^{137}Cs - Comments on evaluation of decay data
by R.G. Helmer and V.P. Chechev

This evaluation was completed by R.G. Helmer in September 1996 with minor editing done in February 1998. Updating ^{137}Cs half-life and editing were done by V.P. Chechev in February 2006. The literature available by February 2006 was included.

1 Decay Scheme

There are as many as 2 supposed excited levels in ^{137}Ba below the decay energy that have not been reported in the ^{137}Cs decay and observed only in ^{136}Ba(d, p)-reaction (1997Tu04 evaluation). Since the possible 907 and 1044 levels do not have J^{π} assignments, and the de-exciting γ rays have not been reported, arguments about their feeding can not be made.

The decay scheme is internally consistent and essentially complete since the total decay energy computed by RADLIST is 1174 (3) keV compared to the Q value of 1175.63 (17) keV, a difference of 1.8 (28) keV.

The J^{π} values and half-lives of the excited levels in ^{137}Ba are from the evaluation of 1997Tu04.

2 Nuclear Data

Q value is from 2003Au03.

The experimental ^{137}Cs half-life values available are, in days (values published in years have been converted to days):

12053 (1096)	1951FlAA,	omitted from analysis
10957 (146)	1955Br06,	omitted from analysis
9715 (146)	1955Wi21,	omitted from analysis
10446 (+73-37)	1958MoZY,	omitted from analysis
11103 (146)	1961Fa03	
10592 (365)	1961Gl08	
10994 (256)	1962Fl09	
10840 (18)	1963Go03	
10665 (110)	1963Ri02	
10738 (66)	1964Co35	
10921 (183)	1965Fl01	
11286 (256)	1965Fl01	
11220 (47)	1965Le25	
11030 (110)	1966Re13,	replaced by 1972Em01
11041 (58)	1968Re04,	replaced by 1972Em01
11191 (157)	1970Ha32	
10921 (16)	1970Wa19,	replaced by 1983Wa26
11023 (37)	1972Em01	
11034 (29)	1973Co39	
11020.8 (41)	1973Di01	
10906 (33)	1978Gr08	
11009 (11)	1980Ho17	
10449 (147)	1980RuZX,	replaced by 1990Ma15
10678 (140)	1980RuZY,	replaced by 1990Ma15

10678 (140)	1982RuZV,	replaced by 1990Ma15
11206 (7)	1982HoZJ,	replaced by 1992Un01
10921 (19)	1983Wa26	
10941 (7)	1989KoAA	
10967.8 (45)	1990Ma15	
10940.8 (69)	1992Go24	
11015 (20)	1992Un01,	replaced by 2002Un02
11018.3 (95)	2002Un02	
10970 (20)	2004Sc04	
10976 (30)	**Adopted**	

If the four values from before 1960 are omitted as well as replaced values, the data set for analysis includes the 21 values. The large reduced-χ^2 value (16.3) indicates that these data are quite discrepant; therefore, the adopted value will depend on the method of analysis.

Since no value in this data set contributes more than 50% of the relative weight, the Limitation of Relative Statistical Weight (LRSW) method does not adjust any of the input uncertainties; however, it may expand the final uncertainty to include the more precise value. The Normalized Residual (NORM, 1994Ka08) and RAJEVAL (1992Ra08) methods adjust the input uncertainties for the more discrepant values.

In 1997-1998 R.G. Helmer chose the Normalized Residual (NR) analysis for obtaining the recommended half-life value of 10964(9). That choice was based on a desire for reducing a large relative weight of the value from 1973Di01 and its big contribution to χ^2 value and also to avoid an expansion of the final uncertainty by use of the LRSW analysis. It was stated that the low evaluation result met the tendency of the last measurements (by 1992) and evaluation results to be lower. (Details of Helmer's analysis can be found in the book of 1999BeAA).

The updated NIST value, obtained as a result of continued measurements of six sources (2002Un02), changes the situation. This high value with a small uncertainty (half of that in 1992Un01) has shown that the discrepancy among the most recent and accurate measurements is still kept. Therefore, a small uncertainty of the evaluation result seems to be unrealistic.

Thus, at present we can use the LRSW analysis as one of the methods for the evaluation of the ^{137}Cs half-life.

The weighted average of the twenty one values is 10981.8, with an internal uncertainty of 2.3, a reduced χ^2 of 16.3, and an external uncertainty of 9.5. The unweighted average is 10967(37). The LWEIGHT computer program using the LRSW analysis has chosen the weighted average and expanded the final uncertainty to 39 so range includes the most precise value of 11020.8. Hence, use of the LRSW analysis leads to the evaluation of 10982(39) days for the ^{137}Cs half-life.

This evaluation agrees well with the recent independent evaluations. Woods and Collins (2004Wo02) used 11 experimental values since 1968 and recommended the value of 10990(40) days by similar evaluation technique. Helene and Vanin (2002He06) presented in their paper a very promising statistical procedure (BOOTSTRAP method) to deduce a best value and its standard deviation for a discrepant set of data. They used 19 experimental ^{137}Cs half-life values and obtained the evaluation result as 10987(30) days.

The NORM and RAJEVAL statistical procedures lead to the evaluation results of 10962(7) and 10971(6) days, with the small uncertainties. The Bayesian procedures (BAYS and MBAYS, 1994Ka08) give the equal result of 10982(10) days. Thus, different methods of statistical analysis have led to discrepant results. In such a way the best (the less worst ?) choice is derived from the BOOTSTRAP method. It gives an intermediate result (calculation of Helene and Vanin, 2006) between the unadjusted weighted mean and the adjusted values from different procedures and its uncertainty encompasses all the statistical results.

The adopted value of the ^{137}Cs half-life is **10976(30) days, or 30.05(8) years.**

2.1 Beta - Transitions

The emission probability (in %) of the β^- transition to the ground state has been measured as follows:

4.8 (3)	1957Ri41,	σ increased to 0.6
7.6 (8)	1958Yo01	
6.5 (2)	1962Da05,	σ increased to 0.6
4.8 (10)	1965Me03	
6.0 (5)	1966Hs02	
5.4 (3)	1969Ha05	
6.4 (5)	1978Gr09	
5.57 (7)	1983Be18	
5.69 (19)	Value from LRSW analysis	
5.64 (28)	Adopted value from sect. 4.2	

The uncertainties for early values of 1957Ri41 and 1962Da05 were increased by the evaluator to 0.6 to make them comparable with those of the values measured in the 1966 - 1978 period.

The LRSW analysis gives an internal uncertainty of 0.14, a reduced-χ^2 value of 2.03, and an external uncertainty of 0.19. In this analysis the uncertainty of the 1983Be19 value was increased from 0.07 to 0.19 in order to reduce its relative weight from 78% to 50%.

The average β^- energies and log *ft* values have been calculated using the LOGFT computer program.

The shape of the β^- spectra has been measured by 1983Be18, 1978Ch22, 1978Gr09, 1969Sc23, and 1966Hs02, which is useful in the determination of the relative β^- branch intensities.

The very detailed treatment of the expression for the shape of the β^- spectrum for the 2nd forbidden transition to the ground state argues that the measurement of 1983Be18 should replace all of the previous values. If this were done the $P_{\beta-}(0)$ would decrease by 0.12% and $P_{\beta-}(662)$ would increase by this amount. The $P_\gamma(662)$ would then increase by about 0.08%. However, the value of 1983Be18 has only been allowed to contribute 50% of the relative weight, as is our common practice. It should also be noted that this paper has additional influence since its data are also used in determining the α_T (662) value that is used in the calculation of $P_\gamma(662)$.

The adopted value $P_{\beta-}(662)$ has been computed from the final adopted $P_\gamma(662)$ value. [The uncertainty has increased due to the inclusion of the uncertainty in α_T (662) twice.]

2.2 Gamma Transitions

The adopted α_T (662) value of 0.1102 (19) is from a LRSW analysis of the 5 measured values recommended in the 1985HaZA evaluation, except that the value of 1983Be18 is used in place of value of 1978Ch22; these values are 0.1100 (11) (1965Me03), 0.1121 (5) (1969Ha05), 0.1105 (10) (1973LeZJ), 0.1100 (6) (1975Go28), and 0.1083 (5) (1983Be18, where the uncertainty has been increased to match the lowest other value). For this average, internal uncertainty = 0.0003, the reduced-χ^2 = 7.3, and the external uncertainty = 0.0008. The final uncertainty was increased by the LRSW analysis from 0.0008 to 0.0019 to include the 2 most precise values. Due to the large discrepancies among the 12 measured α values reported, 1985HaZA chose not to recommend any value.

The theoretical α_T value interpolated from the tables of 1978Ro21 is 0.1143 34; but 1990Ne01 has suggested that the α_T values for M4's from 1978Ro21 should be multiplied by 0.975 which gives 0.1114; this agrees with the adopted value to 1.1% which is much smaller than the uncertainty in either value. The theoretical total ICC value interpolated from the tables of 1993Ba60 $\alpha_T(662)=0.1116$.

Other measurements of α_T listed in 1985HaZA include 0.114 (2) (1957Ri41), 0.114 (30) (1962Da05), 0.109 (20) (1963Bo31), 0.1167 (15) (1965Pa17), 0.112 (11) (1965Ra12), 0.1092 (8) (1978Ch22), and 0.114 (3) (1978Gr09).

The adopted value $\alpha_K(662)$ of 0.0896 (15) is from the LRSW analysis of the 4 values recommended in the 1985HaZA evaluation, except for the value of 1983Be18 which is used in place of that from 1978Ch22; these values are 0.0894 (10) (1965Me03), 0.0916 (4) (1969Ha05), 0.0901 (9) (1973LeZJ), and 0.0881 (2) (1983Be18).

The LRSW analysis increases the uncertainty of the 1983Be18 value from 0.0002 to 0.00034 to reduce its relative weight from 75% to 50%. For this average, the internal uncertainty = 0.0002, the reduced-χ^2 = 14.8, and the external uncertainty = 0.0009. The final uncertainty was increased by the LRSW analysis from 0.0009 to 0.0015 to include the most precise value.

The theoretical value α_K(662) interpolated from the tables of 1978Ro21 is 0.0929 28; but 1990Ne01 has suggested that the α_K values for M4's from 1978Ro21 should be multiplied by 0.975 which gives 0.0906; this agrees with the adopted value to 1.1% which is much smaller than the uncertainty in either value. The theoretical α_K(662) value interpolated from the tables of 1993Ba60 α_K (662)=0.0907.

Other measured values of α_K listed in 1985HaZA are 0.097 (3) (1951Wa19), 0.095 (5) (1952He33), 0.11 (1) (1953Do31), 0.096 (5) (1954AZ01), 0.095 (8) (1957Mc34), 0.093 (1957Ri41), 0.092 (6) (1959Wa17), 0.0976 (55) (1958Yo01), 0.093 (6) (1959Hu23), 0.093 (6) (1960De17), 0.095 (4) (1961Hu12), 0.093 (3) (1962Da05), 0.0957 (10) (1965Pa17), 0.092 (9) (1965Ra12), 0.093 (7) (1966Hs01), 0.094 (5) (1966Hu02), 0.093 (9) (1967Ba80), 0.0925 (27) (1967HaZX), 0.0922 (22) (1973Wi10), 0.0901 (10) (1971BrAA), 0.0888 (70) (1978Ch22), and 0.093 (3) (1978Gr09).

3 Atomic Data

The data are from Schönfeld and Janßen (1996Sc06).

3.1 X Radiations

The data are from Schönfeld and Janßen (1996Sc06).

3.2 Auger Electrons

The data are from Schönfeld and Janßen (1996Sc06).

4 Radiation Emissions

4.1 Electron Emission

The β^- data are from RADLIST or LOGFT. The Auger and conversion electron data are from Schönfeld (1996Sc06) calculations. For comparison, these emission probabilities and those from RADLIST (with the atomic data from Schönfeld) are:

Electrons per decay

	Schönfeld	RADLIST
L Auger	0.0728 (12)	0.0728 (22)
K Auger	0.0076 (4)	0.0076 (3)
K-662	0.07644	0.076 (3)
L-662	0.01387	0.0142 (6)

4.2 Photon Emissions

The 662-keV γ-ray energy is from 2000He14 and that for the 283-keV γ is from 1997WaZZ, but more precise values of 283.46 6 and 283.53 4 are available from (n,n'γ) studies.

The intensity of the 662-keV γ ray has been deduced in two ways, (1) the ratio of the measured γ emission rate and the measured source decay rate and (2) from the probability of β- decay to the 662-keV level and α_T (662). These two values are independent as long as they involve independent measurements. Of the many papers that quote P_γ values, several are listed in section 2.1 as giving $P_{\beta\text{-}}(0)$ values and are not included here. References 1965Me03 and 1978ChZZ have been replaced by 1978MeZM and 1983Be18, respectively. This leaves the following three values of P_γ(662) to consider:

85.3 (10)	1973LeZJ
86.0 (9)	1975Go28
84.7 (7)	1978MeZM
85.2 (5)	Weighted average with reduced-χ^2 = 0.65

[It should be noted that in the evaluation of 1991BaZS the value of 1973LeZJ is quoted as 0.8456 (8), which is the value from 1978Ch22. The evaluation of 1997Tu04 adopts the 1991BaZS result and repeats this error.]

The second value of P_γ(662) comes from the average $P_{\beta-}$(0) = 5.69% (19) in section 2.1 and the α_T (662) = 0.1102 (19) in section 2.2, $P_{\beta-}$(662)/[1.0+α(662)] = 84.95% (22). Then, the adopted value is taken to be the weighted average of the values 84.95% (22) and 85.2% (5) which is 84.99% (20).
The decay of ^{137}Cs to the first excited level in ^{137}Ba at 283 keV was observed in 1996Bi23 and 1997WaZZ. The γ-ray intensity relative to that of the 662-keV γ ray is 0.00053 (14) (1996Bi23) and 0.00061 (10) (1997WaZZ) which gives an average of 0.00058 (8) and a corresponding transition intensity of 0.00061 (8).

The final $P_{\beta-}$ values are adjusted to be in agreement with this result and are $P_{\beta-}$(662) = 94.36% (28) and $P_{\beta-}$(0) = 5.64% (28). [The uncertainties here are overestimated because the contribution from α_T (662) has been included twice.]

The X-ray emission probabilities are from the γ-ray emission probability, the internal-conversion coefficients, and the atomic data of 1996Sc06. The difference between the Schönfeld values given and the RADLIST values are within the uncertainties:

Photons per decay

	Schönfeld	RADLIST
$K_{\alpha2}$	0.0195 (4)	0.0195 (7)
$K_{\alpha1}$	0.0358 (7)	0.0359 (13)
K_β	0.0132 (3)	0.0132 (5)
Total K	0.0685 (13)	0.0686 (16)

Double-decay processes which might occur in lieu of the 662-keV γ ray have been studied; two γ's (1960Be20, 1992BaAA, 1993Ba46); a K shell electron plus a γ (1969Lj01, 1971Lj01); and two electrons (1971Lj02, 1971Po04). The paper of 1993Ba46 suggests an upper limit of the ratio of 2γ emission to 1γ emission of 5.10^{-7}.

5 References

1951Wa19 M.A.Waggoner, Phys.Rev. **82** (1951) 906 [α_K]
1952He33 R.L. Heath, Phys.Rev. **87** (1952) 1132 [α_K]
1953Do31 V.M.Dolishnyuk, G.M.Drabkin, V.I.Orlov, L.I.Rusinov, Doklady Akad.Nauk SSSR **92** (1953) 1141 [α_K]
1954Az01 T.Azuma, J.Phys.Soc.Japan **9** (1954) 1 [α_K]
1954Ve09 J.Verhaeghe, J.Demuynck, Compt.Rend. **239** (1954) 1374 [K/L]
1955Br06 F.Brown, G.R.Hall, A.J.Walter, J.Inorg.Nuclear Chem. **1** (1955) 241 [$T_{1/2}$]
1955Wi21 D.M.Wiles, R.H.Tomlinson, Phys.Rev. **99** (1955) 188 [$T_{1/2}$]
1957Mc34 F.K.McGowan, P.H.Stelson, Phys.Rev. **107** (1957) 1674 [α_K]
1957Ri41 R.A.Ricci, Physica **23** (1957) 693 [α_T, α_K,$P_{\beta-}$]
1958MoZY A. J. Moses, H. D. Cook, report TID-7568, part 2 (1958) 192 [$T_{1/2}$]
1958Yo01 Y.Yoshizawa, Nuclear Phys. **5** (1958) 122 [α_K,$P_{\beta-}$]
1959Hu23 S.Hultberg, R.Stockendal, Arkiv Fysik **14** (1959) 565 [α_K]
1959Wa17 A. H. Wapstra, G. J. Nijgh, N. Salomons-Grobben, L. T. M. Ornstein, Nucl. Phys. **9** (1959) 538 [α_K]
1960Be20 W.Beusch, Helv.Phys.Acta **33** (1960) 363 [double particle emission]

1960De17 C. de Vries, E. J. Bleeker, N. Salomons-Grobben, Nucl. Phys. **18** (1960) 454 [α_K]
1961Fa03 H. Farrar, A. K. Dasgupta, R. H. Tomlinson, Can. J. Chem. **39** (1961) 681 [$T_{1/2}$]
1961Gl08 M. P. Glazunov, A. I. Grivkova, B. A. Zaitsev, V. A. Kiselev, Atomic Energy **10** (1961) 622 (page 615 in English) [$T_{1/2}$]
1961Hu12 S.Hultberg, D.J.Horen, J.M.Hollander, Nucl.Phys. **28** (1961) 471 [α_K]
1962Da05 H.Daniel, H.Schmitt, Z.Physik **168** (1962) 292 [α_T, α_K,$P_{\beta-}$]
1962Fl09 D. G. Fleishman, I. V. Burovina, V. P. Nesterov, Atomic Energy **13** (1962) 1225 (page 1224 in English) [$T_{1/2}$]
1962Ge09 J.S.Geiger, R.L.Graham, F.Brown, Can.J.Phys. **40** (1962) 1258 [K/L]
1963Bo31 H.E.Bosch, T.Urstein, Nucl.Instr.Methods **24** (1963) 109 [α_T]
1963Go03 S. G. Gorbics, W. E. Kunz, A. E. Nash, Nucleonics **21**, No. 1 (1963) 63 [$T_{1/2}$]
1963Ri02 B. F. Rider, J. P. Peterson, Jr., C. P. Ruiz, Nucl. Sci. Eng. **15** (1963) 284 [$T_{1/2}$]
1964Ch18 Y.Y.Chu, M.L.Perlman, Phys. Rev. **135** (1964) B319 [K/L]
1964Co35 H. D. Cook, C. J. Rettger, W. J. Sewalk, report WAPD-BT-30 (1964) [$T_{1/2}$]
1964Ge05 H.U.Gersch, E.Hentschel, P.Gippner, W.Rudolph, Nucl. Instr. Methods **25** (1964) 314 [K/L]
1965Fl01 K. F. Flynn, L. E. Glendenin, A. L. Harkness, E. P. Steinberg, J. Inorg. Nucl. Chem. **27** (1965) 21 [$T_{1/2}$]
1965Le25 R. E. Lewis, R. E. McHenry, T. A. Butler, Trans. Amer. Nucl. Soc. **8** (1965) 79 [$T_{1/2}$]
1965Me03 J. Merritt, J. G. V. Taylor, An. Chem. **37** (1965) 351 [α_K, α_T, P_γ, $P_{\beta-}$]
1965Pa17 D.Parsignault, Thesis, Univ.Paris (1965); CEA-R-2631(1965) [α_T, α_K]
1965Ra12 M.R.Rao, S.Jnanananda, Nucl.Instr.Methods **36** (1965) 261; Phys.Abstr. **69** (1966) 666, Abstr.7047 [α_T, α_K]
1966Hs01 S.T.Hsue, L.M.Langer, E.H.Spejewski, S.M.Tang, Nucl.Phys. **80** (1966) 657 [α_K]
1966Hs02 S. T. Hsue, L. M. Langer, S. M. Tang, Nucl. Phys. **86** (1966) 47 [$P_{\beta-}$]
1966Hu02 S.Hultberg, A.A.Bartlett; J. H. Hamilton, Ed., Academic Press, Inc., New York, (1966) 141 [α_K, β^- shape]
1966Re13 S.A.Reynolds, ORNL-3889 (1966) 57 [$T_{1/2}$]
1967Ba80 E. Baldinger, E. Haller, Helv. Phys. Acta **40** (1967) 800 [α_K]
1967HaZX H.H.Hansen, M.Delabaye, Proc.Symp.Standardization of Radionuclides,Vienna, Austria (1966), Intern.At.Energy Agency, Vienna (1967) 361; CONF-661012 (1967) [α_K]
1968Re04 S.A.Reynolds, J.F.Emery, E.I.Wyatt, Nucl.Sci.Eng. **32**2 (1968) 46 [$T_{1/2}$]
1968Wo02 J.L.Wolfson, A.J.Collier, Nucl.Phys. **A112** (1968) 156 [$E_{\beta-}$]
1969Ha05 H. H. Hansen, G. Lowenthal, A. Spernol, W. van der Eijk, R. Vaninbroukx, Z. Phys. **218** (1969) 25 [$P_{\beta-}$, P_γ, α_K]
1969Lj01 A.Ljubicic, B.Hrastnik, K.Ilakovac, V.Knapp, B.Vojnovic, Phys.Rev. **187** (1969) 1512 [double particle emission]
1969Sc23 H.Schneuwly, L.Schellenberg, O.Huber, W.Lindt, Helv.Phys.Acta **42** (1969) 743 [β^- shape]
1970Ha32 G. Harbottle, Radiochim. Acta **13** (1970) 132 [$T_{1/2}$]
1970Wa19 K. F. Walz, H. M. Weiss, Z. Naturforsch. **25a** (1970) 921 [$T_{1/2}$]
1971BrAA. P. Brethon, report CEA-R-4196 (1971) [α_K]
1971Ca08 J.L.Campbell, H.J.Smith, I.K.Mackenzie, Nucl.Instrum.Methods **92** (1971) 237 [P_X]
1971Lj01 A.Ljubicic, B.Hrastnik, K.Ilakovac, M.Jurcevic, I.Basar, Phys.Rev. **C3** (1971) 824 [double particle emission]
1971Lj02 A.Ljubicic, M.Jurcevic, K.Ilakovac, B.Hrastnik, Phys.Rev. **C3** (1971) 831 [double particle emission]

1971Po04 F.T.Porter, M.S.Freedman, F.Wagner Jr., Phys.Rev. **C3** (1971) 2246 [double particle emission]
1972Em01 J. F. Emery, S. A. Reynols, E. I. wyatt, G. I. Gleason, Nucl. Sci. Eng. **48** (1972) 319 [$T_{1/2}$]
1973C039 J. A. Corbett, Nucl. Eng. Int. **18** (1973) 715 [$T_{1/2}$]
1973Di01 L. A. Dietz, C. F. Pachuck1, J. Inorg. Nucl. Chem. **35** (1973) 1769 [$T_{1/2}$]
1973LeZJ J. Legrand, J. P. Brethon, F. Lagoutine, CEAR-4428 (1973) [α_K, α_T, P_γ, $T_{1/2}$, $P_{\beta-}$]
1973Wi10 J.B.Willett, G.T.Emery, Ann.Phys.(New York) **78** (1973) 496 [α_K]
1975Go28 I. W. Goodier, J. L. Makepeace, L. E. Stuart, Int. J. Appl. Radiat. Isot. **26** (1975) 490 [α_T, P_γ, P_β]
1976Bo16 G.L.Borchert, Z.Naturforsch. **31a** (1976) 387 [E_γ]
1978Ch22 P.Christmas, P.Cross, Metrologia **14** (1978) 157 [α_T, α_K]
1978Gr08 W. H. Gries, J. Steyn, Nucl. Instr. and Meth. **152** (1978) 459 [$T_{1/2}$, P_β]

1978Gr09 K.Y.Gromov, T.Kretsu, V.V.Kuznetsov, G.Makarie, Izv.Akad.Nauk SSSR, Ser.Fiz. **42** (1978) 790; Bull.Acad.Sci.USSR, Phys.Ser. **42**, No.4 (1978) 85 [α_T, α_K, β shape, P_γ, $P_{\beta-}$, $T_{1/2}$]
1978MeZM J. S. Merritt, F. H. Gibson, report AECL-6203 (1978) [P_γ]
1978Ro21 F. Rösel, H. M. Fries, K. Alder, H. C. Pauli, Atomic Data Nucl. Data Tables **21** (1978) 91 and 292 [Theoretical ICC]
1980Ho17 H. Houtermans, O. Milosevic, F. Reichel, Intern. J. Appl. Radiat. Isot. 31 (1980) 153 [$T_{1/2}$]
1980RuZX A.R.Rutledge, J.S.Merritt, L.V.Smith, AECL-6788 (1980) 45 [$T_{1/2}$]
1980RuZY A.R.Rutledge, L.V.Smith, J.S.Merritt, AECL-6692 (1980) [$T_{1/2}$]
1982HoZJ D.D.Hoppes, J.M.R.Hutchinson, F.J.Schima, M.P.Unterweger, NBS-SP-626 (1982) 85 [$T_{1/2}$]
1982RuZV A.R.Rutledge, L.V.Smith, J.S.Merritt, NBS-SP-626 (1982) 5 [$T_{½}$]
1983Be18 H. Behrens, P. Christmas, Nucl. Phys. 399 (1983) 131 [α_T, α_K, P_γ]
1983Wa26 K.F.Walz, K.Debertin, H.Schrader, Int.J.Appl.Radiat.Isotop. **34** (1983) 1191 [$T_{1/2}$]
1985HaZA H.H.Hansen, European App.Res.Rept.Nucl.Sci.Technol. 6, No.4 (1985) 777 [α_T, α_K]
1987Me02 D.Mehta, S.Singh, H.R.Verma, N.Singh, P.N.Trehan, Nucl.Instrum.Methods Phys.Res. **A254** (1987) 578 [P_X]
1989KoAA A. E. Kochin, Schmidt-Ott, H.Behrens, Z.Phys. **A337** (1990) 169 [$T_{1/2}$]
1990Ma15 R. H. Martin, J. G. V. Taylor, Nucl. Instr. Meth. **A286** (1990) 507 [$T_{1/2}$]
1990Ne01 Zs. Nemeth, A. Veres, Nucl. Instr. Meth. **A286** (1990) 601 [α_T, α_K]
1990Wo04 M. J. Woods, Nucl. Instr. Meth. **A286** (1990) 576 [$T_{1/2}$]
1991BaZS W.Bambynek, T.Barta, R.Jedlovszky, P.Christmas, N.Coursol, K.Debertin, R.G.Helmer, A.L.Nichols, F.J.Schima, Y.Yoshizawa, IAEA-TECDOC-619 (1991) [^{137}Cs decay data evaluation]
1992BaAA V. K. Basenko, A. N. Berlizov, and G. A. Prokopets, Bull. Russian Acad. Sci. 56 (1992) 1, 94 [P_γ]
1992Go24 J.-J. Gostely, Appl. Radiat. Isot. **43** (1992) 949 [$T_{1/2}$]
1992Ra08 M. U. Rajput, T. D. MacMahon, Nucl. Instr. Meth. **A312** (1992) 289 [$T_{1/2}$ analysis]
1992Un01 M. P. Unterweger, D. D. Hoppes, F. J. Schima, Nucl. Instr. Meth. **A312** (1992) 349 [$T_{1/2}$]
1993Ba46 V. K. Basenko, A. N. Berlizov, and G. A. Prokopets, Bull. Russian Acad. Sci. 57 (1993) 55 [P_γ]
1993Ba60 I.M.Band and M.B.Trzhaskovskaya, At. Data and Nucl. Data Tables 55 (1993) 43. [Theoretical ICC]

1994Ka08 S.I.Kafala, T.D.MacMahon, P.W.Gray, Nucl.Instrum.Methods Phys.Res. **A339** (1994) 151 [$T_{1/2}$ analysis]

1996Bi23 I. Bikit, I. Anicin, J. Slivka, M. Krmar, J. Puzovic, Lj.Conkic, Phys. Rev. C 54 (1996) 3270 [P_γ]
1996Sc06 Schönfeld, H. Janßen, Nucl. Instr. Meth. **A369** (1996) 527 [ω_K, ω_L, relative K x-ray, emission probabilties]
1997WaZZ B. K. Wagner, P. E. Garrett, M. Yeh, S. W. Yates, private communication (1997) [P_γ]
1997Tu04 J. K. Tuli, Nuclear Data Sheets **81** (1997) 579 [Decay scheme]
1999BeAA M.-M. Be, E. Browne, V. Chechev, R. Helmer and E. Schonfeld. Table de Radionucleides. Comments on Evaluations. // CEA-ISBN 2-7272-0211-3. 1999.
2000He14 R. G. Helmer and C. van der Leun, Nucl. Instr. Meth. **A450** (2000) 35 [E_γ]
2002He06 O.Helene and V.R.Vanin, Nucl.Instrum.Methods Phys.Res. **A481** (2002) 626 [$T_{1/2}$ analysis]
2003Au03 G.Audi, A.H.Wapstra, and C.Thibault, Nucl.Phys. **A729** (2003) 337 [Q value]
2004Wo02 M.J.Woods and S.M.Collins, Appl.Radiat.Isot. **60** (2004) 257 [$T_{1/2}$ analysis]