

⁵⁷Ni – Comments on evaluation of decay data by Shiu-Chin Wu

The *Limitation of Relative Statistical Weight* (1988WoZO) (LWM) method, used for averaging numbers throughout this evaluation, provided a uniform approach for the analysis of discrepant data. For two discrepant values, the method chooses the unweighted average. The uncertainty assigned to the recommended values was always greater than or equal to the smallest uncertainty of the values used to calculate the average.

1. Decay Scheme

⁵⁷Ni decays by EC + β^+ to ⁵⁷Co states at 1377.65, 1504.81, 1757.58, 1919.55 and 2804.27 keV. The total β^+ branching has been measured by 1967Li08, 1962Ch20, 1958Ko60 and 1964Ru06. The weighted average of the results gives (45.9 ± 1.0) %, in agreement with the value of 43.5% predicted by theory [1; 1957Zw01].

2. Nuclear Data

The following values of the half-life of ⁵⁷Ni have been used to deduce a recommended value:

1	35.54(5) h	Dickens (1986)
2	35.65(5) h	Grutter (1982)
3	36.16(11) h	Rothman et al. (1974)
4	35.99(12) h	Ebrey and Gray (1965)
5	35.7(2) h	Rudstam (1964)
6	36.4(7) h	Friedlander et al. (1950)
7	35.7(10) h	Maienschein and Meem (1949)

The recommended half-life of ⁵⁷Ni, 35.9(3) h, is an average ($\chi^2/N-1=5.83$, LWM) of the seven values listed above. The LWM method changed the uncertainty of the averaged value from 0.1 h to 0.3 h, in order to overlap with the most precise value of 35.54 h. The value of 43.7(9) h by Rayburn (1961Ra06) differs from the average by about 8 σ , and was not included. Rudstam (1956Ru45) had previously reported a value of 37.6(5) h, which has been superseded by the more precise value of 35.7(2) h (1964Ru06) given above.

2.1 Electron Capture Transitions

Electron-capture energies given in Tables 2.2 have been deduced from the Q value and the level energies. EC + β^+ feedings to the levels are from gamma-ray emission probability balances. The electron-capture and positron emission probabilities to the individual levels are based on theoretical [1] β^+ /EC ratios. The fractional atomic shell electron-capture probabilities are theoretical values [1977Ba48] calculated with the EC-CAPTURE computer program [2]. EC decay to the ground state of ⁵⁷Co has not been observed. This transition would be 2nd forbidden non-unique, with a systematic *lg ft* value of 11.0 or higher. Its

corresponding probability, calculated with the LOGFT computer program [3], is less than 0.01%. Similarly, the EC decay to the 1st excited state has a probability of less than 0.001%.

2.2 Positrons Transitions

Electron-capture and β^+ end-point energies given in Tables 2.1 and 2.2 are equal to $Q_{EC} = 3264.2(26)$ keV (1995Au04) minus the individual level energies, and to the electron-capture energies minus $2 m_0c^2$ (1022 keV), respectively.

2.3 Gamma Rays

Gamma-ray energies were measured with Ge(Li) detectors by Scardino *et al.* (1990Sc23); Rothman *et al.* (1974HeYW); Gatrousis *et al.* (1969Ga14); Lingeman *et al.* (1967Li08) and Piluso *et al.* (1966Pi01). The energies adopted here are the LWM averages, which are usually dominated by the values of 90Sc23.

Adopted	1990Sc23	1974HeYW	1969Ga14	1967Li08	1966Pi01	χ^2_R
127.164(3)	127.164(3)	127.192(25)	127.1(1)	127.6(5)**	127.2(1)	0.59
161.86(3)	161.86(3)		161.8(3)			0.04
304.1(1)	304.1(1)					
379.94(2)	379.94(2)		380.0(2)			0.09
541.9(1)	541.9(1)					
673.44(4)	673.44(4)		673.4(2)			0.04
696.0(4)	696.0(4)					
755.3(1)	755.3(1)					
906.98(5)	906.98(5)		906.8(3)			0.35
1046.54(14) [#]	1046.68(3)		1046.4(2)			0.98
1223.8(3) [#]	1224.00(4)		1223.5(4)			0.78
1279.99(6)	1279.99(6)					
1350.52(6)	1350.52(6)					
1377.62(4)	1377.63(3)	1377.59(4)	1377.6(2)	1378.0(5)	1378.1(2)	1.7
1603.28(6)	1603.28(6)					
1730.45(6)	1730.44(6)		1730.6(3)			0.27
1757.55(3)	1757.55(3)	1757.48(8)	1757.6(2)	1758.2(6)**	1757.7(2)	0.45
1897.0(5) [#]	1897.42(4)		1896.5(4)			2.6
1919.62(14)	1919.52(5)	1919.43(8)	1919.5(2)	1919.9(6)	1920.2(1)	11
2133.04(5)	2133.04(5)		2132.9(3)			0.21
2730.76(14)	2730.91(4)		2730.6(2)	2731(2)		0.61
2804.08(15)	2804.20(3)		2803.9(2)	2805.1(9)		1.2
3177.27(5)	3177.28(5)		3176.9(3)	3177.3(12)		0.78

** Statistical outlier, omitted.

[#] The LWM chose the unweighted average for these discrepant values.

Gamma-ray emission probabilities relative to that of the 1377.62 keV γ -ray measured with Ge(Li) detectors were reported by Scardino *et al.* (1990Sc23); Grutter (1982Gr10); Rothman *et al.* (1974HeYW); Gatrousis *et al.* (1969Ga14); Lingeman *et al.* (1967Li08) and Piluso *et al.* (1966Pi01). The LWM averages have been adopted here.

E_γ keV	Adopted	1990Sc23	1982Gr10	1974HeYW	1969Ga14	1967Li08	1966Pi01	χ^2_R
127.164(3)	19.8(6)	20.4(4)	20.3(2)	16.6(10)	20.0(6)	17.6(9)	15.0(9)	10
161.86(3)	0.025(3) [#]	0.0278(8)			0.022(11)			14
304.1(1)	0.0024(7)	0.0024(7)						
379.94(2)	0.089(7) [#]	0.082(2)			0.10(5)			4.2
541.9(1)	0.0045(6)	0.0045(6)						
673.44(4)	0.0600(18)	0.0601(18) ¹⁾			0.06(3)			0.38
696.0(4)	0.0011(8)	0.0011(8)						
755.3(1)	0.0066(8)	0.0066(8)						
906.98(5)	0.092(18) [#]	0.075(2)			0.110(6)			20
1046.54(14)	0.163(4)	0.164(4)			0.16(1)			0.20
1223.8(3)	0.094(16) [#]	0.077(3)			0.110(6)			18
1279.99(6)	0.0118(9)	0.0118(9)						
1350.52(6)	0.0024(12)	0.0024(12)						
1377.62(4)	100(2)	100	100	100	100	100	100	
1603.28(6)	0.0048(8)	0.0048(8)						
1730.45(6)	0.068(4) [#]	0.064(3) ²⁾			0.072(4)			2.5
1757.55(3)	7.5(5)	7.04(20)	7.63(20)	9.1(8)	7.7(2)	9.5(5)	6.9(3)	6.1
1897.0(5)	0.031(3) [#]	0.034(3)			0.028(14)			2.0
1919.62(14)	15.4(7)	15.0(3)	17.0(4)	18.9(12)	17.0(5)	22.4(11) ³⁾	14.7(2)	10
2133.04(5)	0.041(6) [#]	0.035(2) ²⁾			0.047(24)			13
2730.76(14)	0.024(4)	0.0243(6)			0.03(2)	0.015(2)		18
2804.08(15)	0.126(21)	0.120(4)			0.17(1)	0.088(9)		23
3177.27(5)	0.019(5)	0.0136(7)			0.024(1)	0.021(3)		21

¹⁾ The relative intensity of the 673.44-keV γ -ray was listed in 1990Sc23 as 0.0601(15), and corrected as 0.0601(8) by Bhat (1992Bh05). However, a relative uncertainty of 1% for such a weak peak seems too low, it is probably a typographical error. We used 0.0601(18) here.

²⁾ As suggested by Bhat (1992Bh05), the intensity given in 1990Sc23 for the 1730.44 keV γ -ray (0.0614(3)) was changed to 0.064(3); and the uncertainty of the 2133.04 keV γ -ray (0.0350(2)) was increased by a factor of 10 here (possible typographical errors).

³⁾ Statistical outlier, omitted.

[#] The LWM chose the unweighted average for these discrepant values.

EC + β^+ feeding to the ground state of ^{57}Co has not been observed. A systematic $lg ft \geq 11.0$ for a second forbidden non-unique transition corresponds to $I_{\text{EC}} \leq 0.01\%$ for a possible EC transition to the ground state of ^{57}Co . Thus, we used the sum of the relative emission probabilities of the 1224.00 keV, 1377.63 keV, 1757.55 keV, 1897.42 keV, 1919.52 keV, 2133.04 keV, 2730.91 keV, 2804.20 keV and 3177.28 keV γ -rays to normalize the decay scheme. The 1377.62 keV gamma ray is the strongest transition, for which we used a fractional uncertainty of 2%, suggested by 1992Bh05. Similarly, for the first excited state at 1224 keV, a possible EC + β^+ transition would have a systematic $lg ft \geq 12.6$, which corresponds to an intensity $I_{\text{EC}} \leq 0.001\%$. Conversion coefficients used in these calculations are those of Band *et al.* [1976Ba63].

3. Atomic Data

The X-ray and Auger electron emission probabilities given in section 3 are values calculated by using the computer program EMISSION [4], the electron capture probabilities from section 2.2, and atomic data from 1996Sc06.

4. Radiation Emission

4.1 Electron Emission

The emission probabilities of the Auger electrons have been calculated here using the adopted nuclear and atomic electron capture transition data, and the program EMISSION [4]. The emission probabilities of conversion electrons were calculated using the adopted γ -ray emission probabilities and conversion coefficients (section 2.2).

4.2 Photon Emission

The emission probabilities of X-rays were calculated using the adopted nuclear and atomic electron capture transition data, and the program EMISSION [4]. The evaluation of the gamma-ray emission probabilities was discussed in section 2.3.

Total Average Radiation Energy

The total released average radiation energy (electron capture, neutrinos, nuclear recoil, photons and electrons) in the EC + β^+ decay of ⁵⁷Ni (calculated by using the computer program RADLST [5]) is 3264(32) keV. This value agrees well with 3264.2(26) keV from mass differences (1995Au04), and thus confirms the quality and completeness of the decay scheme.

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