^{52}Mn – Comments on evaluation

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This evaluation was completed in early November 2020. Includes all literature published before this date.

Decay Scheme

^{52}Mn decays 100% by electron capture (ε) and positron emission (β^+) transition to excited levels of ^{52}Cr.
The decay energy value for the ^{52}Mn decay, **Q_{EC}**, was adopted from Wang *et al.* (2017), 4712.0 (19) keV. The spins, parities and level energies are adopted from the most recent mass-chain evaluation published for A=52 (Yang and Huo, 2015). The lifetime of the excited state of 3616 keV (^{52}Cr), 0.15 (10) ps, was adopted from Adymov *et al.* (2011Ad14).
The decay scheme can be incomplete. Two gamma rays of high energy and very low emission intensity that are not yet placed in the decay scheme were reported in the evaluation of Yang and Huo (2015): 1441 (1) keV and 1839.14 (17) keV. Three transitions exhibit a low branching ratio that can be null within the uncertainty. However, their inclusion in the decay scheme allows obtaining good data consistency.

Half-life

The half-life of ^{52}Mn, 5.592 (3) days, was adopted as the weighted mean of 7 experimental values, from Livingood and Seaborg (1938), Burgus *et al.* (1954Bu58), Kafalas and Irvine Jr. (1956Ka33), Rudstam (1956Ru45), Vaninbroukx and Grosse (1966Va26), Pakkanen (1967Pa22) and Nagle and Meyer (1977Na18), respectively. The half-life value reported by A. Hemmedinger, in Phys. Rev. 58 (11), 929-934 (1940He01), is an outlier (7.4 (10) days, which is very different from the other values, because no impurity correction was applied), and it was not taken into account in the statistical analysis. The adopted value, 5.592 (3) days (see the table below), is almost identical with the one from the recent evaluation of Yang and Huo (2015), 2015Ya15, i.e. 5.591 (3) days.

Reference	**T½ (days)**	**uc (days)**	**Comments**
Livingood & Seaborg (1938)	6.5	1.0	
1954Bu58	5.60	0.01	
1956Ka33	5.69	0.03	
1956Ru45	5.82	0.06	
1966Va26	5.62	0.20	
1967Pa22	5.5, 6	1.0, 2	The weighted mean of the 2 results was adopted: 5.6 days, with the combined uncertainty 0.9 days
1977Na18	5.591	0.003	
Crit (χ^2)	3.79		
χ^2	0.25		
UWM	5.603		
LWM	5.592		
uc(WM)int. :	0.003		
uc(WM)ext. :	0.0014		
Adopted:	**5.592**	**0.003**	

The adopted data set is consistent and the recommended half-life is the weighted mean of the seven listed values (LWM analysis, according to LWEIGHT4 computer program, version for MS Excel), with an uncertainty which is the maximum of the internal and external uncertainties. In the opinion of the evaluator, new half-life measurements are needed, because the most recent measurement reported is almost 40 years old (1977Na18).

Electron Capture and β^+ Transitions

Electron capture (EC) and β^+ energies, as well as shell and sub-shells capture probabilities, were obtained from the nuclear level energies and the Q value, using the BetaShape code (2015M010, 2019Mo35).

The ground state of ^{52}Cr is populated only through the gamma-ray transition of 1434.06 keV. There are four electron capture transitions feeding the excited states from 3113.883 keV to 4627.13 keV, and only two β^+ transitions. Three additional transitions have very low emission intensities with uncertainties covering a null probability. A β^+ competition is energetically possible. These transitions have been taken into account in order to obtain good consistency of the decay scheme.

The most important β^+ emission, with a maximum energy of 576.1 (19) keV, has an intensity of 30.85 (43) %. The maximum positron energy is in good agreement with the experimental values of 572 (6) keV and 575 (4) keV, measured by Katoh *et al.* (1960) and by Konijn *et al.* (1967), respectively. The ratio of K-capture to positron emission intensity (K/β^+) adopted in the present evaluation from BetaShape (1.718 (28)) is in excellent agreement with the experimental value from 1967Ko10 (1.72 (11)). The number of positrons emitted per 100 disintegrations (30.85 (43)) is also close to the experimental values from 1967Ko10: 1.72 (11) and 29.2 (8) and 26.2 (11).

The probabilities of the electron capture and β^+ transitions were calculated from the decay scheme balance and the theoretical ratio (EC/β^+) computed by the BetaShape program (2015M010, 2019Mo35). The total (EC + β^+) transition probability to the excited state of 3113.883 keV (^{52}Cr) is 90.7 (8) %. The BetaShape program was also used to calculate the log ft values for the EC and β^+ transitions. The resulting 511 keV photons emission intensity is 62.3 (15) %.

Gamma-rays energy and intensity; Normalization factor

Several measurements of the gamma-ray energies and their relative intensities were found in the literature: Iwata and Yoshizawa (1980); Yaffe and Meyer (1977); Babenko *et al.* (1975); Gehrke and McIsaac (1972); Pakkanen (1967); Freedman *et al.* (1966); Wilson *et al.* (1962) and Katoh *et al.* (1960).

A reference intensity of 100 was adopted for the 1434.06 (1) keV gamma rays. The adopted gamma-ray energies and their relative intensities are the weighted means of the experimental values published in the above-mentioned references (the method of Limitation of Relative Statistical Weight, LWM, was applied, using the computer code LWEIGHT4 for MS Excel, from CEA/LNE-LNHB, France). A few outliers indicated by the computer code (noted with * in the tables below) were not taken into account in the statistical analysis. Other older measurements of gamma-rays relative intensity (highly discrepant with most recent measurements available), using lower resolution detection systems, were also excluded in case of doublets (two close gamma-ray peaks in the spectra), such as 398.09 keV and 399.54 keV, or 1246.36 keV and 1247.85 keV, respectively. In these cases, the results (**) reported by the different authors correspond to the sum of the two peaks from the doublets. In the case of the 501.97 keV relative intensity, there are two groups of results; the lower values were adopted, based on the fact that these include the most recent measurements, made by Iwata and Yoshizawa (1980) and Yaffe and Meyer (1977), which are in very good agreement.

^{52}Mn Gamma-rays energy (keV):

Yaffe & Meyer	Wilson *et al.*	Freedman *et al.*	Babenko *et al.*	Gehrke & McIsaac	Pakkanen	Katoh *et al.*	**Adopted (LWM)**
200.577 (41)							**200.58 (4)**
346.01 (4)	345.74 (8) *	346.0 (3)	345.27 (2) *	346.062 (50)	346.0 (3)		**346.03 (3)**
398.08 (9)		398 (1)			398.5 (6)		**398.09 (9)**
399.56 (5)			399.54 (2)	399.2 (4)			**399.542 (19)**
502.05 (5)		504 (1) *	501.84 (5)	502.17 (10)	502.8 (8)		**501.97 (8)**
600.14 (5)	630 (60) *		600.65 (2)	600.225 (50)	600.6 (10)		**600.42 (23)**
647.45 (6)			647.58 (4)	647.531 (51)	647.0 (10)		**647.537 (30)**
744.214 (5)	743.8 (3)	744.3 (2)	744.75 (3)	744.179 (30)	744.1 (2)	746.8 (2) *	**744.213 (6)**
848.16 (5)	847.4 (6)	849.8 (10) *	847.14 (3) **	848.125 (30)	848.4 (4)		**848.134 (26)**
901.87 (18)							**901.87 (18)**
935.52 (1)	935.1 (4)	935.8 (2)	934.09 (6) *	935.504 (30)	935.5 (2)	938.1 (4) *	**935.519 (10)**
1045.72 (8)							**1045.72 (8)**
1246.246 (7)	1245.6 (4)	1247.4 (3) *	1246.61 (3)	1246.250 (40)	1246.1 (6)		**1246.36 (12)**
1247.85 (9)							**1247.85 (9)**

Yaffe & Meyer	Wilson *et al.*	Freedman *et al.*	Babenko *et al.*	Gehrke & McIsaac	Pakkanen	Katoh *et al.*	**Adopted (LWM)**
1333.615 (12)	1332 (1) *	1334.3 (3) *	1333.59 (5)	1333.624 (40)	1333.4 (4)		**1333.614 (11)**
1434.056 (12)	1433.6 (4)	1434.5 (2)	1434.13 (5)	1434.047 (30)	1434.3 (2)	1434.7 (8)	**1434.060 (14)**
1645.78 (3)				1645.82 (15)	1645.0 (13)		**1645.781 (29)**
1981.07 (3)				1981.1 (2)	1979 (2)		**1981.07 (3)**
2257.36 (19)							**2257.36 (19)**

^{52}Mn Gamma-rays relative intensity (per 100 disintegrations):

Energy (keV)	Yaffe & Meyer	Wilson *et al.*	Freedman *et al.*	Babenko *et al.*	Gehrke & McIsaac	Pakkanen	Iwata & Yoshizawa	**Adopted (LWM)**
200.58 (4)	0.076 (2)							**0.076 (2)**
346.03 (3)	0.98 (1)	0.89 (20)	0.78 (20)	0.804 (48)	1.2 (1)	1.05 (15)	1.032 (26)	**0.984 (31)**
398.09 (9)	0.089 (7)		0.30 (8) **			0.36 (9) **	0.088 (11)	**0.089 (6)**
399.542 (19)	0.183 (7)			0.218 (41)	0.36 (6) **		0.170 (17)	**0.182 (6)**
501.97 (8)	0.21 (2)		1.0 (5) *	0.75 (13) *	0.14 (2)	0.9 (4) *	0.218 (26)	**0.185 (25)**
600.42 (23)	0.39 (1)			0.343 (57)	0.53 (3)	0.49 (12)	0.387 (26)	**0.414 (29)**
647.537 (30)	0.40 (2)		< 0.5	0.466 (84)	0.40 (3)	0.51 (12)	0.43 (3)	**0.410 (14)**
744.213 (6)	90.0 (5)	81.9 (16) *	82.1 (70) *	87.9 (6)	88.2 (50)	88 (5)	90.8 (3)	**90.0 (8)**
848.134 (26)	3.32 (3)	2.6 (3) *	3.0 (10) *	3.60 (8) *	3.4 (2)	3.3 (4)	3.39 (3)	**3.36 (3)**
901.87 (18)	0.044 (4)							**0.044 (4)**
935.519 (10)	94.5 (5)	83.9 (19) *	93.6 (50)	94.8 (6)	95 (5)	94 (4)	95.0 (3)	**94.9 (3)**
1045.72 (8)	0.07 (2)						< 0.04	**0.07 (2)**
1246.36 (12)	4.21 (4)	5.8 (5) *	4.7 (4) **	5.25 (10) **	4.8 (3) **	4.7 (4) **	4.32 (9)	**4.23 (4)**
1247.85 (9)	0.38 (4)						0.37 (9)	**0.38 (4)**
1333.614 (11)	5.07 (4)	5.7 (10) *	5.1 (4)	5.22 (8)	5.3 (3)	5.1 (4)	5.07 (3)	**5.08 (3)**
1434.060 (14)	**100.0 (4)**	100	100	100	100	100	100.0 (3)	**100.0 (4)**
1645.781 (29)	0.047 (3)	< 0.5	< 0.03		0.055 (8)	0.040 (10)	0.056 (4)	**0.050 (3)**
1981.07 (3)	0.034 (3)	< 0.5	< 0.02		0.039 (6)	0.031 (15)	0.036 (3)	**0.035 (3)**
2257.36 (19)	0.0027 (6)							**0.0027 (6)**

The uncertainty of the relative 1434 keV gamma-ray intensity was not propagated as this intensity was fixed by the evaluator as a reference.

The adopted Internal Conversion Coefficients (ICC) are the theoretical values calculated by the BrIcc program (Kibédi *et al.*, 2008). Several multipolarities (not reported in Yang and Huo, 2015) were assumed by the evaluator to be M1 + 50% E2.

The normalization factor was deduced from the ICC and the condition that 100 % of the transitions populate the ground state of the ^{52}Cr daughter: **0.999 866 (19).** Using this factor and the adopted gamma-ray relative intensities, the absolute gamma-ray emission probabilities were calculated.

Atomic Data

The adopted fluorescence yield data, the relative K X-ray emission probabilities, the ratios P(KLX)/P(KLL) and P(KXY)/P(KLL) were taken from Schönfeld *et al.* (1996Sc06):

$\omega_K = 0.289(5); \overline{\omega}_L = 0.0045(9); \eta_{KL} = 1.508(5)$.

The Auger electron and X-ray absolute probabilities were calculated by the EMISSION program (2000Sc47), from the related decay data (gamma emission probabilities, ICC, P_{EC} probabilities, etc.).

The two tables below present the evaluated data (energy range, emission probabilities and uncertainties) for the main Auger electrons (the conversion electrons emission is a very low probability process, because the gamma-ray transitions energies are high) and X-ray emissions, respectively.

Electron emission probabilities (Auger, *A*):

Electrons	Energy (keV)	Electrons (per 100 disintegrations)
e_{AL} (Cr)	0.42-0.69	6.74 (10)
e_{AK} (Cr): KLL KLX KXY	 4.55-4.79 5.20-5.41 5.84-5.99	Total: 43.4 (7)

X-ray emission probabilities (K and L components):

X-rays	Energy (keV)	Photons (per 100 disintegrations)
XL (Cr)	0.500-0.697	0.030 (7)
$XK\alpha_2$ (Cr)	5.406	5.25 (12)
$XK\alpha_1$ (Cr)	5.415	10.30 (23)
$XK\beta_1$ (Cr) $XK\beta_5$" (Cr)	5.947 5.987	The sum ($K'\beta_1$): 2.09 (5)

Data Consistency

For ^{52}Mn, the adopted Q_{EC} value from Wang *et al.* (2017) is 4712.0 (19) keV, while the value calculated by SAISINUC from the decay data recommended by the present work is 4713 (21) keV. These two values agree very well within the stated uncertainties (the relative difference is 0.027 %).

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