

Adopted Levels, Gammas

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh	ENSDF	30-Sep-2020

Q(β^-)=9926.4 23; S(n)=5958.1 71; S(p)=14522 *syst*; Q(α)=-13868 *syst* [2017We16,2017Wa10](#)

Estimated uncertainties: 400 for S(p) and Q(α).

Q(β^-n)=5362.9 19, S(2n)=10534.1 26, S(2p)=33791 500 (*syst*).

The Q values and separation energies have been deduced by the evaluator from measured mass excesses for ⁷⁷Cu and ⁷⁷Cu by [2017We16](#) and others from [2017Wa10](#).

[1987Ar21, 1989BeYL, 1991Kr15](#): ⁷⁷Cu nucleus identified in thermal neutron fission of ²³⁵U.

[1997Be12](#): ⁷⁷Cu is also produced in (²³⁸U,X) on Pb and Be targets followed by fragment separation.

[2009Pa35](#): ⁷⁷Cu produced in the fission of uranium (target=uranium carbide) by spallation neutrons which were produced by 1 GeV protons hitting a tantalum target. The ⁷⁷Cu nuclei were selected by Resonant Ionization Laser Ion Source (RILIS) and General Purpose mass separator (GPS) at the CERN-ISOLDE facility. The separated ⁷⁷Cu nuclei at a typical energy of 60 keV were implanted on a tape surrounded by three E- Δ E plastic detectors for β -particle detection and two HPGe detectors. Measured γ , $\beta\gamma$ coin, $\beta\beta$ coin, $\gamma\gamma$ coin and delayed-neutron events. The neutrons were detected with the Mainz neutron long counter. The main contamination was from Ga activity. In the presence of the impurities, singles β spectrum could not be obtained.

[2009II01, 2009Wi03](#) (also [2009Gr06](#)): ⁷⁷Cu isotope produced in the reaction ²³⁸U(p,F) with a 50 MeV beam provided by the HRIBF facility at ORNL, RIB facility. The radioactive beams were extracted and mass separated. Detected decay products with a Micro-channel plate detector, an ionization chamber and a moving tape collector. Measured γ , β , $\gamma\gamma$ and $\beta\gamma$ coin with two plastic β -detectors and γ -rays with four clover Germanium detectors. According to [2009Gr06](#) there is no evidence of an isomer in ⁷⁷Cu which may decay to positive-parity states in ⁷⁷Zn.

[2017De30](#): ⁷⁷Cu produced in 1.4-GeV proton bombardment of UC_x target using HRS mass separator, ISCOOL gas-filled segmented linear Paul trap, and RILIS at ISOLDE-CERN facility. Measured hyperfine spectra, hyperfine structure parameters, magnetic dipole moment and electric quadrupole moment by Collinear Resonance Ionization Spectroscopy (CRIS).

[2017We16](#): measured mass excess by tof ion-cyclotron resonance. Measured mass excess(⁷⁷Cu)=-48862.8 keV 12 ([2017We16](#)) as compared to -48620 keV 150 ([2017Wa10](#), from systematic trend).

Additional information 1.

Nuclear structure theory calculations: [2012Sr02](#): 5/2⁻ predicted for g.s. in shell model calculations with LSSM-III interaction.

Theoretical calculations: consult the NSR database at www.nndc.bnl.gov for 12 primary theory references dealing with nuclear structure calculations, and radioactive decays.

⁷⁷Cu Levels

Cross Reference (XREF) Flags

- A ⁷⁷Ni β^- decay (158.9 ms)
- B ⁹Be(⁷⁸Zn,p γ)

E(level) [†]	J π^{\ddagger}	T _{1/2}	XREF	Comments
0	5/2 ⁻	469.8 ms 20	AB	$\% \beta^- = 100$; $\% \beta^- n = 30.1$ 20 (2018Ra27,2010Ho12,2009II01) $\mu = +1.5963$ 17 (2017De30,2019StZV) $Q = -0.26$ 3 (2017De30) Measured change in the mean-squared charge radius: $\delta \langle r^2 \rangle (\text{65Cu, 77Cu}) = +0.59$ fm ² 2(stat) 11(syst) (2020De21 , collinear resonance ionization spectroscopy at ISOLDE-CERN). Measured isotope shift (IS) for ⁷⁷ Cu = -5234 MHz 5 (2020De21 , collinear resonance ionization spectroscopy at ISOLDE-CERN). $\% \beta^- n$: weighted average of 29.2 30 (2018Ra27 , ion- $\beta^- n$); 31.0 38 (2010Ho12 , ion- $\beta^- n$); 30.3 20 (2009II01 , ion- $\beta^- n$, $\gamma\gamma$, their earlier values: 30.0 27 in 2009Wi03 and 36 3 in 2008Wi01). 2012Ko29 (from the same group as 2009II01) also analyzed $\beta^- n = 30$ 2 for ⁷⁷ Cu decay. 2009Pa35 give apparent percent feedings of 21.6% to the first 2 ⁺ level and 4.7% to the first 4 ⁺ level in ⁷⁶ Zn. Measured $\% \beta$

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Adopted Levels, Gammas (continued)

⁷⁷Cu Levels (continued)

<u>E(level)[†]</u>	<u>J^π[‡]</u>	<u>XREF</u>	<u>Comments</u>
			feeding to ⁷⁷ Zn=70 7 (2009Wi03) agrees well with 100-(measured %β ⁻ n)=69.9 20. The analysis in 2018Ra27 is consistent with %β ⁻ 2n=0.000 2, as expected for forbidden β ⁻ 2n decay mode of ⁷⁷ Cu. See also 2020Li32 evaluation Others: %βn≥26 (2009Pa35, β-n); >10 (2000KoZH, β,n); 15 +10-5 (2002Pf04, compilation).
			J ^π : spin from hyperfine structure in 2017De30, and from 2011Ko36, in-source laser spectroscopy at the CERN-ISOLDE facility. Parity from comparison of measured magnetic dipole moment with shell-model calculations, using A3DA-m and PFSDG-U interactions (2011Ko36). Proposed (2011Ko36) configuration=πf _{5/2} with 15% admixture of πp _{1/2} ⊗2 ⁺ (vibrational excitation).
			T _{1/2} : weighted average of 476.8 ms 34 (2014XuZZ, β-γ); 466 ms +21-20 (2010Ho12, ion,β,n; earlier value of 450 ms +13-21 in 2005Ho08); 467.4 ms 21 (2009Pa35, β-n); 480 ms 9 (2009II01, γ decay curves for 114γ, 505γ and 1277γ); 466 ms 5 (2000KoZH, β,n); 469 ms 8 (1991Kr15, n). Other: 471 ms 25 (2018Ra27, n). See also 2020Li32 evaluation.
			μ: from hyperfine structure studies using collinear laser spectroscopy at ISOLDE-CERN (2017De30); measured μ=+1.5945 17 (2017De30) is re-evaluated to +1.5863 17 by 2019StzV. Other: μ=+1.61 5 (2011Ko36, in-source laser method, data analyzed in comparison with magnetic moment=+2.2273456 14 for ⁶³ Cu g.s. with J ^π =3/2 ⁻ used as a reference).
			Average measured neutron energy from ⁷⁷ Cu decay=450 150 (2009Pa35).
293 1	(3/2 ⁻)	AB	XREF: B(271)
946 1	(9/2 ⁻)	AB	XREF: B(902)
1154 1	(7/2 ⁻)	A	
1776 1	(13/2 ⁻)	A	
1955 1	(11/2 ⁻)	A	
2068 1	(7/2 ⁻)	AB	XREF: B(2068)
2605 2	(11/2,13/2 ⁻)	A	
2695? 2	(7/2 ⁻)	A	
2869 2	(11/2,13/2 ⁻)	A	
2909 2	(9/2,11/2 ⁻)	A	
3412 2	(9/2,11/2 ⁻)	A	
3954 2	(7/2,9/2,11/2 ⁻)	A	

[†] Deduced from least-squares fit to E_γ data.

[‡] As assigned by 2017Sa32 in their level-scheme Fig. 3, based partly on shell-model calculations. The ground-state spin of 5/2 is measured by 2011Ko36.

γ(⁷⁷Cu)

<u>E_i(level)</u>	<u>J_i^π</u>	<u>E_γ</u>	<u>I_γ</u>	<u>E_f</u>	<u>J_f^π</u>	<u>Comments</u>
293	(3/2 ⁻)	293 1	100	0	5/2 ⁻	
946	(9/2 ⁻)	946 1	100	0	5/2 ⁻	
1154	(7/2 ⁻)	860 1	78 9	293	(3/2 ⁻)	
		1154 1	100 9	0	5/2 ⁻	
1776	(13/2 ⁻)	830 1	100	946	(9/2 ⁻)	
1955	(11/2 ⁻)	179 1	51 11	1776	(13/2 ⁻)	
		801 1	63 12	1154	(7/2 ⁻)	
		1009 1	100 14	946	(9/2 ⁻)	
2068	(7/2 ⁻)	2068 1	100	0	5/2 ⁻	E _γ =2068 64 in (⁷⁸ Zn,pγ), observed as the strongest γ ray.
2605	(11/2,13/2 ⁻)	829 1	100	1776	(13/2 ⁻)	
2695?	(7/2 ⁻)	2402 [†] 1	100	293	(3/2 ⁻)	
2869	(11/2,13/2 ⁻)	1093 1	100	1776	(13/2 ⁻)	
2909	(9/2,11/2 ⁻)	1133 1	100	1776	(13/2 ⁻)	

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Adopted Levels, Gammas (continued)

 $\gamma(^{77}\text{Cu})$ (continued)

<u>$E_i(\text{level})$</u>	<u>J_i^π</u>	<u>E_γ</u>	<u>I_γ</u>	<u>E_f</u>	<u>J_f^π</u>
3412	(9/2,11/2 ⁻)	543 <i>I</i>	70 20	2869	(11/2,13/2 ⁻)
		1636 <i>I</i>	100 20	1776	(13/2 ⁻)
3954	(7/2,9/2,11/2 ⁻)	3008 <i>I</i>	100	946	(9/2 ⁻)

† Placement of transition in the level scheme is uncertain.

Adopted Levels, Gammas

Legend

Level Scheme

Intensities: Relative photon branching from each level

-----▶ γ Decay (Uncertain)