^{131}I – Comments on evaluation of decay data by V. Chisté and M. M. Bé

The first evaluation was done in 2002; it has been updated in December 2013. Literature available by this date was included.

1) Decay Scheme

^{131}I disintegrates by β^- emission via excited levels of ^{131}Xe, including the isomeric state ^{131m}Xe ($T_{1/2}$ = 11,962 (20) d).
The state of ideal balance, where the activity of ^{131}I is equal to the activity of ^{131m}Xe, is for *tm* = 14,04 (9) days:

$$tm = \frac{1{,}4427 \times T_{1/2}(^{131}I) \times T_{1/2}(^{131m}Xe) \times \ln\left(T_{1/2}(^{131m}Xe)/T_{1/2}(^{131}I)\right)}{T_{1/2}(^{131m}Xe) - T_{1/2}(^{131}I)}$$

The decay of ^{131m}Xe interferes with the decay of ^{131}I only through the 163,9 keV gamma line. For this line, the gamma emission intensity is given, and is only valid, at *tm* (see above).

2) Nuclear Data

The Q value is from Wang *et al.* (2012Wa38).
Level energies, half-lives, spins and parities are from Yu. Khazov *et al*. (2006Kh09).

The measured ^{131}I half-life values are, in days:

$T_{1/2}$

Reference	Value (d)	Comments
Livingood (1938Li05)	8,0 (2)	
Sreb (1951Sreb)	8,1409 (62)	
Sinclair (1951Si25)	8,04 (4)	
Lockett (1953Lo09)	8,06 (2)	
Seliger (1953Se28)	8,075 (22)	
Bartholomew (1953Ba10)	8,05 (1)	
Burkinshaw (1958Bu14)	8,054 (10)	
Keene (1958Ke26)	8,067 (7)	
Yakovleva (1967Ya02)	8,05 (6)	
Kemeny (1968Ke05)	8,04 (4)	
Rupp (1970Ru**)	8,026 (7)	Mean of three values
Zoller (1971Zo02)	8,117 (12)	
Emery (1972Em01)	8,040 (1)	Other result: 8,048 (16)
Karsten (1974Ka37)	8,031 (4)	
Lagoutine (1978La21)	8,020 (3)	
Houtermans (1980Ho17)	8,0213 (9)	

Reference	Value (d)	Comments
Hoppes (1982HoZF)	8,020 (2)	Superseded by 1992Un01
Walz (1983Wa26)	8,0207 (1)	Superseded by 2004Sc04
Unterweger (1992Un01)	8,0197 (22)	Superseded by 2012Fi12
da Silva (2004Da05)	7,999 (9)	
Schrader (2004Sc04)	8,0252 (6)	
Fitzgerald (2012Fi12)	8,0196 (22)	Superseded by 2014Un**
Unterweger (2014Un**)	8,020 (9)	
Crit (χ^2)	3,3	
χ^2 /(n-1)	4,6	
UWM	8,0234	
LWM	8,0233	
uc(WM)int. :	0,0006	
uc(WM)ext. :	0,0012	
Adopted:	**8,0233 (19)**	

The half-life weighted average was calculated by the Lweight program (version 3).
The set of the 16 values (not superseded) is discrepant with a χ^2 /(n-1) = 19,1; the unweighted mean of 8,037 (12) *d* would be chosen.

Only the six most recent values (1974Ka37, 1978La21, 1980Ho17, 2004Da05, 2004Sc04, 2014Un**) were included in the statistical processing. The da Silva *et al.* (2004Da05) value is rejected by the Lweight program, based on the Chauvenet's criterion. The program Lweight 3 increased the uncertainty of the 2004Sc04 value from 0,0006 to 0,00084 in order to reduce its relative weight to 50 %.

The adopted value is the weighted mean: *8,0233 d*, with an uncertainty of *0,0019 d*, expanded so range includes the most precise value of Schrader (2004Sc04).

2.1) β^- Transitions

The β^- probabilities and the associated uncertainties were deduced from γ transition probability balance at each level of the decay scheme, assuming no β^- transition to the ground state. The values of *lg ft* were calculated with the program LOGFT for the Allowed, 1st Forbidden and 1st Unique Forbidden transitions.

2.2) Gamma Transitions

Probabilities

The transition probabilities were derived from the gamma emission intensities and the internal conversion coefficients.
Early experiments showed evidence for a weak β branch populating the 163 keV level and, that the following on isomeric transition goes directly to the ground state with a probability in the range 0,5 % - 1 %, see Bergström (1952Be55) and references therein. Meyer *et al.* (1974Me21) carried out a specific experiment and determined the total population of the 163 keV level to be 1,086 (7) %.

Mixing ratios and internal conversion coefficients

The adopted ICC(s) are the theoretical values interpolated by the BrIcc program (2008Ki07) from the tables of Band *et al.* (2002Ba85), accepting the "frozen orbital (no hole)" approximation.
The 163 keV transition is of M4 character, see ^{131m}Xe Comments for details.

For the 177, 272, 318, 324, 325, 364, 404 and 722 keV gamma transitions, which are all of M1+E2 character, the adopted δ (mixing ratio) are from the Krane's evaluation (1977Kr13) of experimental values obtained from angular distribution and correlation data.

For the **364 keV** gamma transition, several values of δ were found in the literature, as shown in the following table with the corresponding theoretical α_T coefficient:

Reference	Value of δ	Theoretical α_T
Johnson *et al.* – Phys. Rev. 120(1960)1777	-6,7 (5)	0,0227 (7)
Daniel *et al.* – Z. Phys. 179(1964)62	-4,7 (+4 -2)	0,0228 (4)
Langhoff– Nucl. Phys. A158(1970)657	-3,4 (5)	0,0228 (4)
Krane *et al.* – Phys. Rev. C5(1972)1671	-3,3 (6)	0,0228 (4)
Koene and Postman – Nucl. Phys. A219(1974)563	4,53 (12)	0,0228 (4)
Irving *et al.* – J. Phys. G5(1979)1595	3,8 (3)	0,0228 (4)
Krane - Atomic Data and Nuclear Data Tables 19(1977)363	-4,53 (11) (adopted value)	0,0228 (4)

It can be shown that the value of δ has a weak influence on the α_T value.
The corresponding theoretical α_K value of 0,0190 (3) is consistent with the measured values of 0,021 (Haskins and Kurbatov, 1952Ha**) and 0,0174 (Wolfson *et al.*, 1962Wo09).

For the **325 keV** gamma transition, a value of δ (= -4,4 (16)) measured by Koene *et al.* (1975Ko15) is not close to the adopted one (δ = -0,8 (7)) from Krane's evaluation which was derived from Bargholtz *et al.* (1976Ba42), and the two resulting α_K values are 0,0267 (4) and 0,0277 (8), respectively. They are not consistent with the measured by Graeffe and Walters (1967Gr05) α_K = 0,0236 (28) and Hargrove (1963Ha08) = 0,03. The uncertainties on the theoretical ICCs (with δ = -0,8 (7)) are enlarged to 3 % in the final tables.

For the **404 keV** gamma transition, values of δ (= -8,1 (+7,1 ; -4,3)) from Irving (1979Ir01) and $0,2 \leq \delta \leq 2,0$ from Koene and Postman (1974Ko02) were found in the literature. The Krane's recommendation is: δ = +1,0 (+10, -8).
The interpolated theoretical α_T for this δ is 0,0177 (12) .

For the **722 keV** gamma transition, the following values of δ were found in the literature:

Reference	Value of δ	Theoretical α_T
Koene and Postman – Nucl. Phys. A219(1974)563	0,207 (5)	0,00451 (7)
Irving *et al.*– J. Phys. G5(1979)1595	-0,12 (+5, -2)	0,00454 (7)
Krane - Atomic Data and Nuclear Data Tables 19(1977)363	0,207 (5) (adopted value)	0,00451 (7)

The theoretical α_K = 0,00390 (6) value can be compared with the measured α_K values of 0,0034 (Haskins) and 0,0038 (1963Ha08). The value of 0,0028 (30) from Bell (1952Be95) is consistent within the uncertainty limits.

For the other transitions, measurements aren't precise, and only ranges of values are given for δ. But some values were published for the ICCs.

For the **80 keV** gamma transition, the theoretical values of α_K and α_L interpolated for a M1 character are consistent with the experimental results. A small contribution of E2 character can exist. An uncertainty of 3 % has been adopted in the final tables.

Reference	ICC, α_K	Multipolarity	Theoretical ICC
Bell (1952Be95)	1,73 (20)	M1	α_K = 1,32 (4)
Jungclausen (1963Ju02)	1,33 (16)		
Graeffe (1967Gr05)	1,2 (3)		
Suri (1970SuZQ)	1,31 (18)		
Hargrove (1963Hr08)	1		
Daniel (1964Da19)	α_L = 0,17 (2)	M1	α_L = 0,175 (5)

For the **503 keV** gamma transition, an E2 character is adopted.

Reference	ICC, α_K	Multipolarity	Theoretical α_K
Graeffe (1967Gr05)	0,0085 (13)	E2	0,00748 (11)
Hargrove (1963Hr08)	0,006		

The **284** and **636 keV** transitions were found of E2 character (1960Jo11, 1963Ha08 1970Be46, 1970SuZQ, 1979Ir01).
Measured α_K values for the 284 keV: 0,052 (1952Ha**) and 0,036 (1963Hr08) for the 284 keV, theoretical value α_K = 0,0408 (6).
Several results were published for the 636 keV transition:

Reference	ICC, α_K	Multipolarity	Theoretical ICC
Bell (1952Be95)	0,0037 (25)		α_K = 0,00401 (6)
Haskins (1952Ha**)	0,0040		
Graeffe (1967Gr05)	0,0043 (4)	E2	
Hargrove (1963Hr08)	0,0039		
Daniel (1964Da19)	0,0039 (3)		

3) Atomic Data

Atomic values (ω_K, ϖ_L and n_{KL}, Kβ/Kα, etc.) are from Schönfeld and Janβen (1996Sc06).

The X-ray and Auger electron emission intensities were calculated from the decay scheme data by using the program EMISSION.
L and K X-rays were measured by Chand *et al.* (1989Ch45) in relative values. The evaluators have converted them to absolute values adopting Iγ (364) = 81,2 (5) %. K X-rays values of Lépy *et al.* (2014Le**) were given directly in absolute values. Both are compared with the values derived from the decay scheme data.

	Chand	Lépy	Calculated
Lℓ	0,0114 (16)		0,01220 (40)
Lα	0,294 (18)		0,321 (9)
Lβ	0,233 (15)		0,256 (6)
Lγ	0,0292 (24)		0,0377 (9)
Kα	4,18 (12)	4,13 (6)	4,33 (7)
K'β1	0,741 (25)		0,816 (19)
K'β2	0,1705 (50)		0,193 (6)
Kβ	0,912 (25)	0,970 (14)	1,009 (20)
Kβ/Kα	0,218 (9)	0,235 (5)	0,233 (6)

4) Radiation emissions

4.1) Gamma ray emissions

Gamma ray energies (in keV) are from level energies and R. A. Meyer (1990Me15).

For gamma ray emission intensities, two publications of Meyer *et al.* (1974Me21, 1990Me15) are available. In both, the measurement results are given in absolute values and are the same but the uncertainties have been re evaluated in the second publication. Only the latest one was taken into account. They are compared in the following table with the results of Lépy *et al.* (2014Le**) who took the opportunity to determine absolute intensities from the activity value of a ^{131}I solution carefully determined by using 4πβγ coincidence method. Both results are, generally, in agreement within the uncertainty limits.

Absolute γ ray intensities:

keV	Meyer	Lépy
80	2,60 (3)	2,593 (28)
85,9	0,00009 (5)	0,0051 (7)
177	0,263 (2)	0,2868 (33)
232	0,0014 (18)	
272	0,056 (1)	0,0581 (17)
284	6,01 (6)	6,227 (40)
295	0,0007 (4)	
302	0,005 (1)	
318	0,079 (3)	0,0830 (19)
324	0,022 (4)	0,02786 (47)
325	0,249 (4)	0,2698 (24)
358	0,0091 (2)	0,0162 (20)
364	80,6 (16)	81,3 (5)
404	0,056 (2)	0,0565 (18)
449	0,007 (2)	
503	0,358 (7)	0,3529 (34)
636	7,21 (9)	7,132 (45)
642	0,218 (4)	0,2183 (19)
722	1,79 (4)	1,795 (12)

The measured emission intensities listed in Table 1 are given in values relative to the 364 keV line adopted equal to 100.
The oldest values from 1952Be95, 1963Ju02, 1963Ha08, 1964Da19, 1966Mo10, 1967Gr05 and 1967Yt02 were omitted from the analysis because they are less precise than those of 1972Si**, 1989Ch45, 1990Me15 and 2014Le**and because they exhibit a large range of values, *e.g.* from 6,0 (10) to 8,2 (8) for the 284 keV ray.
The emission intensity values from Meyer (1990Me15) were converted to the 364-keV ray relative intensity taken equal to 100.
For the 163 keV gamma transition probability, $P_{abs}(163\ keV)$, an absolute value of 1,086 (7) %, determined by Meyer, has been accepted.

The normalization factor N to convert the relative emission intensities to absolute intensities can be calculated using the formula:

$$N = (100 - 1{,}086(7)) \,/\, \sum (1 + \alpha_T) P_{rel}$$

where the sum is done over all probabilities of the gamma transitions to the ground state, except for 163 keV transition.

From the adopted α_T and the evaluated relative emission intensities (Table 1), the normalization factor N deduced in such a way is 0,814 (6). The uncertainties were obtained through their propagation on the above formula.
From the two absolute intensity values measured by Meyer and Lépy for the reference line (see table above) a weighted mean of 81,24 % with an external uncertainty of 0,48 is obtained. This value agrees well with the previous one and is somewhat more precise.
Then, the adopted intensity of the 364 keV γ ray is **81,2 (5) %**. And, the adopted normalization factor is 0,812 (5).

4.2) Conversion electrons

The conversion electron emission intensities were deduced from the gamma-ray emission intensities and the theoretical ICC values.

Energy conservation

The total average energy of 969 (5) keV, for one disintegration, calculated from the current evaluated data corresponds well to the available energy of 970,8 (6) keV (Q^{-}) from the mass tables confirming the consistency of the decay scheme and the reliability of this evaluation.

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Table 1 – Gamma emission intensities, relative values

Ref	80,1853	85,918	177,214	232,175	272,501	284,3047	295,848	302,444	318,093
1952Be95	2,71 (19)					6,6 (25)			
1963Ju02	2,6 (4)					6,0 (10)			
1963Ha08	3,5 (8)		0,29 (6)			7,9 (8)			
1964Da19	3,1 (2)		0,27 (10)			6,6 (3)			
1966Mo10	3,10 (18)		0,313 (26)			7,4 (6)			
1967Gr05	2,72 (15)		0,36 (2)		0,08 (1)	7,05 (40)			0,110 (15)
1967Yt02	3,4 (4)	~ 0,1	0,38 (8)		~ 0,07	8,2 (8)			~ 0,05
1972Si**	3,21 (5)		0,30 (2)			7,49 (5)			0,110 (5)
1989Ch45	3,26 (7)		0,334 (6)	0,0039 (5)	0,0735 (18)	7,56 (8)	0,0022 (10)	0,0057 (8)	0,096 (2)
1990Me15	3,23 (6)	0,00011 (6)	0,326 (7)	0,0017 (10)	0,0695 (19)	7,46 (15)	0,00087 (50)	0,0056 (11)	0,0980 (42)
2014Le**	3,189 (38)	0,0063 (9)	0,3528 (44)*		0,0715 (21)	7,66 (6)			0,1022 (23)
χ^2 crit.	3,8		3,8		4,6	3,8			3,8
χ^2 /(n-1)	0,3		5,7		1,2	1,7			3,0
UWM :	3,2223		0,328	0,0028	0,072	7,543	0,0015	0,0056	0,102
WM :	3,2098		0,3410		0,0716	7,5558			0,0994
uc(WM)int. :	0,0258		0,0031		0,0011	0,0339			0,0014
uc(WM)ext. :	0,0141		0,0075		0,0012	0,0441			0,0024
LWM:	3,210 (26)		0,341 (12)		0,0716 (12)	7,556 (44)			0,0994 (24)
Adopted	3,210 (38)	0,0063 (9)	0,341 (8)	0,0028 (11)	0,0716 (18)	7,56 (5)	0,0015 (7)	0,0057 (8)	0,0994 (24)

[O] Value omitted from the data set used for averaging.
* The original uncertainty (as given in the table) has been increased to limit its weight to 50 %.

Table 1 – Gamma emission intensities, relative values (Cont.)

Ref	324,6307	325,791	358,419	364,49	404,816	503,005	636,991	642,7237	722,909
1952Be95				100			11,6 (19)		3,5 (31)
1963Ju02							9,0 (10)		3,0 (4)
1963Ha08		0,35 (8)		100		0,52 (17)	8,8 (7)		2,05 (16)
1964Da19		0,26 (10)		100		0,54 (5)	8,3 (3)		1,9 (1)
1966Mo10		0,279 (25)		100		0,45 (6)	9,1 (11)		2,05 (26)
1967Gr05	0,04 (1)	0,45 (3)	0,020 (4)	100	0,080 (7)	0,36 (2)	8,0 (4)	0,180 (15)	2,10 (15)
1967Yt02		0,37 (5)		100	~ 0,06	0,37 (8)	8,2 (8)		1,8 (2)
1972Si**		0,32 (1)		100	0,022 (5)^{O}	0,30 (5)^{O}	7,79 (10)^{O}	0,13 (1)^{O}	1,79 (9)^{O}
1989Ch45	0,025 (3)	0,361 (5)	0,0304 (11)	100	0,066 (2)	0,438 (5)	8,75 (9)	0,269 (5)	2,19 (2)
1990Me15	0,0273 (50)	0,309 (8)	0,01129 (33)	100 (2)	0,0695 (28)	0,444 (12)	8,95 (21)	0,270 (7)	2,22 (7)
2014Le**	0,0343 (6)*	0,3319 (34)*		100,0 (8)	0,0695 (23)	0,4341 (47)	8,77 (7)	0,2685 (27)	2,208 (19)
χ^2 crit.	4,6	3,8			4,6	4,6	4,6	4,6	4,6
χ^2 /(n-1)	2,9	13,3			0,9	0,4	0,4	0,02	0,3
UWM :	0,029	0,330	0,020845		0,068	0,439	8,823	0,269	2,206
WM :	0,0300	0,3371			0,0680	0,4365	8,7746	0,2688	2,2002
uc(WM)int. :	0,0018	0,0028			0,0013	0,0033	0,0534	0,0022	0,0135
uc(WM)ext. :	0,0031	0,0101			0,0012	0,0020	0,0333	0,0003	0,0068
LWM:	0,0300 (31)	0,337 (10)			0,0680 (13)	0,4365 (33)	8,77 (5)	0,2688 (22)	2,200 (14)
Adopted	0,0300 (31)	0,337 (10)	0,021 (10)	100 (8)	0,068 (2)	0,436 (5)	8,77 (7)	0,2688 (27)	2,200 (19)

^{O} Value omitted from the data set used for averaging.
* The original uncertainty (as given in the table) has been increased to limit its weight to 50%