^{59}Ni - Comments on evaluation of decay data

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1) Decay Scheme

^{59}Ni disintegrates mainly by electron capture (2nd forbidden non-unique) to the ground state of ^{59}Co.
^{59}Co ground state has $J_\pi = 7/2^-$ (2002BA42).

2) Nuclear Data

The Q value is from new values of 2009AuZZ: Q_ε = 1072,76 (19) keV. Other: 1075,1 (13) keV (1976BE02).

Only one direct measurement has been performed for the ^{59}Ni half-life. The value of 7,6 (0,5) × 10^4 years given by 1981Ni08 from two samples by absolute activity measurement has been adopted as the recommended value.
Some other indirect measurements from nuclear reactions have been performed.

The measured ^{59}Ni half-life values, in years, are:

Reference[a]	Value (a) (×10^4)	Procedure	Comments
2008WAZW	9,7 (0,7)	^{60}Ni(n,2n)^{59}Ni reaction	Corrected 1994Ru19 result with newest $\sigma_{thermal}$ and K_α yield. E(n) = 17-19 MeV
1994RU19	10,8 (1,3)	^{58}Ni(n,γ)^{59}Ni and ^{54}Fe(n,γ)^{55}Fe reactions	E(n) = 14.8 MeV
1991NO08	29 (10)	^{60}Ni(n,2n)^{59}Ni reaction	Authors used σ = 104 (25) mbarn measured by 1988BO31 (very poor statistics)
1981NI08	7,6 (0,5)	Absolute activity measurement	Recommended value
1956SA32	10,0 (2,5)	^{58}Ni(n,γ)^{59}Ni reaction	E(n)= thermal. $T_{1/2}$ was not the purpose of the work
1951BR05	7,5 (1,3)	^{58}Ni(n,γ)^{59}Ni and ^{59}Co(n,γ)^{60}Co reactions	E(n)= thermal. Data used for these reactions σ = 4.2 and σ = 34.5 respectively
1951WI14	75	^{58}Ni(n,γ)^{59}Ni reaction	No uncertainty given

[a]Evaluator used the NSR (Nuclear Science References, Brookhaven Lab.) keynumbers.

The only absolute activity measurement has been performed by 1981NI08. This value was deduced from 2 samples prepared by means of the reaction ^{59}Co(p,n)^{59}Ni, purified by ion-exchange columns in order to remove ^{58}Co activity. 6,93 keV Co K_α X-rays were measured by a Xe filled proportional counter. The value of 7,6 (5) ×10^4 years estimated by 1981NI08 has been adopted as the recommended value as it comes from a direct measurement.
The five other measurements were all made in a very similar way. After neutron irradiation ^{59}Ni atoms are counted by mass spectrometry. Purification is performed to avoid iron or cobalt impurities. The induced activity in the samples has been counted via the Co K X-ray after the ^{59}Ni K capture.

2008WAZW corrected the half-life result given by 1994RU19 using the recently published thermal cross-section of ^{58}Ni (2004RA23) of 4,13 (5) barns instead of the old value of 4,6 (3) barns from 1981MUZQ. The ^{59}Ni half-life is reduced about 10 % but still higher than the recommended value. 2008WAZW analyzed the contribution to the uncertainty of the ^{59}Ni half-life mainly from the uncertainties in the cross-sections.
1991NO08 used the cross-section of ^{60}Ni(n,2n) measured by 1988BO30 but this value was obtained with very poor statistics (as mentioned by authors of 1991NO08).
The oldest value (with uncertainty) given by 1951BR05 was estimated using thermal-neutron cross-sections for ^{58}Ni(n,γ) and ^{59}Co(n,γ) of 4,17 and 34,5 barns respectively.

If a statistical analysis is made for the five indirect measurements, the Lweight code rejects 1991NO08 datum based on Chauvenet's criterion. For the other four values, the weighted mean with external uncertainty is 9,5 (6) $\times 10^4$ years.
Due to the high discrepancy of the results depending on the technique used, new experimental direct measurements are needed.

2.1) Electron Capture and Positron Transitions

Experimental β^+/K ratios are reported in Table 2 and compared with theoretical estimations:

Reference	β^+/K		β^+/EC	
	experimental	theoretical	experimental	theoretical
1991JA02	4,2 (13) $\times 10^{-7}$			
1976Be02			1,5 $\times 10^{-7}$	
Theory (Logft Code)		1,75 $\times 10^{-5}$		1,55$\times 10^{-5}$

The LOGFT program (theory) was used with the recent published Q value from 2009AuZZ.

For a 2nd forbidden ε the Logft code gives a theoretical value of $P_{\beta+}$ (1072,76) = 0,001 55 (4) % and P_ε (1072,76) = 99,998 44 (4) %with a logft of 11,89 (3). Notice that the theoretical β^+/ε branching is in complete disagreement with the experimental results of 1,5 $\times$ 10^{-7} (1976Be02) and 4,2 (13) $\times$ 10^{-7} (1991Ja02). The reason for this discrepancy remains unknown.

The EC-Capture program gives: P_K= 0,8870 (16), P_L= 0,0966 (13), P_M= 0,0156 (5), P_N= 0,0008 (2)

From the experimental value β^+/K = 4,2 (13) $\times$ 10^{-7} and assuming K/EC = 0,8870 (16) then we have β^+/EC = 3,7 (12) $\times$ 10^{-7}.

And from β^+ + EC = 100 we obtain:

$P_{\beta+}$ = 3,7 (12) $\times$ 10^{-5} %
Pε = 99,999 96 (1) %

Which are the adopted values.

3) Atomic Data

3.1) Atomic values (ω_k, ϖ_L and η_{KL}) are from 1996SC06.

3.1.1) X-Radiations, 3.1.2) Auger electrons

The X-ray and Auger electron emission probabilities have been estimated by using the computer code EMISSION. Results were verified with the RADLST computer code.

Good agreement has been found between the total decay energy of 1072,56 (19) keV computed for this decay scheme by RADLST code and the Q value of 1072,76 (19) keV.

4) Gamma emissions

The annihilation radiation emission probability ($I_{\gamma 511}$) is computed as $2 \times P_{\beta+}$, without the correction factor for the annihilation-in-flight process in the medium, that is $I_{\gamma 511}$= 7,4 (24) $\times 10^{-5}$ %.

5) References

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