

Adopted Levels

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

$Q(\beta^-)=23.32\times 10^3$ 7; $S(n)=50$ 32 [2021Wa16](#)

$S_{2n}=-160$ keV 10 ([2024An11](#)).

Q-values are computed using S_{2n} from ([2024An11](#)) and other mass values from ([2021Wa16](#)).

[1973Bo30,1974Bo05](#): Spallation products from 4.8 GeV proton bombardment of natural uranium targets at the LBNL Bevatron were identified via ΔE -E and time-of-flight techniques. The particle stability of ${}^{14}\text{Be}$ and ${}^{17}\text{B}$ isotopes was confirmed, but there was some uncertainty about ${}^{13}\text{Be}$ because of a relatively high background. It was later found to be particle unbound. The first observation of ${}^{13}\text{Li}$ resonance structure was at GSI using the ALADIN-LAND setup ([2008Ak03](#)).

In early theoretical work, a $J^\pi=3/2^-$ ground state ([1985Po10](#) and [1996Ch38](#)) was predicted to be unbound to ${}^{11}\text{Li}+2n$ decay by 3.34 MeV ([1985Po10](#)). The lowest excited states with $J^\pi=7/2^-$ and $1/2^-$ were also predicted by ([1985Po10](#)) to lie at $E_x=1.42$ and 2.09 MeV, respectively. See also ([2018Fo07](#)).

 ${}^{13}\text{Li}$ LevelsCross Reference (XREF) Flags

A ${}^1\text{H}({}^{14}\text{Be},2p)$
B ${}^9\text{Be}({}^{14}\text{Be},{}^{13}\text{Li})$

E(level) [†]	J^π	Γ	$E_{c.m.}({}^{11}\text{Li}+2n)(\text{MeV})$	XREF	Comments
0	$3/2^-$	125 keV +60–40	0.16 1	AB	%2n=100 E(level): From (2024An11). J^π, Γ : From (2013Ko03). J^π : Analysis of the T and Y Jacobi systems find emission of a strongly correlated 1s_0 n-n pair with dineutron character and indicate $J^\pi=3/2^-$, which is the J^π of ${}^{11}\text{Li}$.
0.29×10^3 6			0.45 6	A	E(level): From (2024An11). Decays to ${}^{11}\text{Li}_{g.s.}+2n$.
1.31×10^3 31		2 MeV 1	1.47 31	A	%2n=100 E(level), Γ : From (2008Ak03). Decays to ${}^{11}\text{Li}_{g.s.}+2n$.
2.6×10^3 2			2.8 2	A	E(level): From (2024An11). Decays mainly to ${}^{11}\text{Li}_{g.s.}+2n$, but evidence is also found for sequential branches to ${}^{12}\text{Li}_{g.s.}+n$ and ${}^{12}\text{Li}^*(0.4\text{ MeV})+n$.

[†] From $E_{c.m.}({}^{11}\text{Li}+2n)+S_{2n}$, where $S_{2n}=-160$ keV 10 from ([2024An11](#)).

$^1\text{H}(^{14}\text{Be},2\text{p})$ 2024An11,2008Ak03,2010Jo07

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2008Ak03:XUNDL dataset compiled by ANL, 2008.

First observation of ^{13}Li nuclide as neutron-unbound resonance was achieved using the ALADIN-LAND setup.

A beam of $E(^{14}\text{Be})=304$ MeV/nucleon ions, from the GSI/FRS facility, impinged on a 50 mm long cylindrical liquid-hydrogen target with an effective thickness of 350 mg/cm^2 that was placed at the ALADIN large-gap dipole magnet target position. Residual lithium ions resulting from 1-proton knockout reactions from the ^{14}Be were momentum analyzed using position-sensitive multi-wire proportional counters and the ALADIN dipole while the coincident neutrons were momentum analyzed using the large area neutron detector LAND array.

A peak at $E_{\text{res}}(^{11}\text{Li}+2\text{n})=1.47$ MeV *3I* was observed in the $^{11}\text{Li}+2\text{n}$ relative energy spectrum.

2010Jo07: A re-analysis of the (2008Ak03) $^{11}\text{Li}+\text{n}+\text{n}$ data was carried out by using a sophisticated model to evaluate the three-body correlations. In this re-analysis, the data indicated a similar structure to that observed for ^{10}He : where a $J^\pi=0^+$ ground state and $J^\pi=2^+$ excited state are favored. In the case of ^{13}Li , the authors interpreted the data as a broad $J^\pi=3/2^-$ ground state at $E_{\text{res}}=1.47$ MeV comprising s-wave neutrons coupled with the $J^\pi=3/2^-$ ^{11}Li core. In addition, they suggested an unresolved group of broad and overlapping excited states whose structure yields $J^\pi=1/2^-, 3/2^-, 5/2^-$ and $7/2^-$; these unobserved excited states are understood as a 2^+ coupling with the $J^\pi=3/2^-$ ^{11}Li core.

2024An11: A cocktail beam comprising ^{11}Li (70%), ^{12}Be (2.5%) and ^{14}Be (9%) components was produced at the RIKEN/RIBF facility. The beams, with energies of $E=246, 340$ and 265 MeV/nucleon, respectively, impinged on a 15 cm thick solid hydrogen target that was surrounded by the MINOS time-projection chamber (TPC). In the ^{13}Li study, the reaction vertex position was determined from the TPC analysis of the two reaction protons. The ^{13}Li products decayed instantly, and the invariant mass of the system was determined using the momentum of the two neutrons, analyzed using two 16-element hodoscopes from the NEBULA arrays, and the momentum of the ^{11}Li remnant that was measured using the SAMURAI spectrometer.

The invariant mass spectrum is dominated by a peak at $E(^{11}\text{Li}+2\text{n})=0.160$ keV with strong indications of a higher peak at 450 keV. The spectrum is featureless at higher energies, but the region was analyzed assuming two additional peaks: first was a peak at $E(^{11}\text{Li}+2\text{n})=1.47$ MeV (consistent with the group reported by (2008Ak03)), and second with a peak at $E(^{11}\text{Li}+2\text{n})=2.8$ MeV. The experimental method was found unreliable for determining resonance widths.

The four resonance regions were then analyzed to identify whether the states decay directly to $^{11}\text{Li}_{\text{g.s.}}+2\text{n}$ or sequentially via $^{12}\text{Li}+\text{n} \rightarrow ^{11}\text{Li}+2\text{n}$. The lower states are found to decay directly to $^{11}\text{Li}_{\text{g.s.}}+2\text{n}$, while the $E(^{11}\text{Li}+2\text{n})=2.8$ MeV state is found to decay dominantly to $^{11}\text{Li}+2\text{n}$ with smaller branches to $^{12}\text{Li}+\text{n}$. In their Figure 3, the decay arrow thicknesses are intended to indicate relative decay intensities.

 ^{13}Li Levels

$E(\text{level})^\dagger$	J^π	Γ	$E_{\text{c.m.}}(^{11}\text{Li}+2\text{n})(\text{MeV})^\ddagger$	Comments
0			0.16 <i>I</i>	Decays to $^{11}\text{Li}_{\text{g.s.}}+2\text{n}$.
0.29×10^3 <i>6</i>			0.45 <i>6</i>	Decays to $^{11}\text{Li}_{\text{g.s.}}+2\text{n}$.
1.31×10^3 <i>3I</i>	$(3/2^-)$	2.1 MeV <i>II</i>	1.47 <i>3I</i>	Decays to $^{11}\text{Li}_{\text{g.s.}}+2\text{n}$. Γ : From (2010Jo07); see also $\Gamma=2$ MeV <i>I</i> from (2008Ak03). J^π : The $J^\pi=3/2^-$ spin deduced by (2010Jo07) for the $E_{\text{res}}=1.47$ MeV state is complicated by the subsequent observations of (2013Ko03) where a lower-lying $E_{\text{res}}=120$ keV state is identified with $J^\pi=3/2^-$ character.
2.6×10^3 <i>2</i>			2.8 <i>2</i>	Decays mainly to $^{11}\text{Li}_{\text{g.s.}}+2\text{n}$; evidence is also found for additional branches to $^{12}\text{Li}_{\text{g.s.}}+\text{n}$ and $^{12}\text{Li}^*(0.4 \text{ MeV})+\text{n}$.

† From $E_{\text{c.m.}}(^{11}\text{Li}+2\text{n})+S_{2\text{n}}$, where $S_{2\text{n}}=-160$ keV *IO* from (2024An11).

‡ From (2024An11), except for the $E_{\text{c.m.}}(^{11}\text{Li}+2\text{n})=1.47$ MeV state, which is from (2008Ak03).

 $^9\text{Be}(^{14}\text{Be}, ^{13}\text{Li})$ **2013Ko03**

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Full Evaluation	J. H. Kelley, C. G. Sheu and J. E. Purcell		NDS 198,1 (2024)	1-Aug-2024

2013Ko03: XUNDL dataset compiled by TUNL, 2013.

A beam of 53.6 MeV/nucleon ^{14}Be ions was produced using the NSCL/A1900 fragment separator. The beam impinged on a 477 mg/cm² Be target where 1-proton removal reactions produced ^{13}Li nuclei that decayed to $^{11}\text{Li}+2n$. The MONA+sweeper magnet system detected the 2 neutrons and ^{11}Li ions, respectively.

Data were analyzed to obtain the $^{11}\text{Li}+2n$ relative energy spectrum; a causality cut was included that minimized contributions from the double scatter of a single neutron. The results were compared with a Monte Carlo simulation that was used to evaluate the device acceptances and energy dependent efficiencies, etc.

A peak at $E_{\text{res}}=120 \text{ keV } +60-80$ with $\Gamma=125 \text{ keV } +60-40$ was observed. ^{13}Li is bound to one neutron emission, but unbound to 2n emission. Analysis of the Y and T Jacobi systems indicates that the emitted pair of neutrons have a strong dineutron character; this implies $J^\pi=3/2^-$.

 ^{13}Li Levels

<u>E(level)</u>	<u>J^π</u>	<u>Γ</u>	<u>$E_{\text{c.m.}}(^{11}\text{Li}+2n)(\text{MeV})$</u>	<u>Comments</u>
0	$3/2^-$	125 keV +60-40	0.120 +60-80	