^{141}Ce - Comments on evaluation of decay data by E. Schönfeld and V.P. Chechev

This evaluation was completed in 1998; it has been updated in February 2012. The literature available by this latter date has been included.

1. Decay Scheme and Decay Energy

^{141}Ce decay scheme is complete as there are no other excited levels of ^{141}Pr below the decay energy Q^-, except for the 7/2+ single level with an energy of 145.443 keV (2001Tu02).
Q^- value has been taken from the atomic mass adjustment by Audi and Wang (2012Au06).

2. Half-Life

The following values of the ^{141}Ce half-life presented in Table 1 were considered here:

Table 1. Results of ^{141}Ce half-life measurements (in days)

Reference	Author(s)	Value	Comments
1949Wa23	Walker	32.11 (23)	Omitted; uncertainty strongly underestimated in an unknown amount
1950Fr58	Freedman and Engelkemeir	**32.50 (20)**	
1957Ke26	Ketelle and Brozi	32.51 (2)	Omitted; uncertainty strongly underestimated in an unknown amount
1965An07	Anspach *et al.*	32.550 (7)	Omitted; superseded in 1992Un01
1967Ob01	O'Brien and Eldridge	32.38 (2)	Omitted; uncertainty strongly underestimated in an unknown amount
1971Ba28	S. Baba and H. Baba	**32.60 (20)**	
1971De11	Debertin	32.51 (6)	Omitted; superseded in 1983Wa26
1972Em01	Emery *et al.*	**32.45 (13)**	
1973MeYE	Merritt and Taylor	32.51 (6)	Omitted; superseded in 1980RuZY
1976Va30	Vaninbroukx and Grosse	**32.501 (13)**	
1980RuZY	Rutledge *et al.*	**32.50 (3)**	
1983Wa26	Walz *et al.*	**32.51 (10)**	
1992Un01	Unterweger *et al.*	32.510 (24)	Omitted; superseded in 2002Un02
2002Un02	Unterweger	**32.510 (24)**	

From the seven values (in boldface) used in the data analysis, the LWEIGHT computer program has consistently identified two outliers (1971Ba28 and 1972Em01), and deduced a weighted mean (32.503) and

an internal uncertainty (0.011) with χ^2/ν = 0.03. This result suggests that the uncertainties had been overestimated.

The recommended value for the ^{141}Ce half-life is **32.503 (11) days**.

3. β^- Transitions

The energy of the $\beta^-_{0,1}$ - transition has been deduced from the Q^- value and the 145 keV ^{141}Pr level energy.
The emission probability of the $\beta^-_{0,1}$ - transition is equal to $P_{\gamma+ce}$ for the 145 keV gamma-ray transition.
The probability of feeding the ground state was deduced from the relation $1-P(\beta^-_{0,1})$.

4. Gamma-Ray Transition

The energy was taken from the recommended data by Helmer and van der Leun (2000He14).
The emission probability $P_{\gamma+ce}$ was deduced using the relation $P_{\gamma+ce} = P_\gamma (1 + \alpha_T)$. (For P_γ see Section 7.2).
The multipolarity (M1+E2) is based on the measurements of conversion electrons of 1961Co04, 1961Ne12, 1965Ge04, 1966Di02, 1966Pa09, 1968Ge02, 1972Ca07, 1975Le09, 1979Ha09, 1992Sc24.
The E2/M1 mixing ratio δ = 0.068 (5) is a weighted average of measurements from 1962Sc11 (0.068 (8)), 1963Ha07 (0.066 (22)) and 1979Ha21 (0.069 (7)).
The internal conversion coefficients (ICC) α_T , α_K , α_L , α_L , α_M , α_N , α_O , α_P and their associated uncertainties were interpolated from theoretical values of Band *et al.* (2002Ba85) using the BrIcc computer program (2008Ki07) for the "frozen orbital" approximation, version 2.3S.

The values of the total conversion coefficient α_T , measured and deduced (1966 - 1992); are presented below. A value for the total conversion coefficient of the 145 keV gamma transition was obtained from special coincidence measurements by Hansen *et al.* (1979Ha09) and Schönfeld *et al.* (1992Sc24). Another useful quantity used by them was the measured ratio of the emission probabilities of KX rays and the 145-keV gamma ray.

Total conversion coefficient α_T

1966Di02	0.440 (11)	Dingus *et al.*	deduced from α_K
1966Pa09	0.441 (9)	Pancholi	deduced from α_K
1975Le09	0.421 (21)	Legrand *et al.*	measured
1979Ha09	0.439 (13)	Hansen *et al.*	measured
1979Ha09	0.448 (7)	Hansen *et al.*	deduced from X_K/γ ratio
1979Ha09	0.436 (17)	Hansen *et al.*	coinc. meas., extrapol. technique
1992Sc24	0.452 (8)	Schönfeld *et al.*	coinc. meas., special technique
1992Sc24	0.435 (7)	Schönfeld *et al.*	deduced from X_K/γ ratio
	0.449 (7)	**Present evaluation** (BrIcc)	

5. Atomic Data

The fluorescence yields, X-ray energies and relative emission probabilities, and Auger electron energies and relative emission probabilities based on data in 1996Sc06 and 1977La19 are from the SAISINUC computer program.

6. Electron Emissions

The energies of the conversion electrons were obtained from the gamma-ray transition energy and the atomic electron binding energies in 1977La19.
The emission probabilities of the conversion electrons were deduced using the evaluated P(γ) and internal conversion coefficient values for the various atomic shells.
The total absolute emission probabilities of K and L Auger electrons were calculated using the EMISSION computer program (1996Sc06, 2000Sc47).

7. Photon Emissions

7.1 X - Ray emissions

The Pr KX- and LX- absolute emission probabilities given in the Tables Section (Table 5.1) were deduced using the computer program EMISSION. Measured values of P_{X_K} / P_γ are compared with a value of 0.350 (6), which was deduced using the computer program EMISSION.

0.338 (5)	Nemet (1961Ne12)
0.347 (12)	Nemet (1961Ne12)
0.342 (9)	Campbell *et al.* (1971Ca49)
0.334 (9)	Campbell and Mc Nelles (1972Ca07)
0.349 (5)	Hansen *et al.* (1979Ha09)
0.339 (5)	Schönfeld *et al.* (1992Sc24)
0.350 (6)	**Present evaluation**

The recommended value in the present evaluation is in good agreement with the experimental results, especially with the value from 1979Ha09.

7.2 Gamma-Ray Emission

The recommended 145 keV gamma-ray absolute emission probability is the weighted mean of 4 values (2, 3, 4, 6). The following values (based on absolute activity determinations) were considered:

1	0.493 (6)	Eldridge	1966El09
2	0.4844 (41)	Legrand *et al.*	1975Le09
3	0.482 (3)	Hansen *et al.*	1979Ha09
4	0.485 (4)	Rutledge *et al.*	1980RuZY
5	0.489 (4)	Schötzig *et al.*	1980Sc07
6	0.480 (5)	Schönfeld *et al.*	1992Sc24
	0.4829 (19)	LWM (2, 3, 4, 6) recommended value. $\chi^2/\nu = 0.28$.	

Value 1 was not used when calculating the average because the uncertainty seems to be underestimated by an unknown amount. Value 5 was also not used because it is considered to be superseded by value 6. The remaining 4 values were used to calculate a weighted mean. (The uncertainty of value 2 is stated to be 3 σ but is has been assumed here to be 1 σ as this seems to be more realistic and comparable to the other values).

References

1949Wa23 D. Walker, Proc. Phys. Soc.(London) 62A, 799 (1949) [Half-life]

1950Fr58 M. S. Freedman and D. W. Engelkemeir, Phys. Rev. 79, 897–899 (1950) [Half-life]

1957Ke26 B.H. Ketelle, A.R. Brosi, Priv. Comm. (October 1957). Quoted in Nuclear Data Tables 8, No. 1-2, p. 115, 153 [Half-life]

1961Co04 J.R. Cook, Proc. Phys. Soc. (London) 77, 346 (1961) [Conversion electrons, γ-ray multipolarity]

1961Ne12 L. Nemet, Izvest. Akad. Nauk SSSR, Ser. Fiz. 25, 68 (1961); Columbia Tech. Transl. 25, 68 (1962) [P(KX)/P(γ) ratio]

1962Sc11 J.F. Schooley, D.D. Hoppes, A.T. Hirshfeld, J. Res. Nat. Bur. Std. 66A, 317 (1962) [E2/M1 mixing ratio]

1963Ha07 J.N. Haag, D.A. Shirley, and David H. Templeton, Phys. Rev. 129, 1601–1613 (1963) [E2/M1 mixing ratio]

1965An07 S.C. Anspach, L.M. Cavallo, S.B. Garfinkel, J.M.R. Hutchinson, C.N. Smith, NP 15663 (1965) [Half-life]

1965Ge04 J.S. Geiger, R.L. Graham, I. Bergstrom, F. Brown, Nucl. Phys. 68, 352 (1965) [Conversion electrons, γ-ray multipolarity]

1966Di02 R.S. Dingus, W.L. Talbert, Jr., M.G. Stewart, Nucl. Phys. 83, 545 (1966) [Experimental ICCs]

1966El02 J.S. Eldridge, P. Crowther, W.S. Lyon, Nucleonics 24, No.3, 62 (1966) [γ-ray emission probability]

1966Pa09 S.C. Pancholi, Nucl. Phys. 81, 417 (1966) [Experimental ICCs]

1967Ob01 H.A. O'Brien, Jr., J.S. Eldridge, Nucleonics 25, No.2, 41 (1967) [Half-life]

1968Ge02 W. Gelletly, J.S. Geiger, R.L. Graham, Phys. Rev. 168, 1336 (1968) [Conversion electrons, γ-ray multipolarity]

1971Ba28 S. Baba, H. Baba, H. Natsume, J. Inorg. Nucl. Chem. 33, 589 (1971) [Half-life]

1971Ca49 J.C. Campbell, P. O'Brien, L.A. McNelles, Nucl. Instrum. Methods 92, 269 (1971) [P(KX)/P(γ) ratio]

1971De11 K. Debertin, Z. Naturforsch. 26a, 596 (1971) [Half-life]

1972Ca07 J.L. Campbell, L.A. McNelles, Nucl. Instrum. Methods 98, 433 (1972) [P(KX)/P(γ) ratio]

1972Em01 J.F. Emery, S.A. Reynolds, E.I. Wyatt, G.I. Gleason, Nucl. Sci. Eng. 48, 319 (1972) [Half-life]

1973MeYE J.S. Merritt, J.G.V. Taylor, AECL 4657, p.30 (1973) [Half-life]

1975Le09 J. Legrand, J.P. Perolat, C. Bac, J. Gorry, Int. J. Appl. Radiat. Isotop. 26, 179 (1975) [γ-ray emission probabilities, experimental ICCs]

1976Va30 R. Vaninbroukx, G. Grosse, Int. J. Appl. Radiat. Isotop. 27, 727 (1977) [Half-life]

1977La19 F.P. Larkins, At. Data Nucl. Data Tables 20, 311 (1977) [Atomic electron binding energies]

1979Ha09 H.H. Hansen, E. Celen, G. Grosse, D. Mouchel, A. Nylandsted Larsen, R. Vaninbroukx, Z. Phys. A290, 113 (1979) [KX- and γ-ray emission probabilities, experimental ICCs]

1979Ha21 H.H. Hansen, Z. Phys. A291, 43 (1979) [Experimental ICCs, E2/M1 mixing ratio]

1980RuZY A.R. Rutledge, L.V. Smith, J.S. Merritt, AECL 6692 (1980) [Half-life, γ-ray emission probability]

1980Sc07 U. Schotzig, K. Debertin, K.F. Walz, Nucl. Instrum. Methods 169, 43 (1980) [γ-ray emission probability]

1983Wa26 K.F. Walz, K. Debertin, H. Schrader, Int. J. Appl. Radiat. Isot., Vol. 34, 1983, P. 1191-1199 [Half-life]

1992Sc24 E. Schönfeld, H. Janssen, U. Schotzig, Appl. Radiat. Isot. 43, 1071 (1992) [KX- and γ-ray emission probabilities, experimental ICCs]

1992Un01 M.P. Unterweger, D.D. Hoppes,F.J. Schima, Nucl. Instrum. Meth. Phys. Res., Vol. A312, 1992, 349-352 [Half-life]

1996Sc06 E. Schönfeld, H. Janssen, Nucl. Instr. Methods A369 (1996) 527 [Atomic data]

2000He14 R.G. Helmer and C. van der Leun, Nucl. Instrum. Meth. Phys. Res. A450 (2000) 35 [Gamma-ray energy]

2000Sc47 E. Schönfeld, H. Janssen, Appl. Radiat. Isot. 52, 595 (2000) [Calculation of emission probabilities of X-rays and Auger electrons]

2001Tu01 J. Tuli, Nucl. Phys. A682, 236c (2001) [^{141}Ce decay scheme, ^{141}Pr levels]

2002Ba85 I. M. Band, M. B. Trzhaskovskaya, C. W. Nestor, Jr., P. O. Tikkanen, S. Raman, Atomic Data Nucl. Data Tables 81(2002)1 [Theoretical ICCs]

2002Un02 M.P. Unterweger, Appl. Radiat. Isot. 56, 125 (2002) [Half-life]

2008Ki07 T. Kibédi, T.W. Burrows, M.B. Trzhaskovskaya, P.M. Davidson, C.W. Nestor, Jr., Nucl. Instrum. Methods Phys. Res. A589, 202 (2008) [Band-Raman theoretical ICCs]

2012Au06 M. Wang, G. Audi, *et al.* Chinese Physics C36 (2012) 1603 [Qβ-]