^{68}Ga - Comments on evaluation
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This evaluation was completed in 1996, it was reviewed in November 2011. The literature available by this date was included.

1 Decay Scheme

The decay scheme of Ga-68 is taken from Vo *et al.* (1994Vo15) who discovered 5 very weak transitions between already known levels in the decay scheme established by Lange *et al.* (1973La01). From other excitation modes, the existence of levels with energy (J^π): 2370,3 (15); 2417,44 (6) $(4)^+$; 2510,2 (15); 2750,38 (8) keV (3^-) was shown, however radiations originating from these levels were not observed in the Electron Capture decay of Ga-68 (1994Vo15). Transitions to the 2417 and 2510 keV levels would be third and second forbidden and therefore if they exist, their intensities would be very weak.
The values of the half- lives of the excited states of ^{68}Zn are taken from Burrows (2002Bu29).

2 Nuclear Data

The Q^+ value is from Audi *et al.* (2003Au03), adopted from Slot (1972Sl03) measurement, Q^+ = 2921,1 (12) keV.
A value of 2912 (10) keV was also measured by Kojima *et al.* (2001Ko07).

The following values of the half-life of ^{68}Ga have been taken into consideration:

Reference	**$T_{1/2}$ (min)**	Remarks
M. L. Perlman	68,0	omitted
G. L. Gleason (1960Gl04)	67,7 (3)	
L. A. Rayburn (1961Ra06)	69,2 (14)	outlier
T. G. Ebrey (1965Eb01)	68,33 (9)	Coin. Count. NaI(Tl), statistical uncertainty only
M. Borman (1965Bo42)	68,2 (1)	
J. M. Ootukalam (1971Oo01)	68,5 (5)	NaI, brief note, statistical uncertainty only
Smith and Williams (1971Sm02)	67,80 (8)	IC
Iwata et al. (1983Iw02)	67,629 (24)	Ge(Li)
Luca et al. (2012Lu*)	67,87 (10)	IC
Adopted	**67,83 (20)**	χ^2 crit = 2,8 ; χ^2 = 11

The set of 7 values used in the averaging process is not consistent with a reduced χ^2 of 11. The limitation of relative statistical weight procedure has then increased the Iwata's uncertainty to 0,05 in order to reduce the relative weight of this value to 50 %.
Therefore, the resulting (and adopted) weighted mean is 67,83 min with an expanded uncertainty of 0,20 to cover the most precise value.

2.1, 2.2 Electron Capture Transitions and β$^+$ Transitions

The sum of the EC + β$^+$ transition probabilities were deduced from the sum of the gamma transition probabilities populating and depopulating each level of the decay scheme. The EC/β$^+$ ratios were calculated by using the Logft program, a relative uncertainty of 5 % was assumed. For level 0, the theoretical value is quite close to the experimental values of 0,10 (2) (1959Ra04) ; for level 1, it lies between 1,28 (12) and 1,63 (11), experimentally determined by Ramaswamy (1959Ra04) and Sykora (1992Sy**) respectively.
The individual EC and β$^+$ probabilities have then been derived.

	P(EC+β$^+$) %	EC/β$^+$	P(EC) %	P(β$^+$) %
Level 0	96,62 (3) %	0,102 (5)	8,94 (41)	87,68 (41)
Level 1	3,00 (3) %	1,51 (7)	1,80 (5)	1,20 (4)
Level 2	0,0338 (23) %	127,5 (64)	0,0335 (23)	0,00026 (2)

From the values above, the sum of P(β$^+$) amounts for 88,88 (41) %, it corresponds to a 511 keV photon intensity of 177,8 (8) %, this result can be compared with experimental values.
Several authors measured the 511 keV photon emission, I_{511}, relatively to the 1077 emission:

Reference	**I_{511}/I_{1077}**	**u_c**	
Horen (1959Ho85)	5460	600	
Craseman (1956Cr29)	2880	340	Omitted
Carter (1968Ca15)	5930	600	
Ramaswamy (1959Ra04)	3900	420	Outlier
Schönfeld (1994Sc44)	5537	52	Uc increased to 220 to limit its weight to 50 %
Luca (2012Lu*)	5569	264	
Weighted mean ; internal uncertainty	5570	160	With I_{g1077} = 3,235 (30) %, the total I_{511} is 180 (5) %.

Moreover, two authors measured directly the I_{511} in absolute values: Schönfeld (1994Sc44), 178,29 (22) % and Luca (2012Lu*), 181 (6) %.
All these results are consistent within the uncertainty limits.

The energies are derived from the *Q* value and the level energies. The fractional probabilities for EC are calculated using the "Tables for Calculation of Electron Capture" (E. Schönfeld, PTB-Laboratory report 6.33-95-2 (1995)). These values are based on wave functions of Mann and Waber (1973) with exchange and overlap corrections of Bahcall and Vatai; see W. Bambynek et al., *Rev. Mod. Phys.* 49(1977)77. Note that the sum $P_K+P_L+P_M$ is not equal to 1 because of a very small fraction of capture from the N shell.

2.3 Gamma Transitions

The level differences (as well as the gamma-ray energies in Section 4.2) are taken from a compilation of Helmer (1997HeZZ) which takes into account also data from sources other than the Ga-68 decay.

The transition probabilities were derived from the emission intensities and the conversion coefficients.
The conversion coefficients are interpolated from Band's tables by using the program BrIcc with the "frozen orbital approximation" (Kibédi *et al.* 2008Ki07). The adopted mixing ratios are derived from the experimental results as summarized below. For the 1261 keV transition where the values are discrepant the adopted value comes from the γ-γ directional correlation measurements of Vo *et al.(*1994Vo15). Eight transitions are pure E2 because the initial or the final level has J = 0.

Experimental mixing ratios δ :

Eγ (keV) Reference	483	805	938	1261	1744
1960Ra06				-1,8 (2)	
1962Ko01		+4 (+3 -2)			
1963Ta03				-2,25 (30)	
1971Ot01		-1,45 (15)		-0,21 (+6 -4)	0,24 (13)
1973La01		-1,46 (14)		0,14 (4)	0,29 (5)
1994Vo15	-0,12 (16) -1,7 (9)	-1,55 (5)	-0,7 (3)	-0,15 (2)	0,27 (2)
Adopted	1,0 (5) [e]	-1,53 (5) [w]	-0,7 (3)	-0,15 (2) [v]	0,272 (18) [w]
M1 / E2 (%)	50 (25)	70 (1)	33 (8)	2,2 (1)	6,9 (1)

[e] : estimated ; [w] : weighted mean ; [v]: 1994Vo15.

3 Atomic Data

All these data are taken from E. Schönfeld and H. Janssen, *Nucl. Instr. and Methods in Phys. Res.* A 369(1996)527.

3.1 X Radiations

The energies are based on the wavelengths compiled by J. A. Bearden, *Rev. Mod. Phys.* 39(1967)78. The relative probabilities for K_α radiation are based on $P(K_\beta)/P(K_\alpha)$ and $P(K_{\alpha2})/P(K_{\alpha1})$ values as given in the above cited paper of Schönfeld and Janßen (1994). The relative probabilities for L quanta are derived from the corresponding absolute values (Section 4.2) setting $P(K_{\alpha1})$ = 100.

3.2 Auger Electrons

The energies of KLL and KLX Auger electrons are taken from the paper of F. P. Larkins, Atomic Data and Nuclear Data Tables 20 (1977) 313. The relative emission probabilities of K Auger electrons are taken from the above cited paper of Schönfeld and Janßen (1994). The relative emission probabilities of L Auger electrons are derived from the corresponding absolute probabilities (Section 4.1) setting *P*(KLL) = 100.

4. Electron Emissions

The energies of the Auger electrons are the same as above. The energies of the conversion electrons are calculated from the energies of the gamma rays and the corresponding electron binding energies. The emission intensities of the Auger electrons are calculated from the transition probabilities of the EC transitions (2.1) and gamma transitions (2.3) using the atomic data given in Sections 3 and 3.2, the fractional electron capture probabilities and the conversion coefficients. The emission intensities of conversion electrons are calculated from the transition probabilities and conversion coefficients given in Section 2.3.

5. Photon Emissions

The X ray energies are the same as in 3.1. The energies of the gamma rays are taken from Helmer (1997HeZZ). The emission intensities of X rays were calculated from the decay scheme data.
Schönfeld *et al.* (1994Sc44) measured the ratio R of K x-ray intensities following the decay of Ge-68 and Ga-68, they obtained R = 9,57 (8). From the evaluation of Ge-68 decay data and the present one, a value R = 9,36 (26) is derived. They are in agreement within the uncertainty limits.

To determine the relative gamma-ray emission intensities the following values have been considered:

	Vaughan 1969Va16	Carter 1968Ca15	Lange 1973La01	Vo 1994Vo15	Schönfeld 1994Sc44	Luca 2012Lu*	χ^2 /n-1	Adopted
227	-	-	-	0,0037 (15)				0,0037 (15)
483	-	-	-	0,0082 (9)				0,0082 (9)
579	0,7 (1) *	1,1 (2)	1,00 (12)	1,05 (15)	1,14 (15)	1,35 (30) *	0,2	1,06 (7)
683	-	-	-	0,0097 (6)		-		0,0097 (6)
806	2,2 (2) *	2,8 (2)	2,95 (12)	2,81 (14)	2,90 (31)	2,68 (34)	0,3	2,87 (8)
939	-	-	-	0,0055 (5)		-		0,0055 (5)
1077	100	100	100	100	100	100		
1166	-	-	-	0,0005 (3)		-		0,0005 (3)
1261	3,1 (2)	2,9 (2)	3,00 (7)	2,75 (14)	3,06 (31)	2,60 (28)	1	2,95 (6)
1744	0,5 (1)	0,28 (4)	0,30 (4)	0,295 (15)		-	1,4	0,297 (16)
1883	4,8 (3)	4,1 (4)	4,33 (12)	4,6 (2)	3,86 (59)	3,94 (42)	1,1	4,39 (10)
2338	<0,1	0,04 (2)	0,050 (6)	0,031 (3)		-	4	0,035 (5)
2821	-	-	0,015 (2)	0,0139 (11)				0,0144 (11)

* Omitted from statistical processing

Where there are only values from Vo *et al.*, these results have been adopted unchanged. In all other cases weighted means were calculated by using the Lweight program, the adopted uncertainty being the highest of the internal or external uncertainty.
Two published papers report absolute measurements of the gamma intensities, for the 1077 keV emission, they are:
- Schönfeld *et al.* (1994): 3,22 (3) %
- Luca *et al.* (2012): 3,25 (11) %

From these two results, an absolute value of the 1077 keV intensity is adopted which is the simple mean with the lowest experimental uncertainty, that is: I_{g1077} = 3,235 (30) %.
All the other absolute intensity values were derived from I_{g1077} and the relative values as determined above.

A possible 1656 keV transition was observed only indirectly via conversion electrons by Slot *et al.* (1972Sl03) ($P_{ce}(1656)/P_{ce}(1077)$ = 0,010 (2)).

The absolute emission intensity of the annihilation photon (having 511 keV energy) is deduced from the decay scheme data and the theoretical EC/β^+ ratios as described in § 2.1

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