Adopted Levels

S(p)=−100 *30* 2021Wa16
S(2p)=−2111 keV *19* (2021Wa16).
The atomic mass excess of ^{8}C is given as 35064 keV *18* (2021Wa16) from the average of 35030 keV *30* (2011Ch32), 35.10 MeV *3* (1976Tr01), and 35.06 MeV *5* (1976Ro04). The mass excess of ^{8}C was the same in (2017Wa10). Using this mass excess value, the binding energy of ^{8}C is 24.812 MeV *18* (2021Wa16). In some of the theoretical articles referenced below, this is the quantity that is calculated. Sometimes the binding energy is given relative to the ^{4}He+4p threshold. The latter is 3.483 MeV *18* based on AME-2020 (2021Wa16).
^{8}C is unstable with respect to single proton decay (Q=100 keV *30*), two proton decay (Q=2111 keV *19*), three proton decay (Q= 1518 keV *53*), and four proton decay (Q=3483 keV *18*). The Q-values that are mentioned here are from AME-2020 (2021Wa16). Results reported in (2010Ch42, 2023Ch46) indicate that ^{8}C decays by emitting two pairs of protons – ^{8}C→^{6}Be+2p→(^{4}He+2p)+2p. Also see (2011ChZW).
For theoretical studies that include ^{8}C see (1974Ce05, 1974Ir04, 1987Bl18, 1987Sa15, 1988Co15, 1996Gr21, 1996Ka14, 1996Su24, 1997Ba54, 1997Po12, 1998Wi10, 1999Ha61, 2000Wi09, 2001Co21, 2002Ba90, 2002Fo11, 2003Ba99, 2006Sa29, 2006Wi07, 2007Ma79, 2009Ba41, 2010Ti04, 2011ChZW, 2012My02, 2012My04, 2014Eb02, 2014Mi17, 2014My03, 2019Ka50, 2019Sh36, 2021My01, 2021Wy01, 2021Xi06, 2022De06, 2024Ya25). IMME studies including A=8 are reported in (1974Ro17, 1976Tr01, 1984An18, 1998Br09, 2011Ch53, 2013La29, 2022Zo01). Calculations of the ^{8}C rms radii are reported in (2017Ka45, 2023My01, 2023My02).

^{8}C Levels

Cross Reference (XREF) Flags

A	^{1}H(^{9}C,d)	D	^{12}C(α,^{8}He)
B	^{9}Be(^{9}C,^{8}C)	E	^{14}N(^{3}He,^{9}Li)
C	^{9}Be(^{13}O,^{8}C)		

E(level)	J^{π}[b]	Γ	XREF	Comments
0	0^{+}	130 keV *50*	ABCDE	%2p=100 T=2 Γ: From ^{9}Be(^{9}C,^{8}C) (2011Ch32); other values from ^{12}C(α,^{8}He) Γ=0.22 MeV *+8−14* (1974Ro17), ^{14}N(^{3}He,^{9}Li) Γ=290 keV *80* (1976Ro04), ^{12}C(α,^{8}He): either Γ=230 keV *50* from a Gaussian shaped fit or Γ=183 keV *56* from a Breit-Wigner shaped fit (1976Tr01), and ^{9}Be(^{13}O,^{8}C) Γ=88 keV *61* (2023Ch46: supplemental material). The higher statistics in (2011Ch32) compared to the earlier results leads to the choice of Γ=130 keV *50*. The value from ^{9}Be(^{13}O,^{8}C) given in the supplemental material of (2023Ch46) is neglected here. The decay proceeds by ^{8}C→2p+^{6}Be$_{g.s.}$→4p+^{4}He (2010Ch42, 2023Ch46). The latter study deduced $E_{c.m.}$(4p+α)=3490 keV *20*, from which we determined the mass of ^{8}C to be 8.03765 u *16*.
3.40×10^{3}[a] *25*	2^{+}	3.0[a] MeV *5*	A	T=2 (2024Ko04) J^{π}: The L=1 neutron transfer deduced by the DWBA analysis of (2024Ko04: ^{1}H(^{9}C,d)) leads to J^{π}=(0, 1, 2)$^{+}$. (2024Ko04) assigned J^{π}=2^{+} based on comparisons of the deduced experimental spectroscopic factors for each allowed J^{π} value and those obtained using shell model calculations. Only for the case of J^{π}=2^{+}, the theoretical spectroscopic factors reproduced the experimental ones. The other possible assignments would have a negligibly small spectroscopic factors, and thus were rejected. T: From comparison of the E_x(^{8}C*(2^{+}_{1})) with those of other proton- and neutron-rich nuclei (2024Ko04). The extracted T=2 suggests the closure of the semi-magic Z=6 sub-shell for this state. The mirror energy difference, ΔE_x=E_x(^{8}C*(2^{+}_{1}))−E_x(^{8}He*(2^{+}_{1}))=−0.14 MeV *25* (2024Ko04), suggests that the isospin mirror symmetry is maintained for this state.

Continued on next page (footnotes at end of table)

Adopted Levels (continued)

^{8}C Levels (continued)

E(level)	Γ	XREF	Comments
			This state is thought to have a $1p-1h$ configuration based on shell model calculations and a two-body model in (2024Ko04).
18.6×10^{3}[a] *5*	3.9[a] MeV *11*	A	

[a] From (2011Ch32).

[b] From the finite-range DWBA analysis with L=1 in (2024Ko04) using the DWUCK5 computer code. The neutron transfer was considered to be from the $1p_{3/2}$ orbital. Those authors ruled out L=0 for both ^{8}C(0, 3.4 MeV) states.

^{1}H(^{9}C,d) 2024Ko04

2024Ko04: E=55 MeV/nucleon; applied the missing mass technique to reconstruct the excitation energy spectrum of ^{8}C (integrated up to $\theta_{c.m.}$=45°) from the ^{1}H(^{9}C,d) reaction. A cocktail secondary beam containing 5% ^{9}C at 55 MeV/nucleon, 10% ^{8}B, 65% ^{7}Be, and 20% ^{6}Li was produced from projectile fragmentation of a 75 MeV/nucleon ^{12}C beam on a 2.2-mm Be target at GANIL. The LISE fragment separator directed this beam to a 1.5-mm-thick cryogenic liquid hydrogen target. Six position sensitive Si-ΔE backed by CsI(Tl)-E crystals from the MUST2 array, which covered θ_{lab}=2°−36° were used to measure the energies and scattering angles of the deuterons from the ^{1}H(^{9}C,d) reaction. The energy resolution was 40 keV (FWHM) at E_α=5.5 MeV. However, the uncertain deuterons energy losses through the target limited the experimental energy resolution to 0.50 MeV *5* (r.m.s.).

The excitation function displayed the $^8C_{g.s.}$ and two newly observed ^{8}C resonances at E_x=3.40 MeV *25* (with Γ=3.0 MeV *5*) and E_x=18.6 MeV *5* (with Γ=3.9 MeV *11*), which were fitted using Voigt functions convoluted with a background from the simulated non-resonant breakups due to 1p and 4p emissions. A DWBA analysis was performed using the DWUCK5 computer code to deduce L and C^2S for the ^{8}C(0, 3.4 MeV) states. Shell model calculations were performed to obtain J^π values from a comparison of the theoretical and experimental spectroscopic factors. A two-body model was employed to further explore the mirror symmetry between the unbound 2^+_1 states in ^{8}C and ^{8}He.

^{8}C Levels

E(level)[a]	J^π[b]	Γ[a]	L[b]	C^2S_{exp}[b]	Comments
0	0^+	130 keV *50*	1	0.69 *14*	Γ: From the ^{8}C Adopted Levels and mentioned in (2024Ko04). C^2S_{theory}=∼0.87 from shell model calculations using CK and YSOX interactions for J^π=0^+ (2024Ko04).
3.40×10^3 *25*	2^+	3.0 MeV *5*	1	0.15 *3*	T=2 (2024Ko04) Γ: After the ^{4}He*(2^+_1) state, this state has the broadest known width among the 2^+_1 states in even-even nuclei (2024Ko04). J^π: The L=1 neutron transfer leads to J^π=(0, 1, 2)$^+$. However, the resulting experimental spectroscopic factors could only be reproduced using shell model for the case of J^π=2^+ (see below). The other possible assignments would have a negligibly small spectroscopic factors (2024Ko04). C^2S_{theory}=0.13 from shell model calculations using CK and YSOX interactions for J^π=2^+ (2024Ko04). So, those authors recommended J^π=2^+. This state is thought to have a $1p-1h$ configuration based on shell model calculations and a two-body model (2024Ko04).
18.6×10^3 *5*		3.9 MeV *11*			

[a] From (2024Ko04) unless otherwise noted.
[b] From the finite-range DWBA analysis in (2024Ko04) using the DWUCK5 computer code. The neutron transfer was considered to be from the $1p_{3/2}$ orbital. Those authors ruled out L=0 for both ^{8}C(0, 3.4 MeV) states.

^{9}Be(^{9}C,^{8}C) 2010Ch42,2011Ch32

2010Ch42: The authors measured the multi-proton decay properties of ^{8}C by measuring the complete kinematics of remnant α+4p decay products. The proton correlations indicate that the decay follows a $^{8}C \rightarrow {}^{6}Be+2p \rightarrow \alpha+2p+2p$ multi−step path. A beam of 70 MeV/nucleon ^{9}C was produced by fragmentation of an ^{16}O beam at the NSCL. The ^{9}C beam impinged on a ^{9}Be target and short lived unbound nuclei produced in the reactions were studied by reconstruction of the breakup particle kinematics. The proton-proton pairing correlations indicate that 92% *5* of events proceed through the 2p+$^{6}Be_{g.s.}$ decay channel. Combined with results on ^{6}Be, this indicates a $^{8}C \rightarrow {}^{6}Be+2p \rightarrow \alpha+2p+2p$ decay path. Data on ^{8}B* decay is consistent with 2p decay from ^{8}B*(10.61 MeV) which is the IAS of $^{8}C_{g.s.}$.

2011Ch32: The authors impinged a 70 MeV/nucleon ^{9}C beam on a thick ^{9}Be target and detected ejected reaction products with a large area position sensitive ΔE-E array. Reconstruction of the complete kinematics permitted an analysis of excitation energies, decay pathways and associated branching ratios for several nuclei. A beam of 150 MeV/nucleon ^{16}O ions was fragmented on a thick ^{9}Be target to produce a 70 MeV/nucleon ^{9}C beam using the A1900 fragment separator at the NSCL. The ^{9}C beam impinged on a 1mm thick ^{9}Be target and reaction products were detected in 14 position sensitive ΔE-E detectors of the HiRA array. The coincident reaction products were analyzed via kinematic energy reconstruction to evaluate excitation energies and decay paths. The authors obtained the ^{8}C mass excess $\Delta M(^{8}C)$=35.030 MeV *30* and the width Γ=130 keV *50*.

^{8}C Levels

E(level)	Γ[a]	Comments
0	130 keV *50*	(2011Ch32) obtained mass excess 35.030 MeV *30*.

[a] From (2011Ch32).

^{9}Be(^{13}O,^{8}C) 2023Ch46

2023Ch46: XUNDL file compiled by TUNL (2023).

The authors report first evidence for states in ^{9}N; the states are found to decay via 1-proton decay to $^{8}C_{g.s.}$.

The measurement utilized a beam of ≈60 MeV/nucleon ^{13}O ions from the NSCL/A1900 fragment separator that was purified in the Radio Frequency Fragment Separator before impinging on a 1 mm thick ^{9}Be target (see supplemental material and prior reports such as (2023Ch22)). Fragmentation reactions populated the short-lived ^{9}N nucleus, which proton decayed before exiting the target. The complete kinematics of the charged-particle reaction products were measured using the HiRA array, which comprised a set of 14 64 mm × 64 mm position sensitive ΔE-E telescopes that covered the forward direction of the outgoing beam (θ_{lab}≈2.1° to 12.4°). We assume the telescopes were arranged in vertical towers with a 2-3-4-3-2 configuration where the central tower had a gap between the upper and lower two telescopes to permit the beam a downstream exit at θ=0°, as in past experiments.

Part of the analysis of the ^{9}N properties required an independent analysis of the ^{8}C ground state properties where the 4p+α sub-events were analyzed by fitting the data with a Breit-Wigner lineshape and a smooth background component. A $^{8}C_{g.s.}$ peak was found with $E_{c.m.}$(4p+α)=3490 keV *20* and Γ=88 keV *61* (supplemental materials). *Note:*^{8}C is known to decay sequentially by two 2-proton decays having an intermediate state involving $^{6}Be_{g.s.}$; ^{8}C→2p+[$^{6}Be_{g.s.}$→2p+^{4}He].

^{8}C Levels

E(level)	J$^{\pi}$	T$_{1/2}$	Comments
0	0^{+}	88 keV *61*	E(level): From $E_{c.m.}$(4p+α)=3490 keV *20* (2023Ch46). From this energy, the mass of ^{8}C was deduced to be 8.03765 u *16*. T$_{1/2}$: From (2011Ch32). The decay proceeds by ^{8}C→2p+$^{6}Be_{g.s.}$→4p+^{4}He (2023Ch46).

^{12}C(α,^{8}He) 1974Ro17,1976Tr01

1974Ro17: E=156 MeV; measured Q of ^{8}He spectrum, σ, deduced ^{8}C mass excess and width. This is the article in which ^{8}C is first recognized (2012Th01). The differential cross section was found to be about 20 nb/sr at θ_{lab}=2°. The mass excess of ^{8}C was found to be ΔM(^{8}C)=35.30 MeV *20*. As indicated above, ^{8}C decays by proton emission. Assuming a Gaussian line shape, the width of the observed ^{8}C state is found to be Γ=0.22 MeV *+8−14*.

Since the ^{8}He spectrum is the observed quantity in this experiment, a change in the measured mass of ^{8}He would lead to a change in the mass of ^{8}C. In (1974Ce05) a more accurate value of the mass defect of ^{8}He led to a revision of the measured mass defect of ^{8}C, ΔM(^{8}C)=35.38 MeV *17*.

1976Tr01: E=123.5 MeV; measured σ, deduced mass excess and width. The mass excess of ^{8}C was found to be ΔM(^{8}C)= 35.10 MeV *3*. The width was found to be Γ=230 keV *50* assuming a Gaussian fit and 183 keV *56* assuming a Breit-Wigner fit. An IMME study of A=8 nuclei is reported in this article.

^{8}C Levels

E(level)	Γ	Comments
0	230 keV *50*	Γ: From (1976Tr01). See also Γ=0.22 MeV *+8−14* (1974Ro17). (1976Tr01) obtained mass excess 35.10 MeV *3*.

$^{14}N(^{3}He,^{9}Li)$ 1976Ro04

1976Ro04: The ^{3}He beam with energy E=76 MeV from the MSU cyclotron collided with a target of either a solid melamine ($C_3N_6H_6$) or N_2 gas and the ^{9}Li spectrum was observed. Measured laboratory cross sections with approximately 40% uncertainties are $d\sigma/d\Omega$=3 nb/sr and 5 nb/sr at θ_{lab}=8° and 10°, respectively. The authors determined the mass excess of ^{8}C to be $\Delta M(^{8}C)$=35.06 MeV *5*. Assuming a Gaussian shape for the line shape, the width was found to be Γ=290 keV *80*.

^{8}C Levels

E(level)	Γ	Comments
0	290 keV *80*	(1976Ro04) obtained mass excess 35.06 MeV *5*.

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