$^{55}_{27}$Co$_{28}$

Evaluation of the decay data

Valery P. Chechev, Nikolay K. Kuzmenko

V.G. Khlopin Radium Institute, 28 Second Murinsky Ave, St. Petersburg, 194021, Russia

Xiaolong Huang

China Nuclear Data Center, China Institute of Atomic Energy, P.O.Box 275 (41), Beijing 102413, China

^{55}Co is used in reactor dosimetry as a product of the reaction ^{59}Co (n, 5n) ^{55}Co. The first DDEP evaluation was done by V.P. Chechev and N.K. Kuzmenko in 2016. The present revised evaluation was carried out in 2024 with all the literature available up to May 2024.

$^{55}_{27}Co_{28}$

1 Decay Scheme

^{55}Co decays 75,61 (43) % by β^+ emission and 24,39 (43) % by electron capture to the excited states of ^{55}Fe.

Le ^{55}Co se désintègre à 75,61 (43) % par émission β^+ et à 24,39 (43) % par capture électronique vers les niveaux excités du ^{55}Fe.

2 Nuclear Data

$T_{1/2}(^{55}Co)$	:	17,54	(4)	h
$T_{1/2}(^{55}Fe)$	:	2,75614	(41)	a
$Q^+(^{55}Co)$	:	3451,4	(3)	keV

2.1 Electron Capture Transitions

	Energy (keV)	Probability (%)	Nature	log ft	P_K	P_L	P_M
$\epsilon_{0,11}$	342,70 (42)	0,359 (19)	Allowed	5,70	0,88098 (31)	0,10191 (21)	0,01607 (9)
$\epsilon_{0,10}$	512,5 (5)	0,100 (7)	Allowed	6,61	0,88226 (31)	0,10084 (21)	0,01587 (9)
$\epsilon_{0,9}$	579,10 (36)	0,182 (12)	Allowed	6,46	0,88256 (31)	0,10059 (21)	0,01583 (9)
$\epsilon_{0,8}$	873,7 (5)	0,0441 (45)	Allowed	7,43	0,88331 (30)	0,09995 (21)	0,01572 (9)
$\epsilon_{0,7}$	1150,34 (37)	3,46 (18)	Allowed	5,78	0,88367 (30)	0,09965 (21)	0,01566 (9)
$\epsilon_{0,6}$	1239,53 (38)	1,95 (7)	Allowed	6,09	0,88375 (30)	0,09959 (21)	0,01565 (9)
$\epsilon_{0,5}$	1307,40 (42)	0,58 (6)	Allowed	6,66	0,8838 (3)	0,09954 (21)	0,01564 (9)
$\epsilon_{0,4}$	2042,95 (33)	10,85 (30)	Allowed	5,79	0,88415 (30)	0,09925 (21)	0,01559 (9)
$\epsilon_{0,3}$	2134,86 (33)	1,11 (22)	Allowed	6,82	0,88418 (30)	0,09923 (21)	0,01559 (9)
$\epsilon_{0,2}$	2520,11 (33)	5,69 (6)	Allowed	6,26	0,88427 (30)	0,09915 (21)	0,01557 (9)
$\epsilon_{0,1}$	3039,98 (37)	0,066 (22)	Unique 2nd Forbidden	11,45	0,88334 (30)	0,09994 (21)	0,01571 (9)

2.2 β^+ Transitions

	Energy (keV)	Probability (%)	Nature	log ft
$\beta^+_{0,7}$	128,34 (37)	0,00391 (21)	Allowed	5,78
$\beta^+_{0,6}$	217,53 (38)	0,0187 (7)	Allowed	6,09
$\beta^+_{0,5}$	285,40 (42)	0,0159 (16)	Allowed	6,66
$\beta^+_{0,4}$	1020,95 (33)	25,8 (10)	Allowed	5,79
$\beta^+_{0,3}$	1112,86 (33)	3,5 (9)	Allowed	6,82
$\beta^+_{0,2}$	1498,11 (33)	46,0 (5)	Allowed	6,26
$\beta^+_{0,1}$	2017,98 (37)	0,20 (9)	Unique 2nd Forbidden	11,45

2.3 Gamma Transitions and Internal Conversion Coefficients

	Energy (keV)	$P_{\gamma+ce}$ (%)	Multipolarity	α_K (10^{-3})	α_L (10^{-3})	α_M (10^{-3})	α_T (10^{-3})
$\gamma_{4,3}$(Fe)	91,91 (19)	2,0 (9)					
$\gamma_{3,2}$(Fe)	385,25 (18)	0,545 (36)	M1+0,49(42)%E2	1,108 (18)	0,1065 (18)	0,01468 (24)	1,23 (2)
$\gamma_{1,0}$(Fe)	411,42 (21)	1,115 (37)	M1+0,8(16)%E2	0,96 (4)	0,092 (4)	0,0127 (5)	1,06 (4)
$\gamma_{4,2}$(Fe)	477,16 (19)	19,89 (45)	M1+0,5(6)%E2	0,680 (11)	0,0651 (11)	0,00897 (15)	0,754 (12)
$\gamma_{2,1}$(Fe)	519,87 (25)	0,84 (8)	E2	1,082 (16)	0,1045 (15)	0,01437 (21)	1,202 (17)
$\gamma_{6,4}$(Fe)	803,42 (28)	1,97 (7)	M1+4,2(8)%E2	0,224 (4)	0,0213 (3)	0,00294 (5)	0,248 (4)
$\gamma_{5,3}$(Fe)	827,46 (33)	0,24 (5)					
$\gamma_{2,0}$(Fe)	931,29 (13)	74,75 (10)	M1+13,8(18)%E2	0,169 (3)	0,01611 (24)	0,00222 (4)	0,188 (3)
$\gamma_{7,3}$(Fe)	984,52 (25)	0,52 (9)					
$\gamma_{5,2}$(Fe)	1212,71 (33)	0,268 (28)					
$\gamma_{3,0}$(Fe)	1316,54 (13)	7,03 (8)	E2	0,0943 (14)	0,00897 (13)	0,001235 (18)	0,137 (2)
$\gamma_{7,2}$(Fe)	1369,77 (25)	2,94 (16)	E2	0,0867 (13)	0,00824 (12)	0,001134 (16)	0,1419 (20)
$\gamma_{4,0}$(Fe)	1408,45 (14)	16,8 (1)	E2	0,0818 (12)	0,00777 (11)	0,001070 (15)	0,1472 (21)
$\gamma_{9,3}$(Fe)	1555,76 (24)	0,048 (9)					
$\gamma_{10,3}$(Fe)	1622,36 (42)	0,044 (5)					
$\gamma_{11,3}$(Fe)	1792,16 (33)	0,083 (8)					
$\gamma_{9,2}$(Fe)	1941,01 (24)	0,016 (6)					
$\gamma_{5,0}$(Fe)	2144,0 (3)	0,095 (7)					
$\gamma_{11,2}$(Fe)	2177,41 (33)	0,270 (17)					
$\gamma_{8,0}$(Fe)	2577,7 (4)	0,0441 (45)					
$\gamma_{9,0}$(Fe)	2872,3 (2)	0,118 (5)					
$\gamma_{10,0}$(Fe)	2938,9 (4)	0,056 (5)					
$\gamma_{11,0}$(Fe)	3108,7 (3)	0,0058 (16)					

3 Atomic Data

3.1 Fe

ω_K	:	0,355	(4)
$\bar{\omega}_L$	:	0,0060	(6)
n_{KL}	:	1,447	(4)

3.1.1 X Radiations

		Energy (keV)	Relative probability
X_K			
	$K\alpha_2$	6,39091	51,07
	$K\alpha_1$	6,40391	100
	$K\beta_1$	7,05804	} 20,67
	$K\beta_5''$	7,1083	}
X_L			
	$L\ell$	0,617	
	$L\alpha$	0,7075 - 0,7084	
	$L\eta$	0,6306	
	$L\beta$	0,7148 - 0,8454	
	$L\gamma$	0,72841 - 0,72841	

3.1.2 Auger Electrons

	Energy (keV)	Relative probability
Auger K		
KLL	5,370 - 5,645	100
KLX	6,158 - 6,400	27,4
KXY	6,926 - 7,105	1,87
Auger L	0,5223 - 0,8421	

4 Electron Emissions

		Energy (keV)	Electrons (per 100 disint.)
e_{AL}	(Fe)	0,5223 - 0,8421	33,50 (28)
e_{AK}	(Fe)		
	KLL	5,370 - 5,645	13,93 (26)
	KLX	6,158 - 6,400	
	KXY	6,926 - 7,105	
$ec_{3,2\ T}$	(Fe)	378,14 - 385,25	0,000669 (46)
$ec_{1,0\ T}$	(Fe)	404,31 - 411,42	0,00118 (6)
$ec_{4,2\ T}$	(Fe)	470,05 - 477,16	0,01499 (41)
$ec_{2,1\ T}$	(Fe)	512,76 - 519,87	0,00101 (10)
$ec_{6,4\ T}$	(Fe)	796,31 - 803,42	0,000489 (19)
$ec_{2,0\ T}$	(Fe)	924,18 - 931,29	0,01405 (23)
$ec_{3,0\ T}$	(Fe)	1309,43 - 1316,54	0,000963 (18)
$ec_{7,2\ T}$	(Fe)	1362,66 - 1369,77	0,000417 (23)
$ec_{4,0\ T}$	(Fe)	1401,34 - 1408,45	0,002473 (38)
$\beta^+_{0,1}$	max:	2017,98 (37)	0,20 (9)
	avg:	934,72 (17)	
$\beta^+_{0,2}$	max:	1498,11 (33)	46,0 (5)
	avg:	647,25 (15)	
$\beta^+_{0,3}$	max:	1112,86 (33)	3,5 (9)
	avg:	475,23 (15)	
$\beta^+_{0,4}$	max:	1020,95 (33)	25,8 (10)
	avg:	434,82 (14)	
$\beta^+_{0,5}$	max:	285,40 (42)	0,0159 (16)
	avg:	122,56 (17)	
$\beta^+_{0,6}$	max:	217,53 (38)	0,0187 (7)
	avg:	94,65 (16)	
$\beta^+_{0,7}$	max:	128,34 (37)	0,00391 (21)
	avg:	57,76 (15)	

5 Photon Emissions

5.1 X-Ray Emissions

		Energy (keV)	Photons (per 100 disint.)	
XL	(Fe)	0,617 - 0,8454	0,174 (6)	
$XK\alpha_2$	(Fe)	6,39091	2,28 (5)	$K\alpha$
$XK\alpha_1$	(Fe)	6,40391	4,46 (10)	
$XK\beta_1$	(Fe)	7,05804	0,922 (22)	$K'\beta_1$
$XK\beta_5''$	(Fe)	7,1083		

5.2 Gamma Emissions

	Energy (keV)	Photons (per 100 disint.)
$\gamma_{4,3}$(Fe)	91,9 (2)	2,0 (9)
$\gamma_{3,2}$(Fe)	385,4 (3)	0,544 (36)
$\gamma_{1,0}$(Fe)	411,5 (3)	1,114 (37)
$\gamma_{4,2}$(Fe)	477,2 (2)	19,88 (45)
$\gamma^{\pm}$	511	151,1 (29)
$\gamma_{2,1}$(Fe)	520,0 (3)	0,84 (8)
$\gamma_{6,4}$(Fe)	803,7 (2)	1,97 (7)
$\gamma_{5,3}$(Fe)	827,0 (4)	0,24 (5)
$\gamma_{2,0}$(Fe)	931,1 (3)	74,74 (10)
$\gamma_{7,3}$(Fe)	984,6 (3)	0,52 (9)
$\gamma_{5,2}$(Fe)	1212,8 (3)	0,268 (28)
$\gamma_{3,0}$(Fe)	1316,6 (3)	7,03 (8)
$\gamma_{7,2}$(Fe)	1370,0 (3)	2,94 (16)
$\gamma_{4,0}$(Fe)	1408,5 (3)	16,8 (1)
$\gamma_{9,3}$(Fe)	1556,0 (4)	0,048 (9)
$\gamma_{10,3}$(Fe)	1622,3 (4)	0,044 (5)
$\gamma_{11,3}$(Fe)	1792,1 (3)	0,083 (8)
$\gamma_{9,2}$(Fe)	1940,6 (4)	0,016 (6)
$\gamma_{5,0}$(Fe)	2144,2 (6)	0,095 (7)
$\gamma_{11,2}$(Fe)	2177,6 (6)	0,270 (17)
$\gamma_{8,0}$(Fe)	2578,7 (6)	0,0441 (45)
$\gamma_{9,0}$(Fe)	2872,4 (6)	0,118 (5)
$\gamma_{10,0}$(Fe)	2938,9 (5)	0,056 (5)
$\gamma_{11,0}$(Fe)	3108,3 (6)	0,0058 (16)

6 Main Production Modes

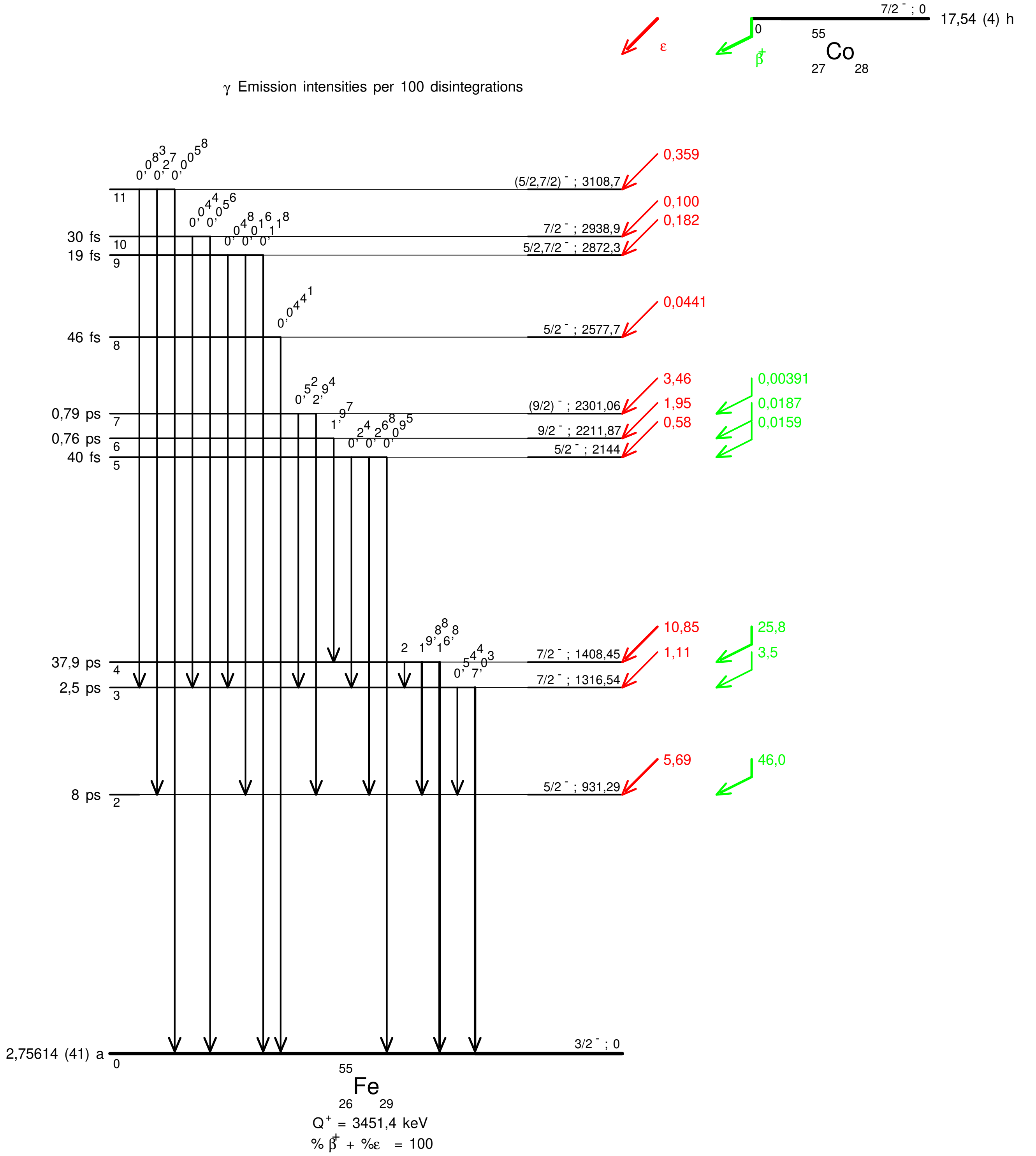
^{54}Fe(d,n)^{55}Co
Possible impurities: ^{56,57,58}Co

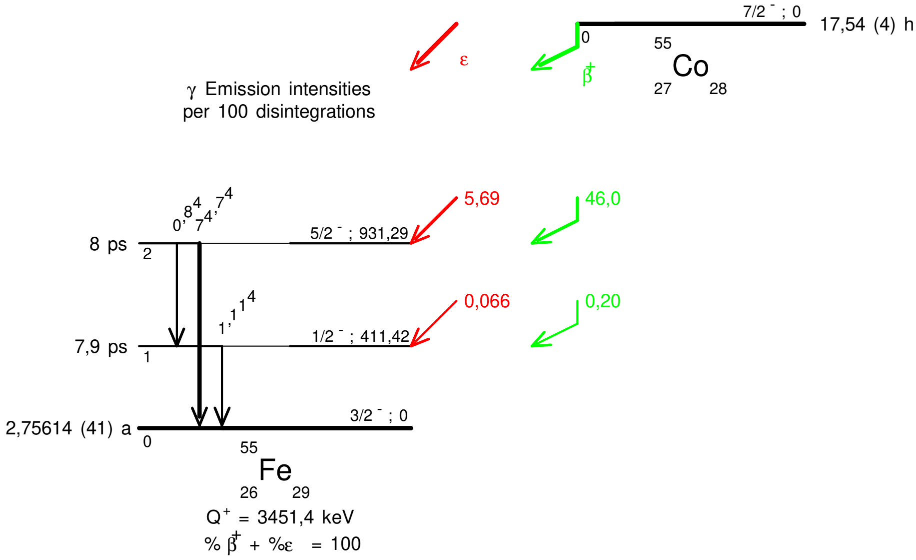
^{54}Fe(p,γ)^{55}Co
Possible impurities: ^{56,57,58}Co

^{56}Fe(p,2n)^{55}Co
Possible impurities: ^{56,57,58}Co

7 References

- G.Rudstam, P.C.Stevenson, R.L.Folger. Phys. Rev. 87 (1952) 358
  (Half-life)
- W.Haupt, D.Lange, H.G.Eckert, A.Flammersfeld. Z. Phys. 188 (1965) 256
  (Relative γ-ray emission probabilities)
- H.J.Fischbeck, F.T.Porter, M.S.Freedman, F.Wagner Jr., H.H.Bolotin. Phys. Rev. 150 (1966) 941
  (Relative γ-ray emission probabilities)
- P.J.Karol, J.M.Miller. Phys. Rev. 66 (1968) 1089
  (Half-life)
- A.Luukko, P.Paukku, S.Penttinen. Z. Phys. 239 (1970) 429
  (Relative γ-ray emission probabilities)
- L.D.McIsaac, R.J.Gehrke. ANCR-1088 (1972) 384
  (γ-ray energies and relative emission probabilities)
- S.J.Rothman, N.L.Peterson, W.K.Chen, J.J.Hines, R.Bastar, L.C.Robinson, L.J.Nowicki, J.B.Anderson. Phys. Rev. C9 (1974) 2272
  (Half-life)
- V.V.Babenko, I.N.Vishnevsky, V.A.Zheltonozhsky, E.E.Petrosyan, V.V.Trishin. Program and Theses, Proc. 25th Ann. Conf. Nucl. Spectrosc. Struc. At. Nuclei, Leningrad (1975) 55
  (γ-ray energies and relative emission probabilities)
- R.Michel, H.Weigel. Radochim. Acta 24 (1977) 50
  (Half-life, relative γ-ray emission probabilities)
- M.C.Lagunas-Solar, J.A.Jungerman. Int. J. Appl. Radiat. Isotop. 30 (1979) 25
  (Half-life)
- A.Grutter. Int. J. Appl. Radiat. Isotop. 33 (1982) 533
  (Half-life, relative γ-ray emission probabilities)
- E.Schönfeld, H.Janssen. Nucl. Instrum. Methods. Phys. Res. A369 (1996) 527
  (Atomic data, X-rays, Auger electrons)
- E.Schönfeld, H.Janssen. Appl. Radiat. Isot. 52 (2000) 595
  (Calculation of emission probabilities of X-rays and Auger electrons, Emission program)
- C.Dulieu, M.-M.Bé, V.Chisté. Proc. Intern. Conf. Nuclear Data for Science and Technology (2008) p.97
  (Saisinuc)
- T.Kibédi, T.W.Burrows, M.B.Trzhaskovskaya, P.M.Davidson, C.W.Nestor Jr. Nucl. Instrum. Methods Phys. Res. A589 (2008) 202
  (Theoretical ICC values, BrIcc computer program)
- J.Huo. Nuclear Data Sheets 109 (2008) 787
  (ENSDF evaluation, ^{55}Co decay scheme, ^{55}Fe level characteristics, γ-ray multipolarities)
- X.Mougeot. Appl. Rad. Isotopes 154 (2019) 108884
  (BetaShape program, electron capture theory)
- M.Wang, W.J.Huang, F.G.Kondev, G.Audi, S.Naimi. Chin. Phys. C45,3 (2021) 030003
  (Q-value)


γ Emission intensities per 100 disintegrations
7/2 - ; 0
17,54 (4) h
ε
β+
55 Co 27 28
(5/2,7/2) - ; 3108,7
7/2 - ; 2938,9
5/2,7/2 - ; 2872,3
5/2 - ; 2577,7
(9/2) - ; 2301,06
9/2 - ; 2211,87
5/2 - ; 2144
7/2 - ; 1408,45
7/2 - ; 1316,54
5/2 - ; 931,29
3/2 - ; 0
0,359
0,100
0,182
0,0441
3,46
1,95
0,58
10,85
1,11
5,69
0,00391
0,0187
0,0159
25,8
3,5
46,0
30 fs
19 fs
46 fs
0,79 ps
0,76 ps
40 fs
37,9 ps
2,5 ps
8 ps
2,75614 (41) a
55 Fe 26 29
Q+ = 3451,4 keV
% β+ + %ε = 100


7/2 - ; 0
17,54 (4) h
0
55
Co
27
28
ε
β+
γ Emission intensities
per 100 disintegrations
0,84
7,74
5,69
46,0
8 ps
2
5/2 - ; 931,29
1,11
0,066
0,20
7,9 ps
1
1/2 - ; 411,42
2,75614 (41) a
0
3/2 - ; 0
55
Fe
26
29
Q+ = 3451,4 keV
% β+ + %ε = 100

^{55}Co - Comments on evaluation of decay data

V.P. Chechev†, N.K. Kuzmenko (Original on December 2016)

V.G. Khlopin Radium Institute, 28 Second Murinsky Ave, St. Petersburg, 194021, Russia

and

X. Huang (Update on May 2024)

China Nuclear Data Center, China Institute of Atomic Energy, P.O. Box 275 (41), Beijing 102413, China

† Deceased.

^{55}Co is used in reactor dosimetry as a product of the reaction ^{59}Co (n, 5n) ^{55}Co. The first DDEP evaluation was done by V.P. Chechev and N.K. Kuzmenko in 2016. The present revised evaluation was carried out in 2024 with all the literature available up to May 2024.

1. Decay Scheme

^{55}Co decays 75.61 (43) % by positron (β^+) emission and 24.39 (43) % by electron capture (ε) to various excited levels of ^{55}Fe. The decay scheme is adopted from ENSDF evaluation by J. Huo (2008). A total of 23 γ-rays de-exciting 11 nuclear levels in ^{55}Fe have been reported. Except for the two strong 477-keV and 931-keV transitions, emission of conversion electrons for other γ-rays are very low. Pair production is possible for transitions with $E_\gamma \geq 1022$ keV. The Jπ values, level energies and γ-ray multipolarities are also from J. Huo (2008). The half-life of ^{55}Fe ground state is from the latest DDEP evaluation (P. Cassette, 2024).

The evaluators have normalized the ^{55}Co decay scheme assuming no (ε+β^+) feeding to the ^{55}Fe ground state. The electron capture and β^+ emission probabilities to excited states in ^{55}Fe were determined from γ-ray transition intensity balance at each level and theoretical ε/β^+ ratios calculated using the BETASHAPE program.

2. Nuclear Data

The Q value (3451.4 (3) keV), is from the AME 2020 atomic mass evaluation by Wang et al. (2021).

The experimental and recommended half-lives of ^{55}Co are given in Table 1.

Table 1. Experimental and recommended values of the ^{55}Co half-life

N	Reference	Half-life (hours)	Comments
1	Rudstam *et al*. (1952)	17.9 (3)	Geiger-Müller counter
2	Karol *et al*. (1968)	17.9	NaI scintillation counter Without uncertainty, *omitted*
3	Rothman *et al.* (1974)	17.54 (4)	Well-type NaI(Tl) scintillation counter, measurement duration – 10 half-lives
4	Michel *et al*. (1977)	17.7 (2)	Ge(Li) detector, measurement duration – 3 half-lives
5	Lagunas-Solar *et al*.(1979)	18.5 (2)	Ge(Li) detector, measurement duration – 3 half-lives *Omitted* as statistical outlier (on the Chauvenet's criterion)
6	Grutter (1982)	17.52 (4)	Two Ge(Li) detectors, measurement duration – 8 half-lives Original author's uncertainty of 0.03 was only a statistical error and has been increased by the evaluators to 0.04 to include a systematical error
	Recommended value	**17.54 (4)**	**LWM**

The value 2 has not been taken into account as it is without an uncertainty and was obtained only to control another experiment; it was not a specific half-life study. The value 5 has been rejected by the LWEIGHT computer program using a limitation of relative statistical weight method (LWM) and a Chauvenet's criterion for identification of statistical outliers.

The unweighted average of the remaining four values is 17.67 (9) hours. A weighted average of the remaining four values calculated by LWEIGHT is 17.537 h with the internal uncertainty of 0.028 h and the external uncertainty of 0.024 h. The ratio of the reduced χ^2 / $(\chi^2)_{crit}$ is 0.77/3.79 suggested adopting the weighted mean. The adopted uncertainty has been expanded to 0.040 to cover the smallest measured uncertainty. Thus, the recommended value of ^{55}Co half-life is **17.54 (4) hours.**

2.1. Electron Capture and β^+ Transitions

The electron capture and the β^+ emission energies have been computed using the Q value and ^{55}Fe level energies given in Table 2. The energies, spins, parities and half-lives of ^{55}Fe levels have been adopted from ENSDF evaluations of J. Huo (2008). It is noted that the asymmetric uncertainties of half-lives in ^{55}Fe levels have been symmetrized following AME method. The half-life of ^{55}Fe ground state is from the latest DDEP evaluation (P. Cassette, 2024).

The electron capture P_ε and β^+ emission probabilities P_{β^+} to excited states in ^{55}Fe were determined from γ-ray transition intensity balance at each level and theoretical ε/β^+ ratios calculated using the BetaShape program (X. Mougeot, 2019) (Table 2).

Table 2. ^{55}Fe levels populated in the ^{55}Co decay

Level	Energy (keV)	Spin and parity	Half-life	$P_{\beta+}$ (×100)	P_ε (×100)	$P_{\varepsilon+\beta+}$ (×100)
0	0.0	3/2–	2.75614 (41) y			
1	411.42 (21)	1/2–	7.9 (46) ps	0.20 (9)	0.066 (22)	0.27 (9)
2	931.29 (13)	5/2–	8 (3) ps	46.0 (5)	5.69 (6)	51.7 (5)
3	1316.54 (13)	7/2–	2.5 (11) ps	3.5 (9)	1.11 (22)	4.6 (9)
4	1408.45 (14)	7/2–	37.9 (17) ps	25.8 (10)	10.85 (30)	36.7 (10)
5	2144.0 (3)	5/2–	40 (10) fs	0.0159 (16)	0.58 (6)	0.60 (6)
6	2211.87 (24)	9/2–	0.76 (21) ps	0.0187 (7)	1.95 (7)	1.97 (7)
7	2301.06 (21)	(9/2)	0.79 (36) ps	0.00391 (21)	3.46 (18)	3.46 (18)
8	2577.7 (4)	5/2–	46 (6) fs		0.0441 (45)	0.0441 (45)
9	2872.3 (2)	5/2–, 7/2–	19 (6) fs		0.182 (12)	0.182 (12)
10	2938.9 (4)	7/2–	30 (9) fs		0.100 (7)	0.100 (7)
11	3108.7 (3)	5/2–, 7/2–			0.359 (19)	0.359 (19)

The log *ft* values, the fractional atomic shell electron capture probabilities and the average β+ energies have been calculated with the BetaShape program.

2.2. Gamma Transitions and Internal Conversion Coefficients

The γ-ray transition probabilities P(γ+ce) were calculated from the γ-ray emission probabilities, total conversion coefficients, and adopted internal-pair-formation coefficients.

The adopted ICC(s) and internal-pair-formation coefficients, α_π, are theoretical values interpolated by the BrIcc computer program based on BrIccFO approximation (T. Kibédi *et al.* 2008). The γ-ray multipolarities and mixing ratios δ have been taken from J. Huo (2008).

3. Atomic Data

The SAISINUC software has been used to determine the atomic data (fluorescence yields, X-ray energies and relative probabilities, and Auger electrons energies and relative probabilities).

4. Electron and Pair Emissions

The energies of the conversion electrons have been obtained from the γ-ray transition energies and the electron binding energies.

The absolute emission probabilities of the conversion electrons have been deduced using recommended Pγ and ICC values.

The absolute emission probabilities of K and L Auger electrons have been calculated using the EMISSION computer program (E. Schönfeld *et al.* 2000) and atomic data from E. Schönfeld *et al.* (1996).

The number of electron-positron pairs per 100 disintegrations have been obtained using the adopted α_π values.

5. Photon Emissions

5.1. X-ray Emissions

The absolute emission probabilities of Fe KX- and LX- rays have been calculated using the EMISSION computer program (E. Schönfeld et al. 2000).

5.2. γ-ray energies

There are five measurements of γ-ray energies for ^{55}Co decay. The experimental and evaluated γ-ray energies for ^{55}Co are given in Table 3.

The evaluator selected all experimental data to perform a statistical processing with the LWEIGHT program and found that the weighted means are very close to the measurements of V.V. Babenko et al. (1975) which measured uncertainties are very small. No detailed information is provided except the measured values. H.J. Fischbeck *et al.* (1966) mentioned some non-linearity problems in the energy calibration above 1408 keV. This was also most probably the case for L.D. McIsaac and R.J. Gehrke (1972), which could explain the 8-10 keV shift in these two datasets. The γ-ray energies from R. Michel *et al.* (1977) are in very good agreement with the calculated values from the level energies, taking into account the recoil energy, using ENSDF evaluations by J. Huo (2008). Therefore, the present adopted γ-ray energies are directly taken from R. Michel *et al.* (1977), not from the LWEIGHT weighted means.

Table 3. Measured and recommended values of γ-ray energies (in keV) for ^{55}Co ε decay

Fischbeck (1966)	Luukko (1970)	McIsaac (1972)	Babenko (1975)	Michel (1977)	**Adopted**
91.97 (10)	91.8 (3)		92.00 (3)	91.9 (2)	**91.9 (2)**
385.2 (1)	385.0 (3)	385.2 (4)	385.16 (3)	385.4 (3)	**385.4 (3)**
411.4 (2)	411.0 (3)	411.1 (5)	411.37 (3)	411.5 (3)	**411.5 (3)**
477.2 (1)	477.2 (2)	477.29 (20)	477.10 (4)	477.2 (2)	**477.2 (2)**
520.0 (2)	520.3 (5)		519.55 (8)	520.0 (3)	**520.0 (3)**
803.8 (3)	803.8 (3)		803.58 (3)	803.7 (2)	**803.7 (2)**
	827.5 (5)		827.33 (6)	827.0 (4)	**827.0 (4)**
931.1 (2)	931.5 (3)	931.27 (15)	930.84 (4)	931.1 (3)	**931.1 (3)**
	984.5 (7)		984.09 (6)	984.6 (3)	**984.6 (3)**
	1213.1 (5)		1212.38 (9)	1212.8 (3)	**1212.8 (3)**
1316.4 (2)	1316.7 (3)	1316.39 (30)	1315.97 (8)	1316.6 (3)	**1316.6 (3)**
1369.7 (2)	1370.0 (3)	1369.75 (20)	1369.26 (9)	1370.0 (3)	**1370.0 (3)**
1408.3 (2)	1408.7 (3)	1408.55 (10)	1407.94 (9)	1408.5 (3)	**1408.5 (3)**
	1555.4 (7)	1576.4 (2)	1556.38 (10)	1556.0 (4)	**1556.0 (4)**
1632.3 (20)			1622.82 (11)	1622.3 (4)	**1622.3 (4)**
1800.7 (20)	1792.3 (7)		1792.29 (9)	1792.1 (3)	**1792.1 (3)**
1949.0 (30)				1940.6 (4)	**1940.6 (4)**
2152.7 (20)	2143.6 (7)	2035.2 (5)	2143.30 (9)	2144.2 (6)	**2144.2 (6)**
2186.7 (20)	2176.8 (5)	2180.41 (30)	2177.45 (9)	2177.6 (6)	**2177.6 (6)**
2589.5 (20)	2578.2 (5)	2231.43 (20)	2578.53 (8)	2578.7 (6)	**2578.7 (6)**
2881.3 (20)	2871.9 (7)	2250.9 (10)	2872.35 (9)	2872.4 (6)	**2872.4 (6)**
2947.3 (20)	2939.0 (5)		2938.94 (16)	2938.9 (5)	**2938.9 (5)**
3116.5 (30)	3108.6 (7)		3108.24 (18)	3108.3 (6)	**3108.3 (6)**

5.3. γ-ray emission probabilities

The measured γ-ray relative intensities and their evaluated (adopted) values are listed in Table 4. The evaluators analyzed the work of A. Grutter (1982) and have added a 2% systematic uncertainty component to the total uncertainty of measurements in R. Michel *et al.* (1977) to account for uncertainty in the detector efficiency due to using calibration sources. Statistical processing has been performed with the LWEIGHT computer program.

The evaluator selected all experimental data to perform a statistical processing with the LWEIGHT program. The weighted mean strongly depends on the experimental data of V.V. Babenko *et al.* (1975). If a systematic uncertainty component of 2% is added to the data of V.V. Babenko *et al.* (1975), the weighted averages are still close to the data of V.V. Babenko *et al.* (1975). As no detailed information is provided except the measured values, the data from V.V. Babenko *et al.* (1975) have been omitted. Meanwhile, the measurements of W. Haupt *et al.* (1965)

and L.D. McIsaac *et al.* (1972) have been also omitted due to their poor consistency with the results of R. Michel *et al.* (1977) and A. Grutter (1982).

Table 4. ^{55}Co relative γ-ray emission probabilities, experimental and evaluated data

	E_γ (keV)	Haupt (1965)*	Fischbeck (1966)*	Luukko (1970)*	McIsaac (1972)	Babenko (1975)*	Michel (1977)*	Grutter (1982)	**LWM**
$\gamma_{4,3}$	**91.9**	0.69 (21)	4.1 (6)	3.6 (7)		3.20 (8)	1.55 (9)	1.64 (9)	**2.7 (12)@**
$\gamma_{3,2}$	**385**		0.90 (28)	0.80 (27)	2.9 (6)	0.68 (3)	0.72 (5)		**0.728 (48)**
$\gamma_{1,0}$	**411**	1.63 (3)	1.24 (42)	1.33 (27)	2.3 (5)	1.25 (3)	1.43 (9)	1.53 (6)	**1.490 (49)**
$\gamma_{4,2}$	**477**	15.1 (45)	22.2 (17)	27.1 (20)	29 (3)	24.2 (1)	26.9 (19)	27.4 (8)	**26.6 (6)**
$\gamma_{2,1}$	**520**		1.23 (41)	1.33 (40)		1.12 (4)	1.09 (12)		**1.12 (11)**
$\gamma_{6,4}$	**803**	3.1 (2)	2.44 (33)	2.80 (30)		2.31 (4)	2.49 (17)	2.70 (12)	**2.63 (9)**
$\gamma_{5,3}$	**827**			0.41 (13)		0.28 (4)	0.28 (8)		**0.32 (7)**
$\gamma_{2,0}$	**931**	100	100	100	100	100	100	100	**100**
$\gamma_{7,3}$	**984**	1.2 (4)		0.67 (40)		1.11 (4)	0.69 (13)		**0.69 (12)**
$\gamma_{5,2}$	**1212**			0.43 (10)		0.27 (3)	0.347 (40)		**0.358 (37)**
$\gamma_{3,0}$	**1316**	8.1 (9)	9.8 (13)	9.5 (10)	8.3 (12)	9.39 (4)	9.45 (13)	9.20 (25)	**9.40 (11)**
$\gamma_{7,2}$	**1370**	5.3 (5)	4.1 (6)	4.00 (44)	3.7(7)	4.25 (2)	3.87 (29)		**3.94 (22)**
$\gamma_{4,0}$	**1408**	16.8 (9)	25.0 (20)	22.0 (18)	23 (3)	22.0 (1)	22.53 (13)	21.3 (6)	**22.48 (13)**
$\gamma_{9,3}$	**1556**			0.093 (40)		0.79 (1)	0.061 (13)		**0.064 (12)**
$\gamma_{10,3}$	**1622**		0.055 (19)			0.065 (6)	0.060 (7)		**0.059 (7)**
$\gamma_{11,3}$	**1792**		0.109 (15)	0.133 (40)		0.117 (7)	0.109 (17)		**0.111 (11)**
$\gamma_{9,2}$	**1940**		0.10 (5)				0.019 (8)		**0.021 (8)**
$\gamma_{5,0}$	**2144**		0.136 (16)	0.147 (28)		0.16 (1)	0.120 (11)		**0.127 (9)**
$\gamma_{11,2}$	**2177**		0.341 (33)	0.373 (44)		0.77 (1)	0.39 (5)		**0.361 (23)**
$\gamma_{8,0}$	**2578**		0.068 (28)	0.067 (14)		0.89 (1)	0.057 (7)		**0.059 (6)**
$\gamma_{9,0}$	**2872**		0.164 (19)	0.160 (15)		0.172 (5)	0.157 (8)		**0.158 (7)**
$\gamma_{10,0}$	**2938**		0.078 (9)	0.067 (14)		0.072 (4)	0.076 (13)		**0.075 (7)**
$\gamma_{11,0}$	**3108**		0.0082 (41)	0.011 (5)		0.011 (2)	0.0067 (27)		**0.0078 (21)**

*: Renormalized by evaluator to Iγ(931 keV) = 100%

@：LWEIGHT adopted the unweighted mean and expanded uncertainty to 1.2.

The present adopted γ-ray relative intensities are from the weighted average of the measured values of H. J. Fischbeck *et al.* (1966), A. Luukko *et al.* (1970), R. Michel *et al.* (1977) and A. Grutter (1982) calculated by LWEIGHT and the ratio of the reduced χ^2 / $(\chi^2)_{crit}$ is considered. The adopted uncertainties are standard deviations, but are never lower than the smallest experimental uncertainty.

The γ-ray emission probabilities are calculated based on the adopted γ-ray relative intensities in Table 4 and normalization factor N. Using ^{55}Co decay scheme and assuming no (ε+β^+) feeding to ^{55}Fe ground state, i.e. Σ [I(γ+ce) to ground state] = 100%, N is calculated to be 0.7474 (10).

The recommended γ-ray emission probabilities are the adopted γ-ray relative intensities in Table 4 multiplied by 0.7474 (10).

The annihilation radiation emission probability ($I_{\gamma\pm}$), without the correction factor for the annihilation-in-flight process in the medium, are deduced by $2 \times (\Sigma P_{\beta+} + \Sigma I_{\gamma\pm}) = 151.1$ (29) %.

6. Energy Conservation

The total decay energy of 3450 (18) keV, obtained with the SAISINUC software (C. Dulieu *et al.* 2008) from the current evaluated data and decay scheme, is in agreement with the adopted value of 3451.4 (3) keV by Wang *et al.* (2021), indicates that decay scheme is complete and confirm the reliability of the current evaluation.

7. References

- G. Rudstam, P.C. Stevenson, R.L. Folger. Phys. Rev. 87, 358(1952) [Half-life]
- W. Haupt, D. Lange, H.G. Eckert, A. Flammersfeld. Z. Physik 188, 256 (1965) [Relative γ-ray emission probabilities]
- H.J. Fischbeck, F.T. Porter, M.S. Freedman, F. Wagner, Jr., H.H. Bolotin. Phys. Rev. 150, 941 (1966) [Relative γ-ray emission probabilities]
- P. J. Karol, J. M. Miller. Phys. Rev. 66, 1089 (1968) [Half-life]
- A. Luukko, P. Paukku, S. Penttinen. Z. Phys. 239, 429 (1970) [Relative γ-ray emission probabilities]
- L.D. McIsaac, R.J. Gehrke. ANCR-1088, p. 384 (1972) [γ-ray energies and relative emission probabilities]
- S.J. Rothman, N.L. Peterson, W.K. Chen, J.J. Hines, R. Bastar, L.C. Robinson, L.J. Nowicki, J.B. Anderson. Phys. Rev. C9, 2272 (1974) [Half-life]
- V.V. Babenko, I.N. Vishnevsky, V.A. Zheltonozhsky, E.E. Petrosyan, V.V. Trishin. Program and Theses, Proc. 25th Ann. Conf. Nucl. Spectrosc. Struc. At. Nuclei, Leningrad , p. 55 (1975) [γ-ray energies and relative emission probabilities]
- R. Michel, H. Weigel. Radochim. Acta 24, 50 (1977) [Half-life, relative γ-ray emission probabilities]
- M.C. Lagunas-Solar, J.A. Jungerman. Int. J. Appl. Radiat. Isotop. 30, 25 (1979) [Half-life]
- A. Grutter. Int. J. Appl. Radiat. Isotop. 33, 533(1982) [Half-life, relative γ-ray emission probabilities]

- E. Schönfeld, H. Janssen. Nucl. Instrum. Methods. Phys. Res. A 369, 527 (1996) [Atomic data, X- rays, Auger electrons]

- E. Schönfeld, H. Janssen. Appl. Radiat. Isot. 52, 595 (2000) [Calculation of emission probabilities of X-rays and Auger electrons, EMISSION program]

- C. Dulieu, M.-M. Bé, V. Chisté, Proc. Intern. Conf. Nuclear Data for Science and Technology p.97 (2008) [SAISINUC]

- T. Kibédi, T.W. Burrows, M.B. Trzhaskovskaya, P.M. Davidson, C.W. Nestor Jr. Nucl. Instrum. Methods Phys. Res. A 589, 202 (2008) [Theoretical ICC values, BRICC computer program]

- J. Huo. Nuclear Data Sheets 109, 787 (2008) [ENSDF evaluation, ^{55}Co decay scheme, ^{55}Fe level characteristics, γ-ray multipolarities]

- X. Mougeot. Appl. Radiat. Isot. 154, 108884 (2019) [BETASHAPE program, electron capture theory]

- M. Wang, W.J. Huang, F.G. Kondev, G. Audi, S. Naimi. Chin. Phys. C 45, 3, 030003 (2021) [Q-value]

- P. Cassette. DDEP evaluation of ^{55}Fe decay (2024) [Half-life]