^{75}Se - Comments on evaluation of decay data by V. Chisté and M. M. Bé

1 Decay Scheme

^{75}Se disintegrates 100 % by electron capture to excited levels and to the ground state of ^{75}As.

A good agreement was found between the effective Q value (860 (18) keV) calculated from the decay scheme data and the adopted and recommended value from the mass adjustment of Audi (2003Au03).

2 Nuclear Data

The Q value is from Audi and Wapstra (2003Au03).

Level energies, spins and parities are from the mass-chain evaluation of A. R. Farhan and B. Singh (1999Fa05).

Experimental ^{75}Se half-life values (in days) are given in Table 1:

Table 1 : Experimental values of ^{75}Se half-life.

Reference	Experimental value (d)	Comments
H. N. Friedlander (1947Fr08)	115 (5)	Outlier
W. S. Cowart (1948Co07)	127 (7)	Outlier
J. M. Cork (1950Co58)	128	Not used: no uncertainty.
H. M. Wright (1957Wr37)	119.9 (6)	Outlier
H. T. Easterday (1960Ea02)	120.4 (2)	Outlier
F. Lagoutine (1975La16)	118.45 (25)	Outlier
M. J. Martin (1976MaZW)	120 (1)	Outlier
H. Houtermans (1980Ho17)	119.779 (4)	
U. Schötzig (1980Sc07)	119.76 (5)	
D. D. Hoppes (1982HoZJ)	119.80 (7)	
A. Iwahara (1994Iw04)	119.0 (5)	Outlier
M. He (2002He19)	115.0 (117)	Not used
M. P. Unterweger (2002Un02)	119.809 (66)	
Recommended value	119.781 (24)	χ^2 = 0.14

The value in 2002He19 was omitted because this value is just a verification of how good their experimental set-up was. The first 6 values (1947Fr08, 1948Co07, 1957Wr37, 1960Ea02, 1975La16, 1976MaZW) and the Iwahara value (1994Iw04) have been shown to be outliers, based on the Chauvenet's criterion and thus were omitted in the final calculation. With the 4 remaining values (1980Ho17, 1980Sc07, 1982HoZJ and 2002Un02), a weighted average was calculated using the LWEIGHT computer code (version 3). The largest contribution to the weighted average comes from the value of Houtermans (1980Ho17), amounting to 63 %. The LWEIGHT increases the uncertainty of 1980Ho17 value from 0.004 to 0.034 in order to reduce its relative weight from 63 % to 50 %.

The adopted value is the weighted average of 119.781 d with an internal uncertainty of 0.024 d. The reduced-χ^2 value is 0.14.

2.1 Electron Capture Transitions

The energies of the electron capture transitions have been obtained from the Q(EC) value (2003Au03) and the level energies given by A. R. Farhan (1999Fa05).

The adopted electron capture transition probabilities and associated uncertainties were deduced from the γ transition probability balance at each level in the decay scheme.

The partial sub shell capture probabilities given in this section were calculated using the computer program EC-Capture.

2.2 γ Transitions

The γ transition probabilities were deduced using the γ-ray emission intensities and the relevant internal conversion coefficients (see **5.2 Gamma Emissions**).

Table 2 shows the multipolarities (no mixing ratios given) of γ transitions, deduced from the conversion coefficient (1999Fa05) analysis.

Table 2: Multipolarities of γ transitions.

Multipolarity	E_γ (keV)
E1	121.1155 (11), 136.0001 (6), 400.6572 (8),
[E2]	80.9365 (15), 373.61 (24), 556.90 (18), 821.56 (18)
E2	96.7340 (9)
E3	303.9236 (10)
[M1, E2]	249.3 (3), 419.1 (4), 468.6 (4), 542.02 (18), 617.8 (4)
M1 (+E2)	14.8847 (13)
M2 + (E3)	24.3815 (14)

For (M1 + E2) γ transitions (66-, 198-, 264-, 279- and 572-keV), the mixing ratios (δ) are given in Table 5, they were deduced by comparison between experimental values of K internal conversion coefficients and the theoretical values calculated using the BrIcc computer code (2008Ki07).

Since the γ transitions with E_γ = 121- and 136-keV were determined to be pure E1, their α_K coefficients can be interpolated from theoretical values and then used to deduce the α_K coefficient of the 264-keV γ-ray which has been used as the reference line in all the measurements. Then:

$$\alpha_k(264) = \frac{\alpha_k(136) \times I_\gamma(136)}{I_{CEK}(136)}$$

and

$$\alpha_k(264) = \frac{\alpha_k(121) \times I_\gamma(121)}{I_{CEK}(121)} \quad \text{(see Table 4)}$$

where:

– I_{CEK} is the weighted average of the experimental values of the relative conversion electron intensities shown in Table 3a (2nd and 3rd columns, respectively);

– I_γ is the weighted average of the experimental values of the relative γ-ray emission intensities given in Table 8 (see **5.2 Gamma Emission**).

Table 3a: Experimental and recommended values of relative conversion electron intensities (I_{CEK}) and photon (I_γ) intensities for (M1 + E2) γ-rays.

Energy (keV) Reference	121	136	66	198	264	279	572
1955Sc09	173 (14)	420 (34)	68 (10)	6.4 (9)	100	53 (7)	
1959Me76		377 (20)			100	53.6 (16)	
1960De06	180 (12)	450 (30)	80 (12)	6.8 (10)	100	63 (5)	
1960Gr03	154 (5)	384 (13)	73.7 (49)	7.30 (37)	100	49.2 (33)	0.055 (22)
1961Ed02	187 (15)	378 (30)	99 (12)	7 (1)	100	53 (5)	
1965Br19	167 (26)	520 (70)		7.0 (12)	100	52 (7)	
1970Pa25	174 (17)	399 (32)	72.3 (10)	7.36 (41)	100	52.5 (23)	0.0099 (9)
2005Ra29	169.91 (27)	377.94 (41)	88.47 (20)	6.41 (5)	100	42.93 (22)	0.0103 (34)
Recommended I_{CEK}	169.88 (42)	377.95 (41)	81 (8)	6.44 (7)	100	53.2 (12)	0.0100 (13)
χ^2	2.4	0.08	7.5	1.9		0.05	2.1
Recommended I_γ	28.7 (6)	97.8 (34)	1.792 (34)	2.48 (10)	100	42.36 (6)	0.06165 (49)
χ^2	4.16	5.08	6.07	4.43		0.51	1.43

Table 3b: Experimental and recommended values of relative conversion electron intensities I_{CEK} and photon (I_γ) intensities for additional (M1 + E2) γ-rays.

Energy (keV) Reference	24	80	96	303	400	419	556	617
1955Sc09		~ 8.1 (7)*	~ 720 (60)*	15.6 (13)	3.6 (5)			
1959Me76				15.4 (9)	3.6 (4)			
1960De06		14 (3)	940 (60)	16 (1)	3.8 (3)			
1960Gr03	1250 (150)	7 (1)	645 (32)	16.1 (9)	3.76 (28)			
1961Ed02			753 (60)	17.2 (17)	3.8 (3)			
1965Br19			750 (110)	17.0 (26)				
1970Pa25			724 (19)	16.6 (5)	3.71 (4)	0.006 6 (7)		0.000 85 (9)
2005Ra29	1010 (1)	4.04 (4)	502 (1)	16.4 (8)	3.98 (4)	0.012 0 (4)	0.009 5 (32)	0.001 1 (4)
Recommended I_{CEK}	1010.0 (16)	5.9 (18)	610 (110)	16.16 (29)	3.84 (13)	0.006 8 (9)	0.009 5 (32)	0.000 86 (9)
χ^2	2.6	6.2	12	0.45	3.9	1.8		0.37
Recommended I_γ	0.046 (11)	0.0161 (9)	5.71 (12)	2.2267 (44)	19.384 (36)	0.020 6 (11)	0.004 7 (2)	0.007 71 (9)
χ^2	4.56	1.13	13.53	0.80	1.5	5.03		0.179

* Not used

Table 4: Determination of α_{K264}.

Energy (keV)	I_{CEK} (%)	I_γ (%)	α_K (by BrIcc)	α_{K264}
121	169.88 (42)	28.7 (6)	0.037 2 (6)	0.006 28 (17)
136	377.95 (41)	97.8 (34)	0.026 3 (4)	0.006 81 (26)
			Adopted	**0.006 44 (24)**

The adopted α_K coefficient for the 264-keV γ transition is 0.006 44, weighted average with an external uncertainty of 0.000 24 and a reduced-χ^2 of 2.87.

Table 5 shows the final results of experimental α_K (deduced using α_{K264} = 0.006 44 (24)), together with mixing ratios δ (deduced from a comparison between experimental (column 2) and theoretical (column 5, calculated with the BrIcc computer code) α_K values).

Table 5: Recommended conversion coefficients and mixing ratios.

E_γ (keV)	I_{CEK}/I_γ	α_K experimental (= (α_{K264} * I_{CEK}/I_γ))	δ (mixing ratio)	α_K theoretical (given by BRICC)	Multipolarities
24	22 (5) 10^3	141 (34)		165.4 (24)	M2 + (E3)
66	45.2 (45)	0.291 (31)	0.121 (33)	0.29 (3)	M1 + E2
80	370 (110)	2.4 (7)		1.481 (21)	[E2]
96	107 (19)	0.69 (13)		0.772 (11)	E2
198	2.60 (11)	0.016 7 (9)	0315 (39)	0.016 7 (9)	M1 + E2
264	1	0.006 44 (24)	-0.10 (7)	0.006 46 (25)	M1 + E2
279	1.256 (28)	0.008 09 (35)	-0.578 (44)	0.008 1 (4)	M1 + E2
303	7.26 (13)	0.046 7 (19)		0.046 9 (7)	E3
400	0.198 (7)	0.001 28 (6)		0.001 202 (17)	E1
419	0.330 (47)	0.002 13 (31)		0.003 0 (10)	[M1,E2]
556	2.0 (7)	0.013 0 (44)		0.001 628 (25)	[E2]
572	0.162 (21)	0.001 04 (14)	0.19 (1)	0.001 04 (1)	M1 + E2
617	0.112 (12)	0.000 72 (8)		0.001 03 (18)	[M1,E2]

Then, for all γ transitions, the total internal conversion coefficients (ICC) and associated uncertainties have been obtained using the BrIcc computer program with "the frozen orbital approximation" (2008Ki07).

3 Atomic Data

Atomic values, ω_K, ϖ_L and n_{KL} and X-ray and Auger electron relative probabilities are from Schönfeld and Janβen (1996Sc06).

4 Electron emissions

The conversion electron emission probabilities were deduced from ICC values and γ-ray emission probabilities.

5 Photon Emissions

5.1 X-rays

The X-ray absolute intensities were deduced from the decay data using the EMISSION computer code and are compared in Table 6 with measured values found in the literature. A good agreement has been found between the experimental and our values deduced from decay scheme.

Table 6: Experimental and recommended (calculated) values of X-ray absolute intensities.

	1966Ra09*	1970Pa25*	1974Ca29*	1983Si25*	1992Sc09*	1996Sa22	2000Zhang	Recommended
K x-ray	55.5 (14)	53.1 (15)	53.5 (29)	57.5 (13)	54.7 (11)	58.3 (14)	55.6 (12)	56.0 (13)
Kα x-ray				49.2 (13)	47.6 (11)		48.3 (10)	48.4 (13)
Kβ x-ray				8.25 (24)	7.13 (17)		7.3 (2)	7.58 (25)

*Using normalization factor of 0.5875 (19) (see Table 7, **5.2 Gamma Emissions**)

5.2 Gamma emissions

The energies of the γ-rays given in section 5.2 are from A. F. Farhan (1999Fa05).

The experimental relative γ-ray emission intensities from ^{75}Se have been obtained from all the available relative and absolute values. The normalization factor to convert relative γ-ray emission probabilities to absolute values is from a weighted average of measured absolute values for the 264-keV γ-ray absolute intensity.

Table 7: Experimental 264-keV absolute gamma-ray emission intensities.

References	Experimental values
Y. Yoshizawa (1983Yo03)	0.580 (9)
U. Schötzig (1992Sc09)	0.5950 (54)
H. Miyahara (1994Mi22)	0.5870 (17)
Recommended value	**0.5875 (19)**, χ^2 = 1.35

The experimental γ-ray emission probabilities relative to 100 for the 264-keV γ-ray are given in Table 8.

Our recommended relative and absolute γ-ray emission probabilities are given in Table 9.

The adopted values are the weighted means calculated by the LWEIGHT program (version 3) with the following restrictions:
*: Omitted from averaging because data set is discrepant.
@: data set was present in 1987JeZZ, then these references have been omitted from the analysis.
µ: the experimental value has been shown to be an outlier value by the Lweight program.

Table 8: Experimental data sets of the relative γ-ray emission intensities (%) (cont. next page).

Energy (keV) Reference	14	24	66	80	96	121	136	198	249	264
1955Sc09			1.8 (1)		6.6 (15)	28 (5)	94 (12)			100
1958Va02			2.1 (8)		5.8 (6)	24.5 (30)	76 (5)	3.6 (4)		100
1959Vo30										100
1960De06						28 (5)	86 (15)			100
1960Gr03			1.53 (15)		5.5 (3)	27.9 (13)	96 (5)	2.6 (2)		100
1961Ed02			1.63 (6)		5.57 (18)	28.0 (6)	95.5 (18)	2.4 (1)		100
1965Br19						30 (10)	130 (40)			100
1966Ra09			1.64 (5)		5.53 (16)	27.8 (8)	94.9 (20)	2.28 (5)		100
1969Ra12			1.4 (4)		4.83 (10)	29.2 (29)	96.0 (96)	2.25 (23)		100
1970Pa25		0.044 (6)	1.72 (4)	0.015 (3)	5.12 (10)	27.7 (5)	95.0 (18)	2.38 (7)		100
1970Na14			1.54 (8)		5.43 (16)	28.5 (9)	94.0 (28)	2.78 (14)		100
1971Ge07			1.77 (1)		5.6 (5)	28.2 (14)	98.3 (46)	2.43 (12)		100
1971Pr07		0.032 (10)								
1973Su10*			0.97 (6)		4.7 (2)	25.4 (12)	90.3 (28)	2.5 (1)		100
1973Te06			2.0 (5)		5.0 (5)	25.8 (25)	94.6 (82)	2.2 (2)		100
1973Th07	0.034 (6)	0.063 (8)	1.50 (15)	0.011 (3)	5.4 (4)	26.7 (30)	95.7 (70)	2.59 (20)		100
1974Ca29		0.036 (4)								100
1977Ge12			1.86 (11)		5.90 (35)	29.8 (13)	102.0 (30)	2.53 (11)		100
1978Pr08		0.065 (8)	1.46 (20)	0.012 (4)	5.22 (20)	27.1 (40)	95.5 (60)	2.5 (4)		100
1983Yo03					5.78 (17)	29.24 (32)	99.2 (10)	2.51 (4)		100
1984Si06		0.052 (9)	1.91 (3)	0.014 (4)		29.96 (26)	102.5 (10)	2.52 (6)		100
1987JeZZ - n°1		0.045 (6)	1.850 (31)		5.93 (8)	29.23 (19)	99.9 (5)	2.518 (16)		100
1987JeZZ - n°2		0.127 (12) µ	1.82 (7)		5.68 (19)	29.1 (9)	96.3 (28)	2.52 (9)		100
1987JeZZ - n°3			1.76 (9)		6.13 (22)	27.9 (9)	94.6 (30)	2.25 (9)		100
1987JeZZ - n°4			1.95 (6)		6.47 (19)	29.2 (5)	99.9 (14)	2.568 (35)		100
1987JeZZ - n°5						29.3 (7)	99.9 (13)	2.48 (6)		100
1987JeZZ - n°6			1.78 (7)		5.41 (16)	28.5 (7)	95.9 (27)	2.38 (6)		100
1987JeZZ - n°7			2.00 (18)		5.13 (33)	30.0 (13)	99.5 (40)	2.53 (10)		100
1987JeZZ - n°8			1.860 (22)		5.790 (42)	28.65 (18)	98.2 (6)	2.509 (20)		100
1987JeZZ - n°9			1.960 (41)		5.63 (5)	28.96 (18)	99.9 (6)	2.581 (16)		100
1987JeZZ - n°10		0.0446 (20)	1.910 (25)		5.91 (7)	29.16 (33)	99.7 (11)	2.534 (28)		100
1987JeZZ - n°11			1.940 (34)		5.88 (8)	29.43 (32)	100.4 (11)	2.514 (28)		100
1987JeZZ - n°12			1.88 (1)		5.830 (22)	29.31 (11)	101.2 (3)	2.586 (11)		100
1987JeZZ - n°13			1.950 (24)		5.91 (6)	29.24 (29)	99.4 (12)	2.500 (35)		100
1990An07@			1.962 (29)		5.93 (9)	29.24 (41)	100.0 (17)	2.50 (5)		100
1990Me15		0.0460 (46)	1.87 (9)	0.0190 (41)	5.71 (35)	29.8 (15)	100 (6)	2.54 (24)		100
1990Wa09@			1.960 (49)		5.91 (12)	29.1 (6)	99.5 (20)	2.50 (6)		100
1992Sc09@		0.0446 (20)	1.910 (25)		5.91 (7)	29.16 (33)	99.7 (11)	2.534 (28)		100
1994Bh07*	0.003 (2)	0.056 (6)	1.912 (3)	0.013 (4)		30.1 (9)	102.3 (11)	2.51 (8)		100
1994Mi22					5.779 (45)	29.76 (19)	100.2 (6)	2.555 (20)		100
1997Lo10						28.05 (27)	98.41 (36)	2.58 (7)		100
2005Ra29	0.035 (1)	0.035 (1)	1.79 (1)	0.017 (1)	5.10 (4)	27.40 (22)	94.1 (8)	2.42 (2)	0,0067 (2)	100
Evaluated	0.035 (1)	0.046 (11)	1.792 (34)	0.0161 (9)	5.71 (12)	28.7 (6)	97.8 (34)	2.48 (10)	0.0067 (2)	100
χ^2	0.027	4.56	6.07	1.13	13.53	4.16	5.08	4.43		

Energy (keV) Reference	279	303	373	400	418	468	542	557	572	617	821
1955Sc09	45.7 (40)	2.0 (5)		24.8 (25)							
1958Va02	52 (5)			28 (2)							
1959Vo30	44.1 (44)	3.2 (12)		22.7 (15)					0.068 (46)		
1960De06	42.5 (20)	2.15 (30)		23 (2)							
1960Gr03	41.0 (25)	2.5 (3)		22.3 (23)					0.18 (6)		
1961Ed02	42.2 (6)	2.29 (14)		19.5 (6)							
1965Br19	53 (15)										
1966Ra09	43.0 (9)	2.39 (5)		22.3 (5)	0.0322 (6)				0.0636 (13)	0.00777 (15)	
1969Ra12	41.3 (41)	2.06 (21)		19.2 (19)	0.020 (3)				0.053 (8)	0.0076 (10)	
1970Pa25	42.0 (8)	2.19 (7)		20.4 (5)	0.023 (2)	0.0010 (5)			0.063 (2)	0.0075 (2)	
1970Na14	41.9 (13)	2.20 (11)		19.5 (6)							
1971Ge07	43.2 (22)	2.31 (12)		19.6 (12)							
1971Pr07						0.00054 (18)					0.000216 (10)
1973Su10*	42.5 (15)	2.20 (8)		19.0 (6)	0.0140 (16)				0.054 (3)	0.0075 (31)	
1973Te06	40.0 (22)			19.6 (7)							
1973Th07	42.1 (8)	2.11 (30)		18.0 (4)	0.017 (3)				0.048 (5)	0.059 (7)	
1974Ca29											
1977Ge12	42.4 (18)	2.21 (7)		19.1 (6)							
1978Pr08	42.6 (8)	2.3 (4)	0,0042 (4)	18.8 (6)	0.018 (4)	0.00062 (10)	0.00022 (4)[µ]	0.00006 (2)[µ]	0.050 (4)	0.0062 (8)	0.00028 (2)
1983Yo03	42.43 (29)	2.234 (20)		19.42 (16)	0.0231 (21)				0.0634 (29)	0.0078 (21)	
1984Si06	42.4 (4)										
1987JeZZ - n°1	42.53 (23)	2.248 (13)		19.27 (13)	0.0206 (7)				0.0602 (20)	0.0072 (7)	
1987JeZZ - n°2	43.9 (13)	2.25 (7)		19.7 (6)	0.024 (9)				0.0625 (26)	0.0067 (10)	0.0016 (12)[µ]
1987JeZZ - n°3	42.2 (13)	2.21 (8)		19.1 (6)							
1987JeZZ - n°4	42.6 (6)	2.091 (27)		19.41 (24)							
1987JeZZ - n°5	42.6 (9)	2.24 (5)		19.50 (42)							
1987JeZZ - n°6	42.4 (9)	2.23 (6)		19.17 (39)	0.0102 (32)				0.0580 (41)	0.0076 (6)	0.00030 (15)
1987JeZZ - n°7	42.6 (16)	2.24 (8)		19.5 (7)	0.0154 (11)				0.0590 (34)	0.0080 (6)	0.0013 (7)[µ]
1987JeZZ - n°8	42.48 (31)	2.234 (19)		19.60 (14)					0.0610 (18)		
1987JeZZ - n°9	42.36 (22)	2.224 (12)		19.79 (10)					0.0617 (14)	0.0063 (18)	
1987JeZZ - n°10	42.5 (5)	2.242 (25)		19.49 (22)	0.0196 (12)				0.0610 (11)	0.0078 (5)	
1987JeZZ - n°11	42.4 (5)	2.220 (27)		19.08 (23)	0.0217 (5)				0.0603 (9)	0.0077 (3)	
1987JeZZ - n°12	42.25 (7)	2.219 (9)		19.36 (4)	0.0247 (13)				0.067 (2)	0.0108 (12)	
1987JeZZ - n°13	42.69 (37)	2.239 (22)		19.51 (17)					0.064 (3)		
1990An07[@]	42.7 (5)	2.238 (31)		19.51 (24)					0.064 (5)		
1990Me15	42.2 (21)	2.23 (11)		19.5 (10)	0.0180 (31)				0.0600 (42)	0.0077 (6)	0.000220 (23)
1990Wa09[@]	42.4 (9)	2.25 (5)		20.19 (43)	0.0209 (5)				0.0589 (12)	0.0076 (2)	
1992Sc09[@]	42.5 (5)	2.242 (25)		19.49 (22)	0.0196 (12)				0.0610 (11)	0.0078 (5)	
1994Bh07*	42.55 (10)										
1994Mi22	42.78 (25)	2.239 (18)		19.31 (12)							
1997Lo10	43.63 (29)	2.199 (11)		18.84 (16)					0.066 (3)		
2005Ra29	43.07 (34)	2.27 (2)	0.0044 (2)	20.13 (16)	0.035 (1)	0.0036 (2)[µ]	0.00074 (1)	0.0047 (2)	0.062 (1)	0.0078 (2)	0.0015 (2)[µ]
Evaluated	42.36 (6)	2.2267 (44)	0.00436 (18)	19.384 (36)	0.0206 (11)	0.00061 (9)	0.00074 (1)	0.0047 (2)	0.06165 (49)	0.00771 (9)	0.00028 (14)
χ^2	0.51	0.80	0.2	1.55	5.03	0.38			1.43	0.179	2.85

Table 9: Recommended relative and absolute γ-ray intensities (%).

Eγ (keV)	Relative γ-ray intensity (%)	Absolute γ-ray intensity (%)	Eγ (keV)	Relative γ-ray intensity (%)	Absolute γ-ray intensity (%)	Eγ (keV)	Relative γ-ray intensity (%)	Absolute γ-ray intensity (%)
14	0.035 (1)	0.020 6 (6)	198	2.48 (10)	1.46 (6)	418	0.020 6 (11)	0.012 1 (6)
24	0.046 (11)	0.027 (6)	249	0.006 7 (2)	0.003 94 (12)	468	0.000 61 (9)	0.000 36 (5)
66	1.792 (34)	1.053 (20)	264	100	58.75 (19)	542	0.000 74 (1)	0.000 435 (6)
80	0.016 1 (9)	0.009 5 (5)	279	42.36 (6)	24.89 (9)	557	0.004 7 (2)	0.002 76 (12)
96	5.71 (12)	3.35 (7)	303	2.226 7 (44)	1.3082 (50)	572	0.061 65 (49)	0.036 22 (31)
121	28.7 (6)	16.86 (36)	373	0.004 36 (18)	0.002 56 (11)	617	0.007 71 (9)	0.004 53 (5)
136	97.8 (34)	57.7 (20)	400	19.384 (36)	11.388 (42)	821	0.000 28 (14)	0.000 134 (8)

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