$^{135}Xe^{m}$ - Comments on evaluation of decay data

M. Galán

1) Decay Scheme

$^{135}Xe^{m}$ disintegrates by IT (99,996 (2) %) to the ground state of ^{135}Xe and by β^- (0,004 (2) %) to ^{135}Cs excited levels. β^- branching has been reported by several authors: < 0,25 % (1976FE04); 0,004 % (1974MEZV and 1982WA21). 1974FOZY reported a transition from the 526 keV-level in ^{135}Xe to the 786,9 keV- level in ^{135}Cs with a lg *ft* = 8,7.
The β-decay scheme is that proposed by 1974MEZV (see also 2008SI01).
The $^{135}Xe^{m}$ isomeric state is at 526 keV and has J_{π} = 11/2$^-$ (1989RA17, 2008SI01).

2) Nuclear Data

$Q^-(^{135}Xe^{m})$ = 1692 (4) keV has been deduced using a value of $Q(^{135}Xe)$ = 1165 (4) keV from 2003Au03.

The measured $^{135}Xe^{m}$ half-life values are:

Reference	Value (min)
1960AL12	15,8 (4)
1960KO02	15,65 (10)
1968AL16	15,2 (7)
1968TO20	15,4 (9)
1971HA13	15,287 (22)
1975FU12	15,29 (5)
Number of input values	6
Reduced χ^2	2,84
Weighted Mean	15,303
Internal uncertainty	0,020
External uncertainty	0,034
Adopted value	15,30 (3)

None of the values has been rejected by Chauvenet's criterion. The largest contribution to the weighted average comes from the value of Hawkings (1971HA13).
The recommended value for the $^{135}Xe^{m}$ half-life is the LWM mean of 15,30 with an external uncertainty of 0,03 d.

DECAY OF $^{135}Xe^{m}$ to ^{135}Xe

2.1) Gamma-ray Transition

Transition Energy

The evaluated γ-ray transition energy is equal to the photon energy plus the nuclear recoil energy.

Isomeric Transition Probability

The 526-keV γ-ray has M4 multipolarity. The ICCs have been interpolated from the recent tables of Band *et al.* (2002BA85) using the BrIcc Computer Code. The uncertainties on these theoretical conversion coefficients (average deviations from the experimental values) are estimated to be 1,4 %.
Some experimental values (1960AL12, 1972AC02) together with the theoretical values (Band *et al.* 2002; Häger and Seltzer, 1968) are shown in the following table:

Reference	α_K	K/L
1960AL12	0,21 (5)	5,8 (11)
1972AC02	0,198 (12)	
1968HA52	0,193	
2002BA85	0,1908 (27)	5,25 (10)

A beta branching has been estimated as 0,004 (2) % (see below- **DECAY OF $^{135}Xe^{m}$ to ^{135}Cs**). Thus the recommended value of P(IT) is 99,996 (2) %.

3) Atomic Data

Atomic fluorescence yields (ω_k, ϖ_L and n_{KL}) are from 1996SC06

The X-ray and Auger electron emission probabilities have been calculated from γ-ray and conversion electron data using the EMISSION code.

4) Radiation emissions

4.1) Conversion electrons

The conversion electron emission probabilities have been deduced from the ICC values and from the γ-ray emission probability.
The total conversion electron emission probability is:
$P_{ce} = P(IT) - P_{\gamma} = 19{,}16\ (25)\ \%$

4.2) g-Ray Emission

Various measurements of the γ-ray energy found in the bibliography are given below:

Reference	Value (keV)
1960AL12	527,4 (8)
1960KO02	528 (3)
1972AC02	526,5 (3)
1979BO26	526,579 (7)
1982WA21	526,561 (7)
Number of input values	5
Reduced χ^2	3,32
Weighted Mean	526,570
Internal uncertainty	0,0050
External uncertainty	0,0054

The recommended value is the LWM mean of 526,570 keV with an external uncertainty of 0,005.

The absolute γ-ray emission probability is given by:
$P_\gamma = 100 / (1 + \alpha_T) =$ 80,84 (20) %.

b$^-$ DECAY OF $^{135}Xe^{m}$ to ^{135}Cs

2.1) Gamma-ray Transition

Transition Energy

The γ-ray transition energies are from 1974MEZV.

Mixing ratios and internal conversion coefficients

Neither mixing ratios nor internal conversion coefficients have been measured for these γ-ray transitions.

2.2) Gamma-ray Emission

γ-Ray *Emission Probabilities*

Only Meyer (1974) reported γ-ray intensities associated with a possible $^{135}Xe^{m}$ ß-decay. The γ-ray relative intensities measured by 1974MEZV are those given in the following table ("?" purports "uncertain γ"):

Transition energy (keV)	I_γ	Photons per 100 disint.
786,91	44 (22)	0,003 6 (18)
1133	3?	0,000 24
1192	0,4?	0,000 032
1358	2?	0,000 16

In the second column relative intensities I_γ are relative to 10^6 photons of 526 keV-$\gamma_{1,0}$(Xe) as reported in 1974MEZV. A 50 % uncertainty in Iγ(787) has been assumed.
For the absolute γ intensities the total conversion coefficient of 0,237 (3) for the 526 keV transition has been taken into account. Then the absolute γ intensities are estimated by multiplying the relative intensities by 100/123,7.

2.3) b Transitions

The energies of the β^- transitions have been deduced from the Q value and the level energies in ^{135}Cs (2008Si01). The adopted values have been verified against those produced from a least-squares fit to gamma-ray energies by the computer code GTOL.

As no direct β^- transition to the ground state was reported by Meyer, the normalization factor was deduced assuming no feeding to the g.s. by using the equation:
[Iγ(526) (1 + α(526)) + Iγ (787) (1 + α(787)] N = 100 %

The β^- emission probabilities in Sec. 2.1 are from the absolute gamma-ray emission probabilities, as given in the following table:

Transition	Energy (keV)	P(β) %	Log *ft*
$ß_{1,1}$	905,1	0,003 6 (18)	8,7
$ß_{1,2}$	559	0,000 24	9,2
$ß_{1,3}$	500	0,000 032	9,9
$ß_{1,4}$	334	0,000 16	8,7

Lg *ft*'s were calculated with the LOGFT computer code. The adopted beta branching ratio is 0,004 (2) %.

The possible 1692-keV ß transition

If there exits a beta transition to the ground state this might be a 1st forbidden unique transition. The lg f_1t value is > 8,5. Using the lg f tables of Gove and Martin (1971) or the LOGFT code, we have:

$\lg f_1/f_0 = 0{,}935$ and $\lg f_1 = 3{,}35$.

Now, $\lg(f_1 t) = \lg(f_1) + \lg(t)$ and $t = \dfrac{T_{1/2}(s)}{B.R.}$, with these two expressions we can estimate the ß branching ratio.

So, $\lg(t) > 8{,}5 - 3{,}35 = 5{,}15$ ⟶ $t > 1{,}42 \times 10^5$

Finally we get, $\mathrm{B.R.} < \dfrac{920}{1{,}42 \times 10^5} = 0{,}0065$ or B.R.< 0,65 % for the upper limit of the beta branching. If we consider this beta feeding to the ground state, then the normalization factor can be estimated as:
[Iγ(526) (1 + α(526)) + Iγ (787) (1 + α(787)] N = 100 % - 0,65 %

Then the values would be:
P(IT)= 99,346 (2) %
β^-= 0,0035 (18) %
P_γ= 80,31 (20) %

References

1960AL12 T. Alvager, Arkiv Fysik 17, 521 (1960)
[Half-life, γ-ray energy, α_K, K/L ratio]

1960KO02 K. Kotajima and H. Morinaga, Nuclear Phys. 16, 231 (1960)
[Half-life, γ -ray energy]

1968AL16 P. Alexander and J.P. Lau, Nucl.Phys. A121, 612 (1968)
[Half-life]

1968HA52 R.S. Hager and E.C. Seltzer, Nucl. Data A4 (1968) 1
[Theoretical ICC]

1968TO20 K. Tomura and N. Miyaji. Radiochim, Acta 10, 173 (1968)
[Half-life]

1971GO40 N.B. Gove and M. Martin, At. Data. Nucl. Data Tables A10 (1971) 205
[log *ft*]

1971HA13 R.C. Hawkings, W.J. Edwards and W.J. Olmstead, Can. J. Phys. 49, 785 (1971)
[Half-life]

1972AC02 E. Achterberg, F.C. Iglesias, A.E. Jech, J.A. Moragues, D. Otero, M.L. Perez, A.N. Proto, J.J. Rossi, W. Scheuer and J.F. Suarez, Phys.Rev. C5, 1759 (1972)
[γ -ray energy, α_K, multipolarity]

1974MEZV R.A. Meyer (private communication)
[γ -ray energy, γ probabilities, ß probabilities]

1974FOZY J. Fontanilla, A.L. Prindle, J.h. Landrum and R.A. Meyer, Bull. Am. Phys. Soc. 19 (1974) 501
[log *ft*]

1975FU12 T. Fukuda and S. Omori, J. At. Energy Soc.Jap. 17, 177 (1975)
[Half-life]

1976FE04 H. Feuerstein and J. Oschinski, Inorg.Nucl.Chem.Lett. 12, 243 (1976)
[ß probabilities]

1979BO26 H.G. Börner, W.F. Davidson, J. Almeida, J. Blachot and J.A. Pinston, P.H.M. Van Assche, Nucl. Instr. Meth. 164, 579 (1979)
[γ-ray energy]

1982WA21 W.B. Walters, S.M. Lane, N.L. Smith, R.J. Nagle and R.A. Meyer, Phys. Rev. C26, 2273 (1982)
[γ -ray energy, ß probabilities]

1989RA17 P. Raghavan, At. Data and Nucl. Data Tables 42 (1989) 189
[Nuclear moments]

1996SC06 E.Schönfeld and H. Janssen, Nucl. Instrum. Meth. A 369 (1996) 527
[Atomic data]

2002BA85 I.M. Band, M.B. Trzhaskovskaya and C.W. Nestor, Jr, At. Data Nucl. Data Tables 81 (2002) 1
[Theoretical ICC]

2003AU03 G. Audi, A.H. Wapstra and C. Thibault, Nucl. Phys. A729, 337 (2003)
[Q value]

2008SI01 B. Singh, A.A. Rodionov and Y.L. Khazov, Nuclear Data Sheets 109, 517 (2008)
[Decay scheme, level energies, gamma-ray multipolarities]