^{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).

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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

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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.

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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