Adopted Levels

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^-)=17037 *10*; S(n)=−450 *10*; S(p)=22700 *30*; Q(α)=−9770 *50*

S_{2n}=2720 keV *10*.

S(n): Here we use S_n=−0.45 MeV *10* as described below, and we compute relevant values using mass values from (2021Wa16). In AME (2021Wa16) the value S_n=−0.51 MeV *10*, based only on (2010Ko17), is used.

See shell model analyses in: 1983Va31,1984Va06,1985Po10, 1987Sa15, 1992Go17, 1996Wa35, 2007Gu03.

See Mean Field model analyses in: 1996Su24, 1997Ba23, 1997Ba54, 1997Re07, 2005Ar12, 2006Sh20, 2020Al27.

See Cluster Model and AMD analyses in: 1981Se06, 1994De32, 1995De31, 2005Ne03, 2005Th06, 2012Ka10, 2013Ma53, 2021Co07.

See other analyses in: 1995Ta32, 1999Ka67, 2000Bh07, 2004De60, 2004La24, 2004Ne16, 2004Sa50, 2006Ko02, 2007Bl02.

See discussion on low-lying ^{13}Be levels and possible level inversion in: 1985Po10, 1995De31, 1997Re07, 1999La20, 2004Ta03, 2008Ha16, 2009BlZZ, 2010Bl12, 2012Bo15, 2012Fo22, 2013Fo03, 2014Fo21, 2014Ho08, 2015Fo06, 2018Fo07, 2019Fo02.

In the present analysis the data are somewhat discrepant. The experimental approaches often provide incomplete measurements of the reaction observables and result in what appear as incompatible observations. The ^{14}C(^{11}B,^{12}N) and ^{14}C(π^-,p) results have been used to guide an initial level scheme since these results are insensitive to ambiguities present in level energy determination based on n+^{12}Be momentum reconstruction. The modern results where n+^{12}Be kinematics are measured provide meritous information on levels energies and decay modes and have been heavily consulted.

In surveying the results a trend appears where two groups around E_{rel}(n+^{12}Be)≈0.5-0.7 MeV and 2.3-2.5 MeV can reasonably fit the energy spectrum. However in studies utilizing γ+n+^{12}Be coincidence events, where ^{12}Be excited states are considered, evidence is found for a larger number of neutron groups corresponding to levels at E_{res}(n+$^{12}Be_{g.s.}$)≈0.4, 0.8, 2.0 and 3.0 MeV. The importance of including γ emission in analyzing the n+^{12}Be spectra is highlighted below with comments on two mesurements. First, in (2001Th01) the ^{9}Be(^{18}O,^{13}Be→^{12}Be+n) reaction was measured; evidence for two components, at E_{res}≈0 and 2.0 MeV, was found in the relative energy spectrum; however subsequent understanding supports the interpretation that these groups are connected to a E_{res}(n+^{12}Be)≈2 MeV level that decays to $^{12}Be_{g.s.}$ with E_n≈2 MeV and also decays to the high energy tail of $^{12}Be^*$(2.1 MeV) . Second, in the initial analysis of the ^{1}H(^{14}Be,^{13}Be→^{12}Be+n) resonance spectrum of (2010Ko17), resonances at E_{res}=0.51 MeV *1* with Γ=0.45 MeV *3* and E_{res}=2.39 MeV *5* with Γ=2.4 MeV *2* were found, but the discussion indicated the E_{res}=2.39 MeV region could also be reproduced with groups at E_{res}=2.0 MeV and E_{res}=2.9 MeV as suggested by (1992Os04,1998Be28). A reanalysis of (2010Ko17) in (2013Ak02) found evidence for 5 levels that decay to ^{12}Be ground and excited states.

Lastly, the virtual play-by-play analysis of experimental results given in the discussion of Fortune′s (2012-2019) articles provides insight into the evolution of our understanding of this nucleus. In these articles, extensive discussion on experimental work is given along-side a simple potential model analysis. Early on, the statement is made that, “The (lowest) *s* state in ^{13}Be is unbound, and unbound neutron *s* states are notoriously hard to handle.” Throughout the series of articles, listed above, the discussion focuses on likely structure configurations, the order of low-lying level spins and reasonable widths, and decay modes that can reasonably explain the data. See related discussion in (2021Co07).

^{13}Be Levels

Cross Reference (XREF) Flags

A	^{1}H(^{14}Be,^{13}Be):1	G	^{9}Be(^{18}O,^{13}Be)	M	^{14}C(π^-,p)
B	^{1}H(^{14}Be,^{13}Be):2	H	^{9}Be(^{48}Ca,X)	N	^{14}C(π^-,pd)
C	^{1}H(^{14}B,^{13}Be)	I	C(^{14}Be,^{13}Be)	O	^{14}C(^{7}Li,^{8}B)
D	^{2}H(^{12}Be,p)	J	C(^{14}B,^{13}Be)	P	^{14}C(^{11}B,^{12}N)
E	^{2}H(^{12}Be,^{13}Be)	K	^{13}C(π^-,π^+)	Q	U(p,X),^{232}Th(^{15}N,X)
F	^{9}Be(^{13}B,^{13}Be)	L	^{13}C(^{14}C,^{14}O)		

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Adopted Levels (continued)

^{13}Be Levels (continued)

E(level)[‡#]	J$^{\pi}$	Γ	E′ (MeV)[†]	XREF	Comments
0	1/2^{-}	0.43 *20*	0.45 *1*	AB e J Q	%n=100 From E$_{res}$=0.46 MeV *1* (see fit to (2010Ko17) ^{1}H(^{14}Be,^{13}Be) given in (2013Ak02)), 0.44 MeV *1* (2013Ak02) ^{1}H(^{14}Be,^{13}Be) and 0.40 MeV *3* (2014Ra07) C(^{14}B,^{13}Be). Also see E$_{res}$=0.51 MeV *1* initially reported in (2010Ko17). Γ: From unweighted average of Γ=0.11 MeV *2* (see fit to (2010Ko17) given in (2013Ak02)), 0.39 MeV *5* (2013Ak02) and 0.80 MeV *20* (2014Ra07). J$^{\pi}$: From (2010Ko17) whose analysis of the n+^{12}Be momentum distribution and the resonance width indicate an inversion of the $1s_{1/2}$ and $0p_{1/2}$ shells. The inversion is further supported from analysis of the low-lying ^{14}Be level structures (1999La20). (2007Bl02, 2018Ri05,2019Fo02) discuss the expectation for a J^{π}=1/2^{-} state to be populated in neutron stripping from ^{14}Be and to be absent in proton stripping from ^{14}B; hence J^{π}=1/2^{-} is recommended for this resonance.
0.39×10^{3} *3*	1/2^{+}	1.78 MeV *16*	0.84 *3*	A C eF J M P	%n=100 XREF: A(0.36E3)F(0.28E3)M(0.20E3). From E$_{res}$=0.81 MeV *6* (analysis of (2004Le29) C(^{14}B,^{13}Be) given in (2013Ak02)), 0.86 MeV *4* (2018Ri05) ^{1}H(^{14}B,^{13}Be), 0.85 MeV *15* (2014Ra07) C(^{14}B,^{13}Be) and 0.80 MeV *9* (1998Be28) ^{14}C(^{11}B,^{12}N). Γ: From Γ=2.1 MeV *3* (see fit to (2010Ko17) given in (2013Ak02)) and Γ=1.70 MeV *15* (2018Ri05). See other value Γ=0.30 MeV *30* in (2014Ra07). J$^{\pi}$: From (2015Ma62) ^{9}Be(^{13}B,^{13}Be) where the ^{12}Be+n resonance is *s*-wave in character, see additional discussion in (2013Ak02, 2019Fo02). E(level): Decays via ^{12}Be$_{g.s.}$+n.
1.61×10^{3} *3*	5/2^{+}	0.40 MeV *+4−5*	2.06 *3*	ABCDEFGHIJKLM OP	%n=100 XREF: A(1.50E3)B(1.9E3)F(2.11E3)J(1.90E3)K(2.0E3)M(1.42E3). From E$_{res}$=2.07 MeV *3* (2010Ko17 in 2013Ak02) ^{1}H(^{14}Be,^{13}Be), 1.95 MeV *5* (2013Ak02) ^{1}H(^{14}Be,^{13}Be), 2.11 MeV *5* (2018Ri05) ^{1}H(^{14}B,^{13}Be), 2.01 MeV *5* (1992Os04) ^{13}C(^{14}C,^{14}O), 1.87 MeV *10* (1998Go30) ^{14}C(π^{-},p), 1.9 MeV *5* (1983Al20) ^{14}C(^{7}Li,^{8}B), 2.02 MeV *6* (1998Be28) ^{14}C(^{11}B,^{12}N) and 2.22 MeV *+4−5* (2023Ko21) ^{2}H(^{12}Be,^{13}Be). Γ: From (2023Ko21). See also 0.3 MeV *1* in (1998Go30), 0.3 MeV *2* in (1992Os04), ≈0.5 MeV in (2013Ak02), ≈0.4 MeV in (2018Ri05) and ≈0.3 MeV in (2007Si24).

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Adopted Levels (continued)

^{13}Be Levels (continued)

E(level)[‡#]	J$^{\pi}$	Γ	E′ (MeV)[†]	XREF	Comments
					J$^{\pi}$: From (2013Ak02) ^{1}H(^{14}Be,^{13}Be) where *d*-wave decay is reported in $^{12}Be_{g.s.}$+n and *s*-wave character is reported in ^{12}Be(2^{+})+n decay. In (1998Be28) the ^{12}C(^{11}B,^{12}N) and ^{14}C(^{11}B,^{12}N) spectra are shown to be similar, which supports 5/2^{+} for this state. E(level): Decays via $^{12}Be_{g.s.}$+n [E_{res}=2.11] and $^{12}Be^{*}$(2.109)+n [E_{res}<0.1 MeV] (2013Ak02,2018Ri05,2019Co12).
2.53×10^{3} *4*	(5/2^{+})	≈0.4 MeV	2.98 *4*	A C IJ M P	%n=100 XREF: C(2.47E3)J(1.90E3). E(level): From E_{res}=2.98 MeV *4* (2010Ko17 in 2013Ak02) ^{1}H(^{14}Be,^{13}Be), 3.02 MeV *9* (2013Ak02) ^{1}H(^{14}Be,^{13}Be), 2.90 MeV *13* (1998Be28) ^{14}C(^{11}B,^{12}N). Γ: From ≈0.5 MeV (2010Ko17, 2013Ak02), ≈0.4 MeV (2007Si24) and ≤0.15 MeV (1998Go30). J$^{\pi}$: From (2018Ri05) ^{1}H(^{14}B,^{13}Be). The state′s population in proton knockout, where negative parity states are suppressed, supports a positive parity assignment. The state is thought to decay most strongly to ^{12}Be(0^{+}_{2}), but this branch is difficult to observe; see discussion in (2019Fo02). E(level): Decays via $^{12}Be_{g.s.}$+n (2013Ak02,2018Ri05); an unobserved branch via ^{12}Be(0^{+}_{2})+n is expected.
≈3.55×10^{3}	(3/2^{+})	≈0.4 MeV	4.0	C	%n=100 E(level),J$^{\pi}$,Γ: From (2018Ri05) ^{1}H(^{14}B,^{13}Be). J$^{\pi}$: Populated in proton knockout from ^{14}B indicating π=+; see further discussion in (2019Fo02) indicating a J^{π}=3/2^{+} state is expected in this vicinity with similar decay properties. E(level): Decays via $^{12}Be_{g.s.}$+n [E_{res}=4.0] and $^{12}Be^{*}$(2109)+n [E_{res}≈2.1 MeV].
4.63×10^{3} *5*	(3/2^{-},5/2^{+})	1.4 MeV *2*	5.08 *5*	AB D LM P	%n=100 XREF: A(4.75E3)M(4.51E3)P(4.49E3). E(level): From E_{res}=5.2 MeV *1* (2010Ko17 in 2013Ak02) ^{1}H(^{14}Be,^{13}Be), 5.1 MeV *13* (2019Co12) ^{1}H(^{14}Be,^{13}Be), 5.13 MeV *7* (1992Os04) ^{13}C(^{14}C,^{14}O), 4.96 MeV *20* (1998Go30) ^{14}C(π^{-},p) and 4.94 MeV *8* (1998Be28) ^{14}C(^{11}B,^{12}N). Γ: From (2010Ko17 in 2013Ak02). Others

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Adopted Levels (continued)

^{13}Be Levels (continued)

E(level)[‡#]	Γ	E′ (MeV)[†]	XREF	Comments
				are 0.4 MeV *2* (1992Os04) and ≈1.7 MeV (1998Go30). J$^{\pi}$: From (2013Ak02) ^{1}H(^{14}Be,^{13}Be) where *s*-wave neutron emission from a 3/2^{-} state (or *p*-wave emission from a 5/2^{+} state) to ^{12}Be(1^{-}) are preferred. E(level): (2013Ak02) report the state decays to ^{12}Be*(2.71 MeV) while (2019Co12) report the state decays to ^{12}Be*(2.1 MeV).
5.43×10^{3} *10*		5.88 *10*	B P	%n=100 E(level): From (1998Be28) ^{14}C(^{11}B,^{12}N); see also E$_{res}$=5.7 MeV *14* in (2019Co12) ^{1}H(^{14}Be,^{13}Be). E(level): Decays to ^{12}Be*(2.71 MeV)+n (2019Co12).
6.55×10^{3} [@]		7.0	D	E(level): From (1995Ko10, 1995Ko27) ^{2}H(^{12}Be,p).
8.1×10^{3} [@] *2*	0.9 MeV *3*	8.5 *2*	L P	XREF: P(7.5E3). E(level),Γ: From E$_{res}$=8.5 MeV *2* (1992Os04) ^{13}C(^{14}C,^{14}O); see also 7.9 MeV *2* (1998Be28) ^{14}C(^{11}B,^{12}N).
9.6×10^{3} [@]		10.0	D	E(level): From (1995Ko10, 1995Ko27) ^{2}H(^{12}Be,p).
18.7×10^{3} [@]	9.0 MeV *15*		K	E(level),Γ: From (1992Wa11) ^{13}C(π^{-},π^{+}).
≈30×10^{3} [@]			N	E(level): From (2016Ko22) ^{14}C(π^{-},pd).

† E′ is a relative excitation energy scale with E′=0 at the neutron separation energy. We use this scale because most articles report level energies with respect to the n+^{12}Be$_{g.s.}$ center of mass energy.

‡ The ground state is taken as E$_{c.m.}$(n+^{12}Be$_{g.s.}$)=0.45 MeV *1*.

\# Broad states are reported at E$_{c.m.}$(^{12}Be$_{g.s.}$+n)=2.56 MeV and 2.35 MeV in ^{9}Be(^{13}B,^{13}Be) and C(^{14}B,^{13}Be), respectively. The present evaluation assumes these correspond to a combination of unresolved groups at E$_{c.m.}$(^{12}Be$_{g.s.}$+n)=2.0 MeV and 2.98 MeV.

@ Decay mode not reported; likely mode is %n=100.