Adopted Levels

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	K. Setoodehnia, J. H. Kelley, J. E. Purcell	ENSDF	28-September-2023

$Q(\beta^-)=23.06\times10^3$ *syst*; $S(n)=0.81\times10^3$ *syst* 2021Wa16

^{7}H is the nucleus with, by far, the most unbalanced neutron to proton ratio. The first experimental indication of ^{7}H being a resonant state came in 2003 from RIKEN (2003Ko11). This study argued that it is unlikely that ^{7}H exists as a bound state, but a resonant state near the ^{3}H+4n threshold with $J^\pi=1/2^+$ seems likely. It was assumed that such a state would likely decay either into five outgoing particles (^{3}H+4n) or two particles (^{3}H+^{4}n) if the tetraneutron exists.

Most recent observations (2020Be01, 2021Mu04, 2021Hu28, 2022Ca10, and 2023Ni06) indicate that ^{7}H ground state is a low-lying, narrow (due to neutron pairing) resonance 1.3 MeV *4* above the ^{3}H+4n mass with a width of $\Gamma<300$ keV (2020Be01), and with $J^\pi=1/2^+$ measured in (2022Ca10). Such a state would be consistent with an extended 4-neutron halo interacting with a ^{3}H core, which would decay by emission of a tetraneutron. The decay of the four-neutron-unbound ground state of ^{7}H via direct emission of a tetraneutron has not yet been experimentally observed. However, the ongoing analysis of (2021Hu28) seems to be suggestive of this mode of decay.

As for the excited states of ^{7}H, the first one is observed ~4 MeV above the ground state with a plausible $J^\pi=(5/2^+)$ assignment. This state is expected (2021Mu04) to decay via $^5H_{g.s.}$+2n, where $^5H_{g.s.}$, in turn, decays to ^{3}H+2n. So, the decay may be sequential. The first excited state may be part of a doublet containing another state at higher energy with $J^\pi=(3/2^+)$. A candidate state for the latter was reported in (2021Mu04) but its existence is uncertain. An even higher energy excited state was observed in (2021Mu04) at 9.7 MeV, whose structure may be indicative of the p+6n configuration.

Theory: Numerous investigations have been carried out to study the $^7H_{g.s.}$ properties. These are summarized below.

1985Po10: An early shell model calculation obtained $J^\pi=1/2^+$ for the ^{7}H ground state using two different models.

2000Fi22: Using resonating-group method, the wave function of ^{7}H as a cluster system of ^{3}H+n+n+n+n was calculated and analyzed hyperharmonically.

2002Ti05: Calculations using the 7-body hyperspherical harmonics functions with no core shell model predicted a ^{7}H binding energy of −7.61 MeV, estimated by exponential extrapolation. This estimation was about 300 keV lower than that for ^{5}H (2001Ko52), which would agree with the hypothesis of (2001Ko52) that ^{7}H may exist as a low lying resonance with the only decay channel being $^7H \rightarrow {}^3H+n+n+n+n$. Later, (2004Ti02) performed the same kind of calculations after improving a Casimir operator such that the hyperharmonics had well defined symmetry when constructed within the shell model approach. This work deduced the ^{7}H resonance ~3 MeV above the ^{3}H+4n threshold. This theoretical result also favored a sequential decay of ^{7}H into ^{3}H+n+n+n+n.

2004Ao05: A coupled channels calculation treated ^{7}H as a combination of both a triton plus four neutrons and as a proton plus three dineutrons. The calculated ground state binding energy is about 1.5 MeV, which is about 7 MeV above the ^{3}H+4n threshold.

2009Ao03: This calculation used the Antisymmetrised Molecular Dynamics with generator coordinate and stochastic variational methods that included basis states with a triton and two dineutrons as well as basis states with a triton and 4 neutrons. This study obtained a ^{7}H ground state with a binding energy of 2.8 MeV, which is about 4.2 MeV above the ^{3}H+4n threshold. This work describes the ground state of ^{7}H as a ^{3}H+^{2}n+^{2}n. These two pairs of neutrons act as two bosons bound together by their interaction with the ^{3}H core in a di-neutron condensate.

2011Gr13: Simultaneous four neutron emission by ^{7}H is discussed in this work. They demonstrate, by using simplified 3-body and 5-body Hamiltonians, that few body dynamics of 2n and 4n emissions result in collective barriers that rise quickly with increasing the number of emitted particles. This translates into longer lifetimes being expected for nuclei which decay via 4n than those that decay via the emission of 2n. This work considered the $^7H_{g.s.}$ as a true 4n emitter and estimated that the ground state of ^{7}H has a narrow width of $\Gamma\leq1$ keV.

2019Sh36: Simultaneous non−sequential 4n emission is considered in a phenomenological five−body (core+4n) decay. This theoretical work assumes that the internal structure of the ground state of ^{7}H is dominated by a $0p^4_{3/2}$ configuration. The decay of ^{7}H may cause a mixing of configurations such as $0s^2_{1/2}0p^2_{3/2}$ due to Pauli focusing effect. This would result in correlations in energy, angular distribution, and phase space, which could be used as observable fingerprints of a simultaneous non-sequential 4n decay and to understand the decay dynamics.

2021Li62: The energies and neutron-emission widths of the unbound hydrogen isotopes were computed using the no core Gamow shell model. The ground state of ^{7}H was considered as a rigid ^{3}H core and 4 valence neutrons (coupled to J=0), which immediately gives $J^\pi(^7H_{g.s.})=1/2^+$. The many body basis of the Gamow shell model for the $^7H_{g.s.}$ was generated from natural orbitals. The resonance energy of ^{7}H was deduced. The results vary between 1-3 MeV with an uncertainty of 400-600 keV,

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depending on the different phenomenological NN interactions used. These results are more or less in agreement with the previous experimental results. A width of $\Gamma\approx0.1$ MeV was deduced for the $^{7}H_{g.s.}$, and it was recommended that the ground state of ^{7}H is a very narrow resonance due to the $0p_{3/2}$ being a closed sub neutron shell in ^{7}H.

2022Hi06: The ground state of ^{7}H was considered as a five-body consisting of a solid ^{3}H core interacting with 4 valence neutrons. The properties of the $^{7}H_{g.s.}$ were computed in the 5-body cluster approximation (^{3}H-n-n-n-n), which is considered to be the dominant decay channel for a low energy resonant state. A n-^{3}H local interaction was constructed without any tensor component and adjusted in order to reproduce the n-^{3}H phase shifts. These were calculated by solving the ab-initio four-nucleon scattering problem. The Gaussian Expansion Method was used to solve the five-body Schrödinger equation for the ^{3}H-n-n-n-n system. The Stabilization Method was used to estimate the complex energies of the ^{7}H resonant state. As a result, instead of a narrow ^{7}H resonant state in the vicinity of the ^{3}H+4n threshold, a resonance was found at 9.5 MeV with a width of $\Gamma=3.5$ MeV. This result is in agreement with that of (2004Ao05), but it is in sharp contrast with the result of (2021Li62). The authors of (2022Hi06) argue that the Gamow shell model used in (2021Li62) underestimates the width. The results of (2022Hi06) are also inconsistent with the recent experimental results for the $^{7}H_{g.s.}$ (2003Ko11, 2007Ca28, 2010Ni10, 2020Be01). Thus, it was mentioned in (2022Hi06) that the deduced wide resonance at 9.5 MeV may be linked to the experimental results of (2020Be01), where a resonance was found at E=6.5 MeV *5* with a width of $\Gamma=2.0$ MeV *5*. It should be noted that the 6.5 MeV state measured in (2020Be01) is an unresolved doublet consisting of the first excited state and a candidate for the second excited state of ^{7}H.

In the following reactions, excitation and resonance energies in ^{7}H are given relative to the ^{3}H+4n threshold.

^{7}H Levels

Cross Reference (XREF) Flags

A	^{252}Cf SF decay	E	$^{9}Be(\pi^{-},pp)$
B	$^{1}H(^{8}He,pp)$	F	$^{11}B(\pi^{-},p^{3}He)$
C	$^{2}H(^{8}He,^{3}He)$	G	$^{12}C(^{8}He,^{13}N)$
D	$^{7}Li(\pi^{-},\pi^{+})$	H	$^{19}F(^{8}He,^{20}Ne)$

E(level)[‡]	J^{π}	Γ(MeV)	$E_{res}(^{3}H+4n)$(MeV)	XREF	Comments
0	$1/2^{+}$	<300[@] keV	1.3 *4*	BC FGH	$E_{res}(^{3}H+4n)$=1.3 MeV *4* is the weighted average of 0.73 MeV *+58−47* (2022Ca10), 0.57 MeV *+42−21* (2008Ca22), 1.8 MeV *5* (2020Be01), and 2.2 MeV *5* (2021Mu04). E(level): The missing mass spectra of (2020Be01, 2021Mu04) are more easily understood than those of (2007Ca47, 2008Ca22, 2022Ca10). The former spectra show clear evidence of the ground and excited states of ^{7}H, which are accounted for in the analysis of (2020Be01, 2021Mu04). However, the missing mass spectrum displayed on Fig. 3 of (2022Ca10) shows two wide peaks corresponding to the production of ^{7}H from the (^{8}He,^{3}He) reactions on ^{19}F and ^{12}C targets. These two peaks are ~5 MeV wide at FWHM (for the case of $^{19}F(^{8}He,^{3}He)$) and several MeV wide at FWHM (related to the ^{12}C contribution). Such a wide range may already include at least the first excited state of ^{7}H. So, it is unclear (a) why (2022Ca10) did not consider any excited states, and (b) how the interplay between the production of the $^{7}H_{g.s.}$ and potential excited states were deconstructed from the detector response function. Therefore, even though the $E_{res}(^{3}H+4n)$ is computed from the weighted average of the results of (2020Be01, 2021Mu04, 2008Ca22, 2022Ca10), the evaluator has a preference for the analysis and results of (2020Be01, 2021Mu04).

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^{7}H Levels (continued)

E(level)‡	J$^{\pi}$	Γ(MeV)	E$_{\mathrm{res}}$(^{3}H+4n)(MeV)	XREF	Comments
					E(level): Using E$_{\mathrm{res}}$=1.3 MeV *4* and assuming the observed resonance is the ^{7}H ground state, the ^{7}H mass excess is ΔM=48.5 MeV *4*; this compares with ΔM=49.135 MeV *1004* given in 2021Wa16. Γ(MeV): See also the Γ=0.18 MeV *+47−16* measured in (2022Ca10), Γ=0.09 MeV *+94−6* measured in (2007Ca47, 2008Ca22), theoretical estimation of Γ≤1 keV in (2011Gr13), and theoretical estimation of Γ≈0.1 MeV in (2021Li62). J$^{\pi}$: From L=0 in a DWBA fit to the measured angular distribution of the ^{19}F(^{8}He,^{20}Ne)^{7}H transfer reaction data from (2022Ca10). The L=0 is inferred since the best fit for the DWBA calculation assumes that ^{20}Ne is in its ground state, and that the proton is removed from the ground state of ^{8}He (2022Ca10). The decay mode is most likely to ^{3}H+^{4}n, but the direct emission of a tetraneutron from the ^{7}H$_{\mathrm{g.s.}}$ is not yet experimentally observed. The preliminary analysis of (2021Hu28) seems to be suggestive of this decay mode.
4.2×10^{3} *5*	(5/2^{+})&	0.75# MeV	5.45† *3*	C	E(level): This state was unresolved in (2020Be01) and identified at E$_{\mathrm{res}}$(^{3}H+4n)=6.5 MeV *5* with a width of Γ=2.0 MeV *5*. This state is expected (2021Mu04) to decay via ^{5}H$_{\mathrm{g.s.}}$+2n, where ^{5}H$_{\mathrm{g.s.}}$, in turn, decays to ^{3}H+2n. So, the decay may be sequential.
6.3×10^{3}? *5*	(3/2^{+})&	0.9# MeV	7.6† *3*	C	E(level): This state was unresolved in (2020Be01) and identified at E$_{\mathrm{res}}$(^{3}H+4n)=6.5 MeV *5* with a width of Γ=2.0 MeV *5*. E(level): the existence of this state is uncertain (2021Mu04, 2023Ni06). Γ(MeV): A width of Γ=2.7 MeV can also provide a reasonable fit but the statistical arguments made by (2021Mu04) favors Γ=0.9 MeV. Moreover, there is no mention of Γ=2.7 MeV fit in (2023Ni06).
9.7×10^{3} *5*			11.0† *3*	C	This state may have a structure of dissolved core, where ^{3}H breaks into p+n+n resulting in a p+6n configuration. But no experimental evidence exists.

† From (2021Mu04).

‡ E$_{x}$ is deduced using E$_{\mathrm{res}}$(^{3}H+4n)=1.3 MeV *4*.

from Fig. 15 in (2021Mu04) and Fig. 4 in (2023Ni06).

@ from (2020Be01).

& from L=0 in a DWBA (using FRESCO) fit to the measured (2020Be01, 2021Mu04) efficiency corrected angular distributions of the ^{2}H(^{8}He,^{3}He)^{7}H reaction. The L=0 is inferred by the evaluator based on the J$^{\pi}$ assignments of the nuclei involved and the fact that the FRESCO calculation for the J$^{\pi}$=3/2^{+} and 5/2^{+} excited states were performed in (2020Be01, 2021Mu04) assuming that the populations of these states occur, due to the collective excitation, via the proton transfers from the ^{8}He(2^{+}) state with β_2=0.45.