## Adopted Levels

Q($\beta^-$)=23.418×10$^3$ *25*; S(n)=−82 *33*; S(p)=19.99×10$^3$ *SY*; Q($\alpha$)=−14.23×10$^3$ *29* 2012Wa38

The particle instability of $^{16}$B:

1974Bo05: Spallation products induced by 4.8 GeV Bevatron protons on a uranuim target were analyzed and identified using standard techniques. The measurement was carried out inside a 91 cm diameter scattering chamber, where the ΔE detector was placed 17 cm from the spallation target and the E detector was 12 cm from the ΔE detector. The time-of-flight between signals in the ΔE and E detectors was measured, and particle identifications were made using ΔE vs E and ΔE vs ToF techniques. The particle instability, limited by the flight time between the ΔE and E detectors, was shown by the lack of observation of any $^{16}$B counts along with the positive observation of the neighboring $^{15}$B and $^{17}$B nuclides.

1985La03: The particle instability of $^{16}$B was confirmed at GANIL in a study of the nuclides produced in the fragmentation of a 44 MeV/nucleon $^{40}$Ar beam on a thick tantalum target. The fragments were momentum analyzed in the LISE spectrometer, with a 18 meter flight path, and then detected using a ΔE-ΔE-E-VETO telescope at the focal plane. The $^{13,14,15,17}$B isotopes were identified in the measurement, but the absence of $^{16,18}$B isotopes provide evidence that they are not particle stable (within the limits of the short flight path).

1996Kr05: The authors analyzed the experimental conditions of prior studies and estimated lifetime limits of ≈9 ns (1974Bo05) and ≈260 ns (1985La03). With the aim on better constraining the $^{16}$B lifetime, a new experiment was carried out that reached an upper limit of T<170 ps for $^{16}$B.

An 880 MeV $^{17}$C beam was produced using the NSCL/A1200 fragment separator. The beam was identified by ΔE vs time-of-flight techniques immediately before impinging on a 114 mg/cm$^2$ $^{nat}$C target. Reaction products were stopped in a four element ΔE-ΔE-ΔE-E Si detector telescope that was placed immediately behind the secondary target and covered $\theta$<15°. No peak corresponding to $^{16}$B events was observed in the spectrum, and a limit of T<170 ps *69* was suggested. A significant discussion on ”background” events was given in the text.

2013Th07: The authors suggest two novel techniques for measuring lifetimes of neutron unbound nuclides.

Decay in Target: An analysis of the average velocity difference of neutrons vs. charged “core” fragments is suggested as an approach to determine a difference in energy loss in the target that can give average lifetime information.

Decay in Magnetic Field: For relatively long-lived neutron unbound nuclides, if the decaying nuclides are introduced into a dipole magnetic field the average deflection of the neutron yield away from 0° could be correlated with the lifetime.

Theoretical analysis:

1985Po10: The binding energies of the four lowest $^{16}$B states were predicted in a shell model calculation. The ground state was predicted near the neutron binding threshold with J$\pi$=0$^-$; excited states were predicted at E$_x$=0.95, 1.1, 1.55 MeV having J$\pi$=2$^-$, 3$^-$, 4$^-$, respectively.

1992Wa22: Shell-model calculations in an *s, p, sd, f, p* valence space predicted a J$\pi$=0$^-$ ground unbound by 164 keV, with J$\pi$=3$^-$, 2$^-$ and 4$^-$ excited states at E$_x$=0.78, 0.84 and 1.44 MeV, respectively.

2011Du01, 2011Du16: An extended two-cluster model predicts a J$\pi$=0$^-$ resonance near the E($^{15}$B+n)$_{res}$≈80 keV state presently identified as the ground state, but also suggests the existence of other J$\pi$=1$^-$, 2$^-$ states that may be closer to the neutron separation threshold.

See general predictions of the ground state binding energy and other properties in (1981Se06, 1993Pa14, 1997Ba54, 2004La24, 2004Ne16, 2006Ko02, 2012Yu07) and discussion in (1999Ka67).

### $^{16}$B Levels

#### Cross Reference (XREF) Flags

| | |
|---|---|
| A | $^9$Be($^{17}$C,$^{16}$B) |
| B | C($^{17}$B,N15B) |
| C | C($^{17}$C,N15B) |
| D | $^{14}$C($^{14}$C,$^{12}$N) |

| E(level) | Γ | XREF | Comments |
|---|---|---|---|
| 0 | <100 keV | ABCD | %n=100<br>E(level): We accept the ΔM = 37112. keV *25* value of (2012Wa38), but note this value |

Continued on next page (footnotes at end of table)

## Adopted Levels (continued)

### $^{16}$B Levels (continued)

| E(level) | Γ | XREF | Comments |
|---|---|---|---|
| | | | differes slighty (+8 keV) from the weighted value obtained from (2010Sp02, 2009Le02, 2000Ka21). Furthermore, the excited state energies have been adjusted from those reported in (2000Ka21) to account for the difference in the adopted ground state mass.<br>Γ: From (2009Le02). The resolution was ≈100 keV; a fit to the spectrum, convoluted with the resolution, uses Γ≈0.5 keV.<br>ΔM= 37112. keV *25*, which implies $S_n$=−82 keV *33*. |
| $2.32\times10^3$ | ≈150 keV | D | Decay mode not specified. |
| $6.02\times10^3$? | | D | Decay mode not specified. |

## $^{9}$Be($^{17}$C,$^{16}$B) 2010Sp02

2010Sp02: The authors measured the unbound ground state of $^{16}$B by carrying out a $^{17}$C single proton knockout reaction (E=55 MeV/nucleon). The resulting unbound $^{16}$B nuclei decayed into $^{15}$B+n which were detected using the NSCL/MoNA array and a charged particle detector.

The $^{16}$B ground state energy was determined by kinematic reconstruction of the $^{15}$B+n pairs. A single peak with $E_{rel}$=60 keV *20* was observed, and though no detailed analysis was carried out, the authors indicate the narrow width is consistent with Γ=0.5 keV suggested in (2009Le02).

### $^{16}$B Levels

| E(level) | $T_{1/2}$ | Comments |
|---|---|---|
| 0 | <100 keV | E(level): corresponds to $E_{rel}$($^{15}$B+n)=60 keV *20*. |

## C($^{17}$B,N15B) 2004SuZX

2004SuZX: In a RIKEN progress report, the authors reported on a measurement of the $^{15}$B+n relative energy reconstruction. A beam of $E_{effective}$=75 MeV/nucleon $^{17}$B ions was produced at the RIKEN/RIPS facility. The beam impinged on a 377 mg/cm$^2$ $^{nat}$C target. Charged reaction products were momentum analyzed in a dipole magnet and characterized using a set of position sensitive drift chambers and a hodoscope; neutrons were characterized using a pair of plastic scintillator walls. A narrow peak at 70 keV is present in the reconstructed $^{15}$B+n relative energy spectrum.

### $^{16}$B Levels

| E(level) |
|---|
| 0 |

## $C(^{17}C,N15B)$ 2004Le29,2009Le02

2004Le29, 2009Le02: Details on an experimental study of $^{16}B$ levels, populated in $^{17}C$ one-proton removal reactions, were first reported in (2004Le29) then later in (2009Le02). A 35 MeV/nucleon $^{17}C$ beam was selected using the GANIL/LISE3 fragment separator. The trajectory of the beam was measured as it impinged on a 95 mg/cm$^2$ $^{nat}C$ target. The reaction products were momentum analyzed by using either a position sensitive ΔE-ΔE-E (Si-Si-CsI) telescope (for charged particles) or the 97 element DEMON liquid scintillator neutron array.

The $^{15}B$+n relative energy, with an estimated resolution of 100 keV FWHM, is best fit with a narrow peak, $E_{res}$=85 keV *15*, and a broad background component. The authors assume the decay populates $^{15}B_{g.s.}$ and that the peak then corresponds to $^{16}B_{g.s.}$. The observed width of the peak is similar to the experimental resolution; hence Γ<100 keV. The best fit utilizes Γ=0.5 keV.

The authors carried out a *s-p-sd-fp* shell model calculation to gain some insight into the expected Jπ. Their analysis suggests the lowest states of $^{16}B$ should have, in order, Jπ=$0^-$, $3^-$, $2^-$.

### $^{16}B$ Levels

| E(level) | $J^\pi$ | $T_{1/2}$ | Comments |
|---|---|---|---|
| 0.0 | ($0^-$) | <100 keV | A resonance is observed at 85 keV *15* above the neutron+$^{15}B$ threshold. The resonance has Γ<<100 keV and decays mainly via d-wave neutron emission. A fit shown in Fig. 3 of 2009Le02 uses resonance parameters $E_{res}$=85 keV *15* Γ=0.5 keV. It is also consistent with $S_n$=−40 keV *60* observed in 2000Ka21. |

## $^{14}$C($^{14}$C,$^{12}$N) 1995Bo10,2000Ka21

1995Bo10, 2000Ka21:
The authors used ≈335 MeV beams of $^{14}$C to study multi-nucleon transfer reactions on a variety of targets at the Hahn-Meitner-Institut. In the present case, a 336 MeV $^{14}$C beam impinged on a $^{14}$C target. The reaction products are momentum analyzed and identified in the focal plane of a Q3D magnetic spectrometer with an energy resolution near 600 keV.
Along with several $^{12}$C($^{14}$C,$^{12}$N)$^{14}$C contaminant peaks in the spectrum, three peaks in the spectrum are attributed to $^{16}$B states. A state presumed to be the $^{16}$B ground state is observed with a mass excess of ΔM=37.08 MeV *6*; extraction of its parameters is complicated because it falls between the $^{14}$C*(8.03,10.15) states produced by $^{12}$C impurities in the target. The ΔM= 37.08 MeV *6* corresponds to $^{16}$B being bound by $S_n$=40 keV *60*. This results is consistent with the unlikely case that $^{16}$C could be bound by as little as 20 keV. The authors suggest the valence neutron occupies a $1d_{5/2}$ orbital, which could yield a relatively long lifetime, even if $^{16}$B is particle unstable. Two additional states are identified at $^{16}$B*(2.36,6.06). See also (1999Ka67).

### $^{16}$B Levels

| E(level) | $J^\pi$ | $T_{1/2}$ | Comments |
|---|---|---|---|
| 0.0 | $(4,3,1,2)^-$ | <100 keV | The authors suggest ΔM= 37.08 MeV *6*, which implies $S_n$=40 keV *60*.<br>$J^\pi$: Shell model arguments are used to suggest spin/parity values. The authors suggest a tentative $J\pi=(4^-)$ value based on various expectations. |
| $2.36\times10^3$ *7* | | ≈150 keV | |
| $6.06\times10^3$? *8* | | | |

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