Mn-56 – Comments on evaluation of decay data
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Re-evaluated: January 2004

Evaluation Procedures

Limitation of Relative Statistical Weight Method (LWM) was applied to average numbers throughout the evaluation. The uncertainty assigned to the average value was always greater than or equal to the smallest uncertainty of the values used to calculate the average.

Decay Scheme

A reasonably simple and consistent decay scheme has been constructed from the gamma-ray measurements of 1967Au01, 1968Sh07, 1973Ar15, 1974Ti01, 1974Ho25 and 2004MiXX. Ten distinct gamma-ray emissions were identified with ^{56}Mn decay in these studies. An additional gamma ray at 3119.3 keV was identified by 1968Sh01, but this emission has been discarded due to a lack of evidence from the other studies.

Nuclear Data

The gamma-ray emissions of ^{56}Mn are reasonably well-defined, and this radionuclide has suitable decay characteristics for use as a calibrant over the gamma-ray energy range 840 to 2550 keV.

Half-life

Half-life adopted from the evaluation of Woods for the IAEA-CRP: Update of X- and Gamma-ray Decay Data Standards for Detector Calibration. The measurements of 1968Sh07, 1971GoYM, 1972Em01, 1973La12, 1980RuZY, 1992An13 and 1994Ya02 were considered.

Reference	Half-life (days)
1968Sh07	0.10771(4)
1971GoYM	0.10742(33)
1972Em01	0.10779(25)
1973La12	0.107438(8)
1980RuZY	0.107350(33)
1992An13	0.107454(4)[§]
1994Ya02	0.1040(20)[*]
Evaluated value	0.107449(18)

[§] Uncertainty increased to ± 0.000008 to ensure weighting factor not greater than 0.50.
[*] Method development study: removed from data set due to uncharacteristically large uncertainty.

Woods evaluation for IAEA-CRP (2004WoZZ): recommended half-life of 0.107449(19) days or 2.57878 (46) h (using above data set, but also excluding 1994Ya02 data), adopted for this evaluation.

Gamma Rays

Energies

A number of well-defined gamma-ray energies were adopted from the recommended standards of 2000He14. All other gamma-ray energies were calculated from the structural details of the proposed decay scheme and the nuclear level energies of 1999Hu04 (as derived from the energy measurements of 1973Ar15, 1974Ho25 and 1974Ti01). An additional gamma ray with an energy of 3119.3(5) keV was only detected by 1968Sh01, and has been discarded due to a lack of evidence in all of the other studies.

Emission Probabilities

Weighted mean relative emission probabilities were determined for all of the gamma rays assigned to the decay scheme, using the relevant data from the measurements of 1967Au01, 1968Sh07, 1973Ar15, 1974Ho25, 1974Ti01 and 2004MiXX. All gamma-ray emissions were expressed relative to the 846.7638 keV transition, which was arbitrarily assigned an uncertainty of 3% (100(3)%).

Gamma-ray Emission Probabilities: Relative to P_g(846.7638 keV) of 100%

E_g(keV)	P_g^{rel}						
	1967Au01	1968Sh07	1973Ar15	1974Ho25	1974Ti01	2004MiXX	Recommended Values*
846.7638(19)†	100(3)	100(3)	100(3)	100(3)	100(3)	100.000(103)	100(3)
1037.8333(24)†	-	-	0.06(1)	0.03(1)	0.040(5)	-	0.040(4)§
1238.2736(22)†	-	-	0.14(3)	0.13(1)	0.10(1)	0.097(2)	0.098(2)§
1810.726(4)†	30(3)	29.4(16)	28.6(15)	26.9(13)	27.5(8)	26.610(72)	27.2(4)
2113.092(6)†	17.4(17)	16.0(9)	16.0(8)	14.3(7)	14.5(4)	13.956(53)	14.4(3)§
2523.06(5)‡	1.10(15)	1.6(5)	1.14(5)	1.01(5)	1.00(3)	1.025(9)	1.03(2)
2598.438(4)†	-	-	0.026(5)	0.02(1)	0.019(2)	-	0.020(2)
2657.56(1)‡	0.60(10)	0.66(6)	0.71(4)	0.66(7)	0.66(2)	0.648(8)	0.652(7)§
2959.92(1)‡	0.31(6)	0.26(3)	0.30(2)	0.32(3)	0.31(1)	0.314(6)	0.311(5)§
3119.3(5)#	-	0.08(4)	-	-	-	-	-
3369.84(4)‡	0.22(5)	0.20(4)	0.15(2)	0.16(2)	0.17(1)	-	0.17(1)

† Energy adopted from 2000He14.
‡ Energy calculated from the nuclear level energies specified by 1999Hu04.
# Energy from 1968Sh07, but transition not included in proposed decay scheme.
* Weighted mean values adopted using LWEIGHT, unless stated.
§ Recommended values adopted from a combination of the normalised residuals and Rajeval methods (see 2004MaYY).

The normalisation factor for the gamma-ray emission probabilities was calculated from the proposed decay scheme via two routes:

(a) beta population of all ^{56}Fe nuclear levels derived from gamma-ray depopulation/population and summed, assuming β decay to ^{56}Fe ground state is zero (spin and parity considerations ($3^+ \rightarrow 0^+$)).

for all nuclear levels populated by β decay $\Sigma P_{\beta i} = (101.163 \pm 1.479) \times NF = 100$

$NF = 0.989\ (15)$

(b) population of ^{56}Fe ground state by gamma transitions, assuming β decay to ^{56}Fe ground state is zero.

$\Sigma P_{\gamma i} (1 + \alpha_i) NF = [P_\gamma (3369.84\ keV) + P_\gamma(2959.92\ keV) + P_\gamma(2657.62\ keV) + P_\gamma(846.7638\ keV) (1 + \alpha_i)] \times NF = 100$

$101.163(23) \times NF = 100$

$NF = 0.9885(3)$

Hence, a normalisation factor of 0.9885(3) was adopted on the basis of the more accurate determination.

Multipolarities and Internal Conversion Coefficients

The nuclear level scheme specified by 1999Hu04 has been used to define the multipolarities of the gamma transitions on the basis of known spins and parities. Studies of the internal conversion coefficients of the some of these gamma transitions support the proposed transition types: (97%M1 + 3%E2) for the 1810.726 keV gamma rays (taken from 1989Co01); (99.96%M1 + 0.04%E2) and 100%E2 for the 1037.8333 and 1238.2736 keV gamma rays, respectively (taken from 1974Ho25).

Multipolarity Assignments

Reference	E_g (keV)	Multipolarity
1974Ho25	1037.83	99.96%M1 + 0.04%E2
	1238.27	E2
	1810.726(4)	96.5%M1 + 3.5%E2
	2113.092(6)	93.4%M1 + 6.6%E2
	2523.06(5)	94.1%M1 + 5.9%E2
	2598.438(4)	93.4%M1 + 6.6%E2
1989Co01	1810.726(4)	97%M1 + 3%E2
	2113.092(6)	96%M1 + 4%E2

Beta-particle Emissions

Energies

All beta-particle energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies of 1999Hu04 and the Q-value were used to determine the energies and uncertainties of the beta-particle transitions to the various levels.

Emission Probabilities

The beta-particle emission probabilities were calculated from the recommended gamma-ray emission probabilities and the theoretical internal conversion coefficients of 1976Ba63 (latter estimated by interpolation of the data). Log *ft* systematics can be applied to the beta-particle transition to the ground state of ^{56}Fe ($\Delta J=3$, $\Delta\pi$ = no), with a lower limit for log *ft* of 13.9 (1998Si17), to give a beta-particle emission probability of < 0.0005 (set to zero).

Beta-particle Emission Probabilities

E_b(keV)	P_b
	Recommended Values*
250.2(3)	0.00020(2)
325.7(3)	0.0120(3)
572.6(3)	0.00040(4)
735.6(3)	0.145(3)
1037.9(3)	0.275(4)
1610.4(3)	0.00057(6)
2848.7(3)	0.566(7)

* Recommended emission probabilities derived from evaluated gamma-ray emission probabilities and theoretical internal conversion coefficients.

Atomic Data

The x-ray data have been calculated using the evaluated gamma-ray data, and the atomic data from 1996Sc06, 1998ScZM and 1999ScZX.

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