^{60}Co - Comments on evaluation of decay data
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This evaluation was originally completed in September 1996 with minor editing in February 1997 and post-review editing in January 2006; the literature available by January 2006 was included by M.-M. Bé (LNE-CEA/LNHB).

1 Decay scheme

In addition to the levels reported in this decay, there are levels in ^{60}Ni below the decay energy at 2284 keV (0+) and 2626 (3+). However, based on the limits on the β^- branches to these levels (see sect. 2.1), this scheme is considered complete. The scheme is internally consistent since the total decay energy computed from the decay scheme is 2823.0 (5) keV compared to the Q value of 2823.07 (21) keV.

2 Nuclear Data

Q value is from Audi *et al.* (2003Au03).

The half-life values available, in days, are listed. If the value was published in years, it is shown here in years and also converted to days (365.242 198 days/year).

	Years	Days	Uc	Remarks
1940Li01	5.3 ± 0.7	1936	256	As quoted in 1963Go03 - Outlier (CHV)
1949Se20	5.08 ± 0.08	1855	29	As quoted in 1963Go03 - Outlier (3*S)
1950Br76	5.26 ± 0.17	1921	62	
1951Si25	5.25 ± 0.02	1917.5	7.3	As quoted in 1963Go03
1951To25	5.27 ± 0.07	1925	26	As quoted in 1963Go03
1953Ka21	5.21 ± 0.04	1903	15	Outlier (CHV)
1953Lo09	4.95 ± 0.04	1808	15	Omitted from analysis
1957Ge07	5.24 ± 0.03	1914	11	
1958Ke26	5.33 ± 0.04	1947	15	As quoted in 1965An07 - Outlier (CHV)
1963Go03	5.263 ± 0.003	1922.3	1.1	
1965An07	5.242 ± 0.008	1914.6	2.9	
1968La10	5.270 ± 0.007	1924.8	2.6	
1970Wa19	5.2719 ± 0.0011	1925.5	0.4	Replaced by 1983Wa26
1973Ha60	5.24 ± 0.21	1914	77	
1977Va30	5.283 ± 0.003	1929.6	1.1	
1980Ho17		1925.2	0.4	
1982HoZJ	5.282 ± 0.007	1929.2	2.6	Replaced by 1992Un01
1982RyZX		1924.8	1.0	
1982RyZX		1925.5	0.3	Omitted – unpublished result
1983Ru04		1925.02	0.47	
1983Wa26		1925.5	0.4	
1992Un01		1925.12	0.46	Replaced by 2002Un02
2002Un02		1925.20	0.25	
Adopted	**5.2711 ± 0.0008**	**1925.21**	**0.29**	

One input value (1949Se20) is outlier by 3 sigma, three others are outlier due to Chauvenet criterion (1940Li01, 1953Ka21, 1958Ke26).
For the remaining 14 values, the critical χ^2 is 2.1 ; the reduced χ^2 is 3 ; no value contributes over 50 % of the relative weight. The weighted average is 1925.21 with an internal uncertainty of 0.17 and an external uncertainty of 0.29.

2.1 β^- Transitions

In addition to the main decay to the $J^\pi = 4^+$ level at 2505 keV, there is the possibility of β^- decay from the 5^+ parent to the 0^+ levels at 0 and 2284 keV, the 2^+ levels at 1332 and 2158 keV, and the 3^+ level at 2626 keV.

The β^- decay to the 0+ levels at 0 and 2284 keV are unique 4th forbidden with expected log *ft* values (1973Ra10)> 23 and corresponding $P_{\beta^-} < 1 \times 10^{-10}$ % and $< 1 \times 10^{-13}$ %, respectively. The decay to the 3+ level at 2626 is 2nd forbidden with an expected log *ft* > 11 and a corresponding $P_{\beta^-} < 0.01$ %. This level decays mainly by γ's of 467 and 1293 keV; the $P_\gamma(467)$ has been reported as < 0.00023 % (1976Ca18) and < 0.0004 % (1969Va20), which indicates $P_{\beta^-}(2626) < 0.001$ %.

The β^- decay to the 1332 level is unique 2nd forbidden with an expected log *ft* ≥ 12.8 and a corresponding $P_{\beta^-} \leq 12$ %. The measured values are (in %): 0.15 (1) (1954Ke04), 0.010 (2) (56Wo09), 0.12 (61Ca05), and 0.08 (2) (1968Ha03). The average of 0.12 (3) % is adopted.

The decay to the 2158-keV level is unique 2nd forbidden with an expected log *ft* ≥ 12.8 and a corresponding $P_{\beta^-} \leq 0.02$ %. This branch is given as 0.000 (2) % from 1969Ra23. (Value is given as 0.18 (3) % in 1968Ha03, but this is apparently from a misinterpretation of the γ-ray spectrum.)

The decay to the 2505-keV level is then 100.0 - P_{β^-} (1332) - $P_{\beta^-}(2158)$ = 0.12 (3) - 0.000 (2) = 99.88 (3) %.

The β^- energies and log *ft* values are from the program LOGFT.

2.2 Gamma Transitions

The multipolarities are from the adopted γ data in the Nuclear Data Sheets (1993Ki10).
The total and K-shell internal-conversion coefficients, α and α_K, for the 1173- and 1332-keV γ rays are from the evaluation of the experimental measurements (1985HaZA) and the remaining values were interpolated from the Band tables (2002Ba85).

The internal-pair-formation coefficients were interpolated from the theoretical values of 1979Sc31 and are $\alpha_\pi(1173) = 0.000\ 006\ 2\ (7)$ and $\alpha_\pi(1332) = 0.000\ 034\ (4)$. The former is negligible since it is only about 5 % of the corresponding α, but the latter is about 25 % of the α, so it needs to be taken into account.

3 Atomic Data (Ni, Z=28)

The data are from Schönfeld and Janßen (1996Sc06).

3.1 & 3.2 X Radiation and Auger Electrons

The data were computed by RADLIST with the Schönfeld atomic data.

4 Radiation Emission

4.1 Electron Emission

Data were computed by the program RADLIST.

4.2 Photon Emissions

The γ-ray energies are from 2000He14 for the 1173-keV and 1332-keV lines and the others are deduced from the level energies resulting from a fit to the γ-ray energies. Besides the 1173 and 1332 values, the input to this fit included:

346.93 (7) from 1976Ca18 where the authors average their result and that of 1969Va20;
other: 346.95 (10) (1969Va20);

826.06 (3) from ^{59}Co(p,γ)^{60}Ni (1975Er05); others: 826.18 (20) (1969Va20) and 826.28 (9) (1976Ca18, but includes value of 1969Va20);

2158.57 (10) from ^{59}Co(p,γ) (1975Er05); others: 2158.8 (4) (1970Di01) from ^{60}Co decay and 2158.9 (2) (1969Ra07) and 2159.6 (8) (1969Ho22) from ^{60}Cu decay.

For the relative γ-ray emission probabilities, the following data were used.

Relative γ-ray emission probability

γ energy (keV)	347	467	826	1173/1332	2158	2505
Reference						
1949Fl				100		< 2.5 10^{-5}
1955Wo44	< 0.005			100	0.0012 (2)	
1959Mo				100		-4 10^{-5}
1968Ha03			0.19 (2)	100		
1969Ra23			< 0.02	100	< 0.002	
1969Va20	0.0078 (12)	< 0.0004	0.0055(47)	100		
1970Di01	< 0.006		< 0.04	100	0.0092 (16)	< 4 10^{-5}
1972Le14			0.003 (2)	100	0.0005 (2)	
1973Fu15				100	0.0020 (13)	9 (7) 10^{-6}
1976Ca18	0.00758 (50)	< 0.00023	0.00762 (80)	100.0	0.00111 (18)	
1977HaXC				100		< 0.001
1977Lo01	0.0069 (10)	< 0.0012		100		
1978Fa03				100		< 1.0 10^{-5}
1978Fu05				100		2.0 (4) 10^{-6}
1988Se09				100		5.2 (20) 10^{-6}
Adopted	0.0075 (4)		0.0076 (8)	100	0.0012 (2)	2.0 (4) 10^{-6}

These relative emission probabilities were normalized by requiring that the total β$^-$ emission probability is 100 %. For the 1332-keV γ ray, this means:

$$P_\gamma(1332) = \{100.00 - P_\gamma(2158) \times [1+\alpha(2158)] - P_\gamma(2505) \times [1+\alpha(2505)]\} / [1.00+\alpha(1332)+\alpha_\pi(1332)]$$
$$= [100.00 - 0.0012\ (2) - 0.000\ 002\ 0\ (4)] / [1.000 + 0.000\ 128\ (5) + 0.000\ 034\ (4)]$$
$$= 99.998\ 8\ (2) / 1.000\ 162\ (6) = 99.982\ 6\ (6)\ \%.$$

In the evaluation 1991BaZS, this value is computed in the same fashion, but is given as 99.983 (6) %; the origin of the larger uncertainty is not clear. Similarly, for the 1173-keV γ ray, this means:

$$P_\gamma(1173) = \{P_{\beta^-}(2505) - P_\gamma(347) \times [1+\alpha(347)] - P_\gamma(2505) \times [1+\alpha(2505)]\} / [1.00+\alpha(1173)+\alpha_\pi(1173)]$$
$$= [99.88\ (3) - 0.007\ 5\ (4) - 0.000\ 002\ 0\ (4)] / [1.000 + 0.000\ 168\ (4) + 0.000\ 006\ 2\ (7)]$$
$$= 99.87\ (3) / 1.000\ 174\ (4) = 99.85\ (3)\ \%.$$

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