Adopted Levels, Gammas

$Q(\beta^-)=1.574\times10^4$ *24*; $S(n)=2.98\times10^3$ *25*; $S(p)=2.956\times10^4$ *57*; $Q(\alpha)=-2.237\times10^4$ *28*   2017Wa10

The mass excess adopted by (2017Wa10) is 37.50 MeV *23*. See also 1987Gi05, 1988Wo09, 1991Or01, 2012Ga45.

Enhancement of neutron density profile:

The ^{20}C nucleus has been suggested to be a relatively well-bound non-halo nucleus based on measurements of various interaction cross sections and momentum distributions of breakup products. See discussions in:

2016To10: $E(^{20}C)$=280 MeV/nucleon, Carbon target, $\sigma_{interaction}$=1.111 b *8*(stat) *9*(syst); R^{matter}_{rms}=2.97 fm *+3−5*.

2012Ko38 $E(^{20}C)$=241 MeV/nucleon, Carbon target, $\sigma(C)_{1n}$=58 mb *5* and FWHM(parallel momentum dist)= 77 MeV/c, $\sigma(C)_{2n}$=155 mb *25* and FWHM(parallel momentum dist) =211 MeV/c.

2010Ta04, 2011Ya13: $E(^{20}C)$ =40 MeV/nucleon, Liquid H_2 target, $\sigma_{reaction}$=0.791 b *34*, $\sigma(H_2)_{1n}$=22 mb *8*, $\sigma(H_2)_{2n}$=107 mb *15*, and $\sigma_{charge\ changing}$=525 mb *25*.

2001Oz03: $E(^{20}C)$=905 MeV/nucleon, Be target, $\sigma_{interaction}$=1.187 b *20*, R^{matter}_{rms}=2.98 fm *5*.

For theoretical reviews mainly on the nuclear radii of ^{20}C and other carbon nuclides see: 1997Am05, 1997Do14, 2000De24, 2000Ma28, 2008Ya04, 2009Ch45, 2010Ma38, 2011Fo18, 2011Ib02, 2013Ac02, 2013Lu02, 2014Sa13, 2015Ma68 2017Sh18.

For broader theoretical reviews on nuclear radii including ^{20}C see:

1971St40, 1996Sh13, 1997Ki22, 1999Kn04, 2002Sa29, 2003Bh06, 2004Ne16, 2005Ga31, 2006Sa29, 2008Ca29, 2008Sc02, 2008Sc19, 2010Ca15, 2011Al11, 2013Ha33, 2013Sh05, 2014Fr11, 2015Ha11, 2015Ka02.

Theoretical reviews mainly of ^{20}C: 2004Ar12, 2006Ma48, 2010Ma24, 2012PeZY, 2014Ha15, 2015Ha11.

General theoretical reviews of carbon isotopes: 1993Sa16, 1996Ka14, 1996Re19, 1997Ka25, 1998Sh16, 1999Ha61, 2000Be58, 2003Sa50, 2003Th06, 2004Sa58, 2004Th11, 2005Ka03, 2005Sa63, 2006Le33, 2008Zh16, 2009Um05, 2010Co05, 2011Ya11, 2012Ch48, 2012Id04, 2012Yu04, 2013Ac02, 2013Fo11, 2013Ka33, 2014Ja14, 2014Ma97, 2015Ka02, 2015Zh19, 2016Fo24, 2016La17, 2017Me03.

General theoretical reviews including many nuclides: 1971Fi11, 1978Na07, 1987Bl18, 1987Sa15, 1993Po11, 1995Ho13, 1996Gr21, 1996Su24, 1997Ba54, 1997Ho04, 2001Ka66, 2002Ka73, 2002Me12, 2002Sa12, 2003Jh01, 2004La24, 2004Ne16, 2005Ka02, 2002Ka54, 2006Ko02, 2009Pa46, 2009Yu07, 2011Co18, 2011Eb02, 2011Re05, 2012Yu07, 2014Eb02, 2015Sh21, 2016Pr01.

^{20}C Levels

Cross Reference (XREF) Flags

A	$^1H(^{20}C,^{20}C'\gamma)$	F	$^{181}Ta(^{40}Ar,^{20}C)$
B	$^9Be(^{22}O,^{20}C\gamma)$	G	$^{181}Ta(^{48}Ca,^{20}C)$
C	$^9Be(^{40}Ar,^{20}C)$	H	$Th(p,^{20}C)$
D	$^9Be(^{48}Ca,^{20}C)$	I	$U(p,^{20}C)$
E	$C(^{36}S,X\gamma)$		

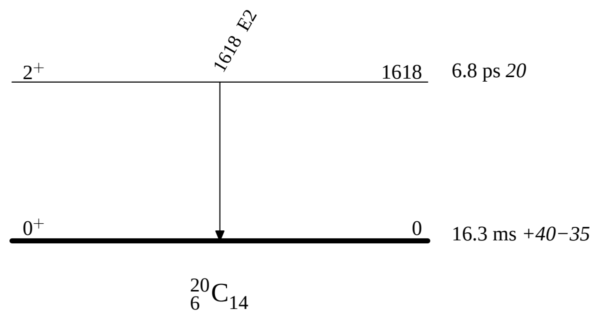
E(level)	J^π	$T_{1/2}$	XREF	Comments
0	0^+	16.3 ms *+40−35*	ABCDEFGH	$\%\beta^-$=100; $\%\beta^-n$=65 *18*; $\%\beta^-2n$<18.6 (2003Yo02) $T_{1/2}$: from weighted average of: 16 ms *+14−4* (1989Le16), 14 ms *+6−5* (1990Mu06),16.7 ms *35* (1995ReZZ, 2008ReZZ), 22 ms *+15−7* (2003Yo02), see also 16.2 ms *35* in the review of (2015Bi05).
1618 *11*	2^+	6.8 ps *20*	AB E	E(level): from the E_γ measurements of 2011Pe21 using Doppler corrected germanium spectra. $T_{1/2}$: from 2011Pe21. The mean lifetime τ=9.8 ps *28*(stat) *+5−11*(syst) is deduced corresponding to $T_{1/2}$=6.8 ps *19*(stat) *+5−11*(syst).

$\gamma(^{20}C)$

E_i(level)	J^π_i	E_γ	E_f	J^π_f	Mult.	Comments
1618	2^+	1618 *11*	0	0^+	E2	B(E2)↓=0.00075 *+32−20* B(E2)↓: from B(E2)=7.5 *+30−17*(stat) *+10−4*(syst) e^2fm^4 (2011Pe21). See also (2016Pr01, 2017Pr04).

Adopted Levels, Gammas

Level Scheme



$^{1}H(^{20}C,^{20}C'\gamma)$ 2009El03

Beam=^{20}C, Target=Liquid H_2, ^{208}Pb.
2009El03:
XUNDL set compiled by S. Geraedts and B. Singh (McMaster) 2009.
A beam of E=41.4 MeV/nucleon ^{20}C was produced at the RIKEN/RIPS facility by fragmenting 63 MeV/nucleon ^{40}Ar ions on a ^{181} Ta target. The ^{20}C impinged on liquid H_2 and ^{208}Pb targets. The scattered particles were identified using a plastic ΔE-E telescope and ΔE vs. time-of-flight over an 80 cm flight path.
In addition, the authors measured Eγ, Iγ using the 160 NaI(Tl) crystal DALI2 array; the spectra measured on ^{1}H and ^{208}Pb were Doppler shift corrected and compared with shell model calculations using a p-shell proton and sd-shell neutron model space.
Also deduced σ(Pb)=35 mb *8* and $\sigma(^{1}H)$=24 mb *4* at E(^{20}C)= 41.4 MeV/nucleon.

^{20}C Levels

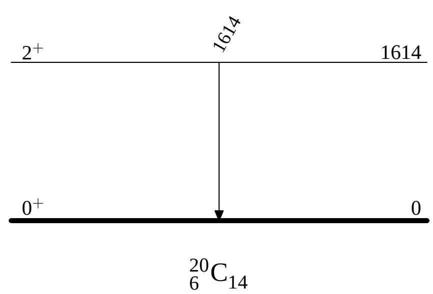
E(level)	J^{π}	Comments
0	0^+	
1614 *11*	2^+	B(E2)↑<0.00184 (2009El03) Neutron transition probability M_n^2=0.0292 b *52* (2009El03).

$\gamma(^{20}C)$

E_γ	E_i(level)	J_i^{π}	E_f	J_f^{π}	Comments
1614 *11*	1614	2^+	0	0^+	E_γ: from scattering on hydrogen target. Eγ=1631 keV *37* from ^{208}Pb target.

$^{1}H(^{20}C,^{20}C'\gamma)$ 2009El03

Level Scheme



^{9}Be(^{22}O,^{20}Cγ) 2011Pe21

Beam=^{20}C, Target=^{9}Be.
2011Pe21:
XUNDL set compiled by J.H. Kelley and C.G. Sheu 2011.
The authors measured the lifetime of the ^{20}C $J^{\pi}=2^{+}$ first excited state with the aim of analyzing the systematics of the B(E2) values of the first excited states of neutron rich carbon isotopes.
Neutron rich ^{20}C ions were produced at the NSCL in a multistep process, by first fragmenting a 140 MeV/nucleon ^{48}Ca beam in a 775 mg/cm^2 ^{9}Be target to produce a $\Delta p/p=2.5\%$ momentum analyzed 101 MeV/nucleon ^{22}C beam. The ^{22}C beam then impinged on a 500 mg/cm^2 ^{9}Be target where ^{20}C ions were produced via 2-proton knockout reactions. Analysis suggests roughly 30% of ^{20}C were produced in their $J^{\pi}=2^{+}$ first excited state.
The lifetime was determined using the recoil distance method (see for example (2008De30)). A 3.8 g/cm^2 W degrader foil was placed 0.1 mm downstream of the 500 mg/cm^2 ^{9}Be reaction foil; γ-rays emitted before/after the degrader foil experience different Doppler shifts and the state lifetime can be deduced from the ratio ($v/c_i=0.418$ and $v/c_f\approx0.350$). Reactions in the W degrader foil introduce a systematic error.
Finally, discussion based on shell model calculations is given suggesting a significantly increasing B(E2) value as a function of increasing A in the carbon isotopes.

^{20}C Levels

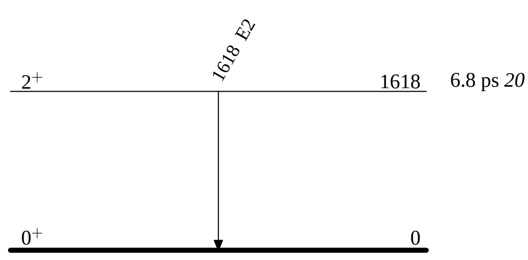
E(level)	J^{π}	$T_{1/2}$	Comments
0	0^+		
1618 *11*	2^+	6.8 ps *20*	$T_{1/2}$: from 2011Pe21. The mean lifetime τ=9.8 ps *28*(stat) *+5−11*(syst) is deduced corresponding to $T_{1/2}$=6.8 ps *19*(stat) *+5−11*(syst).

γ(^{20}C)

E_γ	E_i(level)	J^{π}_i	E_f	J^{π}_f	Mult.	Comments
1618 *11*	1618	2^+	0	0^+	E2	B(E2)=7.5 *+30−17*(stat) *+10−4*(syst) e^2fm^4.

^{9}Be(^{22}O,^{20}Cγ) 2011Pe21

Level Scheme



$^{20}_{6}C_{14}$

^{9}Be(^{40}Ar,^{20}C) 2000Oz01,2003Oz01

2000Oz01: Production yields for fragmentation of 1 GeV/nucleon ^{40}Ar projectiles on a Be target were measured SIS/FRS facility for a variety of nuclides. $\sigma(^{20}C)\approx 2.04\times 10^{-8}$ b was deduced.

2003Oz01: Production yields for fragmentation of 94 MeV/nucleon ^{40}Ar projectiles were measured at RIPS. For a beryllium target, $\sigma\approx 2.7\times 10^{-9}$ b was deduced. Also, $\sigma\approx 3.4\times 10^{-8}$ b was deduced for a tantalum target.

^{20}C Levels

E(level)
0

^{9}Be(^{48}Ca,^{20}C) 1981St23

1981St23: Production yields for fragmentation of 213 GeV/nucleon ^{48}Ca projectiles on a berylium target were measured at the Bevalac using a 0° magnetic spectrometer. The neutron-rich fragments were focused on a stack of Lexan plastic track detectors; analysis of the tracks provided the range, charge and magnetic deflection of the produced isotopes. A charge resolution of 0.2 was obtained along with a mass resolution of approximately ≤0.2 u.

The analysis showed clear indications of ^{18}C, ^{19}C, ^{20}C. Ambiguous results on ^{21}C are found. This work is credited with the discovery of ^{20}C and ^{27}F. For ^{20}C, the cross section of roughly 0.1 μb was deduced.

^{20}C Levels

E(level)
0

C(^{36}S,Xγ) 2008St18,2004St10

2004St10,2004St29,2008St18:
XUNDL sets compiled by S. Geraedts and B. Singh (McMaster) 2007-2008.
The authors populated ^{20}C using a cocktail beam of neutron-rich nuclides [^{25}Ne, ^{26}Ne, ^{27}Na, ^{28}Na, ^{29}Mg, and ^{30}Mg] that were produced by fragmenting an initial 77.5 MeV/nucleon ^{36}S beam at the GANIL/SISSI beamline. The cocktail beam was selected using the α spectrometer and focused on a carbon target that was coupled to a plastic scintillator.
Eγ, $\gamma\gamma$, γ(fragment) coincidences were measured using 74 BaF_2 detectors that surrounded the target with 4π and the SPEG spectrometer. The ^{20}C were identified using time-of-flight, energy loss and focal-plane position information. A single γ-ray transition was observed. Results are compared with shell-model calculations for analysis of J$^{\pi}$ values.
All data are from (2008St18).

^{20}C Levels

E(level)	J$^{\pi}$†	Comments
0	0$^+$	
1588 *20*	2$^+$	J$^{\pi}$: Systematics of e-e nuclei and shell-model predictions.

† From literature, and consistent with shell-model predictions shown in figure 4 of (2008St18).

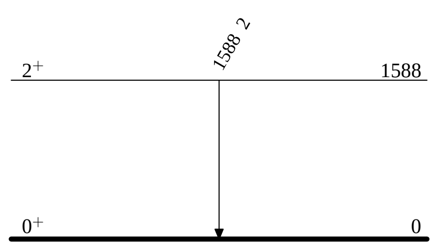
γ(^{20}C)

E$_{\gamma}$	I$_{\gamma}$	E$_i$(level)	J$^{\pi}_i$	E$_f$	J$^{\pi}_f$
1588 *20*	2	1588	2$^+$	0	0$^+$

C(^{36}S,Xγ) 2008St18,2004St10

Level Scheme

Intensities: Relative I$_{\gamma}$



$^{20}_{6}C_{14}$

^{181}Ta(^{40}Ar,^{20}C) 1987Gi05

1987Gi05: The authors measured the masses of several nuclides, produced in the fragmentation of 60 MeV/nucleon ^{40}Ar ions on a 350 mg/cm^2 ^{nat}Ta target at GANIL, by measuring their time-of-flight over a roughly 80 meter flight path. The nuclides were detected and identified in the SPEG spectrometer focal plane. A mass resolution near 5×10^{-4} was achieved.

The mass excess ΔM=37.2 MeV *11* was deduced.

^{20}C Levels

E(level)
0

^{181}Ta(^{48}Ca,^{20}C) 1991Or01,2012Ga45

1991Or01: The authors measured the masses of several nuclides, produced in the fragmentation of 55 MeV/nucleon ^{48}Ca ions on a 330 mg/cm^2 ^{nat}Ta target at GANIL, by measuring their time-of-flight over a roughly 80 meter flight path. The nuclides were detected and identified in the SPEG spectrometer focal plane. A mass resolution near 3×10^{-4} was achieved.

The mass excess ΔM=37.4 MeV *46* was deduced.

2012Ga45:

XUNDL set compiled by J.H. Kelley and C.G. Sheu 2012.

The authors fragmented a ^{48}Ca beam to produce a "cocktail" beam comprised of a variety of neutron rich nuclei. Then, by measuring the magnetic rigidity and time-of-flight (TOF) through a well defined path, the mass of the various "coctail" beam components was determined.

A beam of E=60 MeV/nucleon ^{48}Ca was fragmented on a ^{nat}Ta target that was located between the SISSI solenoid spectrometers at GANIL. The ejectiles were transported 82 m to the focal plane of the SPEG spectrometer where they were identified by ΔE-E and their magnetic rigidity was determined. Furthermore their TOF was measured for the path between the SPEG spectrometer and a micro-channel plate detector located after a set of dipole magnets that followed the production target. Two sets of field settings (Bρ=2.4 Tm and 2.88 Tm) were used to reduce systematic uncertainties.

Masses were determined for a set of calibration nuclei and nuclei of interest. The mass excess ΔM=37.36 MeV *27* was deduced from momentum and Time-of-Flight.

^{20}C Levels

E(level)	J^π
0	0^+

Th(p,^{20}C) 1988Wo09

1988Wo09: Mass measurements of several neutron-rich light nuclei were carried out using an improved fitting technique for deducing nuclear mass values from measurements of time-of-flight (ToF) through the LANL/TOFI spectrometer; the ToF through the spectrometer depends on the mass-to-charge ratio and is independent of ion velocity.

The rare isotope species were produced by proton spallation reactions on a Th target. Typical flight times of 500 ns, with timing uncertainties near 180 ps yielded typical mass-to-charge resolutions of 3.6×10^{-4} from analysis of multiple runs that involved multiple charge states.

A mass excess of 37.6 MeV *22* was deduced.

^{20}C Levels

E(level)
0

U(p,^{20}C) 1974Bo05

1974Bo05: Spallation yield cross sections, on a uranium target, were measured at the Bevatron using 4.8 GeV protons. Reaction products were identified using ΔE, E and time-of-flight determinations. The cross section limit for ^{20}C production was set at approximately ≤ 1 μb.

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