^{139}Ce - Comments on evaluation of decay data
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1 Decay Scheme

This evaluation was completed in September 1996 and reviewed in 2007. The literature available by December 2007 was included.
This decay scheme is complete since the only excited level below the ^{139}Ce decay energy is populated (1989Bu12).

2 Nuclear Data

A Q value of 270 (3) keV is deduced from P_K measurements (see §2.1). It can be compared with a Q value of 264.6 (20) keV from measurement of the internal bremsstrahlung spectrum of 1996Hi14.

The ^{139}Ce half-life values available are, in days:

140	(1)	1948Po01	# (Pool and Krisberg as quoted in 1965An07)
137.5	(3)	1965An07	(Anspach et al.)
137.2	(4)	1972Em01	(Emery et al.)
137.63	(10)	1973MeYE	# (Merritt), replaced by 1982RuZV
137.65	(7)	1976Me	# (Merritt), replaced by 1982RuZV
137.66	(4)	1976Va30	(Vaninbroukx and Grosse)
137.59	(4)	1978La21	(Lagoutine et al.), uncertainty quoted as 0.12 at 3σ level
137.65	(3)	1980RuZY	# (Rutledge et al.), replaced by 1982RuZV
137.74	(8)	1982HoZJ	# (Hoppes et al.), replaced by 1992Un01
137.65	(3)	1982RuZV	(Rutledge et al.)
137.8	(2)	1982RyZX	(Rytz) BIPM value in NBS-SP-626
137.73	(9)	1992Un01	(Unterweger et al.)
137.641	(20)	Weighted average & adopted	

The value of 1948Po01 was omitted due to its large uncertainty. Omitting this value and the several (#) that were replaced by latter values, one has seven values to consider. The weighted average of these seven values is 137.641 with an internal uncertainty of 0.020 and a reduced-χ^2 of 0.83. No adjustments were made in the Limitation of Relative Statistical Weight method since the largest relative weight is less than 50 %, namely 44 % for the 1982RuZV value; also the set is consistent.

2.1 Electron Capture Transitions

The energies of the electron-capture transitions (ε) are calculated from the Q value and the level energies. The ε branch to the ground state is 2nd forbidden. From the log *ft* systematics (1998Si17), the expected log *ft* value is > 10.6 and the corresponding limit is $P_\varepsilon(0) < 0.008$ % compared to the measured limit of $P_\varepsilon(0) < 1$ % (1956Ke23) and $P_\varepsilon(0) < 0.000097$ % (1993Mi20) . If asymmetric uncertainties are used, the evaluator suggests the other ε branch probability is 99.9973 +27-53. If only symmetric uncertainties are used, 99.9973 (27) is suggested.

The P_K value for transition to the 165-keV level was deduced from the 17 measured values.

The available measured P_K values are listed in the following table as given in the original papers:

Value (uc)		ω_K	Reference	
0.87	(4)	Independant	Outlier	1954Pr31 (Pruett)
0.73	(2)	Independent		1956Ke23 (Ketelle)
0.68	(2)	Independent		1967Ma07 (Marelius)
0.75	(1)	Independent		1968Ad08 (B.Adamowicz)
0.69	(2)	Independent		1968Va08 (E.Vatai)
0.705	(20)	0.92 (1)		1972Ca07 (Campbell)
0.78	(3)	Independent		1972Sc08 (Schmidt-Ott)
0.73	(3)	(Martin ?)		1975Da08 (Dasmahapatra)
0.726	(10)	Independent		1975Ha43 (Hansen)
0.705	(20)	0.906 (26)		1975Pl06 (Plch)
0.801	(34)	0.906 (26)	Outlier	1976Ha36 (Hartl)
0.76	(3)	0.906 (26)		1978Se **(Sergienko)
0.710	(24)	0.926		1987BeYL (Begzhanov)
0.68	(2)	0.91 (3)		1988Ko** (Konstantinov)
0.74	(3)	0.905 (4)		1994Ku43 (Kumar)
0.704	(6)	0.907, $K\beta$ =0.193		1996Hi14 (Hindi)
0.714	(25)	0.906 (26)		1997Ka** (Kalyani)
Critical χ^2	2			
Reduced χ^2	2.4			
WM	0.716	External Unc.= 0.006 Expanded Unc. = 0.012		
Adopted	**0.716**	**0.006**		

Two values (1954Pr31 and 1976Ha36) were found outlier due to Chauvenet's criterion. The remaining set of 15 values is slightly discrepant with a reduce χ^2 of 2.4.
The most important contribution comes from the Hindi's value amounting for 40 %, this value was deduced from the measurement of the Q value.

From this P_K value of 0.716 (6), a Q value of 270 (3) keV is derived.
A value of Q=279 (7) was obtained in 2003Au03 using the same methodology but with a reduce set of 10 P_K values (from 1954Pr31 to 1976Ha36).

See 1988Ri08 (Riisager) for possible effects on the capture rates of the finite widths of the atomic levels.

2.2 Gamma Transitions

The probability for the 165-keV γ- transition is equal to the probability of the preceding ε- transition.

The γ- ray is mostly M1 and the %E2 is taken to be 0.0. The reported δ(E2/M1) are: +0.034 (34) [1963Ha07 from (γ, θ, T) and polarization]; 0.045 (+26-45) (1965Ge04 from $L_1/L_2/L_3$); 0.029 (+18-29) with the nuclear penetration parameter λ = 2.8 (13) (1979Ha21 from analysis of published data); and < 0.0055 with λ = 4.2 (8) (1977Ry01 from analysis of published measured data and a new calculation of a values). Also, λ = 3.1 (7) with δ = 0.0 (1975Pl06 from experimental α_K and other published α data) and λ = 3.6 (18) with δ = 0.0 (1975Mo12). The weighted average of these four λ values is 3.5 (5) with a reduced-χ^2 = 0.46. Since much of the data used to determine these λ values are common to the various calculations, the values are correlated. Therefore, the uncertainty is increased to the smallest of the four uncertainties, and the value 3.5 (7) is recommended.

The K-shell and total internal-conversion coefficients are from the 1985HaZA evaluation. This evaluation lists the following values :

			Retained in 85HaZA analysis	
a_K	a	**Reference**	a_K	a
0.22		1954Mi56		
0.20 (4)		1954Nu12		
0.20 (5)		1954Pr31		
0.22 (1)		1956Ke23		
0.263		1962Be31		
0.2148 (12)	0.2514 (11)	1962Ta03	yes	yes
0.209 (27)		1967HaZX		
	0.254 (6)	1971Ar43		yes
	0.2446 (12)	1973Le29+1973LeYP		
0.207 (9)		1975Mo12	yes [as 0.214 (5)]	
0.214 (2)	0.251 (2)	1975Pl06	yes	yes
0.2152 (33)	0.2520 (50)	1976Ha11	yes	yes
	0.2519 (6)	1977Sc**		yes [as 0.2519(10)]
0.2146 (10)	**0.2516 (7)**	**1985HaZA recommended and adopted here**		
	0.261 (4)	2005KiZW		Theory for M1 "Frozen orbital"
	0.337 (5)	2005KiZW		Theory for E2 "Frozen orbital"
	0.267	1978Ro22		Theory for M1
	0.264	1968Ha52		Theory for M1
	0.339	1978Ro22		Theory for E2
	0.339	1968Ha52		Theory for E2

The theoretical values are for $\lambda = 0.0$. The α_L and α_M values were computed from the adopted α_K value and the K/L and K/M ratios from the M1 theoretical values interpolated from the table of Rösel (1978Ro22).
Since this transition is hindered and the aspect of nuclear penetration effect discussed by various authors (1975Mo12, 1977Ry01, 1979Ha21, …) the adopted α values are the experimental ones.

3 Atomic Data

The fluorescence yield data are from 1996Sc06 (Schönfeld and Janssen).

3.1 X Radiation

The x-ray energies are based on the wave lengths in the compilation of 1967Be65 (Bearden). The relative K x-ray emission probabilities are taken from 1996Sc06. The value for $P(X_L)/P(K_{\alpha 1})$ is derived from the emission probabilities (sect. 4.2).

3.2 Auger Electrons

The ratios P(KLX)/P(KLL) and P(KXY)/P(KLL) are taken from 1996Sc06. The value for P(eAL)/P(KLL) is derived from the emission probabilities (sect. 4.1).

4 Radiation Emission

4.1 Electron Emission

The electron emission probabilities are calculated from the X and γ-ray emission probabilities in sects. 2.1 and 4.2, the atomic data of sect. 3, and the internal-conversion coefficients of sect. 2.2.

4.2 Photon Emissions

The γ-ray energy is from the evaluation 2000He14 where the values are on a scale on which the strong line from the decay of ^{198}Au is 411.80205 (17).
The γ-ray emission intensity is calculated as $I_e(165)/[1 + \alpha(165)] = 79.90$ (4) which agrees well with the

measured value of 79.95 (6) as quoted in 1982RuZV and those of 79.88 (8) given in 1975Wa**.

Measured relative values, to the 165-keV γ line, of the X-ray emission intensities can be compared with the value deduced from the decay scheme data:

X-ray	Dasmahapatra	Kumar	Campbell	Plch	Decay scheme
γ - 165,40	100	100			79,90 (4)
Kα	80,6 (35)	79,39 (111)			
Kβ1	16,10 (69)	14,30 (21)			
Kβ2	4,35 (19)				
K X				79,4 (9)	80,3 (8)
K X/γ			1,010 (25)	0,99 (1)	1,005 (10)

Detailed measured values of the X-ray emissions carried out by 2001Sc08 are also compared with the values deduced from the decay scheme data:

X-ray	E (keV)	Schönfeld (2001Sc08)	Decay scheme
Ll	4,124	0,40 (11)	0,222 (6)
Lη + Lα	4,52 – 4,65	5,86 (5)	5,78 (13)
Lβ1 + Lβ4 + Lβ3	5,04 – 5,14	4,26 (15)	4,21 (9)
Lβ6 + Lβ2 + Lβ5	5,21 – 5,45	1,07 (4)	1,066 (25)
Lγ5 + Lγ1 + Lγ6	5,62 – 5,88	0,538 (18)	0,565 (15)
Lγ2 + Lγ3 + Lγ4	6,06 – 6,25	0,335 (15)	0,340 (9)
Total L X		12,46 (20)	12,19 (18)
Kα2	33,03	23,05 (28)	22,80 (24)
Kα1	33,44	41,96 (50)	41,9 (4)
K'β1	37,72 – 38,07	12,46 (15)	12,47 (18)
K'β2	38,73 – 38,83	3,11 (4)	3,16 (8)
Total K X		80,6 (6)	80,3 (8)

All the X ray intensities are strongly dependant of the adopted P_K value, the comparisons made in the two tables above show a good agreement between the measured values and those deduced from the decay scheme data. This suggests that the adopted decay scheme is consistent.

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