^{18}F - Comments on evaluation of decay data
by V. Chisté, M.M. Bé and N.K. Kuzmenko

This evaluation was originally completed by V. Chisté and M.-M. Bé in 2004 (2004BeZQ) and was updated by N.K. Kuzmenko in June 2014 to include new references on the ^{18}F half-life and decay energy and thus to re-evaluate the half-life and to correct nuclear transition energies.

1. DECAY SCHEME

^{18}F disintegrates by β^+ emission (96.86 (19) %) and electron capture (3.14 (19) %) to the ground state of the stable nuclide ^{18}O.

2. NUCLEAR DATA

Q value is from the mass evaluation by Wang *et al.* (2012Wa38).

The recommended half-life of ^{18}F is based on the experimental results given in Table 1.

Table 1. Experimental values of the ^{18}F half-life (in minutes)

N	Author(s) and year	Reference	$T_{1/2}$ (min)	Method and comments
1	Snell (1937)	1937Sn10	112 (4)	*omitted*
2	DuBridge *et al.* (1938)	1938Br01	107 (4)	*omitted*
3	Krishnan (1941)	1941Krishan	112 (2)	*omitted*
4	Huber *et al.* (1943)	1943Hu02	115 (4)	*omitted*
5	Blaser *et al.* (1949)	1949Bl26	112 (1)	*omitted*
6	Jarmie (1955)	1955Jarmie	111 (1)	*omitted*
7	Bendel *et al.* (1958)	1958Be74	109.8 (12)	*omitted*
8	Markowitz *et al.* (1958)	1958Ma68	112 (1)	*omitted*
9	Carlson *et al.* (1959)	1959Ca01	109.70 (54)	*omitted* according to Chauvenet's criterion
10	Yule *et al.* (1960)	1960Yu02	110.2 (2)	*omitted* according to Chauvenet's criterion
11	Rayburn *et al.* (1961)	1961Ra06	111.0 (22)	*omitted* according to Chauvenet's criterion
12	Mahony *et al.* (1962)	1962Ma48	109.74 (21)	*omitted* as superseded by 15

13	Beg *et al.* (1963)	1963Be47	109.6 (6)	*omitted* according to Chauvenet's criterion
14	Hofmann (1964)	1964Ho28	110.5 (6)	*omitted* according to Chauvenet's criterion
15	Mahony *et al.* (1964)	1964Ma12	109.72 (6)	β proportional counters
16	Ebrey and Gray (1965)	1965Eb01	109.87 (12)	β proportional counters
17	Bormann *et al.* (1965)	1965Bo42	111.0 (22)	*omitted* according to Chauvenet's criterion
18	Kavanagh (1969)	1969Kavanagh	109.87 (12)	
19	Hogstrom *et al.* (1973)	1973Ho21	95 (7)	*omitted* according to Chauvenet's criterion
20	Rutledge *et al.* (1980)	1980RuZY	109.73 (4)	4π proportional counter
21	Rutledge *et al.* (1980)	1980RuZY	109.71 (2)	Ionization chamber
22	Katoh *et al.* (1989)	1989Katoh	109.48 (8)	*omitted* according to Chauvenet's criterion
23	Schrader (1989)	1989Sc17	109.70 (12)	4πγ ionization chamber; *omitted* as superseded by 24
24	Unterweger *et al.* (2002)	2002Un02	109.771 (20)	4πγ ionization chamber; *omitted* as superseded by 30
25	Schrader (2004)	2004Sc04	109.748 (21)	4πγ ionization chamber
26	Garcia-Torano *et al.* (2010)	2010Ga04	109.723 (14)	Ionization chambers
27	Garcia-Torano *et al.* (2010)	2010Ga04	109.720 (21)	Ge detectors
28	Garcia-Torano *et al.* (2010)	2010Ga04	109.726 (44)	Fast scintillator coincidences
29	Han *et al.* (2012)	2012Ha35	109.72 (19)	HPGe detector
30	Unterweger and Fitzgerald (2014)	2014Un01	109.770 (18)	4πγ ionization chamber
Recommended value			**109.734 (14)**	LWM

The values 1–8 from very early measurements (1937–1958) have been omitted as they are much less accurate. The values 12, 23, 24 were not used because they were replaced ultimately by later results of the same laboratories.

The values 9–11, 13, 14, 17, 19, 22 have been rejected by the LWEIGHT computer program based on the Chauvenet's criterion.

An unweighted average of the remaining 11 values is 109.755 (18) min. A weighted average is 109.734 min. The LWEIGHT program using the limitation of relative statistical weight method (LWM) has chosen the weighted average with the internal uncertainty of 0.0077 min. The external uncertainty is 0.0076 min. The largest contribution to the weighted average gives the value 26 (30 %). The ratio of the reduced χ^2 / $(\chi^2)_{crit}$ is 0.96/2.30. The smallest experimental uncertainty is 0.014 min.

The recommended value of ^{18}F half-life is **109.734 (14) min, or 1.82890 (23) h.**

Electron-Capture and β^+ Transitions

The β^+ and electron capture probabilities shown in Table 2 have been deduced using a $P_K/P_{\beta+}$ ratio of 0.0300 (18) measured by Drever (1956Dr38), P_K/P_{EC} = 0.927 (5) and normalizing to a total probability ($P_{\beta+}$ + P_{EC}) of 100 %.

Table 2. ^{18}O level populated in decay of ^{18}F.

Level	Energy (keV)	Multipolarity	Half-life	P_{EC} (%)	$P_{\beta+}$ (%)
0	0	0+	Stable	3.14 (19)	96.86 (19)

The experimental $P_K/P_{\beta+}$ ratio of Drever is close to the theoretical values:

a) 0.0319 calculated with LOGFT program;

b) 0.0331 given by Fitzpatrick (1973Fitzpatrick);

c) 0.0314 given by Bambynek (1977Ba48).

For this allowed transition, the LOGFT program yields lg ft of 3.57. This value agrees with 3.554 suggested by Ajzenberg-Selove (1972Aj02, 1978Aj03 and 1987Aj02).

The partial shell capture probabilities P_K/P_{EC}, P_L/P_{EC} were calculated using the program EC-CAPTURE for an allowed transition.

The β^+ end-point energy (633.9 (5) keV) has been calculated from the Q value (2012Wa38). This value can be compared with the measured values given in Table 3.

Table 3. Measured values of the β^+ end-point energy.

Reference	Value (keV)
Blaser (1949Bl26)	635 (15)
Ruby (1951Ru24)	649 (9)
Hofmann (1964Ho09)	635 (2)
Alburger (1970Al11)	632.9 (7)
Fitzpatrick (1973Fitzpatrick)	633.3 (3)

3. ATOMIC DATA

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

4. ELECTRON EMISSIONS

The absolute emission probabilities of K Auger electrons have been calculated using the EMISSION computer program.

5. PHOTON EMISSIONS

5.1. X-ray Emissions

The absolute emission probabilities of KX - rays have been calculated using the EMISSION computer program.

5.2. Gamma ray emissions

The annihilation radiation emission intensity ($I_{\gamma\pm}$) is $2 \times P_{\beta+}$, without the correction factor for the annihilation-in-flight process in the medium. That is, $I_{\gamma\pm}$ = 193.72 (38) %.

6. ENERGY CONSERVATION

A total average energy of 1655.9 (34) keV for one disintegration has been calculated from the current evaluated data. This value corresponds very well to an energy of 1655.9 (5) keV (Q_{EC}) obtained from the mass tables (2012Wa38), and confirms the consistency of the decay scheme and reliability of this evaluation.

7. REFERENCES

1937Snell A. H. Snell, Phys. Rev. 51 (1937) 143.
[$T_{1/2}$]

1938Br01 L. A. DuBridge, S. W. Barnes, J. H. Buck, C. V. Strain, Phys. Rev. 53 (1938) 447.
[$T_{1/2}$]

1941Krishnan R. S. Krishnan, Nature (London) 148 (1941) 407.
[$T_{1/2}$]

1943Hu02 O. Huber, O. Lienhard, P. Scherrer, H. Waffler, Helv. Phys. Acta 16 (1943) 33.
[$T_{1/2}$]

1949Bl26 J. P. Blaser, F. Boehm, P. Marmier, Phys. Rev. 75 (1949) 1953.
[End-point energy, $T_{1/2}$]

1951Ru24 L. Ruby, J. R. Richardson, Phys. Rev. 83 (1951) 698.
[End-point energy].

1955Jarmie N. Jarmie, Phys. Rev. 98 (1955) 41.
[$T_{1/2}$]

1956Dr38 R. W. P. Drever, A. Moljk, J. Scobie, Phil. Mag. 1 (1956) 942.
[K/β^+ ratio]

1958Be74 W. L. Bendel, J. McElhinney, R. A. Tobin, Phys. Rev. 111 (1958) 1297.
[$T_{1/2}$]

1958Ko75 J. Konijn, B. Van. Nooijen, H. L. Hagedoorn, A. H. Wapstra, Nucl. Phys. 9 (1958) 296.
[K/β^+ ratio]

1958Ma68 S. S. Markowitz, F. S. Rowland, Phys. Rev. 112 (1958) 1295.
[$T_{1/2}$]

1959Aj76 F. Ajzenberg-Selove and T. Lauritsen, Nucl. Phys. 11 (1959) 1.
[$T_{1/2}$, end point energy, Q, log ft]

1959Ca01 C. H. Carlson, L. Singer, D. H. Service, W. D. Armstrong, Int. J. Appl. Radiat. Isotop. 4 (1959) 210.
[$T_{1/2}$]

1960Yu02 H. P. Yule, A. Turkevich, Phys. Rev. 118 (1960) 1591.
[$T_{1/2}$].

1961Ra06 L. A. Rayburn, Phys. Rev. 122 (1961) 168.
[$T_{1/2}$]

1962Ma48 J. D. Mahony, S. S. Markowitz, UCRL 10624 (1962) 1
[$T_{1/2}$].

1963Be47 K. Beg, F. Brown, Int. J. Appl. Radiat. Isotop. 14 (1963) 137.
[$T_{1/2}$].

1964Ho09 J.C.Hopkins, M.G.Silbert, Nucl. Sci. Eng. 19 (1964) 431
[End-point energy]

1964Ho28 I. Hofmann, Acta. Phys. Austriaca 18 (1964) 309.
[$T_{1/2}$]

1964Ma12 J. D. Mahony, S. S. Markowitz, J. Inorg. Nucl. Chem. 26 (1964) 907.
[$T_{1/2}$].

1965Eb01 T. G. Ebrey, P. R. Gray, Nucl. Phys. 61 (1965) 479.
[$T_{1/2}$]

1965Bo42 M. Bormann, E. Fretwurst, P. Schehka, G. Wrege, H. Büttner, A. Lindner, H. Meldner, Nucl. Phys. 63 (1965) 438.
[$T_{1/2}$]

1969Kavanagh R. W. Kavanagh, Nucl. Phys. A129 (1969) 172.
[$T_{1/2}$]

1970Al11 D. E. Alburger, D. H. Wilkinson, Phys. Lett. 32B (1970) 190.
[End-point energy]

1972Aj02 F. Ajzenberg-Selove, Nucl. Phys. A190 (1972) 1.
[$T_{1/2}$, end point energy, Q, log ft]

1973Ho43 K. R. Hogstrom, B. W. Mayes, L. Y. Lee, J. C. Allred, C. Goodman, G. S. Mutchler, C. R. Fletcher, G. C. Phillips, Nucl. Phys. A215 (1973) 598.
[$T_{1/2}$]

1973 Fitzpatrick M. L. Fitzpatrick, K. W. D. Ledingham, J. Y. Gourlay, J. G. Lynch, J. Phys. A6 (1973) 713.
[K/β^+ ratio, end-point energy]

1977Ba48 W. Bambynek, H. Behrens, M. H. Chen, B. Crasemann, M. L. Fitzpatrick, K. W. D. Ledingham, H. Genz, M. Muttere, R. L. Intemann, Revs. Modern Phys. 49 (1977) 77.
[Electron Capture]

1978Aj03 F. Ajzenberg-Selove, Nucl. Phys. A300 (1978) 1.
[$T_{1/2}$, Q, log ft]

1980RuZY A. R. Rutledge, L. V. Smith, J. S. Merritt, AECL- 6692 (1980) 2.
[$T_{1/2}$]

1987Aj02 F. Ajzenberg-Selove, Nucl. Phys. A475 (1987) 1.
[$T_{1/2}$, Q, log ft].

1989Katoh T. Katoh, K. Kawade, H. Yamamoto, JAERI-M 089-083 (1989).
[$T_{1/2}$]

1989Sc17 H.Schrader, Appl. Radiat. Isot. 40 (1989) 381
[$T_{1/2}$]

2002Un02 M.P. Unterweger, Appl. Radiat. Isot. 56 (2002) 125
[$T_{1/2}$]

2004BeZQ M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch. *Table of Radionuclides (Vol. 1 – A = 1 to 150).* Bureau International des Poids et Mesures, 2004. ^{18}F.
[Previous ^{18}F decay data evaluation]

2004Sc04 H. Schrader, Appl. Rad. Isotopes 60 (2004) 317.
[$T_{1/2}$]

2010Ga04 E.Garcia-Torano, V.Peyres Medina, M.Roteta Ibarra, Appl. Radiat. Isot. 68 (2010) 1561
[$T_{1/2}$]

2012Ha35 J.Han, K.B.Lee, T.S.Park, J.M.Lee, P.J.Oh, S.H.Lee, Y.S.Kang, J.K.Ahn, Appl. Radiat. Isot. 70, (2012) 2581
[$T_{1/2}$]

2012Wa38 M. Wang, G. Audi, A.H. Wapstra, F.G. Kondev, M. MacCormick, X. Xu, B. Pfeiffer. Chin. Phys. C36 (2012) 1603.
[Q]

2014Un01 M.P. Unterweger, R. Fitzgerald. Appl. Radiat. Isot. 87 (2014) 92.
[$T_{1/2}$]