Adopted Levels, Gammas

History			
Type	Author	Citation	Literature Cutoff Date
Full Evaluation	Balraj Singh	ENSDF	30-Nov-2021

Q(β^-)=−12720 *SY*; S(n)=12100 *SY*; S(p)=3988 *25*; Q(α)=−3285 *29* 2021Wa16

Estimated (2021Wa16) uncertainties: 360 for Q(β^-), 300 for S(n).

Q(ε)=9025 *25*, Q(εp)=7028 *25*, S(2n)=28780 *400* (syst), S(2p)=6063 *24* (2021Wa16).

^{89}Ru identified by 1992Ye04 in ^{58}Ni(^{92}Mo,X) E=70 MeV/nucleon followed by fragment mass separation and tof (≈150 ns) techniques.

2001Ki13 (also 2002Fa13,2007WeZX): ^{89}Ru produced in fragmentation of ^{112}Sn beam in ^{9}Be(^{112}Sn,X) reaction at E=1 GeV/nucleon, followed by mass separation. Measured half-life and yield. Other reports from the same group: 2000WeZZ, and E. Wefers et al., GSI annual (2000) report 2001-1, p10.

1999Li33 reported delayed-proton decay from ^{89}Ru formed in reaction ^{58}Ni(^{36}Ar,2p3n) at 220 MeV and transported by He jet system, no mass separation was employed. The authors measured half-life of 1.2 s *2* from (proton)(γ in ^{88}Mo) coin and observation of 741γ and 914γ assigned to ^{88}Mo.

2004De40 also used reaction ^{58}Ni(^{36}Ar,2p3n) at E=235, 255 MeV followed by mass separation. The authors did not observe any evidence for the formation of ^{89}Ru and its εp decay or the existence of 741γ that was reported by 1999Li33. 2004De40 suggested that 741γ seen by 1999Li33 may be from ε decay of ^{89}Tc. An upper limit of %εp=0.15 was deduced by these authors.

2012Lo08: ^{89}Ru produced from fragmentation of a ^{112}Sn beam at E=120 MeV/nucleon on a 195 mg/cm^2 ^{9}Be target at the National Superconducting Cyclotron Laboratory (NSCL). Fragments separated by the A1900 Fragment Separator and the Radio Frequency Fragment Separator (RFFS). Ions were implanted in the double-sided silicon strip detector (DSSD). Detection system: NSCL Beta Counting System in conjunction with the SeGA Array of 16 HPGe detectors. Measured Eγ, Iγ, β spectra, E(p), I(p), $\beta\gamma$-coin, βp-coin, $\gamma\beta$p-coin, half-life, β-delayed proton emission probability. A total of 167 ^{89}Ru ions implanted in DSSD and six βp coin events identified.

2019Pa16: ^{89}Ru produced in ^{9}Be(^{124}Xe,X),E=345 MeV/nucleon followed by separation of fragments of interest using BigRIPS and ZeroDegree spectrometer, and separated ions implanted in WAS3ABi stopper and detector system at RIBF-RIKEN. The γ rays from the decay of ^{89}Ru were detected using the EURICA array of 12 cluster Ge detectors. Measured half-life of ^{89}Ru decay from (implants)β-correlated distribution and β^+-delayed proton emission probability.

2019Vi05: measured mass excess of g.s. of ^{89}Ru using time-of-flight ion-cyclotron resonance (TOF-ICR), and phase-imaging ion-cyclotron resonance (PI-ICR) techniques at the University of Jyvaskyla accelerator facility.

1992MoZV and 1993MoZR are by the same group as 1992Ye04.

Theoretical calculations: consult NSR database at www.nndc.bnl.gov/nsr/ or additional document records in this dataset for five primary references for structure calculations.

Additional information 1.

^{89}Ru Levels

Cross Reference (XREF) Flags

A ^{54}Fe(^{40}Ca,αnγ)

E(level)	J$^\pi$[†]	T$_{1/2}$	XREF	Comments
0[‡]	(9/2$^+$)	1.32 s *3*	A	%ε+%β^+=100; %εp=3.1 *2* (2019Pa16) %εp: measured by 2019Pa16 from the number of β^+p-coin events divided by the total number of decays as determined from the half-life analysis (2019Pa16). Others: 3.0 *+19−17* (2012Lo08, from observation of six β^+p-coin events, uncertainty from assuming a binomial probability distribution with a 95% confidence level); <0.15 (2004De40). J$^\pi$: 9/2$^+$ (1997He24) proposed from systematics, 3/2$^+$ (2019Mo01, theory). Possible band assignment favors 9/2$^+$ (2004Ma86). From analysis of delayed proton spectrum and relative branching ratio with statistical model calculations, 2005Xu04 proposed J^π=5/2$^+$,7/2 for a very low deformation. But 2004De40 did not confirm observation of delayed proton activity using the same reaction as 1999Li33 or 2005Xu04, although,

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Adopted Levels, Gammas (continued)

^{89}Ru Levels (continued)

E(level)	J^{π}[†]	XREF	Comments
			2019Pa16 confirmed delayed-proton activity using a different reaction to produce ^{89}Ru isotope. 2019Pa16 proposed $7/2^+$ based on predicted $\varepsilon+\beta^+$ feedings of g.s. of ^{89}Tc for the two choices of $7/2^+$ and $9/2^+$ for the g.s. of ^{89}Ru, and observation of strong 179-keV γ ray (from the $(7/2^+)$ level in ^{89}Tc) observed in ^{89}Ru decay, thus leaving only small direct feeding of the g.s. of ^{89}Tc, consistent with the predicted value of 8%. However, the decay scheme of ^{89}Ru $\varepsilon+\beta^+$ decay is poorly known, and in the opinion of evaluator, no firm conclusion can be drawn about preference for $(7/2^+)$ for g.s. of ^{89}Ru, instead of $(9/2^+)$ as proposed by 1997He24 based on band assignment.
			$T_{1/2}$: from 2019Pa16 (weighted average of 1.31 s *3* from (implant)β-correlated decay curve and 1.53 s *11* from (implant)β^+p-correlated decay curve, analyzed using multiparameter fits for the decay chain in Bateman equation). Other: 1.5 s *2* (2001Ki13, (implants)β^+-correlated decay curve, analyzed using complete decay chain, 1.6 s *+3−2* in 2000WeZZ and 1.45 s *13* in E. Wefers et al., GSI annual (2000) report 2001-1, p10)); 2.2 s *12* (2012Lo08, (implants)β^+-correlated decay curve fitted with Poisson distribution using log-likelihood function for the complete decay chain); 1.2 s *2* (1999Li33,2005Xu04). Note that production of ^{89}Ru in 1999Li33 and 2005Xu04 was not confirmed by 2004De40 using a similar reaction as in 1999Li33.
863.7[‡] *2*	$(13/2^+)$	A	
1727.7 *6*		A	
1917.4[‡] *3*	$(17/2^+)$	A	
1967.7 *5*		A	
2458.4 *4*		A	
2766.9 *6*		A	
2953.9[‡] *4*	$(21/2^+)$	A	
3028.5 *5*		A	
3221.0 *5*		A	
3302.5[‡] *4*	$(25/2^+)$	A	
4219.3[‡] *7*	$(29/2^+)$	A	
5309.4[‡] *8*	$[33/2^+]$	A	
6239.2[‡] *9*	$[37/2^+]$	A	

[†] As proposed by 2004Ma86 based on systematics and $\gamma\gamma(\theta)$ data for selected transitions.

[‡] Band(A): Yrast sequence. The band is similar to the yrast sequence in ^{90}Ru. The backbends in the experimentally observed band in ^{89}Ru occur at 21/2-25/2 and 33/2-37/2 transitions. From calculations, the first backbend is predicted to be around 25/2 due to the alignment of a pair of $g_{9/2}$ protons, and the second backbend at 33/2 may be due to the crossing of 3qp band with a 5qp band having a pair of $g_{9/2}$ neutrons and a pair of $g_{9/2}$ protons aligned. See 2004Ma86 for detailed shell-model configurations.

$\gamma(^{89}Ru)$

E_i(level)	J_i^{π}	E_γ	I_γ	E_f	J_f^{π}	Mult.
863.7	$(13/2^+)$	863.7 *2*	100	0	$(9/2^+)$	(Q)[†]
1727.7		864.0 *5*	100	863.7	$(13/2^+)$	
1917.4	$(17/2^+)$	1053.7 *2*	100	863.7	$(13/2^+)$	(Q)[†]
1967.7		1104.1 *6*	100	863.7	$(13/2^+)$	
2458.4		490.7 *3*	73 *18*	1967.7		
		541.0 *3*	100 *18*	1917.4	$(17/2^+)$	
2766.9		849.5 *5*	100	1917.4	$(17/2^+)$	
2953.9	$(21/2^+)$	1036.5 *2*	100	1917.4	$(17/2^+)$	(Q)[†]
3028.5		1111.1 *4*	100	1917.4	$(17/2^+)$	

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Adopted Levels, Gammas (continued)

$\gamma(^{89}Ru)$ (continued)

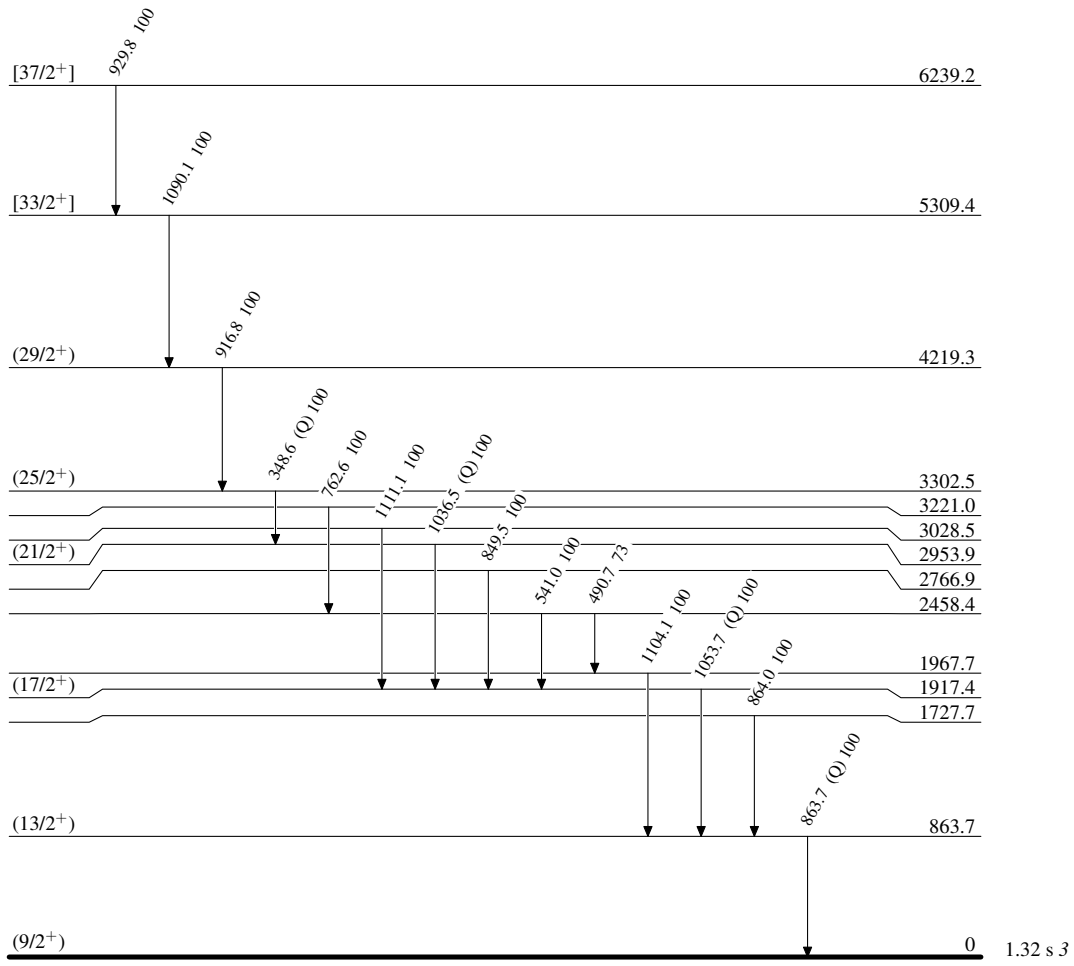
E_i(level)	J_i^π	E_γ	I_γ	E_f	J_f^π	Mult.
3221.0		762.6 *3*	100	2458.4		
3302.5	$(25/2^+)$	348.6 *2*	100	2953.9	$(21/2^+)$	(Q)[†]
4219.3	$(29/2^+)$	916.8 *5*	100	3302.5	$(25/2^+)$	
5309.4	$[33/2^+]$	1090.1 *4*	100	4219.3	$(29/2^+)$	
6239.2	$[37/2^+]$	929.8 *3*	100	5309.4	$[33/2^+]$	

[†] $\gamma(\theta)$ and/or $\gamma\gamma(\theta)$ data are consistent with $\Delta J=2$,Q transition.

Adopted Levels, Gammas

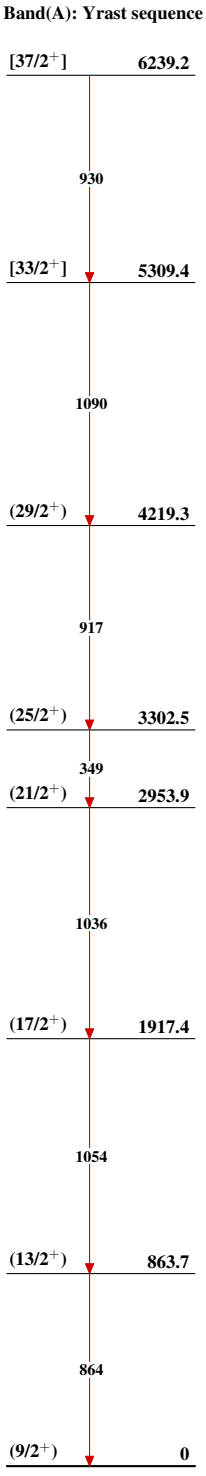
Level Scheme

Intensities: Relative photon branching from each level



$^{89}_{44}Ru_{45}$

Adopted Levels, Gammas



$^{89}_{44}Ru_{45}$