



Evaluation of the decay data

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This evaluation was completed in early November 2020 and includes all the literature available by end of October 2020.

Tables of decay data with the decay scheme p. 2-9

Comments on the present evaluation p. 10-12



1 Decay Scheme

Mn-52m (metastable state of Mn-52) decays by positron emission and electron capture (98.295 %) populating the excited states of Cr-52, and by isomeric transition (1.705 %) to the ground state of Mn-52.

Le Mn-52m (état isomérique du Mn-52) se désintègre par capture électronique et par émission bêta plus (98,295 %) vers plusieurs états excités du Cr-52, et se désexcite par transition gamma (1,705 %) vers l'état fondamental du Mn-52.

2 Nuclear Data

$T_{1/2}(^{52m}\text{Mn})$	:	21,1	(2)	min
$T_{1/2}(^{52}\text{Mn})$	:	5,592	(3)	d
$Q^+(^{52m}\text{Mn})$	:	5089,7	(19)	keV
$Q^{IT}(^{52m}\text{Mn})$	:	377,749	(5)	keV

2.1 Electron Capture Transitions

	Energy (keV)	Probability (%)	Nature	lg ft	P_K	P_L	P_M
$\epsilon_{0,10}$	274,1 (19)	0,0049 (9)	Allowed	5,52	0,88219 (37)	0,10088 (26)	0,01574 (9)
$\epsilon_{0,8}$	1138,5 (21)	0,00069 (30)	Allowed	7,63	0,88523 (34)	0,09832 (23)	0,01529 (9)
$\epsilon_{0,7}$	1318,1 (19)	0,0083 (11)	Allowed	6,67	0,88536 (34)	0,09821 (23)	0,01527 (9)
$\epsilon_{0,6}$	1617,6 (19)	0,023 (8)	Allowed	6,42	0,88551 (34)	0,09809 (23)	0,01525 (9)
$\epsilon_{0,5}$	1928,0 (19)	0,071 (8)	Allowed	6,082	0,88561 (34)	0,09800 (23)	0,01523 (9)
$\epsilon_{0,4}$	2125,0 (19)	0,0085 (12)	Allowed	7,088	0,88566 (34)	0,09796 (23)	0,01522 (9)
$\epsilon_{0,2}$	2720,1 (21)	0,0030 (47)	2nd Forbidden	9,21	0,88532 (34)	0,09825 (23)	0,01527 (9)
$\epsilon_{0,1}$	3655,7 (19)	1,466 (11)	Allowed	5,3288	0,88586 (33)	0,09779 (23)	0,01519 (9)

2.2 β^+ Transitions

	Energy (keV)	Probability (%)	Nature	lg ft
$\beta_{0,8}^+$	116,6 (21)	0,00000083 (37)	Allowed	7,63
$\beta_{0,7}^+$	296,1 (19)	0,00039 (5)	Allowed	6,67
$\beta_{0,6}^+$	595,7 (19)	0,0132 (33)	Allowed	6,42
$\beta_{0,5}^+$	906,0 (19)	0,167 (8)	Allowed	6,082
$\beta_{0,4}^+$	1103,0 (19)	0,0381 (17)	Allowed	7,088
$\beta_{0,2}^+$	1698,2 (21)	0,017 (8)	2nd Forbidden	9,21
$\beta_{0,1}^+$	2633,7 (19)	96,474 (45)	Allowed	5,3288

2.3 Gamma Transitions and Internal Conversion Coefficients

	Energy (keV)	$P_{\gamma+ce}$ (%)	Multipolarity	α_K (10^{-4})	α_L (10^{-5})	α_M (10^{-6})	α_T (10^{-4})	α_π (10^{-4})
$\gamma_{1,0}(\text{Mn})$	377,749 (5)	1,705 (42)	E4	356 (5)	382 (6)	515 (8)	400 (6)	
$\gamma_{6,3}(\text{Cr})$	704,6 (2)	0,029 (9)	M1+E2	2,25 (4)	2,09 (4)	2,75 (5)	2,49 (5)	
$\gamma_{2,1}(\text{Cr})$	935,52 (10)	0,02 (1)	E2	1,657 (24)	1,536 (22)	2,02 (3)	1,83 (3)	
$\gamma_{3,1}(\text{Cr})$	1333,42 (30)	0,029 (10)	E2	0,730 (11)	0,674 (10)	0,887 (13)	1,174 (17)	0,367 (6)
$\gamma_{1,0}(\text{Cr})$	1434,083 (10)	98,288 (42)	E2	0,626 (9)	0,578 (8)	0,760 (11)	1,339 (19)	0,647 (9)
$\gamma_{4,1}(\text{Cr})$	1530,694 (18)	0,0462 (21)	M1+E2	0,546 (8)	0,504 (7)	0,663 (10)	1,593 (23)	0,989 (14)
$\gamma_{5,1}(\text{Cr})$	1727,65 (6)	0,216 (10)	M1+E2	0,396 (6)	0,364 (6)	0,480 (7)	1,88 (3)	1,441 (24)
$\gamma_{6,1}(\text{Cr})$	2038,02 (20)	0,0079 (14)	M1+E2	0,307 (11)	0,282 (11)	0,371 (14)	3,3 (4)	3,0 (4)
$\gamma_{7,1}(\text{Cr})$	2337,61 (15)	0,0069 (10)	M1+E2	0,236 (4)	0,217 (3)	0,286 (4)	4,25 (7)	3,99 (7)
$\gamma_{4,0}(\text{Cr})$	2964,777 (15)	0,00039 (30)	E2	0,1671 (24)	0,1534 (22)	0,202 (3)	7,86 (11)	7,68 (11)
$\gamma_{5,0}(\text{Cr})$	3161,73 (6)	0,0216 (30)	E2	0,1508 (22)	0,1385 (20)	0,182 (3)	8,68 (13)	8,51 (12)
$\gamma_{10,1}(\text{Cr})$	3381,61 (9)	0,0025 (5)	M1+E2	0,133 (3)	0,122 (3)	0,161 (4)	9,0 (6)	8,8 (6)
$\gamma_{7,0}(\text{Cr})$	3771,69 (15)	0,00177 (39)	E2	0,1149 (16)	0,1054 (15)	0,1387 (20)	11,03 (16)	10,91 (16)
$\gamma_{8,0}(\text{Cr})$	3951,2 (10)	0,00069 (30)	M1+E2	0,1055 (22)	0,0968 (20)	0,127 (3)	11,1 (7)	10,9 (7)
$\gamma_{10,0}(\text{Cr})$	4815,69 (9)	0,00247 (40)	E2+M3	0,0809 (13)	0,0742 (12)	0,0977 (16)	14,39 (21)	14,30 (21)

3 Atomic Data

3.1 Cr

ω_K	:	0,289	(5)
$\bar{\omega}_L$	:	0,0045	(9)
n_{KL}	:	1,508	(5)

3.1.1 X Radiations

	Energy (keV)	Relative probability
X_K		
$K\alpha_2$	5,40557	50,91
$K\alpha_1$	5,41479	100
$K\beta_1$	5,94677	} 20,31249
$K\beta_5''$	5,987	

	Energy (keV)	Relative probability
X _L		
L ℓ	0,5003	
L α	0,5729 - 0,57695	
L η	0,5102	
L β	0,57515 - 0,69748	
L γ	0,58496 - 0,58496	

3.1.2 Auger Electrons

	Energy (keV)	Relative probability
Auger K		
KLL	4,554 - 4,794	100
KLX	5,206 - 5,412	26,9
KXY	5,841 - 5,985	1,81
Auger L	0,4263 - 0,6920	

3.2 Mn

ω_K	:	0,321	(5)
$\bar{\omega}_L$	:	0,0047	(7)
n_{KL}	:	1,478	(4)

3.2.1 X Radiations

	Energy (keV)	Relative probability
X _K		
K α_2	5,88772	50,99
K α_1	5,89881	100
K β_1	6,49051	} 20,51954
K β_5''	6,5354	
X _L		
L ℓ	0,5576	
L α	0,6394 - 0,6404	
L η	0,5695	
L β	0,64636 - 0,7694	
L γ	0,65826 - 0,65826	

3.2.2 Auger Electrons

	Energy (keV)	Relative probability
Auger K		
KLL	4,953 - 5,210	100
KLX	5,671 - 5,895	27,2
KXY	6,370 - 6,532	1,85
Auger L	0,4725 - 0,7653	

4 Electron Emissions

		Energy (keV)	Electrons (per 100 disint.)
e _{AL}	(Cr)	0,4263 - 0,6920	0,1549 (17)
e _{AK}	(Cr)		
	KLL	4,554 - 4,794	} 1,003 (13)
	KLX	5,206 - 5,412	
	KXY	5,841 - 5,985	
e _{AL}	(Mn)	0,4725 - 0,7653	0,0922 (11)
e _{AK}	(Mn)		
	KLL	4,953 - 5,210	} 0,0396 (12)
	KLX	5,671 - 5,895	
	KXY	6,370 - 6,532	
ec _{1,0} T	(Mn)	371,210 - 377,749	0,0656 (19)
ec _{1,0} T	(Cr)	1428,094 - 1434,083	0,01316 (19)
$\beta_{0,8}^+$	max:	116,6 (21)	} 0,00000083 (37)
	avg:	52,0 (9)	
$\beta_{0,7}^+$	max:	296,1 (19)	} 0,00039 (5)
	avg:	125,6 (8)	
$\beta_{0,6}^+$	max:	595,7 (19)	} 0,0132 (33)
	avg:	249,9 (8)	
$\beta_{0,5}^+$	max:	906,0 (19)	} 0,167 (8)
	avg:	382,7 (8)	
$\beta_{0,4}^+$	max:	1103,0 (19)	} 0,0381 (17)
	avg:	468,9 (8)	
$\beta_{0,1}^+$	max:	2633,7 (19)	} 96,474 (45)
	avg:	1170,0 (9)	
$\beta_{0,2}^+$	max:	1698,2 (21)	} 0,017 (8)
	avg:	764,4 (10)	

5 Photon Emissions

5.1 X-Ray Emissions

		Energy (keV)	Photons (per 100 disint.)		
XL	(Cr)	0,5003 - 0,69748	0,00070 (14)		
XK α_2	(Cr)	5,40557	0,1212 (26)	}	K α
XK α_1	(Cr)	5,41479	0,238 (5)		
XK β_1	(Cr)	5,94677	0,0484 (11)	}	K' β_1
XK β_5''	(Cr)	5,987			K' β_2
XL	(Mn)	0,5576 - 0,7694	0,000344 (15)		
XK α_2	(Mn)	5,88772	0,00557 (19)	}	K α
XK α_1	(Mn)	5,89881	0,0109 (4)		
XK β_1	(Mn)	6,49051	0,00224 (8)	}	K' β_1
XK β_5''	(Mn)	6,5354			K' β_2

5.2 Gamma Emissions

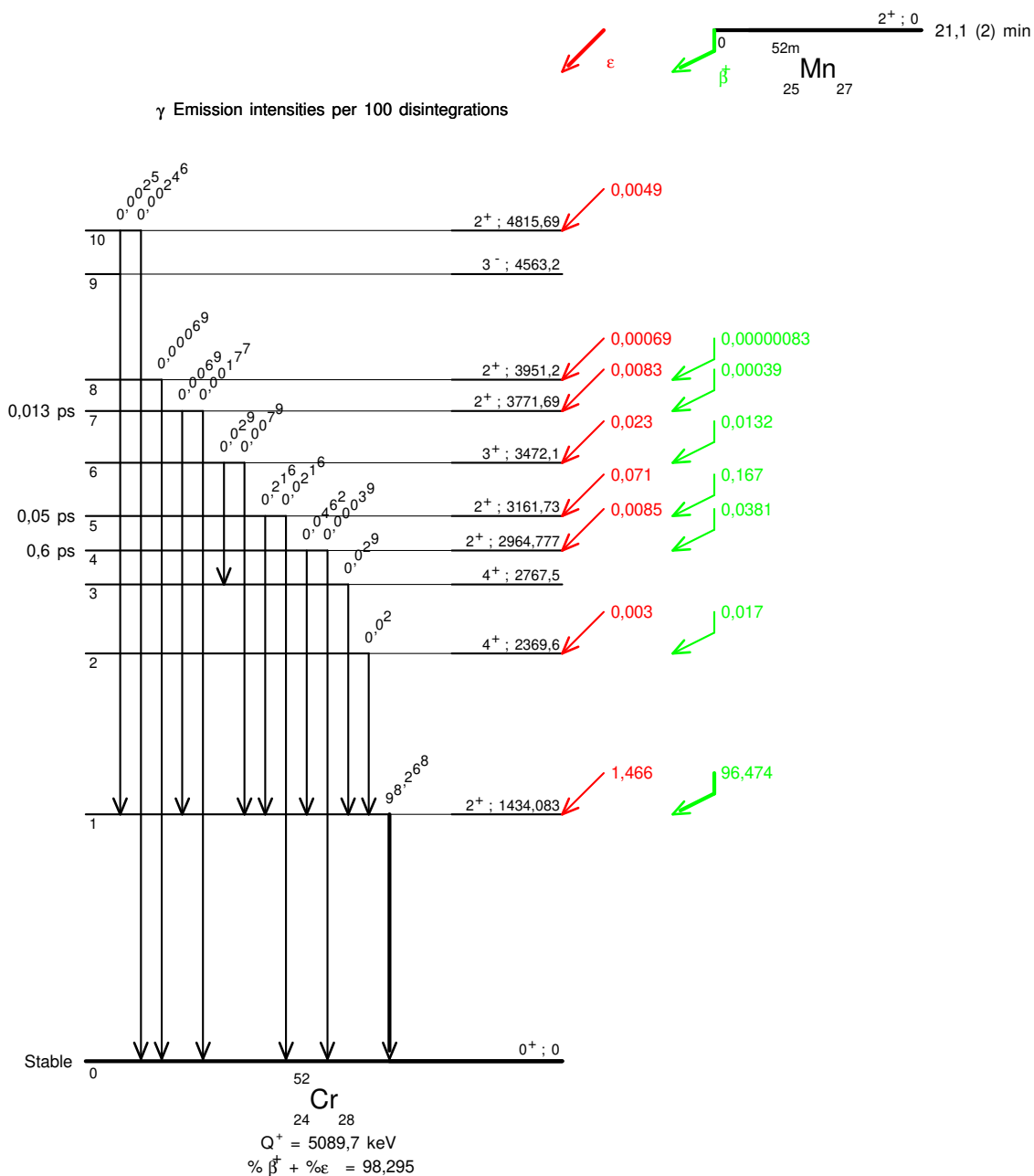
	Energy (keV)	Photons (per 100 disint.)
$\gamma_{1,0}(\text{Mn})$	377,749 (5)	1,639 (40)
$\gamma^\pm$	511	193,42 (9)
$\gamma_{6,3}(\text{Cr})$	704,6 (2)	0,029 (9)
$\gamma_{2,1}(\text{Cr})$	935,52 (10)	0,02 (1)
$\gamma_{3,1}(\text{Cr})$	1332,62 (1)	0,029 (10)
$\gamma_{1,0}(\text{Cr})$	1434,06 (1)	98,268 (42)
$\gamma_{4,1}(\text{Cr})$	1530,67 (1)	0,0462 (21)
$\gamma_{5,1}(\text{Cr})$	1727,53 (7)	0,216 (10)
$\gamma_{6,1}(\text{Cr})$	2038,0 (2)	0,0079 (14)
$\gamma_{7,1}(\text{Cr})$	2337,4 (2)	0,0069 (10)
$\gamma_{4,0}(\text{Cr})$	2965 (1)	0,00039 (30)
$\gamma_{5,0}(\text{Cr})$	3161,8 (1)	0,0216 (30)
$\gamma_{10,1}(\text{Cr})$	3381,5 (1)	0,0025 (5)
$\gamma_{7,0}(\text{Cr})$	3771,7 (2)	0,00177 (39)
$\gamma_{8,0}(\text{Cr})$	3951 (1)	0,00069 (30)
$\gamma_{10,0}(\text{Cr})$	4815,4 (2)	0,00246 (40)

6 Main Production Modes

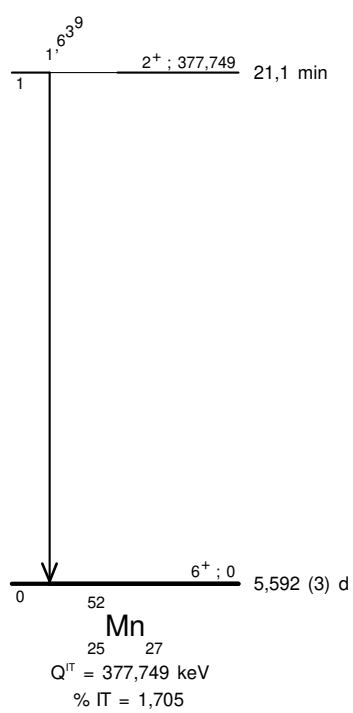
From Fe-52 decay.

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γ Emission intensities
per 100 disintegrations



^{52m}Mn – Comments on evaluation

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This evaluation was completed by early November 2020 and includes all literature published before this date.

Decay Scheme

^{52m}Mn decays 100% by electron capture (ϵ) and isomeric transition (IT) to excited levels of ⁵²Cr and to the ground state of ⁵²Mn, respectively. The IT branching ratio of 1.705 (42) % was adopted from the ⁵²Fe nuclear decay data evaluation published in the DDEP database (A. Luca, 2014, <http://www.lnhb.fr/nuclear-data/nuclear-data-table>). The isomer ^{52m}Mn is created within the decay of ⁵²Fe with an excitation energy of 377.749 (5) keV, according to the evaluation published by Yang and Huo (2015).

Q_{EC} value for ^{52m}Mn decay of 5089.7 (19) keV was calculated as the sum of the level excitation energy (2015Ya15) and the ⁵²Mn decay energy adopted from Wang *et al.* (2017Wa10).

The spins, parities and level energies are adopted from the most recent mass-chain evaluation published for A=52 (2015Ya15). The adopted spin and parity of the 4815.69-keV energy level of ⁵²Cr was 2⁺. The lifetimes of the excited states of ⁵²Cr were adopted from Adymov *et al.* (2011Ad14).

The decay scheme is expected to be complete assuming a direct decay to the 2369.6-keV level. In 1977Ya08, the authors did not observed any gamma rays that could populate the 2369.6-keV level while its gamma transition, emitting 935.5 keV photons, was clearly seen. They assumed a feeding from higher-energy levels, leading to an incomplete decay scheme. Close study of the 33 levels up to the Q-value of ^{52m}Mn (adopted levels from 2015Ya15) led the evaluator to the conclusion that this 2369.6-keV level can only be fed through a direct decay from the initial level in ^{52m}Mn. This conclusion is limited by the current knowledge of the ⁵²Cr levels. However, it is strongly supported by the observation of photons of similar or higher energies with much smaller intensities (e.g. 4815.4 keV with an absolute intensity of 0.002 46 %).

Half-life

Three experimental half-lives were found in the literature and were used to calculate the recommended value, according to the following table:

Reference	T _{1/2} (min)	T _{1/2} unc. (min)	Comments
1959Ju40	21.1	0.2	
1960Ka20	21	1	
1995Ir01	22.7	3.0	Measurements on bare ions (not neutral atoms)
Crit (χ^2)	4.6		
χ^2	0.15		
UWM	21.6	0.6	
LWM	21.1		
uc(WM)int. :	0.20		
uc(WM)ext. :	0.08		
Adopted:	21.1	0.2	

The adopted data set is consistent and the recommended half-life is the weighted mean of the three 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.

New half-life measurements are needed to confirm the most recent result, published by Irnich *et al.* (1995).

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 (2015Mo10, 2019Mo35).

There are eight electron capture transitions feeding the excited states of 1434.08 (the main EC transition), 2369.6, 2964.78, 3161.73, 3472.10, 3771.69, 3951.2 and 4815.69 keV respectively, and seven β^+ transitions, all of them in competition with the electron capture process. The maximum positron energy (2.6337 (19) MeV) is in good agreement with the experimental values measured by Katoh *et al.* (1960Ka20) of 2.61 (3) MeV, by Arbmán and Svartholm (1956Ar33) of 2.631 (15) MeV and by Osborne and Deutsch (1947Os01) of 2.66 (5) MeV respectively.

The probabilities of the electron capture transitions and the 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 1434.083 keV (⁵²Cr) is 97.940 (46) %. The BetaShape program was also used to calculate the log ft values for the EC and β^+ transitions.

The resulting 511-keV photon emission intensity is 193.42 (9) %.

Relative gamma emission probabilities, P_γ

Only two measurements of the gamma-ray energies and relative emission probabilities were found in the literature: Yaffe and Meyer, 1977Ya08, and Pakkanen, 1967Pa22:

	Yaffe and Meyer (1977)		Pakkanen (1967)	
(i,f)	E_γ	P_γ	E_γ	P_γ^{***}
(1,0)*	377.738 (5)	17.09 ± 0.15	377.8 (4)	17 ± 3
(6,3)	704.6 (2)	0.29 ± 0.09		
(2,1)	935.52 (1)**	0.2 ± 0.1		
(3,1)	1332.62 (1)**	0.3 ± 0.1		
(1,0)	1434.06 (1)	1000 ± 5	1434.3	1000
(4,1)	1530.67 (1)	0.47 ± 0.02	1529.6 (12)	0.8 ± 0.3
(5,1)	1727.53 (7)	2.2 ± 0.1	1727.1 (10)	2.0 ± 0.5
(6,1)	2038.0 (2)	0.08 ± 0.01		
(7,1)	2337.4 (2)	0.07 ± 0.01		
(4,0)	2965 (1)	0.004 ± 0.003		
(5,0)	3161.8 (1)	0.22 ± 0.03	3160.0 (17)	$0.3^{+0.2}_{-0.1}$
(10,1)	3381.5 (1)	0.025 ± 0.005		
(7,0)	3771.7 (2)	0.018 ± 0.004		
(8,0)	3951 (1)	0.007 ± 0.003		
(10,0)	4815.4 (2)	0.025 ± 0.004		

* The 377.738-keV gamma ray in the Table is the IT-decay process of Mn-52m directly to the ground state of Mn-52.

** The two uncertainties of 0.01 keV each were added by the evaluator.

*** The published values were multiplied by a factor of 10, to facilitate the comparison with the data set of Yaffe and Meyer (1977).

A reference intensity of 1000 was adopted for the emission probability of the 1434.06 (1) keV gamma ray (this gamma transition follows the ⁵²mMn electron capture and β^+ transitions populating the nuclear levels of ⁵²Cr).

The adopted γ -ray energies and relative emission probabilities are those given by Yaffe and Meyer in the Table above, with the exception of the γ -ray energy of the isomeric transition taken in 2015Ya15, consistently with the latest ⁵²Fe DDEP evaluation (A. Luca, 2014, <http://www.lnhb.fr/nuclear-data/nuclear-data-table>). A few very weak, yet possible γ -ray transitions were neglected in the present evaluation (e.g. 3129 keV). New accurate measurements of the γ -ray relative (and absolute) emission probabilities would be beneficial for improving the knowledge of the decay scheme.

Internal conversion coefficients

The adopted ICC are the theoretical values calculated by the BrIcc program (2008Ki07).

The main γ -ray transition is E2 (1434.06 keV).

Normalization Factor

The normalization condition requires that 98.295 (42) % of the transitions (β^+ , EC, γ - with the exception of the isomeric transition) in the decay of ^{52m}Mn populate the ground state of the ⁵²Cr daughter.

A normalization factor (*N*) of 0.098 255 (42) was deduced from the above, correcting the relative γ -ray emission probabilities by the corresponding ICC and taking the 1434 keV γ transition as a reference. Using this factor and the relative γ probabilities adopted above, the absolute γ -ray emission probabilities were calculated.

Atomic Data

The 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).

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

Data Consistency

The sum of all the energies involved (EC, γ , etc.), with the exception of the γ -ray isomeric transition, is 5089.9 (32) keV, which is in very good agreement with the Q_{EC} value: 5089.7 (19) keV. The same calculation for the isomeric transition gives an energy of 377.71 (22) keV, in excellent agreement with the transition energy 377.749 (5) keV.

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