Adopted Levels

S(n)=14225 *18*; S(p)=1299.6 *24*; Q(α)=−10650 *SY* 2017Wa10

Previous evaluations of ^{9}C are found in (1955Aj61, 1959Aj76, 1966La04, 1974Aj01, 1979Aj01, 1984Aj01, 1988Aj01, 2004Ti02).

Larger theoretical review articles: (2001Ka66, 2001Ar22).

Shell model analyses of the properties of light nuclei: (1970Co28, 1974Ir04, 1993Po11, 1998Na17, 1999Ki28, 2001Co21, 2014Vo09, 2015Ti03).

Cluster model analyses of light nuclei: (1995Va18, 1995Va31, 1996Ka14, 1997Ho04, 1997Ka25, 1997Va05, 2001Ka66, 2001Ar22, 2009Fu09, 2014Ko03).

Hartree Fock analyses of light nuclei: (1987Sa15, 1997Ba54, 1998Sh16, 2003Ch79, 2004Sa58, 2010Ha18, 2011Ha38).

Other theoretical approaches: (1996Re19, 1996Su24, 1997Po12, 1998Su18, 2012No09, 2013Ma60, 2019Fo17).

Studies in the ^{9}C-^{9}Li mirror states, and A=9 analog states. (1995Va18, 1995Va31, 1997Po12, 2012Br07, 2019Fo17).

Discussions on p-p pairing interactions and ^{9}C as a proton halo nucleus: (2002Gu10, 2009Fu09, 2010Ha18, 2014Ko03).

Notable:

2014Vo09: Continuum shell model calculations of levels up to E_x≈10 MeV.

2019Fo17: Potential model analysis of mirror states in ^{9}C and ^{9}Li. Predictions are made for the first *s* and $(sd)^2$ states in ^{9}Li based on ^{9}C observations.

The ^{9}C β^+, β^+p and $\beta^+\alpha$ decay studies are reported in: (1965Ha09, 1972Es05, 1971Ha05, 1971Mo01, 1988Mi03, 1995Ma48, 1996Ma38, 1998Hu08, 2000Ge09, 2001Be51, 2001Bu05, 2002Be53, 2002Bo29, 2004Bo22, 2004Bo43, 2005Mi30).

Compilations of decay properties for a global collection of nuclei are found in (1973Ha77, 1977Ce05, 1993Ch06).

Discussions on searches for evidence of second-class currents in β decay are found in (1970Wi02, 2003Sm02).

Other experimental studies:

1997We03: Analyzed ^{197}Au(^{12}C,X) isotope production at E(^{12}C)≈47 MeV/nucleon to estimate the reaction temperature.

^{9}C Levels

Cross Reference (XREF) Flags

A	^{1}H(^{8}B,p)	H	^{9}Be(^{9}C,^{9}C)	O	^{12}C(p,^{9}C)
B	^{1}H(^{9}C,p)	I	^{9}Be(^{10}C,^{9}C)	P	^{12}C(^{3}He,^{6}He)
C	^{1}H(^{10}C,^{9}C)	J	^{9}Be(^{13}O,X):^{11}O 2p decay	Q	^{12}C(^{9}C,X)
D	^{2}H(^{8}B,^{9}C)	K	^{10}B(p,2n),^{11}B(p,3n),^{12}C(p,d2n)	R	^{12}C(^{12}C,^{9}C)
E	^{6}Li(^{3}He,π^-)	L	^{10}B(^{7}Li,^{8}He)	S	^{12}C(^{14}N,^{9}C)
F	^{7}Be(^{3}He,n)	M	^{10}B(^{14}N,^{15}C)	T	^{93}Nb(^{20}Ne,^{9}C)
G	^{9}Be(π^+,π^-)	N	^{12}C(μ^-,^{9}C),^{14}N(μ^-,^{9}C)		

E(level)	J^π	$T_{1/2}$ or Γ	XREF	Comments
0.0	3/2−‡	126.5 ms *10*	BCDEFG IJKLMNOPQRST	%ε+%β^+=100; %β^+p=62.0 *19*; %$\beta^+\alpha$=37.9 *58* T=3/2; μ=−1.3914 *5* The β decay of ^{9}C always results in p+2α either by ^{9}C(β^+p)^{8}Be→2α or ^{9}C($\beta^+\alpha$)^{5}Li→p+α. The decay rates here are from the respective ^{8}Be: ^{9}C β^+p and ^{5}Li: ^{9}C $\beta^+\alpha$ data sets in ENSDF. There are essentially two precision measurements given in (2000Ge09, 2001Be51). As in (2004Ti02) we take the ^{9}C branch feeding the ^{9}B g.s. to be 54.1 from (2001Be51), where extra care was taken to avoid low-energy threshold concerns; the branches feeding other levels were taken from (2000Ge09) and renormalized to give a 100% feeding (×46.9/54.1≈0.86). (2000Ge09) also found a large *background* branch (approx 4%), which was attributed to tails from higher states; this intensity is included but not attributed to any states. μ from (1996Ma38); see further details in (1994MaZU, 1995MaZW, 1995Ma48, 2002Ma43). See μ=−1.396 μ_N *3* in 1998Hu08. See theoretical discussion in (1997KiZV, 1999Ki28, 2003Su04, 2003Su09, 2003Su28, 2003Sa50, 2004Ut02, 2005Ut02,

Continued on next page (footnotes at end of table)

Adopted Levels (continued)

^{9}C Levels (continued)

E(level)	J^π	$T_{1/2}$ or Γ	XREF	Comments
				2011Za04, 2013Pa10, 2016Me17, 1996Ka14). $T_{1/2}$: From weighted average of 126.5 ms *10* (1971Ha05,1972Es05), 126.5 ms *20* (1971Mo01) and 127 ms *3* (1965Ha09).
2218 *11*	1/2$^-$ ‡	52 keV *11*	A E H P	%p≈100 (2017Br07) T=3/2 E(level): From (1974Be66: ^{12}C(^{3}He,^{6}He)). Γ: From (2017Br07: ^{9}Be(^{9}C,^{9}C)); see also Γ=100 keV *20* in (1974Be66).
3542 *20*	5/2$^-$	673 keV *50*	A H P	%p≈100 (2017Br07) T=3/2 E(level): From (2017Br07). See also 3.6 MeV *2* (2007Ro01, 2019Ho14: ^{1}H(^{8}B,p)) and 3.30 MeV *5* (1991Go13: ^{12}C(^{3}He,^{6}He)). Efforts to observe a lower-energy state corresponding to the precise energy given in (1991Go13) have found no supporting evidence suggesting only one state is in this region. Γ: From (2017Br07); see also Γ=1.1 MeV *7* in (2019Ho14) and an earlier value Γ=1.4 MeV *5* (2007Ro01). In (2019Ho14) discussion on Γ suggests a large background subtraction in (2017Br07) may distort the deduced value when compaired with their larger value, but (2019Ho14) also suggests the narrower value may be in better agreement when comparing with the ^{9}Li analog. J^π: From R-matrix analysis in (2007Ro01).
4400 *40*	5/2$^+$	2.75 MeV *11*	A H P	%p≈100 T=3/2 E(level),Γ: from (2017Br07), see also E_x=4.3 MeV *3* and Γ=4.0 MeV *+20−14* in (2019Ho14). J^π: From R-matrix analysis in (2019Ho14). Decays via p+^{8}B*(770 keV: J^π=1$^+$)→2p+^{7}Be.
5750 *40*		601 keV *50*	H	%p≈100 T=3/2 E(level),Γ: From (2017Br07). Decays via p+^{8}B*(2320 keV: J^π=3$^+$)→2p+^{7}Be.
9×10^{3} †			E	E(level): From (1984Br22: ^{6}Li(^{3}He,π^-)); the state is suggested as the analog to ^{9}Be*(23 MeV: GDR). Γ: broad.
15×10^{3} †			E	E(level): From (1984Br22: ^{6}Li(^{3}He,π^-). Γ: broad.

† Decay mode not specified.
‡ From comparison with the mirror ^{9}Li.

$^{1}H(^{8}B,p)$ 2007Ro01,2019Ho14

2007Ro01: Measured the elastic scattering of ^{8}B on protons using the TwinSol radioactive nuclear beam (RNB) facility at University of Notre Dame. A 29 MeV/nucleon ^{8}B beam, produced via $^{3}He(^{6}Li,^{8}B)$ reactions, impinged on a 9 mg/cm^{2} stopping thickness CH_2 target. Scattered protons, emerging in the forward direction were detected using a set of two ΔE-E Si detectors placed at θ=7.7°. The data were analyzed using standard thick target inverse kinematics techniques to obtain the p+^{8}B excitation function for $E_x(^{9}C)\approx$1.9-4.5 MeV.

An R-matrix analysis was implemented to interpret the excitation function. In addition to the $J^\pi=1/2^-$ E_x=2.22 MeV first excited state, inclusion of a $J^\pi=5/2^-$ state at E_x=3.6 MeV *2* with Γ=1.4 MeV *5* was necessary to produce agreement between the experimental data and the fit. This $J^\pi=5/2^-$ state has a single-particle nature with a spectroscopic factor of S=0.77 *25* which is consistent with theoretical predictions. The fit was somewhat improved with the inclusion of an additional $J^\pi=3/2^-$ state at $E_x\approx$4.1 MeV having Γ≈1.3 MeV; the followup work (2019Ho14) by the same group does not support the existence of this state.

A continuum shell model analysis of the (2007Ro01) data is presented in (2009Vo03).

2019Ho14: Studied level structure of ^{9}C using ^{8}B+p resonant elastic scattering using the TexAT detector at Texas A&M. A ^{8}B beam was produced via $^{6}Li(^{3}He,n)^{8}B$ reaction and scattered from target methane gas (CH_4). An R-matrix analysis of the E_x= 1.8-6.3 MeV excitation function was carried out, but the data couldn't be reproduced with only the inclusion of previously reported levels. The data does not support existence of the suggested $J^\pi=3/2^-$ state at E_x=4.1 MeV (2007Ro01) nor does it support the existence of the E_x=3.30 MeV *5* state (1991Go13). In addition to the E_x=2.2 and 3.6 MeV states reported in (2007Ro01), a new $5/2^+$ state at E_x=4.3 MeV 3 with Γ=4.0 $^{+2.0}_{-1.4}$ MeV was observed. This new state determines the location of the 2*s* shell in the *A*=9, T=3/2 system. The R-Matrix fit is also improved with the inclusion of a $J^\pi=7/2^-$ state at $E_x\approx$6.4 MeV; however, since this lies outside of the measured excitation function this suggestion remains tentative.

Related experimental studies: A study of the the reaction, via the inverse Coulomb dissociation reaction was carried out ar RIPS/RIKEN using a 65 MeV/nucleon ^{9}C beam on a Pb target. The results are analyzed to estimate the astrophysical S-factor (2000MoZP, 2002HiZZ, 2003Mo23, 2003Mo28, 2003MoZY). See other relevant theoretical discussion in (2005Ty02, 2012Fu07).

Theory:

The reaction rates for the astrophysical *hot p-p chain reactions*, $^{8}B(p,\gamma)^{9}C$ and $^{9}C(\alpha,p)^{12}N$, are estimated in (1989Wi24).

A microscopic cluster model analysis of the E1 and E2 components of $^{8}B(p,\gamma)^{9}C$ and $^{8}Li(n,\gamma)^{9}Li$ is given in (1999De03).

A potential model was developed in (2003Mo12) to analyze the $^{8}B(p,\gamma)^{9}C$ and $^{8}Li(n,\gamma)^{9}Li$ capture cross sections.

In (2002Tr14, 2006Tr07) the ^{9}C 1-proton removal data of (1997Bl08)(C, Al, Sn, Pb targets) is analyzed to obtain the Asymptotic Normalization Coefficients, $C^2(p_{3/2})$ + $C^2(p_{1/2})$=1.22 fm^{-1} *13*, and then evaluated the astrophysical S-factor. See also (2003Tr09).

In (2005Gu29, 2005Li35) the $^{2}H(^{8}Li,p)$ reation was measured to obtain the $^{9}Li\rightarrow^{8}Li$+n ANC; this value was used to estimate the ANC for $^{9}C\rightarrow^{8}B$+p, and the astrophysical S-factor was analyzed. See additional comments in (2008Ti09, 2010Ti04, 2011No03, 2013Ti05).

A single-particle potential model was developed in (2010Hu11) to analyze ANCs and spectroscopic factors in a broad range of capture reactions.

^{9}C Levels

E(level)	J^π	Γ	L[#]	S	Comments
2218[†]	$1/2^-$[†]	52 keV	1		Γ: From (2017Br07), the R-matrix analysis was found to be rather insensitive to the width parameter.
3.6×10^{3}[‡] *2*	$5/2^-$[‡]	1.1 MeV *7*	1	0.8 *2*	Γ: From (2019Ho14). The standard deviation is 300 keV; see further discussion in the text including discussion on the ^{9}Li analog state. An earlier analysis in (2007Ro01) found Γ=1.4 MeV *5*. S: From (2007Ro01, 2019Ho14); see further discussion in (2009Ti11).
4.3×10^{3}[#] *3*	$5/2^+$[#]	4.0[#] MeV *+20−14*	0		
≈6.4×10^{3}?[#]	$7/2^-$[#]	≈1.1[#] MeV	1		

† From (1974Be66).
‡ From (2007Ro01).
# From (2019Ho14).

$^{1}H(^{9}C,p)$ 2013Ma23

2013Ma23: XUNDL data set compiled by TUNL (2013). The authors measured the angular distribution of $^{9}C(p,p)$ elastic scattering in inverse kinematics at $E(^{9}C)\approx300$ MeV/nucleon. Results were analyzed to evaluate the ^{9}C matter root-mean-square radius ($R^{r.m.s.}_{matter}$).

A beam of ≈ 277-300 MeV/nucleon ^{9}C ions, from the Chiba fragment separator facility at the Heavy Ion Medical Accelerator, impinged on a 5 mm thick solid hydrogen target. Scattered ^{9}C nuclei, which have no bound excited states, were detected in a downstream plastic scintillator detector while recoiling protons were identified and measured in either of the two recoil proton spectrometer telescopes comprised of a recoil drift chamber, a plastic scintillator and a set of NaI(Tl) calorimeters. Selection of “exclusive” events with protons in coincidence with scattered ^{9}C nuclei permitted isolation of elastic events.

Proton angular distributions were deduced and analyzed over the range θ_{lab}=65°−85°. The $R^{r.m.s.}_{matter}$=2.43 fm +55-28 is deduced.

See another analysis of these data in (2014Ra12).

Theory: 2009Ib01, 2009Ib03: Calculations of the angular distributions of cross section and analyzing power were carried out at 60 and 700 MeV/nucleon using a Glauber diffraction theory model.

^{9}C Levels

E(level)	Comments
0.0	$R^{r.m.s.}_{matter}$=2.43 fm +55-28.

^{1}H(^{10}C,^{9}C) 2019Ho08

2019Ho08: ^{1}H(^{10}C,pn), E=385 MeV/nucleon. The ^{9}C ground state was populated in quasi-free neutron knockout reactions on ^{10}C studied at the GSI/R^{3}B-LAND facility.

See theoretical discussion on the DWIA analysis method in (2019Ph04).

^{9}C Levels

E(level)
0

^{2}H(^{8}B,^{9}C) 2001Be45

2001Be45: ^{2}H(^{8}B,^{9}C), Using an E=14.4 MeV/nucleon ^{8}B beam impinging on a CD_2 target at the RIKEN/RIPS facility, they detected reaction ^{9}C at forward directions in a plastic ΔE-E telescope along with the corresponding neutrons, at backwards angles, using an array of 8 BC401 plastic scintillators. The analysis determined the ^{9}C excitation spectrum, and the asymptotic normalization coefficients (ANC) were deduced via DWBA analysis. Using the ANCs, the astrophysically relevant ^{8}B(p,γ) reaction was analyzed.

^{9}C Levels

E(level)
0

^{6}Li(^{3}He,π^{-}) 1979As01

1979As01: Using a E(^{3}He)=910 MeV beam at the CERN synchrocyclotron, evidence is found for production of the ^{9}C+π^{-} two-body final state, which is termed "doubly coherent π^{-} production". A deviation from the general falloff slope in the high-energy endpoint shape of the π^{-} momentum distribution is attributed to the two-body final state.

1984Br22: The measurement of (1979As01) was repeated at CERN with improved an apparatus that permited better resolution of the ^{9}C states, rather than an enhancement of counts at the endpoint. In this case, three well-resolved groups appeared at the endpoint. At the highest π^{-} momentum (723 MeV/c) a peak is identified and associated with ^{9}C(0,2.2 MeV) states; the only known states at the time. Two additional groups at $P_{\pi^{-}}$=714 and ≈705 MeV/c, corresponding to E_x≈9 and 15 MeV, respectively. The authors suggest the 9 MeV group may be the analog of the E_x=23 MeV GDR of ^{9}Be.

Theory: See theoretical analysis of π production in this reaction in (1982Hi02).

^{9}C Levels

E(level)	Comments
0†	
2.2×10^{3}†	
9×10^{3}	E(level): Suggested as the analog of the ^{9}Be*(23 MeV) GDR. Γ: broad.
15×10^{3}	Γ: broad.

† Unresolved.

^{7}Be(^{3}He,n) 1971Mo01

1971Mo01: The mass and half-life of ^{9}C were measured using at the Office of Naval Research-California Institute of Technology tandem Van de Graff accelerator. The ^{7}Be(^{3}He,n)^{9}C, at ≈9-12 MeV was used to produce the ^{9}C ions on a target mounted on a solenoid-operated arm that switched the activation position and the counting position. The activation period was followed by a counting period that was varied between 0.9 and 2.2 S. The event rate data were binned in 10 ms time bins. Because of the high background rate from the ^{7}Be target, a silicon ΔE-E telescope was used to detect β-p events during the counting period. The half-life was measured as 126.5 ms *2*.

The ^{7}Be(^{3}He,n)^{9}C reaction threshold was also determined as 8980 keV *5*, which corresponds to mass excess ΔM(^{9}C)=28907 keV *4*. The author analyzed the A=9 isospin-quartet states to test the quadratic mass formula and discussed the results and implications.

^{9}C Levels

E(level)	$T_{1/2}$	Comments
0	126.5 ms *2*	E(level): ΔM=28907 keV *4*.

^{9}Be(π^{+},π^{-}) 1980Bu15

1974Ka07: Cross sections for σ(E=30-250 MeV) are calculated along with $\sigma(\theta$, E_{π^-}=175 MeV).

1980Bu15: The ^{9}C ground state energy was used to calibrate the EPICS spectrometer at LAMPF. The ground state peak is well resolved from other reaction components. Measured dσ/dO(θ=5°) at E_{π^-}=180 MeV. In (1986Se04) a similar exercise is carried out at E_{π^-}=292 MeV.

1989Gr06: Measured $\sigma(E_{\pi^-}$=180, 240) for the double charge-exchange (DCX) reaction ^{9}Be(π^{+},π^{-}) and developed a phenominological model to explain the observations.

2007Fo05: Measured (π^{+},π^{-}) and (π^{-},π^{+}) reactions on ^{6,7}Li, ^{9}Be, ^{12}C at E_{π}=120, 180, 240 MeV and for θ=25°, 50°, 80° and 130° at LAMPF. They compared their data with a model where the DCX reaction proceeds via two sequential single charge exchange reactions.

^{9}C Levels

E(level)
0

$^{9}Be(^{9}C,^{9}C)$ 2017Br07

2017Br07: $^{9}Be(^{9}C,^{9}C)$ inelastic scattering to one- and two-proton unbound levels in ^{9}C using a 68 MeV/nucleon ^{9}C beam, from the MSU/A1900. The beam impinged on a 1 mm thick ^{9}Be target that was surrounded by 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 ($\theta_{lab}\approx 2°$ to 13.9°). 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°. In addition, 158 CsI(Na) crystals from the CAESAR array covered polar angles between θ_{lab}=57.5° and 142.4° and measured the coincident γ-ray deexcitations.

Analysis of the $p+^{8}B$ events revealed levels corresponding to decay of the known first and second excited states of ^{9}C to $^{8}B_{g.s.}$. Further analysis of the $2p+^{7}Be$ events revealed a broad asymmetric peak around E_x=5.5 MeV, which was found to include ^{9}C states at $E_x\approx$4.4 and 5.8 MeV that decay sequentially via ^{8}B states at E_x=0.77 and 2.32 MeV, respectively.

Finally, the authors evaluated the ^{9}C*(4.4,5.8) states along with ^{9}B*(19.25,20.42) states that they measured in $^{9}Be(^{9}C,^{9}B)$ reactions. Their analysis of the Coulomb-displacement energies suggests the claim that $^{9}C_{4.4}$-$^{9}B_{19.25}$ and $^{9}C_{5.8}$-$^{9}B_{20.42}$ are analog states.

^{9}C Levels

E(level)	J^{π}	Γ	Comments
2218† *11*	1/2⁻†	52 keV *11*	T=3/2 Decays via $p+^{8}B_{g.s.}$
3549 *20*	5/2⁻‡	673 keV *50*	T=3/2 Decays via $p+^{8}B_{g.s.}$
4400 *40*	$(1/2^{+},5/2^{+})$	2.75 MeV *11*	T=3/2 Decays via $p+^{8}B$*(770 keV: $J^{\pi}=1^{+}$)→$2p+^{7}Be$. Shell model and R-matrix analysis of the Γ suggest $J^{\pi}=(1/2^{+},5/2^{+})$.
5750 *40*		601 keV *50*	T=3/2 Decays via $p+^{8}B$*(2320 keV: $J^{\pi}=3^{+}$)→$2p+^{7}Be$.

† From (1974Be66).
‡ From 2007Ro01.

^{9}Be(^{10}C,^{9}C) 2011Gr08

2011Gr08: Cross sections for neutron knockout from 80 and 120 MeV/nucleon ^{10}C ions on ^{9}Be and ^{12}C targets were mesured at θ=0° at the NSCL/A1900 spectrometer. Results are compared with variational Monte Carlo and no core shell model calculations to gain insight into many-body forces.

^{9}C Levels

E(level)
0

$^{9}Be(^{13}O,X):^{11}O$ 2p decay 2019We03

2019We03: ^{9}C is populated in the 2p-decay of ^{11}O. A beam of 69.5 MeV/nucleon ^{13}O ions, from the NSCL/A1900 fragment separator, was purified in the Radio Frequency Fragment Separator before impinging on a 1-mm thick ^{9}Be target. The reaction products were detected using the HiRA High-Resolution position sensitive ΔE-E telescope array, which covered the polar angles θ_{lab}=2.1° to 12.1°. A broad peak near $E_{res}(2p+^{9}C)\approx4.5$ MeV was observed in the total energy spectrum and attributed to a collection of four 2p-unbound ^{11}O states.

See additional discussion and theoretical analysis in (2019Fo10, 2019Ka50, 2019Wa16).

^{9}C Levels

E(level)
0

^{10}B(p,2n),^{11}B(p,3n),^{12}C(p,d2n) 1965Ha09,1972Es05

1965Ha09: A measurement of the β-delayed proton emissions of ^{9}C utilized the ^{10}B(p,2n), ^{11}B(p,3n) and ^{12}C(p,2nd) reactions to produce ^{9}C ions at the McGill synchrocyclotron. A probe containing the target foil and a Si detector ΔE-E telescope counter were inserted into the internal cyclotron beam for a short activation period, and then the delayed proton emissions were measured. The decay rate of groups in the range of E_p=4-10 MeV and at 12.25 MeV were analyzed and resulted in $T_{1/2}$=127 ms *3*.

1971Ha05,1972Es05: A preliminary report on the ^{9}C lifetime is given in (1971Ha05); the focus is on ^{17}Ne and ^{33}Ar decays, but known properties of ^{9}C decay are used to evaluate the apparatus and method. In (1972Es05), the ^{9}C data are more completely analyzed in a study of both the decay lifetime and the ^{9}B levels populated in the decay. They report on ^{9}C populated in the ^{10}B(p,2n) reaction using a 43 MeV proton beam at the Berkeley 88-in cyclotron. The target was comprised of enriched boric acid that was pressed into five 100 mesh tungsten screens. After activation, a burst of oxygen gas was used to transport the ^{9}C from the screen into the counting chamber. In the counting chamber, a ΔE-E telescope was used to identify the β-delayed protons for a period of about 700 ms. The observed proton energies and intensities were used to determine a decay level scheme in ^{9}B. The reported lifetime is 126.5 ms *10*.

^{9}C Levels

E(level)	$T_{1/2}$	Comments
0	126.5 ms *10*	$T_{1/2}$: From 1972Es05. See also 127 ms *3* in 1965Ha09.

^{10}B(^{7}Li,^{8}He) 2001Ca37

2001Ca37: The experiment was performed at the magnetic spectrograph at MSU. The ground state of ^{9}C was strongly populated in a measurement of ^{10}B(^{7}Li,^{8}He). A 350 MeV beam of ^{7}Li ions impinged on a 340 μg/cm^2 ^{10}B target with a carbon backing that was positioned at the S800 spectrometer target position. Data were taken for θ=0°−12°. The ground state was populated, while no other levels were identified.

^{9}C Levels

E(level)
0

^{10}B(^{14}N,^{15}C) 2004Le12

2004Le12: The $^{9}C_{g.s.}$ was populated in 30 MeV/nucleon ^{14}N beam bombardment of a 0.1 mg/cm^2 ^{10}B target placed at the GANIL/SPEG spectrometer target position. The peak corresponded to ^{9}C+^{15}C*(0.74 MeV).

^{9}C Levels

E(level)
0

^{12}C(μ^-,^{9}C),^{14}N(μ^-,^{9}C) 2000Ha33

2000Ha33: The yield of ^{9}C and other radioisotopes, produced by energetic muons and their secondaries, was measured at the SPS muon beam at CERN. The measurements, carried out at E(μ)=100 and 190 MeV, are aimed at understanding backgrounds at BOREXINO and KAMLAND.

2010Ab05: The authors investigated the yield of radioisotopes, including ^{9}C nuclei, produced in the KamLAND detector by cosmic μ showers. They suggest ^{12}C(π^-,^{3}H) as the primary production mechanism; though in (2016Ab02) the ^{14}N(μ^-,ν5n) reaction is indicated. The subsequent β^+p and $\beta^+\alpha$ decay of ^{9}C gives rise to a high-energy backgrounds in the detector.

2016Ab02: The authors investigated the yield of radioisotopes produced by cosmic μ in the Double Chooz detector. The ^{14}N(μ^-,ν5n), ^{16}O(μ^-,$\nu d5n$) and ^{16}O(μ^-,$\nu p6n$) reactions are suggested as the primary reactions producing ^{9}C.

2019Zh29: The FLUKA Monte Carlo code was used to estimate μ induced activity in the DUNE detector.

^{9}C Levels

E(level)
0

^{12}C(p,^{9}C) 1956Sw77

1956Sw77: First evidence for ^{9}C was found in a photographic emulsion plate that was bombarded with 3 GeV protons. The decay patern is described as a star. The event appears to be initiated by a track entering the plate from the top; when the ^{9}C is produced, it drifts horizontally to the right and stops. The subsequent decay appears as a β^{+} particle ejected downward along with a β-delayed proton track that moves horizontally to the left and a recoiling ^{8}Be traveling to the right that instantly decays into two α particles. Limits on the decay Q-value and mass excess are discussed.

See 1987Zh10 for a calculation of $\sigma(^{9}C(E^{*}))$ for ^{12}C(p,n^{3}H) at 700 MeV.

^{9}C Levels

E(level)
0

$^{12}C(^{3}He,^{6}He)$ 1974Be66,1991Go13

1964Ce04: A 65 MeV beam of ^{3}He ions from the Berkeley 88-inch cyclotron was used to study the ^{9}Li and ^{9}Li nuclei via $^{12}C(^{3}He,^{6}He/^{6}Li)$ reactions. A ΔE-E telescope was rotated in a 36 inch scattering chamber to cover θ=15.8°−33.9°. $^{9}C_{g.s.}$ was observed with the mass excess ΔM=28.95 MeV *15*. the IMME was analyzed for the mass 9 T=3/2 quartet ^{9}Li, ^{9}Be, ^{9}B and ^{9}C. This experiment was credited with the first observation of ^{9}C (2012Th01); however see (1956Sw77).

1970Tr05: Studied $^{12}C(^{3}He,^{6}He)$ at E=68-70 MeV using the ENGE split pole spectrograph at MSU. Measured $\sigma(E(^{6}He),\theta=10.68°)$ and deduced Q=−31.578 MeV *8*. Using this Q-value, $\Delta M(^{9}C)$=28.911 MeV *9* was deduced; the value was compared with ΔM=28.904 MeV *4* from a conference proceedings (1967Ba59). The authors also analyzed the IMME for the A=9 T_Z=3/2 nuclei.

1971Tr03: A more complete description of the (1970Tr05) analysis is given in (1971Tr03). The discussion includes details on the calibration reactions, and results from θ=10.68° to 14.82°. The discussion includes more details on the IMME and comparison with other analyses.

1974Be66: Studied the first excited state of ^{9}C using the $^{12}C(^{3}He,^{6}He)$ reaction at E=74 MeV. In this study, the second T_Z=3/2 states of ^{9}C and ^{9}B ($^{11}B(p,t)$) were populated and analyzed using the MSU Enge spectrograph; results are presented for θ=8°. For the new state ΔM=31131 keV *11*, E_x=2219 keV *10* and $\Gamma_{c.m.}$=100 keV *20* are deduced. The IMME is discussed for the second T_z=3/2 levels of A=9 nuclei.

1991Go13, 1991GoZR: Studied $^{12}C(^{3}He,^{6}He)$ at E=76.7 MeV, measured $\sigma(E(^{6}He))$ and observed known levels at ^{9}C(0,2.2 MeV). In addition, they reported a new level at E_x=3.30 MeV *5* and evidence for a broad level at E_x=4.3 MeV.

Subsequent experiments have not observed a level consisent with E_x=3.30 MeV *5*. However, in their figure 1, lines have been drawn to connect data points as a guide to the eye. Scanning the figure to obtain the data points and viewing the spectrum without the *guides for the eyes* supports the observation of an excess of counts in this region; it is possible that a more sophisticated approach to fitting the data would yield consistency with the E_x=3.6 MeV level reported in later measurements.

^{9}C Levels

E(level)	$J^{\pi\#}$	Γ
0	3/2⁻	
2218† *11*	5/2⁻	100† keV *20*
3.30×10³?‡ *5*		
≈4.3×10³?‡		

† From (1974Be66).
‡ From (1991Go13).
\# From comparison with the ^{9}Li mirror (1974Be66).

^{12}C(^{9}C,X) 1996Oz01

Reaction and interaction cross section measurements including Be, C, Al, Si, Sn and Pb targets.

1996Oz01: Measured total interaction σ of E≈790 MeV ^{9}C on Be, C and Al target at LBNL using the transmission method. Deduced point-proton $r^{p}_{r.m.s}$=2.48 fm *3*, effective charge $r^{ch}_{r.m.s}$=2.61 fm *3*, point-neutron $r^{n}_{r.m.s}$=2.28 fm *3* and point-nucleon $r^{m}_{r.m.s}$=2.42 fm *3*.

1997Bl08: Measured $\sigma_{interaction}$, σ_{1p} and σ_{2p} on carbon, ^{27}Al, tin and lead targets using 285 MeV/nucleon ^{9}C ions at GSI.

2000MoZP, 2002HiZZ, 2003Mo23, 2003Mo28, 2003MoZY: A study of the the reaction, via the inverse Coulomb dissociation reaction was carried out ar RIPS/RIKEN using a 65 MeV/nucleon ^{9}C beam on a Pb target. The results are analyzed to estimate the astrophysical S-factor. See other relevant theoretical discussion in (2005Ty02, 2012Fu07).

2003En05: Measured σ_{1p} and σ_{2p} at 78 MeV/nucleon on a carbon target at the MSU/NSCL. Deduced C^2S=0.94 from analysis of σ_{1p}. They also deduced the Asymptotic Normalization Coefficient, C^2_1=1.27 fm^{-1} *10*, and they evaluated the ^{8}B(p,γ) astrophysical reaction rate coefficient S_{18}(0)=49 eV·b *4*.

2004Wa06: Measured σ_{1p} and σ_{2p} on a Si target in the range of E(^{9}C)=28-68 MeV/nucleon at the MSU/NSCL. Compared with shell model calculations using eikonal reaction theory. In the range of E(^{9}C)=28-51 MeV/nucleon, σ_{2p}=198 mb *16* while σ_{1p}=77 mb *11*, suggesting ^{9}C may be a 2-proton halo nucleus.

2006Wa18: Measured the reaction and proton removal σ(E) for ^{28}Si(^{9}C,X) for E=15-53 MeV/nucleon at the MSU/NSCL. Analyzed the cross section data using a simple Glauber model, and assuming harmonic oscillator wavefuction densities they deduced a matter radius $r^{m}_{r.m.s.}$=2.71 fm *32*. They compared with the results of (1996Oz01).

Theory:

2003Ti10: Analyzed p-p correlations and single-particle overlap integrals. Discussed ^{9}C in terms of a potential 2p-halo nucleus.

2017Ah08: Glauber model analysis of ^{12}C(^{9}C,X) at 720 MeV/nucleon to obtain the charge and matter radii.

2017Ka45: Matter and charge radii, deduced from an optical potential model, were used to calculate the reaction cross sections of ^{9}C and other carbon isotopes at E_p=71-800 MeV.

^{9}C Levels

E(level)	C^2S	Comments
0	0.94	$r^{m}_{r.m.s.}$=2.42 fm *3* (1996Oz01), see also $r^{m}_{r.m.s.}$=2.71 fm *32* (2006Wa18). C^2S: for (^{9}C,^{8}B) from (2003En05); they also deduced the Asymptotic Normalization Coefficient, C^2_1=1.27 fm^{-1} *10*.

^{12}C(^{12}C,^{9}C) 1996Ma38

1996Ma38: ^{9}C ions were produced via fragmentation of a ^{12}C beam on a ^{12}C target at the RIKEN/RIPS facility. The ^{9}C beam at θ_{lab}=5°±1° was purified and collected in a 50μm thick Pt foil that was cooled to 30 K and held in a strong magnetic field; typical measured polarizations were P=−3.4%. Using standard β-NMR techniques, the decay β-ray asymmetry was determined and μ=1.3914 μ_N *5* was deduced (using μ(^{8}B) for calibration). A negative sign is assumed.

^{9}C Levels

E(level)	Comments
0	μ=−1.3914 *5*

^{12}C(^{14}N,^{9}C) 1997Ro17

1997Ro17: Production yields for isotope beams at the JINR/ACCULINA beamline are analyzed for fragmentation of a 51 MeV/nucleon nitrogen beam on a ^{12}C target.

^{9}C Levels

E(level)
0

^{93}Nb(^{20}Ne,^{9}C) 1998Hu08

1998Hu08: A beam of ^{9}C ions was produced at the NSCL/A1200 and implanted into a room temperature Pt foil that was tilted 45° w.r.t. a magnetic holding field. The μ was determined using using standard β-NMR techniques by analyzing the asymmetry of β particles measured in a set of plastic scintallators positioned above and below the collection foil. The value μ=1.396 μ_N *3* was deduced.

^{9}C Levels

E(level)	Comments
0	μ=1.396 *3*

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