reactions were determined from analysis of the HELIOS array data, while recoiling boron isotopes were detected in an array of position sensitive Si detectors that covered θ_{lab}=1.0°−5.6° for 92% of the azimuthal angle range. The resolution for excitation energy was found as ≈ 240 keV FWHM.

The reaction data were analyzed for α-particles in coincidence with any boron isotope; this gave access to population of bound states, as well as, 1-n and 2-n unbound states.

^{13}B Levels

E(level)	J$^{\pi}$	L	Comments
0	3/2^{-}		J$^{\pi}$: From Adopted Levels.
3.6×10^{3}			E(level): three states have previously been observed at E_x=3.53, 3.68 and 3.71 MeV.
10.0×10^{3}			
11.7×10^{3}	(5/2,7/2)$^{+}$ †	(2) †	
12.2×10^{3}	(5/2,7/2)$^{+}$ †	(2) †	

† For 11.7- and 12.2-MeV doublet. Comparison of the angular distribution of the E_x≈12 MeV group with the ^{2}H(^{14}C,α)^{12}B*(5.61, J^{π}=3^{+}) suggests this doublet results from the coupling of a $1s_{1/2}$ neutron to an aligned $[(0p_{3/2})^{-2}]_{3+}$ configuration in ^{12}B.

$^{2}H(^{13}B,^{13}B)$ 2022Li15

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2022Li15: Elastic scattering of ^{13}B ions from a 3.98 mg/cm^2 CD_2 target (rotated by 20° with respect to the beam direction) was measured at the RCNP/Osaka. The 23 MeV/nucleon ^{13}B beam was produced by fragmentation of a ^{18}O beam and purified using an electromagnetic separator. The $\sigma(\theta)$ for $\theta_{c.m.}$=20° to 60° was determined from the measured deuteron scattering distribution and used an exclusive d+^{13}B coincidence requirement. Scattered ^{13}B ions were identified using a position sensitive ΔE-ΔE-E (Si-Si-CsI) telescope placed along the beam axis, while associated deuterons were measued using two additional position sensitive ΔE-ΔE-E telescopes that covered θ_{lab}=31° to 70°. Elastic scattering dominated the observations; though broad unresolved groups were evident at E_x≈4 and 6.5 MeV. The data were compared with optical model calculations obtained using FRESCO.

^{13}B Levels

E(level)
0

$^{2}H(^{12}B,p)$ **2010Ba06**

History			
Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

$J^{\pi}(^{12}B$ g.s.)=1^{+}.

2010Ba06: XUNDL dataset compiled by TUNL, 2010.

A 75 MeV/nucleon beam of ^{12}B ions, produced by bombarding a cryogenic deuterium gas cell with ^{11}B ions at the ANL/ATLAS facility, impinged on a 73 $\mu g/cm^2$ CD_2 target located at the HELIOS (HELIcal Orbit Spectrometer) target position. Reaction protons were emitted in the backwards direction and followed a single helical orbit in the 1.05 T axial magnetic field before reaching a barrel shaped array of position sensitive Si detectors that surrounded the incident beam axis. The forward moving ^{13}C ions were stopped in a ΔE-E telescope that covered θ_{lab}=0.5°−2.8°.

The momentum of the emitted proton was determined and excited states were resolved with ΔE≈100 keV FWHM. The angular distribution for population of ^{13}B(3.48, 3.68 MeV) was determined over $\theta_{c.m.}$=8°−30° by analyzing the p+^{13}B coincidences. The angular distributions were analyzed via DWBA analysis.

2010Le02: XUNDL dataset compiled by TUNL, 2010.

A 75 MeV/nucleon beam of ^{12}B ions, from the ANL/ATLAS facility, impinged on a 150 $\mu g/cm^2$ CD_2 target. A set of three position-sensitive annular Si detectors measured protons at $\theta_{lab.}$=110°−161° while forward moving boron isotopes were identified in a ΔE-E telescope that covered θ_{lab}=1.3°−7.2°. Neutron bound and unbound states of ^{13}B were identified at E_x=0, 3.48, 3.68, 5.105, 5.388 MeV; only the ground state was resolved.

The angular distribution was determined for the ground state over $\theta_{c.m.}$=7.5°−30°, and it was analyzed via DWBA analysis to obtain spectroscopic data useful for determining the astrophysical $^{12}B(n,\gamma)$ reaction rates. Also see 2008WuZY, 2011BaZX for other ANL reports.

See (2021Du10) for a calculation of the cross section at astrophysically relevant energies.

^{13}B Levels

E(level)†	J$^{\pi}$#	L#	S#	Comments
0	3/2−	1	1.1 *3*	
3.48×10^{3}‡	(1/2+)	0,2		$S_{L=2}$ ≤ 0.05 $S_{L=0}$ component (2010Ba06).
3.68×10^{3}‡	(5/2+,3/2+)	2,0		The L=0 component is less than ≈2% of the L=0 component for the 3.48 MeV state. The authors suggest that J^{π}=5/2+ is favored based on absence of L=0 component in the angular distribution and a better fit to the ratios of spectroscopic factor (2010Ba06).
5105‡				
5388‡				

† Nominal values given in (2010Ba06, 2010Le02).
‡ Unresolved in (2010Le02).
# From DWBA analysis of spectroscopic factors in (2010Le02).

$^{4}He(^{12}Be,^{13}B\gamma)$ 2008Ot05

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2008Ot05: XUNDL file prepared by ANL (2008). A beam of 50 MeV/nucleon ^{12}B ions produced by fragmentation of a 100 MeV/nucleon ^{18}O beam at the RIKEN/RIPS facility bombarded a liquid He target located at the final focus of the RIPS. The beam was identified via ΔE vs. time-of-flight techniques before reaching the ≈143 mg/cm^{2}target that was surrounded by an array of six 6-cm by 2-cm HPGe γ-ray detectors from the GRAPE array positioned at θ=140°. The ^{13}B products were detected downstream of the target using a 1 meter^2 position-sensitive ΔE-E plastic scintillator.

The angular distributions of ^{13}B states are determined by gating on relevant de-excitation γ rays in the HPGE detectors. However, only three strong groups are naively visible in the γ spectrum to states at E_x=3681+3713, 4130, 4830 keV and no cascade transitions are observed. A more sophisticated deconvolution of the spectrum using GEANT4 premitted the authors to determine the relative populations of $^{13}B^*$(3483, 3535, 3681, 3713, 4130, 4830). In the present work, only the $^{13}B^*$(4830) angular distribution is analyzed using a DWBA, which found L=0. The authors suggest the state is a deformed J^π=1/2$^+$ intruder state.

Also See (2004OtZY, 2004OtZZ, 2004Sh24, 2008OtZZ).

^{13}B Levels

E(level)	J^π	L	Relative population†	Comments
0	3/2$^-$			J^π: From Adopted Levels, Gammas.
3483			19 *5*	
3535			20 *5*	
3681			74 *7*	
3713			68 *7*	
4131			49 *4*	
4829	1/2$^+$	0	100	L: From DWBA analysis of dσ/dΩ. J^π: From L(p)=0. C^2S=0.20 *2*. Systematic uncertaintity=60%. Configuration=π 1/2[220]$^1\otimes$(^{12}B deformed core); interpreted by 2008Ot05 as an intruder (deformed) state from the sd-shell. No cascading transitions to other states in ^{13}B were seen.

† Relative population is normalized to 100 for 4829 keV state, the quoted uncertainties are statistical only.

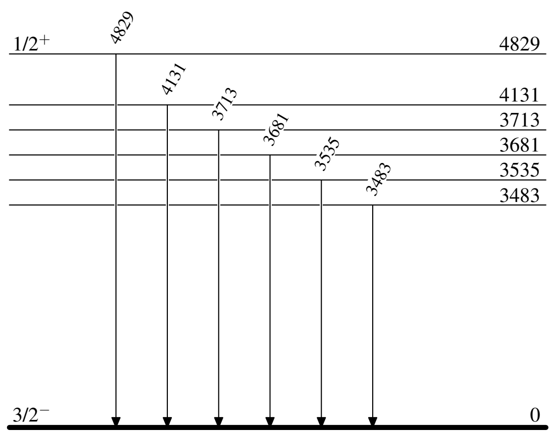
$\gamma(^{13}B)$

E_γ†	E_i(level)	J^π_i	E_f	J^π_f
3483#	3483		0	3/2$^-$
3535#	3535		0	3/2$^-$
3681‡	3681		0	3/2$^-$
3713‡	3713		0	3/2$^-$
4131	4131		0	3/2$^-$
4829	4829	1/2$^+$	0	3/2$^-$

† From commonly accepted γ-ray energy values listed in (2008Ot05).
‡ 3681 and 3713 γ rays form an unresolved doublet.
# 3483 and 3535 γ rays form an unresolved doublet.

$^{4}He(^{12}Be,^{13}B\gamma)$ 2008Ot05

Level Scheme



$^{13}_{5}B_{8}$

^{4}He(^{9}Li,α) 2017Di05,2022Di05

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2017Di05: ^{4}He(^{9}Li,α) E < 32 MeV. The reaction was measured at TRIUMF for $\sigma(E_\alpha,\theta=180°)$ using the TUDA chamber filled with 650-680 Torr of ^{4}He gas. Scattered α particles were detected along the beam axis. The excitation function was analyzed using thick target inverse kinematics to study the excitation region of E_x=14-20 MeV. Peaks at $E_x\approx$16.3 and 19.5 MeV are observed; the peak at 19.5 MeV is asymmetric and suggests participation of multiple states.

2022Di05: Additional data collected by two other telescope arrays used by (2017Di05) are presented. Details on the angular coverage indicate three 50×50 mm^2 ΔE-E Si detector telescopes were used. The ΔE detectors were segmented into quadrants; and the measured α energy was used to deduce the c.m. elastic scattering angle. Telescope 1 (T1) was along the beam axis and provided data for $\theta_{c.m.}\approx175°-178°$. The T2 telescope covered $\theta_{c.m.}\approx156°-174°$; lastly T3 provided data for $\theta_{c.m.}\approx128°-165°$. Using Thick-Target Inverse Kinematics relations for the elastic scattering events, angular resolutions of 0.1° to 3° were obtained from the scattered α-particle energy.

The peaks at $E_x\approx$16.3 and 19.5 MeV remain prominent, while visible suggestions of a third peak appears at 18.4 MeV in the T3 data. Analysis via the AZURE2 R-matrix code revealed evidence for a fourth resonance at E_x=18.9 MeV; the peaks appear to correspond to single broad resonances rather than groups of states as suggested in (2017Di05). Various models were explored in order to explain the resonances. Some success was found using a α+^{9}Li molecular-like rotational model, but findings were inconclusive.

^{13}B Levels

E(level)†	L†
16.3×10^3	4,5
18.4×10^3	5,6
18.9×10^3?	5,6
19.5×10^3	5,6

† From figure 5 in (2022Di05).

^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,pγ) 1972Wy01,2009Iw03

History			
Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1956Al60, 1957No14: ^{7}Li(^{7}Li, p)^{13}B E=1.61 MeV, Measured $\sigma(E_p,\theta=90°)$, deduced reaction Q=5.97 MeV *3* and ΔM=20.39 MeV *3*. First observation of ^{13}B (2012Th01).

1959Mo12: ^{7}Li(^{7}Li,p) E=2 MeV; identified reaction protons using ΔE-E. Deduced Q=5.97 MeV *5* and observed states at 0, 3.70 *5*, 4.16 *5*, 5.05 *8* and 5.5 *1* MeV. The 3.70 MeV state is later identified by (1963Ca09) as a doublet, but with similar precision.

1963Ca09: ^{7}Li(^{7}Li,pγ) E=3 MeV. Evaporated ^{7}LiF target. Measured γ rays in coincidence with associated charge particles using a solid state particle detector and NaI(Tl) detectors. Resolved previously reported first excited state as two groups; deduced E_x=3.50 *5*, 3.70 *5* and 4.16 MeV. Estimated cascade from 4.16 MeV →3.50 is 25% *10*.

1969Th01: ^{7}Li(^{7}Li,pγ) E=5.1-6.3 MeV; measured $\sigma(E_\gamma,\theta(\gamma))$ for γ rays emitted from a 156 μg/cm^2 enriched ^{7}LiF target. Measurements were taken at θ=0°, 90° and 150°. Deduced τ_m of >0.3 ps and <0.38 ps for ^{13}B*(3.53,3.71), respectively. For ^{13}B(4.13) τ_m=62 fs *50* was deduced and J=7/2 was suggested. E_γ for ^{13}B(3.53,4.13) were reported.

1972Wy01: ^{7}Li(^{7}Li,p) E=14 MeV; measured $\sigma(E_p)$. Deduced seven new levels at 5558-8683 keV from analysis of protons measured at θ=10° using Si detectors. Used beam from Van de Graaff at Univ. of Iowa. Published energies are based on ^{13}B(4132) peak, which has subsequently been reduced by 1 keV.

2003Fl02: ^{7}Li(^{7}Li,p) E=50.9 MeV from Florida State Univ. Tandem/LINAC accelerator facility; measured ^{9}Li+α coincidences; reconstructed relative energies and deduced resonance at E_x≈13.6 MeV along with higher-energy unresolved structures.

2009Iw03: ^{7}Li(^{7}Li,p) E=5.4 MeV beam provided by the FN Tandem facility at the Univ. of Cologne. Targets consisted of ^{7}LiF deposited on Au foil. Measured γ rays using EUROBBALL cluster Ge detector at 0° and five coaxial detectors at 140°. They detected particles in coincidence with γ using eight Si photodiodes at θ=62°−81° and used the Doppler-shift method to measure the lifetime of excited states in ^{13}B. A lifetime limit of τ_m<30 fs is deduced for ^{13}B(3.71, 4.13, 4.83). For the 3.68 MeV state, τ_m=55 fs *20* was deduced. For 3.53 MeV the lifetime τ_m=1.3 ps *3* is four times longer than earlier results. The long lifetime of ^{13}B(3.53) suggests it is a 3/2$^-$ intruder state. The double escape peak from 4.54 MeV ^{11}B contaminant γ ray was found to be less than 10% of the 3.53 MeV peak.

Also see (2009IwZZ).

^{13}B Levels

E(level)	J$^\pi$	$T_{1/2}$ †	Comments
0	3/2$^-$		
3536.8 *42*	(3/2$^-$)	0.90 ps *21*	E(level): From Eγ (1969Th01). J$^\pi$: From (2009Iw03). $T_{1/2}$: From τ_m=1.3 ps *2* (2009Iw03). See also τ_m>0.3 ps (1969Th01).
3681	+	38 fs *14*	E(level),$T_{1/2}$: From τ_m=55 fs *20* (2009Iw03). J$^\pi$: From L(t,p)=1 from 3/2$^-$ $^{11}B_{g.s.}$ (quoted by (2009Iw03) from (1964Mi04)).
3700 *50*		≤21 fs	E(level): From (1959Mo04). $T_{1/2}$: From τ_m<30 fs (2009Iw03); see also τ_m<0.38 ps (1969Th01).
4134.1 *78*		≤21 fs	E(level): From Eγ (1969Th01); see also 4160 *50* (1959Mo04). $T_{1/2}$: From τ_m<30 fs (2009Iw03); see also τ_m=62 fs *50* (1969Th01). 1963Ca09 reports a 25% *10* branch to unresolved 3.48+3.53 MeV states, and 75% *10* to ground and an upper limit of <10% to the 3.70 MeV state.
4833‡ *10*		≤21 fs	$T_{1/2}$: From τ_m<30 fs (2009Iw03).
5033‡ *8*			E(level): other: 5050 keV *80* (1959Mo12).
5391‡ *8*			
5557‡ *8*			E(level): other: 5500 keV *100* (1959Mo12).
6169‡ *8*			
6419‡ *8*			
6939‡ *15*			
7516‡ *8*			
7859‡ *20*			

Continued on next page (footnotes at end of table)

$^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,p\gamma)$ **1972Wy01,2009Iw03 (continued)**

^{13}B Levels (continued)

E(level)	Comments
8129‡ *10*	
8682‡ *9*	
13600	E(level): From $^{9}Li+\alpha$ kinematic reconstruction (2003Fl02).

† Deduced from lifetime measured in the Doppler-shift attenuation method (2009Iw03).
‡ From values given in (1972Wy01) that used E_x=4132 as the energy standard. When the energy of the standard was decreased by 1 keV, previous evaluations decreased these energies by 1 keV as is done for values given here.

$\gamma(^{13}B)$

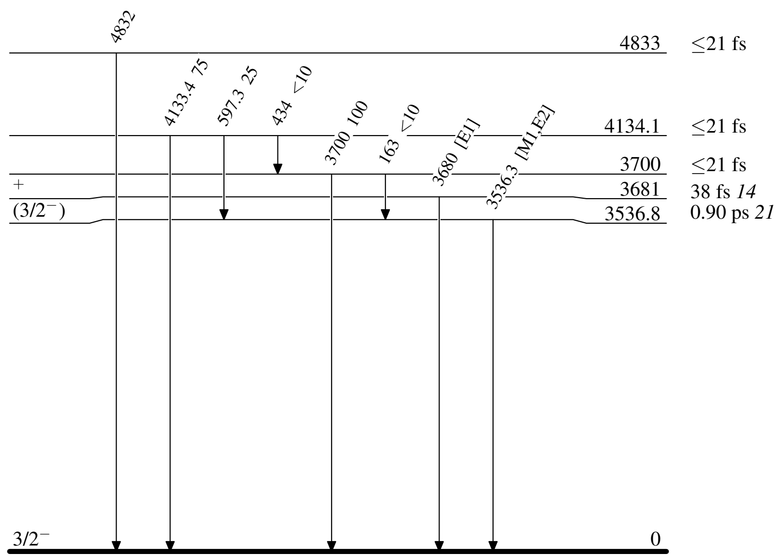
E_i(level)	J^π_i	E_γ†	I_γ‡	E_f	J^π_f	Mult.	Comments
3536.8	(3/2⁻)	3536.3 *42*		0	3/2⁻	[M1,E2]	B(M1)(W.u.)<7.2×10^{-4} (2009Iw03); B(E2)(W.u.)<0.81 (2009Iw03) E_γ: From (1969Th01).
3681	+	3680		0	3/2⁻	[E1]	B(E1)(W.u.)=6.4×10^{-4} *23* (2009Iw03)
3700		163	<10	3536.8	(3/2⁻)		E_γ: No evidence for this transition is reported; (1963Ca09) assign an upper limit of <10%.
		3700	100	0	3/2⁻		
4134.1		434	<10	3700			
		597.3	25 *10*	3536.8	(3/2⁻)		
		4133.4 *78*	75 *10*	0	3/2⁻		E_γ: From (1969Th01).
4833		4832		0	3/2⁻		E_γ: Observed by (2009Iw03).

† From level-energy difference unless otherwise indicated.
‡ From (1963Ca09).

$^{7}Li(^{7}Li,p),^{7}Li(^{7}Li,p\gamma)$ 1972Wy01,2009Iw03

Level Scheme

Intensities: % photon branching from each level



$^{13}_{5}B_{8}$

^{9}Be(^{15}N,^{13}B) 2004Na38

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2004Na37, 2004Na38: ^{9}Be(^{15}N,^{13}B): ^{13}B ions were produced by fragmentation at the HIMAC accelerator in Chiba Japan. The ions were collected at θ=1.5° and implanted into a TiO_2 crystal placed in an external magnetic field to maintain polarization. Analyzed β asymmetry and deduced magnetic moment μ=3.1778 μ_N *5* with Knight shift correction. The quadrupole moment was determined as Q=+36.6 mb *8* (with respect to ^{12}B (2004Na46)). The allignment correlation term was also studied.

2004Na47: ^{9}Be(^{15}N,^{13}B), measured momentum dependences of the nuclear spin polarization and spin alignment.

^{13}B Levels

E(level)	$T_{1/2}$	Comments
0	17.36 ms	μ=3.1778 *5*; Q=+0.0366 *8* μ,Q: From (2004Na38).

^{9}Be(^{14}B,^{13}Bγ),^{197}Au(^{14}B,^{13}Bγ) 2000Gu23

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2000Gu23, 2004Gu21: ^{9}Be(^{14}B,^{13}Bγ), ^{197}Au(^{14}B,^{13}Bγ). One neutron knock-out reactions were used to study the ^{13,14}B systems. A beam of 830 MeV ^{14}B ions, from the NSCL/A1200, impinged on either a ^{9}Be or ^{197}Au target. The ^{13}B products were momentum analyzed using the S800 spectrometer, while coincident were measured using an array of 38 NaI(Tl) scintillator detectors that surrounded the target. The Doppler corrected γ-ray spectrum is obtained. Cross sections to ^{13}B(0, 3.48, 3.68, 4.13) are deduced. Shell model calculations are compared with the data and used to suggest J^{π} values.

^{13}B Levels

E(level)	J$^{\pi}$ †	L	S	Comments
0	[3/2^{-}]	0+2		σ(L=0)=113 mb *15*; σ(L=2)=14 mb *3*; S(L=0)=0.622; S(L=2)=0.306.
3480	[3/2^{+}]	1	0.407	σ=18 mb *3*.
3680	[5/2^{+}]	1	0.886	σ=30 mb *5*.
4130				σ=1.2 mb *12*.

† From comparison with shell model calculations.

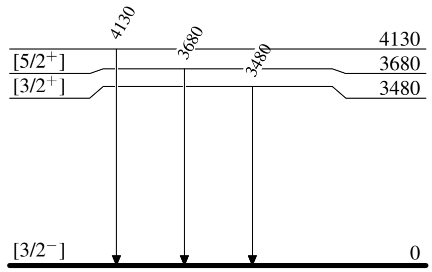
γ(^{13}B)

E$_{\gamma}$ †	E$_{i}$(level)	J$^{\pi}_{i}$	E$_{f}$	J$^{\pi}_{f}$
3480	3480	[3/2^{+}]	0	[3/2^{-}]
3680	3680	[5/2^{+}]	0	[3/2^{-}]
4130	4130		0	[3/2^{-}]

† From Figure 1 in (2000Gu23).

^{9}Be(^{14}B,^{13}Bγ),^{197}Au(^{14}B,^{13}Bγ) 2000Gu23

Level Scheme



$^{13}_{5}B_{8}$

^{9}Be(^{13}B,X) 2014Es07

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1988Ta10: Measured the interaction cross section of ≈790 MeV/nucleon ^{13}B on ^{9}Be, ^{nat}C, ^{27}Al targets at the LBNL/Bevalac. Analyzed cross sections in a Glauber model and deduced the interaction radius, R_I=2.76 fm *10*. They also deduced the rms radii for the proton (2.42 fm *11*), neutron (2.50 fm *12*) and matter (2.46 fm *12*) distributions.

2014Es07: XUNDL dataset compiled by TUNL, 2014.

The authors measured the charge changing reaction cross sections of boron isotopes and deduced their root mean square proton radii.

Beams of ≈850 – 900 MeV/nucleon boron isotopes were produced by fragmenting ^{22}Ne($^{10,14-17}$B) and ^{40}Ar($^{11-13}$B) ions on a thick ^{9}Be foil at the GSI/FRS fragment separator. The beam species were identified by ΔE (ionization chamber) vs time-of-flight before they impinged on a 4.010 g/cm^2 thick carbon target. An ionization chamber located after the target was used to identify charge changing reaction events.

In the discussion, the rms proton radii for ^{10,11}B are obtained from e^- and π^- scattering and muonic X-ray studies, while for heavier boron isotopes the proton radii are obtained by analyzing the charge changing cross sections, σ_α, in a Glauber model. The proton (2.48 fm *3*) and matter (2.41 fm *5*) rms radii values are given for ^{13}B. Finally, the rms proton radii are compared with rms matter radii derived from interaction cross section measurements in the literature.

2017Ta06: Measured reaction cross sections on ^{1}H, ^{9}Be, $^{nat.}$C, and ^{27}Al at the NIRS/Japan. Analyzed data using Glauber model. Deduced matter density distribution.

See other analysis in (1990Li39, 1990Lo10, 1992La13, 1995Pe19, 1996Sh13, 1997Ho04, 1997Ka32, 2000Bh09, 2001Oz04, 2003Um02, 2004Ne16, 2012Ji01, 2017Ah08, 2019Fo08).

^{13}B Levels

E(level)	J^{π}†	Comments
0	3/2$^-$	R_{rms}(proton)=2.48 fm *3* obtained from Glauber model analysis of the charge changing cross section σ_α=723 mb *6* at E(^{13}B)=897 MeV/nucleon.

† From Adopted Levels.

^{9}Be(^{40}Ar,^{13}B) 2007No13

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2007No13: ^{9}Be(^{40}Ar,X), ^{181}Ta(^{40}Ar,X) at E=90 MeV/nucleon and 94 MeV/nucleon, respectively. Measured fragmentation cross sections for A=6-39 nuclei at RIKEN/RIPS.
2012Kw02: ^{9}Be(^{40}Ar,X), Ni(^{40}Ar,X), ^{181}Ta(^{40}Ar,X) at E=140 MeV/nucleon. Measured fragmentation cross sections for A=10-39 nuclei at NSCL.
2015Mo17: ^{9}Be(^{40}Ar,X) at E=95 MeV/nucleon. Analyzed fragment transverse momentum distributions measured at RIKEN.

See also (2000Fa06), who calculated isospin effects in fragmentation production of light nuclei from ^{18}O.

^{13}B Levels

E(level)
0

^{11}B(t,p) 1964Mi04,1978Aj02

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1960Mu07: ^{nat}B(t,p) E=5 MeV; θ=10°−61°; ΔE_{res}=15 keV; Q=−0.233 MeV *4* and ΔM=20.397 MeV *4*. University of Manchester.

1962Ma19: ^{11}B(t,p) E=3.3 MeV; ^{13}B ions were produced in a 2 mg/cm^2 ^{11}B target at the University of Manchester. The ^{10}B content was measured to be less than 0.2%. Beam on/beam off periods were 100 ms, with counting starting 5 ms after the beam was removed and lasting an additional 65 ms. The β and γ particles were measured in singles and coincidence mode using a plastic phosphor detector for βs and a NaI scintillator for γ rays. The decay is mainly to ^{13}C. Deduced ratio of ^{13}B/^{12}B lifetimes =0.86 *2* initially resulting in $T_{1/2}$=18.6 ms *5*; using the present $T_{1/2}$(^{12}B)=20.22 ms *4* gives 17.39 ms *41*. Deduced β branch to ^{13}C*(3.67 MeV *2*) as 7.0% *15* and set an upper limit for delayed neutrons as <1.5%. Other limits are set.

1964Mi04: ^{11}B(t,p) E=11 MeV. Tritons from the Aldermaston Tandem generator impinged on a ≈50 μg/cm^2 98.6% enriched ^{11}B target. Reaction protons were measured using a multi-channel magnetic spectrometer. The ground state and nine excited states were observed and measurements were taken over for θ≈2°−170°. The *l* and J^π values were determined via plane-wave analysis.

1968Ch28: ^{11}B(t,p) E=3.0 MeV. ^{13}B nuclei were produced via triton bombardment of a natural boron target at the Nippon Atomic Industry Group Laboratory in Kawasaki Japan. The beam was chopped and the beam-off period permitted counting for at least 80 ms. The target was surrounded by a pile of paraffin blocks and the yield of β-delayed was counted with a BF_3 scintillator counter. Analysis of the neutron counting rate indicated $T_{1/2}$=16 ms *1*. Additionally, a plastic scintillator counter was placed near the target to count decay β rays. By comparing the β and neutron yields %β-n≈(0.52 *26*) was determined.

1969Jo21: ^{11}B(t,p) E=3.0 MeV. The β decay of ^{13}B was studied at the BNL Van de Graaff. β, $\beta\gamma$ and βn measurements permitted a determination of the branching ratios to ^{13}C states. The β-n branches through ^{13}C*(7.55, 8.86) are measured with 0.094% *20* and 0.16% *3*.

1971Wi07: ^{11}B(t,p) at 3.0 MeV at BNL. Measured βs from ^{13}B decay using a plastic scintillator. Deduced $T_{1/2}$=17.33 ms *17*.

1971Wi09: ^{11}B(t,p). ^{13}B ions, produced using a 2 MeV triton beam on a ^{11}B target at the BNL Van de Graaff, were collected in Au, Pt and Pd metallic stopper foils that were held in a strong magnetic field. Measured g=2.11808 *34*. μ=+3.17712 μ_N *51* was deduced from analysis of the β-decay asymmetries. See also (1973HaZV).

1974Al12: ^{11}B(t,p) E_t=3 MeV. Measured %β-n=(0.022 *7*) at BNL Van de Graaff facility.

1978Aj02: ^{11}B(t,p), A series of (t,p) reactions were studied at E_t=23 MeV at the LANL three-stage Van de Graaff facility. The reaction products were momentum analyzed in a broad range magnetic spectrometer for θ=5°−55°. Eighteen states up to E_x=11.8 MeV were reported. Widths are deduced for the higher-lying states, and L values are deduced for ^{13}B(0, 6.93 MeV).

1983An15: ^{11}B(t,p), The authors determined Q=−233.54 keV *100* by measuring the ^{11}B(t,p) reaction protons at θ=28°−40° using a 30 μg/cm^2 target at the Strasbourg Van de Graff. Using this, ΔM(^{13}B)=16562.17 keV *104* was deduced. The authors evaluated the IMME mass equation for the A=13 quartet.

2006Ge21: The ^{11}B(t,p) excitation function was measured for E_t=2.53-6.95 MeV using the RFNC EGP-10 Tandem accelerator; The measurement utilized activation and off-line counting techniques and deduced information on ^{14}C. $T_{1/2}$=16.59 ms *2* was also deduced. Also see (2002GeZT, 2005GeZY).

^{13}B Levels

E(level)[†]	J^π[‡]	$T_{1/2}$ or Γ[†]	L[‡]	Comments
0	3/2$^-$	17.33 ms *17*	0	μ=+3.17712 *51* (1971Wi09) g=2.11808 *34* (1971Wi09) E(level): (1983An15) deduced Q=−233.36 keV *100* and ΔM=16562.17 keV *104*. Analyzed IMME equation. $T_{1/2}$: From 17.39 ms *41* (1962Ma19) and 17.33 ms *17* (1971Wi07); see also 16 ms *1* (1968Ch28) and 16.59 ms *2* (2006Ge21). J^π: (1960Mu07).
3483 *5*	(1/2,3/2,5/2)$^+$		1	E(level): Weighted average of 3483 keV *5* (1964Mi04) and 3482 keV *10* (1978Aj02).
3533 *5*	(1/2,5/2,7/2)$^-$		2	E(level): Weighted average of 3533 keV *5* (1964Mi04) and 3531 keV *10* (1978Aj02).
3681 *5*	(1/2,3/2,5/2)$^+$		1	E(level): Weighted average of 3681 keV *5* (1964Mi04) and 3681 keV *10* (1978Aj02).
3713 *5*	(1/2,5/2,7/2)$^-$		2	E(level): Weighted average of 3712 keV *5* (1964Mi04) and 3715 keV *10*

Continued on next page (footnotes at end of table)

^{11}B(t,p) 1964Mi04,1978Aj02 (continued)

^{13}B Levels (continued)

E(level)†	Jπ‡	$T_{1/2}$ or Γ†	L‡	Comments
				(1978Aj02).
4129 *10*	(1/2,5/2,7/2)$^-$		2	E(level): Average of 4130 keV *10* (1964Mi04) and 4128 keV *10* (1978Aj02).
4827 *10*				E(level): Weighted average of 4820 keV *10* (1964Mi04) and 4834 keV *10* (1978Aj02).
5017 *10*	(1/2,3/2,5/2)		1	E(level): Average of 5010 keV *10* (1964Mi04) and 5023 keV *10* (1978Aj02).
5106 *10*		60 keV *10*		
5387 *10*		14 keV *4*		E(level): Average of 5380 keV *10* (1964Mi04) and 5393 keV *10* (1978Aj02). Γ: Weighted average of 15 keV *5* (1964Mi04) and 10 keV *10* (1978Aj02).
6165 *10*		<20 keV		E(level): Weighted average of 6170 keV *20* (1964Mi04) and 6164 keV *10* (1978Aj02). Γ: In Fig. 10 of (1978Aj02) this state is narrower than the E_x=5.39 MeV state. Γ<20 keV is assigned.
6434 *10*		36 keV *5*		
6932 *10*		55 keV *15*	>4	L: From (1978Aj02).
8138 *10*		100 keV *15*		
8684 *10*		89 keV *20*		
9.44×10^3 *3*		81 keV *25*		
10.22×10^3 *2*		210 keV *20*		
10.89×10^3 *2*				
11800?				

† From (1978Aj02), except where noted.
‡ From plane-wave analysis in (1964Mi04), except where noted.

$^{11}B(^{18}O,^{16}O)$ 2013Ni06

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2013Ni06: A beam of 85 MeV/nucleon ^{18}O ions impinged on a 78 $\mu g/cm^2$ ^{11}B target at the INFN/Catania. The angular distributions of reaction products were measured for θ=7° to 24° using the MAGNEX spectrometer. Collective 2n transfer peaks are identified and compared with 2n reactions in nearby nuclei. See also (2011CaZX, 2011Ca36, 2018Ag04).

^{13}B Levels

E(level)
0
3.68×10^3
4.13×10^3
5.39×10^3
6.16×10^3 †
6.43×10^3 †
8.32×10^3

† Unresolved.

^{12}C(^{9}Be,^{8}B) 1999Ca48

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1975Wi26: A ^{12}C target was bombarded by a 121 MeV beam of ^{9}Be ions from Lawrence Berkeley Laboratory 88-inch cyclotron. The ^{8}B reaction products were measured at θ=14° using a ΔE-ΔE-E Si detector telescope. Poorly resolved groups of ^{13}B states were observed. The objective was to provide an energy calibration point for a measurement on ^{10}Li.

1999Ca48: ^{12}C(^{9}Be,^{8}B). E=40.1 MeV/nucleon. A ^{9}Be beam, produced by fragmentation at the MSU/NSCL, impinged on a ^{12}C target at the S800 spectrometer target position. The σ(E,θ) was measured for $\theta\approx$3.5°−8.3°. The reaction to $^{13}B_{g.s.}$ was used to calibrate the focal plane.

^{13}B Levels

E(level)†	Comments
0	
3600	E(level): Unresolved multiplet (1975Wi26).
5200	E(level): Possible group of states.
6170	E(level): Unresolved with 6430.
6430	E(level): Unresolved with 6170.

† From (1999Ca48).

$^{12}C(^{14}C,^{13}N)$ 2000Ka21

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2000Ka21: $^{12}C(^{14}C,^{13}N)$ E=336.8 MeV. Measured excitation energy spectra for θ=1.4°−5.0° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed reaction mechanism and likely J^π values. Typo on the last line of p.454: 4^- should be 4^+.

^{13}B Levels

E(level)†	Jπ‡	Γ‡	Comments
0	3/2⁻		dσ/dΩ(5.4°)=2.2 μb/sr *2* (2000Ka21).
3680	(5/2⁻)		E(level): doublet consisting of unresolved states at 3680 and 3710 keV. dσ/dΩ(5.4°)= 5.3 μb/sr *3*.
4130			dσ/dΩ(5.4°)=1.2 μb/sr *2*.
4910			dσ/dΩ(5.4°)=1.8 μb/sr *2*.
5390			dσ/dΩ(5.4°)=5.8 μb/sr *4*.
6370	(5/2,7/2,9/2,11/2)	30 keV	Jπ: Authors suggest this formed via a two-step process with a p-wave proton pickup to ^{15}N followed by a 2n transfer to ^{13}N. dσ/dΩ(5.4°)=15.1 μb/sr *6*.
6960		150 keV	dσ/dΩ(5.4°)=2.0 μb/sr *2*.
7580		170 keV	E(level): This group appears as a small shoulder on the 8.14 MeV peak and may correspond to unresolved states at 7.51 and 7.86 MeV. dσ/dΩ(5.4°)=1.1 μb/sr *2*.
8140		70 keV	dσ/dΩ(5.4°)=5.3 μb/sr *3*.
8690		≤80 keV	dσ/dΩ(5.4°)=1.9 μb/sr *2*.
9440		≤80 keV	dσ/dΩ(5.4°)=1.6 μb/sr *2*.
10220		170 keV	dσ/dΩ(5.4°)=4.0 μb/sr *3*.
10980			E(level): this may be several unresolved states. dσ/dΩ(5.4°)=6.4 μb/sr *4*.

† From (2000Ka21); ΔE≈300 keV.

‡ From analysis of $^{12}C(^{13}C,^{12}N)$,$(^{14}C,^{13}N)$ and $(^{15}N,^{14}O)$ multi-nucleon transfer reactions in (2000Ka21).

^{12}C(^{16}O,^{13}B),(^{18}O,^{13}B) 2022Bo01

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1983Ol07: Measured fragmentation yields for various projectile+target combinations using 1.0−2.0 GeV/nucleon beams of ^{12}C, ^{16}O, ^{18}O and ^{56}Fe at the Bevelac. Cross sections for ^{13}B are given for ^{16}O projectiles on targets from ^{1}H to ^{208}Pb.

2022Bo01: ^{12}C(^{16}O,^{13}B): Using the R^{3}B/LAND facility, measured ^{13}B production yields in the fragmentation of ^{16,20,22}O at E=450, 415, and 414 MeV/nucleon, respectively.

2022Ji03,2022Xu12: A cocktail beam of $^{12-16}$C isotopes was produced at the HIRFL by fragmenting a 240 MeV/nucleon ^{18}O ion beam on a ^{9}Be target. The different isotopes of the cocktail beam were identified by time-of-flight techniques and subsequently used to measure fragment production yields of boron isotopes (elemental analysis).

2023Me12: ^{12}C(^{16}O,^{13}B),(^{16}N,^{13}B): Measured production yields of 240 MeV/nucleon ^{12,14}C, ^{14,16}N and ^{16}O projectiles on a carbon target at the Lanzhou RIBLL2 facility. Deduced cross sections for ^{13}B production using ^{16}O and ^{16}N beams.

^{13}B Levels

E(level)
0

$^{12}C(^{15}N,^{14}O)$ **2000Ka21**

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2000Ka21: $^{12}C(^{15}N,^{14}O)$ E=240.1 MeV. Measured excitation energy spectra for θ=2.0°−5.4° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed reaction mechanism and likely J^{π} values.

^{13}B Levels

E(level)†	J^{π}‡	Γ‡	Comments
0	3/2⁻		dσ/dΩ(9.1°)=0.3 μb/sr *1* (2000Ka21).
3720	(5/2⁻)		E(level): doublet consisting of unresolved states at 3680 and 3710 keV. dσ/dΩ(9.1°)=1.8 μb/sr *2*.
4140			dσ/dΩ(9.1°)=0.7 μb/sr *1*.
5030	(3/2⁻)		dσ/dΩ(9.1°)=0.4 μb/sr *1*.
5380	(7/2⁻)		dσ/dΩ(9.1°)=3.0 μb/sr *2*.
6170		60 keV	dσ/dΩ(9.1°)=1.8 μb/sr *2*.
6430	(9/2⁺)	30 keV	dσ/dΩ(9.1°)=13.4 μb/sr *5*.
6920		150 keV	dσ/dΩ(9.1°)=1.2 μb/sr *2*.
7760		170 keV	E(level): This group appears as a small shoulder on the 8.12 MeV peak and may correspond to unresolved states at 7.51 and 7.86 MeV. dσ/dΩ(9.1°)=0.5 μb/sr *1*.
8120		70 keV	dσ/dΩ(9.1°)=3.4 μb/sr *2*.
8690		≤80 keV	dσ/dΩ(9.1°)=2.8 μb/sr *2*.
9440		≤80 keV	dσ/dΩ(9.1°)=1.6 μb/sr *2*.
10220	(11/2⁻)	170 keV	E(level): other: 10250 (1993Bo03). dσ/dΩ(9.1°)=9.2 μb/sr *4*.
11050		1.8 MeV	E(level): broad structure which may be due to several unresolved states. dσ/dΩ(9.1°)=8.0 μb/sr *4*.
13650		300 keV	dσ/dΩ(9.1°)=1.7 μb/sr *2*.
14390		400 keV	dσ/dΩ(9.1°)=1.4 μb/sr *2*.

† From (2000Ka21); ΔE≈300 keV.
‡ From analysis of $^{12}C(^{13}C,^{12}N)$,$(^{14}C,^{13}N)$ and $(^{15}N,^{14}O)$ multi-nucleon transfer reactions in (2000Ka21).

$^{12}C(^{13}C,^{12}N)$ **2000Ka21**

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1986Vo02: $^{12}C(^{13}C,^{13}B)$ E=30 MeV/nucleon at Grenoble; measured $\sigma(E(^{13}B_{g.s.}))$ using a QD spectrometer at θ=1.8° with ΔE≈800 keV.

1993Bo03: $^{12}C(^{13}C,^{12}N)$ E=336 MeV at the HMI/VICKSI facility. Measured $\sigma(\theta)$ at θ=3.8° using a Q3D spectrometer. Deduced states at ^{13}B(0, 3.65, 5.21, 6.33, 8.24, 10.25 MeV) with no associated uncertainties; the differential cross sections are reported in Table 1.

1994Ic02: $^{13}C(^{12}C,^{12}N)$ E=135 MeV/nucleon from the RIKEN/K=540 MeV ring cyclotron. Measured $\sigma(^{13}B_{g.s.})$ for θ<10° using the SMART spectrograph. Deduced model parameters, reaction mechanism, strong selectivity of ΔS=1, ΔT=1 transitions.

2000Ka21: $^{12}C(^{13}C,^{12}N)$ E=336.4 MeV. Measured excitation energy spectra for θ=1.8°−5.2° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed the reaction mechanism and likely J^{π} values.

^{13}B Levels

E(level)†	Jπ‡	Γ‡	Comments
0	3/2−		dσ/dΩ(6.2°)=1.0 μb/sr *3* (2000Ka21).
3690	(5/2−)		E(level): doublet consisting of unresolved states at 3680 and 3710 keV. dσ/dΩ(6.2°)=1.8 μb/sr *4*.
4120			dσ/dΩ(6.2°)=1.4 μb/sr *3*.
5000			dσ/dΩ(6.2°)=1.4 μb/sr *3*.
5370			dσ/dΩ(6.2°)=3.2 μb/sr *5*.
6400		30 keV	dσ/dΩ(6.2°)=19.0 μb/sr *12*.
7200?		170 keV	E(level): This group appears as a shoulder on the 6.40 MeV peak and may correspond to unresolved states at 7.51 and 7.86 MeV. dσ/dΩ(6.2°)=1.9 μb/sr *4*.
8160		70 keV	dσ/dΩ(6.2°)=3.9 μb/sr *6*.
8680		≤80 keV	dσ/dΩ(6.2°)=3.4 μb/sr *5*.
9310		≤80 keV	dσ/dΩ(6.2°)=2.6 μb/sr *4*.
10220		170 keV	E(level): other: 10250 (1993Bo03). dσ/dΩ(6.2°)=15.1 μb/sr *11*.
11180			E(level): broad structure which may be due to several unresolved states. dσ/dΩ(6.2°)=7.1 μb/sr *7*.

† From (2000Ka21); ΔE≈300 keV.

‡ From analysis of $^{12}C(^{13}C,^{12}N)$,$(^{14}C,^{13}N)$ and $(^{15}N,^{14}O)$ multi-nucleon transfer reactions in (2000Ka21).

^{12}C(^{12}Be,^{13}B) 2008Ch28

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2008Ch28: ^{12}C(^{12}Be,^{9}Li+α) E=50 MeV/nucleon. A beam of ^{12}Be ions from the NSCL/A1900 impinged on a ^{12}C target placed at the S800 spectrometer target position that was surrounded by 16 position sensitive ΔE-E telescopes from the HiRA array. The array covered θ=2.7°−24.8° A kinematic reconstruction of the ^{9}Li+α relative energy spectrum indicated a state at E(^{9}Li+α)≈2.8 MeV. After correcting for the experimental resolution, Γ≤320 keV is deduced.

^{13}B Levels

E(level)	Γ (keV)	Comments
13.6×10^{3} *1*	≤320 keV	E(level): determined from α+^{9}Li correlations using S_{α}=10.82 MeV.

^{13}C(γ,π^+) 1994Ch39

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1982Le26: ^{13}C(γ,π^+)^{13}B(0,3.6) using Bremsstrahlung photons from E_e=190-204 MeV on a 99% enriched ^{13}C target at MIT/Bates. Measured $\sigma(\theta=90°)$ for emitted π^+ energies of 18, 29, 42 MeV. Analyzed $^{13}B_{g.s.}$ population via DWIA. Higher-lying states were unresolved.

1983Mi06: ^{13}C(γ,π^+). Photopion production was deduced from ^{13}C(e,e′π^+) data obtained using a 195 MeV electron beam from the Tohoku/Japan LINAC. Determined $\sigma(E(\pi),\theta)$ for θ=30°−150°. Deduced photopion $\sigma(\theta)$ vs. E_γ. Deduced the M2, M4 transition strength distribution and giant analog resonance excitation. 99% enriched ^{13}C target. $^{13}B^*$(0,3.5, 6.4, 9 MeV) are reported.

1983Sh01: ^{13}C(γ,π^+), deduced from measurement of the ^{13}C(e,π^+)$^{13}B_{g.s.}$ reaction using a 195 MeV electron beam from the Tohoku/Japan LINAC. Measured $\sigma(\theta)$ for θ=30-150°. Compared with DWIA calculations. 99% enriched ^{13}C target.

1988Ka41: ^{13}C(γ,π^+): compiled $\sigma(E\gamma,\theta)$.

1994Ch39, 1994Ch43: ^{13}C(γ,π^+) E_γ=191 MeV produced from 290 MeV electrons from the Saskatchewan 300 MeV electron accelerator. Measured $\sigma(E(\pi),\theta(\pi))$. Groups are reported at ^{13}B(0, 3.5, 6.4, 9.5 MeV). Discussed ΔS=1, ΔT=1 transitions features.

Theoretical analyses.

1973Na14: compared (γ,π^+) vs (γ,π^-) calculated cross sections.

1983To17: ^{13}C(γ,π^+), DWBA, calculated $\sigma(\theta)$.

1982Ch16: ^{13}C(γ,π^+)$^{13}B_{g.s.}$, calculated $\sigma(\theta)$.

1983Ch54: ^{13}C(γ,π^+), calculated $\sigma(\theta)$.

1983Mi06: ^{13}C(γ,π^+) E=162, 173, 186 MeV, calculated $\sigma(\theta)$.

1986Si07: ^{13}C(γ,π^+), calculated $\sigma(\theta)$, deduced Δ-isobar term.

1989Je02: ^{13}C(γ,π^+), calculated $\sigma(\theta)$, theory, E=193 MeV. Chiral Bag Model.

1991Er06: Comparison of calculated (e,e′), (γ,π^+) and (π^-,γ) cross sections at E≈180, 200 MeV.

^{13}B Levels

E(level)	Comments
0	
3.5×10^3 †	
6.4×10^3 †	
9.5×10^3 †	E(level): other: 9000 (1983Mi06).
13000†	

† E_x from (1994Ch39); levels may contain a complex of states. Some states are not associated with Adopted Levels because inadequate details are given in the literature to make an association.

^{13}C(μ^{-},ν)

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1987Su06, 1981SuZS: ^{13}C(μ-,ν), E at rest, measured muonic capture lifetime.

2016Ab02: Deduced cross section limit for the ^{13}C(μ-,ν)^{13}B reaction obtained in the Double Chooz detector and discussed cosmogenic production of radionuclides. See similar discussion in (2010Ab05, 2019Zh29).

Theoretical analyses.

1973Mu11: ^{13}C(μ-,ν), calculated capture cross sections.

1972Bu29: ^{13}C(μ-,ν), estimated capture rates to ^{13}B(0,3.7 MeV).

1979De01: ^{13}C(μ-,ν), theory − shell model, calculated partial transition rates for muon capture on 1p-shell nuclei.

1985Ko39: ^{13}C(μ-,ν), E at rest, calculated partial muon capture rates, deduced gp/gA.

1998Mu17: ^{13}C(μ-,ν), calculated total capture rate. (assumed at rest).

^{13}B Levels

E(level)
0

^{13}C(π^-,γ) 1983Ma16

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1983Ma16: ^{13}C(π^-,γ), Measured stopped π^- capture at the Low Energy Pion Channel of the LANL Clinton P. Anderson Meson Physics Facility. Measured E_γ, I_γ. Deduced feeding to ^{13}B states. See also (1981MaZS).

Theoretical analyses.

1977Do06: Calculated transition probabilities to ^{13}B(0, 3.6, 5.5 MeV).

1978Ki13: Shell model calculations for spin-dipole transitions. Analysis of the gross structure of resonances. Predicted population of several states at E_x=0 to 22 MeV.

1982Gm02: ^{13}C(π^-,γ): compiled available data. Deduced reaction mechanism.

1991Er06: Compared of calculated (e,e′), (γ,π^+) and (π^-,γ) cross sections at E≈180, 200 MeV.

^{13}B Levels

E(level)†	Comments
0	
3.5×10^3	E(level): Possible doublet.
6.5×10^3	
7.6×10^3	
$\approx10.2\times10^3$	Γ: Broad state or group of levels: order of MeV(s).

† From (1983Ma16).

$^{13}C(\pi^-,\pi^0)$ 1994Ha41

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1994Ha41: $^{13}C(\pi^+,\pi_0)$ E=165; measured $\sigma(\theta, E_\pi)$ at LAMPF using π^0 spectrometer to measure the decay γ-γ photons. Reported π_0 to $E_x \approx 9$ MeV T=3/2 state. See also (1999Ha24).

Theoretical analyses.

1980Jo06: $^{13}C(\pi^-,\pi_0)$ E=180 MeV, calculated $\sigma(\theta)$.

1981Os04: $^{13}C(\pi^+,\pi_0)$ E=130-250 calculated $\sigma(E,\theta)$ estimated importance of Δ resonance.

^{13}B Levels

E(level)	Γ	Comments
9.0×10^3	≈8.1 MeV	T=3/2 E(level): Represents the T=3/2 giant resonance built on $^{13}C_{g.s.}$ (1994Ha41).

^{13}C(n,p) 1996Wa06

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1987Br32: ^{13}C(n,p) E= 65 MeV with neutrons produced via ^{7}Li(p,n) at the UC Davis laboratory. Measured σ(E(p),θ) for θ=0° to 40° utilizing a dipole magnet and ΔE-E telescopes. Data presented only for ^{12}C target.

1988Ja01: ^{13}C(n,p) E=198 MeV. Measured σ(E(p),θ) at θ=0° at the TRIUMF charge exchange facility. Related σ(0°) to B_{GT} for $^{13}B_{g.s.}$

1992So02: ^{13}C(n,p) E=60 to 260 MeV. Measured σ(E(p),θ) at θ=0° to 10° for the ground state G-T transition at the LANL/WNR facility. Obtained information on the volume integral of the spin-isospin term of the effective N-N interaction and on the relation between $\sigma(\theta\approx0°)$ and B_{GT}.

1996Wa06: ^{13}C(n,p) E= 65 MeV. Measured σ(E(p),θ) for θ=0° to 40° at the UC Davis laboratory. Observed peaks at E_x=0, 3.5, 6.5, 7.6, 10.2 MeV. Suggest the 6.5 and 7.6 MeV states are spin dipole in character while the broad 10.2 MeV state is likely the giant E1 resonance.

1996Ma58: ^{13}C(n,p)$^{13}B_{g.s.}$ E= 118 MeV. Measured σ(E(p),θ) for θ=0° to 19° at IUCF. Analyzed σ(0°) vs. G-T strength.

1998Ha24: ^{13}C(n,p) E_n=118 MeV. Measured $\sigma(E_p,\theta$=0° and 7.5°) at IUCF. General discussion.

^{13}B Levels

E(level)†	Comments
0	
3.5×10^{3}	
6.5×10^{3}	
7.6×10^{3}	
10.2×10^{3}	Γ: Broad.

† From (1996Wa06). Peaks include unresolved states.

^{13}C(d,^{2}He) 1986Mo27

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1986Mo27: ^{13}C(pol. d,^{2}He) E=70 MeV. Measured $\sigma(\theta)$, $A_y(\theta)$ for $\theta\approx10°$ to 65° at the RCNP/Osaka. Observed groups at E_x=0, 3.8, 5.2, 6.6 MeV, but only analyzed the reaction to the ground state via DWBA analysis.
1993Oh01: ^{13}C(d,^{2}He) E=260 MeV. Measured $\sigma(\theta)$ for θ=0° to 10° at RIKEN. Analyzed σ relation with B(GT).
1995Xu02, 1998GaZS: ^{13}C(d,^{2}He) E=125.2 MeV. Measured $\sigma(\theta=0°)$ at Texas A&M. Analyzed σ relation with B(GT).

^{13}B Levels

E(level)†
0
3.8×10^{3}
5.2×10^{3}
6.6×10^{3}

† From (1986Mo27). Peaks include unresolved states.

^{13}C(t,^{3}He) 2009Gu23

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1998Da05: ^{13}C(t,^{3}He) E=127 MeV/nucleon. Measured dσ/dΩ(0°) at MSU/NSCL using the A1200 as a dispersion-matched energy-loss spectrometer. Measured ^{3}He energy spectrum at θ=0°. Analyzed σ relation with B(GT).

See also (2011Pe12) who analyzed the cross section to $^{13}B_{g.s.}$ and the relationship to B(GT).

2009Gu23: XUNDL dataset compiled by TUNL (2009).

Measured ^{13}C(t,^{3}He) at E_t=115 MeV/nucleon using a 99.3% enriched $^{13}CH_2$ target at the object position of the S800 spectrometer. Measured ^{3}He particles with plastic scintillators and time-of-flight to identify particles. FWHM=480 keV. Measured $\sigma(\theta)$ for dipole transitions up to E_x=20 MeV. Deduced Gamow-Teller strengths. 10% systematic uncertainty. DWBA calculations. Used COSY to reconstruct (non)dispersive angles, position and momentum.

^{13}B Levels

E(level)†	J$^\pi$†	ΔL†‡	dσ/dΩ (mb/sr)†#	Comments
0	3/2$^-$	0,2	13.1 *13*	B(GT)=0.711 *2*; calculated from relevant β-decay log *ft* value. Unit $\sigma(\theta$=0)=22.8 mb/sr *23*.
3.6×10^3	3/2$^-$	0,1	1.07 *9*	E(level): Unresolved multiplet. B(GT)=0.065 *5*; error calculated from the square root of the sum squared of 0.07 mb/sr statistical error and 0.05 mb/sr systematic error.
5.2×10^3 @	(3/2$^+$,5/2$^+$)	1		
7×10^3 @	(3/2$^+$,5/2$^+$)	1		
10×10^3 @	(3/2$^+$,5/2$^+$)	1		

† From DWBA analysis in (2009Gu23). In (1998Da05), broad unresolved groups at E_x=3.9, 4.7 and 6.2 MeV are shown in Fig. 1.

‡ Transferred from the J$^\pi$=1/2$^-$ $^{13}C_{g.s.}$

\# θ=0°, L=0.

@ J^π values are not assigned in the Adopted Levels based on these broad, poorly constrained groups.

$^{13}C(^{7}Li,^{7}Be)$ 1990Na03

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1984Gl06: $^{13}C(^{7}Li,^{7}Be)$ E=78 MeV. Measured $\sigma(E(^{7}Be),\theta)$. Deduced single-step spin-flip charge-exchange process dominance.
1990Na03: $^{13}C(^{7}Li,^{7}Be)$ E=21 MeV/nucleon beam from the AVF cyclotron of the RCNP, Osaka. Measured $\sigma(E(^{7}Be),\theta)$ for $\theta\leq10°$ using the DUMAS spectrometer. Data taken with the RAIDEN spectrometer are also discussed. An energy resolution of ≈300 keV was obtained. Analyzed levels up to E_x=9.5 MeV using DWBA.

^{13}B Levels

E(level)	J^π	Γ	ΔJ^π ‡
0	3/2⁻		1-
3.5×10^3 †			2-
4.0×10^3 †			2-
5.1×10^3 †#			2-+4-
6.3×10^3 †#			2-+4-
7.0×10^3 †#			2-+4-
7.6×10^3 †#			1-
9.5×10^3 †		≈2.3 MeV	1-

† Unresolved states. ΔE≈300 keV.
‡ $(^{7}Li,^{7}Be)$ angular distributions were measured on $^{12}C(J^\pi=0^+)$ and $^{13}C(J^\pi=1/2^-)$ targets, and ΔJ^π values were deduced for population of ^{13}B states by comparison of angular distribution shapes with those to known ^{12}B states.
# Some states are not associated with Adopted Levels because inadequate details to make an association are given in the literature.

$^{14}C(\gamma,p)$ **1991Mc05**

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1991Mc05: $^{14}C(\gamma,p)$ E=threshold(20.8)−29.1 MeV using bremsstrahlung photons produced using the Melbourne betatron. Measured $\sigma(E_\gamma)$ to ^{13}B using activation methods. See also (1993Mc02).

^{13}B Levels

E(level)	J^π
0	$3/2^-$

^{14}C(d,^{3}He) 2016Be08

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1975Ma41: ^{14}C(d,^{3}He) E=52 MeV from Karlshuhe Cyclotron; measured σ(E(^{3}He),θ) for θ=10° to 40° using four ΔE-E telescopes. Deduced levels at ^{13}B(0, 3.71 MeV) with C^2S=3.75 and 0.29, respectively. DWBA analysis. Self supporting 40% enriched ^{14}C 30 μg/cm^2 target. See reanalysis of these data and discussion on the ANC for $^{14}C\rightarrow^{13}B$+p in (2022Ke03).

2016Be08: XUNDL dataset compiled by TUNL (2016).

The authors analyzed the angular distributions of ^{3}He particles from the ^{14}C(d,^{3}He)^{13}B proton-removal reaction, in inverse kinematics, to study the J^π values of ^{13}B states involved in the reaction.

A beam of 17.1 MeV/nucleon ^{14}C ions with the intensity of ≈0.1 pnA, produced in the sputter source at the ANL/ATLAS facility, impinged on 140 μg/cm^2$(Cd_2)_n$ polyethylene foils located at the HELIcal Orbit Spectrometer (HELIOS) target position. The kinematics of ^{3}He particles from (d,^{3}He) reactions were determined from analysis of the HELIOS array data, while recoiling boron isotopes were detected in set of silicon detector ΔE-E telescopes that covered θ_{lab}=1°−5°. The resolution for excitation energies was found as FWHM≈180 keV. Angular distributions were analyzed via DWBA to obtain L, J^π and C^2S values.

The ^{3}He particle reaction data were analyzed in coincidence with any boron isotope to give access to population of unbound states.

^{13}B Levels

E(level)†	J^π†	L†	C^2S†	Comments
0	3/2$^-$	1	2.80 *30*	C^2S: See also C^2S=3.75 (1975Ma41).
3.8×10^3	(1/2$^-$)	1	0.70 *8*	C^2S: See also C^2S=0.29 (1975Ma41).
4.8×10^3 *2*	(1/2$^+$)	0	0.13 *2*	
5.3×10^3 *3*	(1/2,3/2)$^-$	1	0.35 *6*	
6.3×10^3 *4*	$^+$	(0)		E(level): This peak likely contains more than one unresolved state (2016Be08).

† From DWBA analysis of spectroscopic factors in (2016Be08).

^{14}C(^{11}B,^{12}C) 2022Me03

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2022Me03: ^{14}C(^{11}B,^{12}C) E=45 MeV; measured angular distribution for $\theta_{c.m.}$=35° to 70° at the Warsaw cyclotron facility. Analyzed data to obtain ^{13}B+p asymptotic normalization constant. See further analysis in (2022Ke03, 2022Me09, 2022Me11).

^{13}B Levels

E(level)
0

^{14}C(t,^{4}He) 1979Se07

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1979Se07: ^{14}C(t,^{4}He) E=23.0 MeV. Measured $\sigma(\theta)$ for θ=20° to 60° at Los Alamos Scientific Laboratory using a Q3D spectrometer. DWBA analysis does not fit the data well. ^{14}C target on Au foil. See also (1978SeZX).

^{13}B Levels

E(level)	J$^{\pi}$	S
0	3/2^{-}	5.7

^{15}N(p,3p) 1965Po03

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1965Po03: ^{15}N(p,^{13}B) E=2.2 GeV; a proton beam from the BNL Cosmotron bombarded a ^{15}N target in a search for evidence of ^{13}B β-n decay. Ambiguous results were obtained. The authors suggested $\%\beta^{-}n<0.3$.

^{13}B Levels

E(level)
0?

$^{16}O(^{14}C,^{17}F)$ 2000Ka21

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2000Ka21: $^{16}O(^{14}C,^{17}F)$ E=334.4 MeV. Measured excitation energy spectra for θ=1.0°−4.3° using the Q3D spectrometer at HMI. Ambiguity exists in the reported angular coverage. Deduced excited states, discussed reaction mechanism and likely J^{π} values.

^{13}B Levels

E(level)†	J^{π}‡#	Γ‡	Comments
0	3/2⁻		$\pi 1p_{3/2}$. dσ/dΩ(5.4°)=0.28 μb/sr *3* (2000Ka21).
4830	(1/2⁻)		dσ/dΩ(5.4°)=0.09 μb/sr *2*.
6900	(3/2⁻,5/2⁻)	150 keV	dσ/dΩ(5.4°)=0.10 μb/sr *2*.

† From (2000Ka21), ΔE≈600 keV.

‡ From analysis of $^{12}C(^{13}C,^{12}N)$,$(^{14}C,^{13}N)$, $(^{15}N,^{14}O)$ and $^{16}O(^{14}C,^{17}F)$ multi-nucleon transfer reactions in (2000Ka21).

\# For $^{13}N^{*}$(4.3,6.9 MeV) the authors suggest a mechanism with one $1p_{1/2}$ and two $1p_{3/2}$ proton transfers; they suggest the remaining protons couple to 0^{+} for the lower state and 2^{+} for the higher state. These values are not adopted.

$^{48}Ca(^{11}B,^{13}B)$ 1978KeZP

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1978KeZP: $^{48}Ca(^{11}B,^{13}B_{g.s.})$ E=115 MeV. Measured isotope yields from reactions of ^{11}B ions on a 200 $\mu g/cm^2$ ^{48}Ca carbonate target using a QSD spectrometer positioned at θ=8°. LBNL lab report.

^{13}B Levels

E(level)
0

^{136}Xe(p,^{13}B) 2007Na31

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2007Na31: ^{1}H(^{136}Xe,X) E=1 GeV/nucleon. Measured spallation yields (in inverse kinematics) using the GSI fragment separator. Deduced spallation cross sections and isotope production yields.

^{13}B Levels

E(level)
0

$^{181}Ta(^{22}Ne,^{13}B),(^{20}Ne,^{13}B)$ 1988Sa04

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1988Sa04: ^{13}B ions produced by fragmenting a 770 MeV ^{22}Ne beam on a thick ^{nat}Ta target were separated using the NSCL/RPMS. The beam was stopped in a ΔE-E-VETO telescope; detection of an ion in the telescope resulted in an *rf*-inhibit that prevented implantation of further activity. Implanted species were determined via ΔE-E particle identification and the half-life, $T_{1/2}$=17.6 ms *12*, was deduced from an event-by-event analysis of the implantation time vs the decay time.

1997So34: A beam of ^{13}B ions was produced by fragmentation of a 20 MeV/nucleon ^{20}Ne beam on a Ta target at the FLNR U-400 cyclotron facility. The ^{13}B beam was stopped at the center of a 182 element array of ^{3}He counters that incorporated a paraffin neutron moderator. $T_{1/2}$=17.0 ms *4* and P_n<0.03% were deduced for ^{13}B decay.

^{13}B Levels

E(level)	$T_{1/2}$	Comments
0	17.0 ms *4*	$T_{1/2}$: From (1997Sa04). See also T=17.6 ms *12* (1988Sa04). P_n<0.03% (1997Sa04).

^{197}Au(^{15}N,^{13}B) 1991OkZZ

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1991OkZZ: ^{197}Au(^{15}N,^{13}B) E=112 MeV/nucleon. ^{13}B ions were collected in a Pt stopper at θ=2°,4°,6° using RIKEN/RIPS beam swinger facility. The β asymmetry was measured and used to deduce the spin polarization. RIKEN progress report.

2007Gr23: ^{27}Al, ^{93}Nb, ^{197}Au(^{15}N,^{13}B) E≈60, 110 MeV/nucleon; calculated spin polarization after breakup.

^{13}B Levels

E(level)
0

^{208}Pb(^{13}B,^{13}B) 2022Wa16

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2022Wa16: XUNDL dataset compiled by TUNL (2022).

The authors measured elastic scattering of the ^{13}O and ^{13}B mirror nuclei on ^{208}Pb and analyzed the nuclear densities obtained from optical model analyses.

A beam of 254 MeV ^{13}B ions from the HIRFL in Lanzhou impinged on a 12.24 mg/cm^2 thick ^{208}Pb target. Scattered ^{13}B ions were momentum analyzed using an array of four position sensitive ΔE-E Si-detector telescopes that covered $\theta\approx3°$ to 27°. Differential cross sections were analyzed for θ_{lab}=4° to 15°. Authors indicate $^{13}B_{g.s.}$ was resolved from the E_x=3.28 MeV first excited state, but participation of any ^{208}Pb excited states was unresolved.

The data were analysed using two optical model approaches: first, using the double-folding Sao Paulo potential-2 (2021Ch70), and second using the single-folding Xu and Pang potential model (2013Xu06). The data are reasonably fit using standard global parameterization inputs. The discussion details an approach for obtaining the proton, neutron and matter rms radii. A comparison of the ^{13}B results with those of ^{13}O suggests a thin proton skin for ^{13}O.

^{13}B Levels

E(level)	Comments
0	$<r_p^2>^{1/2}$=2.354 fm; $<r_n^2>^{1/2}$=2.641 fm and $<r_m^2>^{1/2}$=2.534 fm.

^{232}Th(^{18}O,^{13}B),^{232}Th(^{22}Ne,^{13}B) 1969Ar13,1977Ar06

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1969Ar13: ^{232}Th(^{18}O,X). The authors analyzed the transfer reaction products resulting from E(^{18}O)=122 MeV bombardment of a 5 mg/cm^2 metallic ^{232}Th foil at Dubna. The reaction products were momentum analyzed in a magnetic spectrometer and then focused on a Si ΔE-E detector telescope, which provided particle identification. ^{13}B was identified.

1977Ar06: ^{232}Th(^{22}Ne,X). The transfer reaction products resulting from E(^{22}Ne)=172 MeV bombardment of a 2.5 mg/cm^2 metalic ^{232}Th foil were measured at Dubna. The reaction products were momentum analyzed in a magnetic spectrometer positioned at θ=12° and 40° and then focused on a ΔE-E Si detector telescope, which provided particle identification. ^{13}B was identified.

^{13}B Levels

E(level)
0

$^{238}U(^{18}O,^{13}B)$ 2018St06

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

2018St06: $^{238}U(^{18}O,X)$ E=8.5 MeV/nucleon. Isotope production cross sections were measured using the GANIL/LISE spectrometer. The momentum distributions of produced isotopes were also analyzed.

^{13}B Levels

E(level)
0

U(p,^{13}B),^{232}Th(p,^{13}B) 1973Bo30

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell	NDS 198,1 (2024)	1-Aug-2024

1973Bo30: Proton spallation cross sections on a uranium target, were measured at the Bevatron using 4.8 GeV protons. Reaction products including ^{13}B were identified using ΔE vs E and ΔE vs time-of-flight techniques.

1991Re02: Spallation products from 800 MeV proton bombardment of a ^{232}Th target were captured by a transport line with a mass-to-charge filter and transferred to the TOFI spectrometer at LAMPF. For ^{13}B, the β-delayed neutron probability %β-n=0.3% *1* was deduced and $T_{1/2}$ = 11 ms *9* was measured. A reanalysis of the (1991Re02) data, with additional data was published in the (1994ReZZ). The reanalysis indicates Pn=0.25% *15* and $T_{1/2}$=16.7 ms *6*. See also (1994KiZU, 1995ReZZ, 2008ReZZ) for different lifetime values deduced from this dataset.

^{13}B Levels

E(level)	$T_{1/2}$	Comments
0	16.7 ms *6*	$T_{1/2}$: From (1994ReZZ).