^{9}Be(α,nγ):res

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

1932Ch02: ^{9}Be(α,n), deduced existence of the neutron.
1953Ta06: ^{9}Be(α,nγ) E≤3.0 MeV; measured γ-radiation yield, two resonances corresponding to ^{13}C*(11.95,12.46 MeV) states were reported.
1954Be08: ^{9}Be(α,n) E<1.5 MeV; measured reaction products, En, In; deduced yields, resonances.
1955Ta28: ^{9}Be(α,n) E=1.2-2.5 MeV; measured dσ/dΩ(90°) for 4.4 MeV γ-rays. In the region of 12 MeV excitation in ^{13}C, the states are not well defined and any attempt to assign such properties as spins and parities must be speculative.
1956Be98: ^{9}Be(α,n) E=4.3-8.7 MeV; measured products; deduced σ, σ(E).
1956Bo61: ^{9}Be(α,n) E=1.8-5.3 MeV; studied excitation curves at θ=0° and 90° for neutrons and γ rays produced in this reaction. Resonances were reported at bombarding energies of 1.9, 2.3, 2.6, 3.98, 4.4, and 5.0 MeV.
1956Ja28: ^{9}Be(α,n) E=0.4-1.3 MeV; measured the angular distributions of the neutron groups. Tentative spin and parity to certain levels in ^{13}C were assigned.
1957Ri38: ^{9}Be(α,n) E=1.7-5.0 MeV; measured angular distribution and 0° excitation curves.
1958Ta05: ^{9}Be(α,n) E=1.15,2.8 MeV; stripping plays only a minor role.
1959Gi47: ^{9}Be(α,n) E=2.5-8.2 MeV; measured absolute neutron yields, several resonances were reported.
1963De27: ^{9}Be(α,n$_{0,1}$) E=14-23 MeV; measured angular distributions for θ≈10° to 170°. Discussed reaction mechanism.
1963Se04: ^{9}Be(α,n) E=3.6-7.6 MeV; measured angular distributions, the excitation function of the 4.43-MeV γ-ray from the ^{9}Be(α,n$_1\gamma_{4.43}$)^{12}C reaction has been studied. Many broad resonances are found.
1965Gi02: ^{9}Be(α,n) E=1.7-10.5 MeV; measured the absolute total (4π) neutron yield. Resonance peaks were reported.
1965Gr22: ^{9}Be(α,n) E=5-12 MeV; measured the neutron cross sections for the ground state and first excited state of ^{12}C. Resonances were reported.
1965Li09: ^{9}Be(α,n) E=1.9-4.5 MeV; measured polarization (E,θ). Natural target.
1966Mi12: ^{9}Be(α,n$_0$) E=5.0-12.0 MeV; ^{9}Be(α,n$_1$) E=4.3-12.0; ^{9}Be(α,n$_2$) E=6.0-10.1; measured σ(E,θ=0°). ^{13}C deduced levels.
1968Da05: ^{9}Be(α,n) E=0.34-0.68 MeV; measured σ(E;En,θ).
1968Le24: ^{9}Be(α,n) E=1-6 MeV; measured σ(E;En). ^{13}C deduced resonance parameters.
1968Ve06: ^{9}Be(α,n) E=6-10 MeV; measured absolute differential cross sections.
1969Kl09: ^{9}Be(α,n) E=1.75,1.96 MeV; measured σ(θ), Q, P(θ). ^{13}C deduced resonances, J, π, level-width.
1970St16: ^{9}Be(α,n) E=2.4-2.9 MeV; measured P(n)(E;θ), deduced J of E$_x$=11.95 MeV.
1970Va23: ^{9}Be(α,n) E=1.5-7.8 MeV; measured σ(E;En,θ).
1971Kl04: ^{9}Be(α,n) E=2.6 MeV; measured P$_n$(θ).
1972Ob01: ^{9}Be(α,n) E=1.69-6.44 MeV; measured σ(E;θ).
1973De14: ^{9}Be(α,n$_0$), (α,n$_1$) E=4.5-5.85 MeV; measured P(E;En,θ). ^{13}C deduced levels, J, π.
1973Ok06: ^{9}Be(α,n) E=22.9 MeV; measured σ(En,θ), P(En,θ).
1973We03: ^{9}Be(α,n) E=5.01,5.44,6.37,7.44 MeV; measured σ(E;En,θ).
1975Ka26: ^{9}Be(α,n) E=2.65 MeV; measured polarization.
1977ScZG,1978Hi06: ^{9}Be(α,n$_0$),(α,n$_1$) E=6.4-6.5 MeV; measured σ(E,θ). ^{13}C deduced resonance parameters.
1978Le10: ^{9}Be(α,n) E=100 MeV; measured En, neutron polarization.
1982RaZP: ^{9}Be(α,n) E=0.51-0.65 MeV; measured σ(E). Resonance observed corresponding to the ^{13}C*(11.076 MeV) level.
1990We10: ^{9}Be(α,n) E=2.4-3.3 MeV; measured σ(θ), polarization.
1994Ha32: ^{9}Be(α,n) E=480-740 keV; measured σ(E); deduced resonance σ, width, tokamak materials study relevance. 4π neutron detector.
1994Wr01: ^{9}Be(α,n) E$_{c.m.}$=0.16-1.87 MeV; measured σ(E), thick target yield. deduced (α,n) reaction rate vs temperature, astrophysical S-factor.
1996Ku07: ^{9}Be(α,n) E=0.5-3.5 MeV; measured yield, σ(E); deduced astrophysical S-factor vs E, reaction rate. ^{13}C deduced resonances, Γ. Astrophysical implications.

Theory:
1975Fo19: ^{9}Be(α,n); compiled, calculated thermonuclear reaction rates.
1989He04: Be(α,n) E=1-9.8 MeV; analyzed thick target neutron yields data.
2003Sh22: ^{9}Be(α,n) E=0.1-10 MeV; calculated σ, neutron spectra. Comparison with data.

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2017Lo04: ^{9}Be(α,n) E=1.6-10 MeV; calculated $\sigma(\theta)$ using R-matrix and comprehensive fit to published data. ^{13}C deduced 13.42 MeV resonance new J, π assignment.

2018Lo07: ^{9}Be(α,n); $E_{c.m.}$=1-5 MeV; analyzed experimental energy spectra, and differential $\sigma(\theta,E)$ data by R-matrix approach, ^{13}C deduced levels above the α threshold of 10.648 MeV, J, π, Γ, $\Gamma_{\alpha 0}$, $\Gamma_{\alpha 1}$, Γ_{n}, and compared with literature data. Discussed possible existence of molecular bands associated to cluster structures.

^{13}C Levels

E(level)†	Jπ	Γ	E_α(res) (keV)	Comments
10754		50.9 keV	153	E(level),Γ: From (1994Wr01).
10815 *2*		18.7 keV *4*	240 *2*	E(level),Γ: From (1994Wr01).
11002 *2*	1/2$^+$	56.43 keV *7*	511 *2*	Jπ: From the resonance phase analysis in (1956Ja28: E_x=11010 keV). E_α(res) (keV): From (1994Wr01), see also 511 keV *7* (1996Ku07) and 530 keV (1954Be08,1956Ja28), 520 keV (1968Da05), 540 keV (1968Le24). Γ: From (1994Wr01); see also 56 keV *5* (1996Ku07), 70 keV (1969Kl09), ≈55 keV (1968Da05). $\omega\gamma$(cm)=2.86 eV *100* determined from S(cm)=2.0×10^5 MeV·b *3* (1996Ku07); see also $\omega\gamma$(cm)=3.97 eV (1968Da05).
11076 *2*		4.681 keV *19*	618 *2*	Γ: From (1994Wr01); see also ≈5.3 keV (1994Ha32), <4 keV (1968Da05) and <4.8 keV (1996Ku07). E_α(res) (keV): From average of 618 keV *2* (1994Wr01) and 620 keV *4* (1996Ku07). See also 610 keV (1954Be08,1956Ja28), 600 keV (1968Da05), 618 keV (1982RaZP), 620 keV (1994Ha32). $\omega\gamma$(cm)=1.31 eV *34* determined from S(cm)=1.4×10^5 MeV·b *3* (1996Ku07); see also $\omega\gamma$(cm)=0.88 eV (1968Da05).
11188?			(780)	E_α(res) (keV): From (1968Le24).
11410?			(1100)	E_α(res) (keV): From (1968Le24).
11618?			(1400)	E_α(res) (keV): From (1968Le24).
11726 *2*		122.5 keV *8*	1557 *2*	E_α(res) (keV): From average of 1567 keV *22* (1996Ku07) and 1557 keV *2* (1994Wr01). Γ: From (1994Wr01); see also 122 keV *20* (1996Ku07). $\omega\gamma$(cm)=2.7 keV *9* determined from S(cm)=6.5×10^3 MeV·b *15* (1996Ku07).
≈11825			≈1700	E_α(res) (keV): From (1996Ku07).
11947 *3*	(1/2$^-$,7/2$^-$)	148.7 keV *4*	1876 *4*	Jπ: See (1956Ja28,1970Va23: 7/2$^-$, 1969Kl09 (neutron polarization): 1/2$^-$). Γ: From (1994Wr01); see also 150 keV *13* (1996Ku07), 200 keV (1956Bo61,1965Gi02) and 70 keV (1969Kl09). $\Gamma_n/\Gamma_\alpha \geq 12$ where Γ_n is width for neutron emission to both ^{12}C*(0,4.44 MeV) states and Γ_α is width for α-particle emission=0.09 MeV *1* (1955Ta28). E_α(res) (keV): Weighted average of 1905 keV *10* (1955Ta28), 1879 keV *7* (1996Ku07) and 1874 keV *2* (1994Wr01). See also 1900 keV (1953Ta06,1954Be08,1956Bo61,1956Ja28), 1920 keV (1965Gi02), 1910 keV (1970Va23). $\omega\gamma$(cm)=50.3 keV *80* determined from S(cm)=3.3×10^4 MeV·b *4* (1996Ku07).
12141 *2*	5/2$^-$	370.2 keV *17*	2156 *2*	Jπ: From (1969Kl09) (neutron polarization). Subsequent results show J^π=1/2$^+$. Γ: From (1994Wr01); see also 243 keV *40* (1996Ku07) and 280 keV (1969Kl09: E_x=12070 keV). E_α(res) (keV): From (1994Wr01); see also 2157 keV *29* (1996Ku07). $\omega\gamma$(cm)=36.8 keV *97* determined from S(cm)=6.9×10^3 MeV·b *10* (1996Ku07).

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^{13}C Levels (continued)

E(level)†	J$^{\pi}$	Γ	E$_{\alpha}$(res) (keV)	Comments
12180	7/2^{+}	120 keV		E(level),J$^{\pi}$,Γ: From (1969Kl09) (neutron polarization). J$^{\pi}$: Subsequent results show J^{π}=3/2^{-}.
12229		≈300 keV	2283	Γ: Average of 400 keV (1965Gi02) and ≈200 keV (1956Bo61). E$_{\alpha}$(res) (keV): Average of 2300 keV (1956Bo61,1968Le24) and 2250 keV (1965Gi02).
12420 *2*	(7/2^{-},1/2^{-})	226 keV *3*	2559 *2*	J$^{\pi}$: See (1956Ja28: (1/2^{-}),1969Kl09 (neutron polarization): 7/2^{-} for E$_{x}$=12440 keV). Γ: From (1994Wr01); see also 336 keV *50* (1996Ku07), ≈200 keV (1956Bo61), 300 keV (1959Gi47, 1965Gi02), 90 keV (1965Gr22: n$_{0}$), 400 keV (1969Kl09). E$_{\alpha}$(res) (keV): From (1994Wr01); see also 2526 keV *29* (1996Ku07), 2650 keV (1953Ta06), 2600 keV (1955Ta28,1956Bo61,1956Ja28) and 2580 keV (1959Gi47, 1965Gi02, 1965Gr22). $\omega\gamma$(cm)=58.5 keV *15* determined from S(cm)=3.5×10^{3} MeV·b *6* (1996Ku07).
≈13002			≈3400	E$_{\alpha}$(res) (keV): From (1996Ku07); see also 3200 keV (1968Le24: E$_{x}$=12864 keV).
13418	9/2^{-}	45 keV *7*	4000	J$^{\pi}$: From R-matrix analysis in (2017Lo04). Γ: (1972Ob01). See also 60 keV (1956Bo61,1965Gr22: n$_{1}$), 80 keV (1959Gi47,1965Gi02). E(level),E$_{\alpha}$(res) (keV): From (1959Gi47, 1965Gi02, 1965Gr22, 1968Le24). E$_{\alpha}$(res) (keV): See also 3980 keV (1956Bo61, 1957Ri38, 1963Se04: n$_{1}\gamma_{4.43}$, 1972Ob01).
13542	(3/2^{+},5/2^{+})	570 keV	4180	E(level),E$_{\alpha}$(res) (keV): From (1965Gr22: n$_{0}$, 1957Ri38, 1973De14). J$^{\pi}$: From (1957Ri38); see also (1973De14: 3/2^{+} (neutron polarization)). Γ: From (1965Gr22: n$_{0}$).
13764	5/2^{+}	≈500 keV	4500	J$^{\pi}$: From (1973De14) (neutron polarization). E(level),E$_{\alpha}$(res) (keV): From (1959Gi47, 1965Gi02, 1973De14); see also E$_{\alpha}$(res)=4400 keV (1956Bo61), 4450 keV (1963Se04), 4480 keV (1965Gr22: n$_{1}$). Γ: From (1959Gi47,1965Gi02); see also ≈400 keV (1956Bo61), 90 keV (1965Gr22).
14110		≈300 keV	5000	E(level),E$_{\alpha}$(res) (keV): From (1956Bo61, 1959Gi47, 1963Se04, 1965Gi02); see also E$_{\alpha}$(res)=4800 keV (1968Le24), 5020 keV (1965Gr22: n$_{1}$). Γ: From (1956Bo61,1959Gi47,1965Gi02); see also 90 keV (1965Gr22).
14387 *69*	(1/2^{-},5/2^{-})	260 keV	5.4×10^{3} *1*	J$^{\pi}$: From (1973De14) (neutron polarization). Γ: Average of 280 keV (1965Gr22: n$_{0}$) and 240 keV (1966Mi12). E$_{\alpha}$(res) (keV): From (1966Mi12); see also 5300 keV (1963Se04,1973De14), 5400 keV (1965Gr22).
14595		210 keV	5700	Γ: From (1965Gr22: n$_{1}$). E$_{\alpha}$(res) (keV): Average of 5750 keV (1959Gi47, 1965Gi02, 1965Gr22: n$_{1}$), 5700 keV (1963Se04), 5600 keV (1968Le24).
14941 *35*	3/2^{+}	375 keV	6200 *50*	J$^{\pi}$: From (1973De14) (neutron polarization). Γ: Average of 350 keV (1965Gr22: n$_{0}$) and 400 keV (1966Mi12). E$_{\alpha}$(res) (keV): From (1966Mi12); see also 6250 keV (1965Gr22,1973De14).
15109.4 *14*	3/2^{-}	5.49 keV *25*	6443.5 *20*	T=3/2 (1978Hi06)

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^{9}Be(α,nγ):res (continued)

^{13}C Levels (continued)

E(level)†	Γ	E_α(res) (keV)	Comments
			J^π,E_α(res) (keV): From (1978Hi06).
			Γ: From (1978Hi06); also used (1973Ad02: ^{11}B(^{3}He,np)) Γ_n/Γ values to obtain Γ_{n0}=0.38 keV *10*, Γ_{n1}=1.43 keV *18*, Γ_{n2}=0.14 keV *10*. Other analysis in the text using $\Gamma_{\gamma 0}/\Gamma$ can be used to obtain $\Gamma_{\gamma 0}\approx$22.8 keV.
			Other discussion in (1978Hi06) finds reduced transition strength, δ(M1)(W.u.)=−0.15 *7* and δ(E2)(W.u.)=1.0 *6* where $\delta\equiv$B(^{13}C)/B(^{13}N)−1.
15280		6690	E_α(res) (keV): From (1968Le24); see also (6700) keV; (broad) state (1965Gi02).
15564 *35*	215 keV	7100 *50*	Γ: Average of 220 keV (1965Gr22: $n_{0,1}$) and 210 keV (1966Mi12).
			E_α(res) (keV): From (1966Mi12); see also 7100 keV (1963Se04,1965Gr22: n_0), 7000 keV (1965Gr22: n_1).
16023	210 keV	7763	Γ: From (1965Gr22: n_1).
			E_α(res) (keV): Average of 7800 keV (1959Gi47, 1965Gi02, 1968Le24), 7700 keV (1963Se04) and 7750 keV (1965Gr22).
16152 *35*	225 keV	7950 *50*	Γ: Average of 210 keV (1965Gr22: n_0) and 240 keV (1966Mi12).
			E_α(res) (keV): From (1966Mi12); see also 7940 keV (1965Gr22).
16948 *35*	330 keV	9100 *50*	Γ: Average of 280 keV (1965Gr22: n_0) and 380 keV (1966Mi12).
			E_α(res) (keV): From (1966Mi12); see also 9100 keV (1965Gi02), 9050 keV (1965Gr22).
17363 *69*	190 keV	9.7×10^3 *1*	Γ: Average of 240 keV (1965Gr22: $n_{0,1}$) and 140 keV (1966Mi12).
			E_α(res) (keV): From (1966Mi12); see also (9600) keV (1965Gr22: n_0), 9700 keV (1965Gr22: n_1), 9800 keV (1968Le24).
17709 *35*	225 keV	10200 *50*	Γ: Average of 170 keV (1965Gr22: n_0) and 280 keV (1966Mi12).
			E_α(res) (keV): From (1966Mi12); see also 10110 keV (1965Gr22).
17986?	40 keV	10600	Γ,E_α(res) (keV): From (1965Gr22: n_0).
18332 *35*	305 keV	11100 *50*	Γ: Average of 210 keV (1965Gr22: n_0) and 400 keV (1966Mi12).
			E_α(res) (keV): From (1966Mi12); see also 10950 keV (1965Gr22).
18750 *21*	70 keV	11700 *30*	Γ: Average of 60 keV (1965Gr22: $n_{0,1}$) and 80 keV (1966Mi12).
			E_α(res) (keV): From (1966Mi12); see also 11600 keV (1965Gr22).

† Level energies are deduced using E_α(res) and ^{9}Be, ^{4}He and ^{13}C masses from (2021Wa16: AME-2020) where E_α(res) is listed. $E_x=S(\alpha)+E_{c.m.}$(relativistic).