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Measurement of γ-ray emission probability in the decay of $^{137}Ce^{g}$ and $^{85}Y^{g}$

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USNDP meeting, BNL, Nov 4-8, 2019

Background

- Dr. Nesaraja presented the case of the γ-ray emission probability in $^{137}Ce^{g}$ decay at the NSDD 2019 meeting, IAEA, Vienna.

Ref.	$I_{\gamma p}/I_{\gamma d}$	$\%P_\gamma(447)$
1975He20 (PRC)	4.91 (15)	2.24 (10)
2007Br23 (NDS)		1.68 (6)
2012To09 (PRC)		1.69

Ref.	$\%P_\gamma(447)$
1983Pe16 (NDS)	2.24 (10)
1990Pe02 (NDS)	1.78 (8)

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Systematic study of the structure of odd-mass lanthanum nuclei. I. Levels in ^{137}La fr
$^{137}Ce^{m+g}$ decay*

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(Received 31 March 1975)

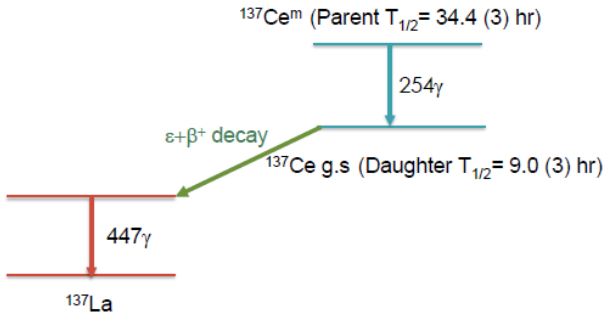


TABLE I. γ rays which follow $^{137}Ce^{s}$ decay.

E_γ	I_γ (rel.) [a]	Assignment from–to
10.56 (4) [b,c]		10–0
148.83 (8)	0.5 (2)	641–493
217.03 (5)	2.2 (3)	926–709
433.22 (9)	29.1 (15)	926–493
436.59 (9)	149 (5)	447–10
447.15 (8)	1000 [d]	447–0

[a] To obtain absolute photon intensities, multiply by 0.002 24(10).
[b] 10.56 keV obtained from energy differences of cascade and crossover transitions, E_γ = 10.61 keV using a LEPS; see text.
[c] Uncertainties in the last significant figures are shown in parentheses.
[d] In transient equilibrium spectra $I(254\gamma)/I(447\gamma)$ = 4.91(15).

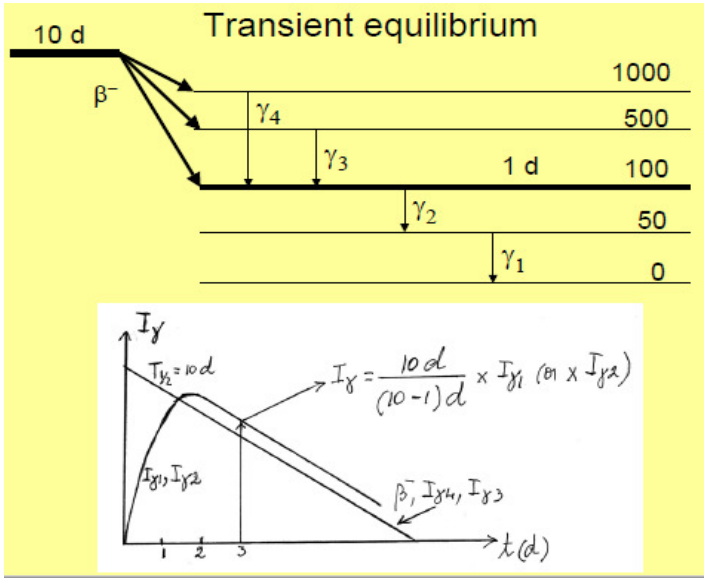
Observations:

Opinion on the ^{137}Ce decay issues presented by Caroline Nesaraja at the 23rd NSDD technical meeting, April 8-12, 2019, Vienna, IAEA.

Shamsuzzoha Basunia
April 12, 2019

Problem Statement:

From ^{137m}Ce IT (34.4 h) decay --→ ^{137g}Ce (9.0 h) EC Decay --→ ^{137}La measurements reported in 1975He20 – a %Iγ (477γ) (^{137}La) =2.24 (10) value may be obtained multiplying the relative intensity of 1000 with a multiplication factor of 0.00224 (10). However, 2007Br23 (Evaluation) give %Iγ (477γ) =1.68 (6) based on a multiplication factor of 0.00168 (6).



- 1975Bu12 (NDS) - 1.4 (3) - based on data from a 1969 MSU Thesis.

[Ref.]	$I_{\gamma p}/I_{\gamma d}$	%P$_\gamma$(447)
1975He20 (PRC)	4.91 (15)	2.24 (10)
1990Pe02 (NDS)		1.78 (8)
2007Br23 (NDS)		1.68 (6)
2012To09 (PRC)		1.69

- New experimental data are needed to solve the discrepancy

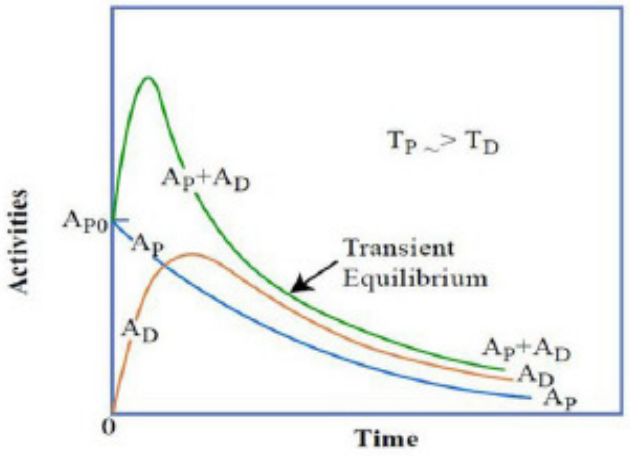
γ-ray emission probability in transient equilibrium

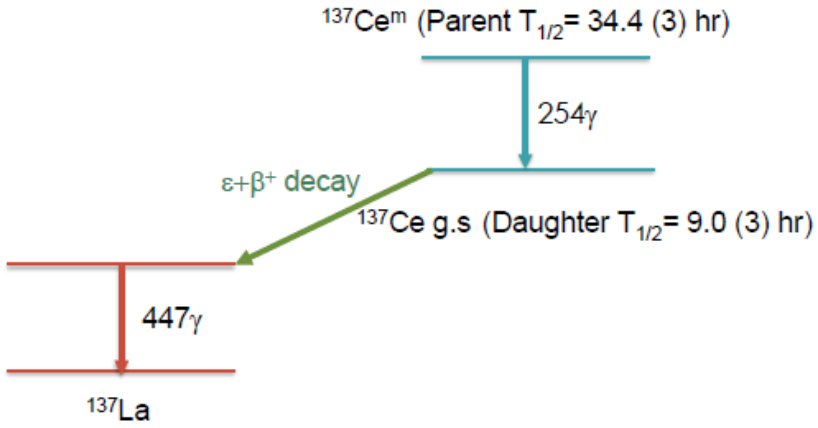
Bateman equation for $A \xrightarrow{\lambda_A} B \xrightarrow{\lambda_B} C$

$$A_d(t) = A_p(0)\frac{\lambda_d}{\lambda_d - \lambda_p} \times \left(e^{-\lambda_p t} - e^{-\lambda_d t}\right) \times BR + A_d(0)e^{-\lambda_d t}$$

$$\frac{P_{\gamma p}}{P_{\gamma d}} = \frac{I_{\gamma p}}{I_{\gamma d}} \times \frac{T_p}{T_p - T_d} = \frac{I_{\gamma p}}{I_{\gamma d}} \times F$$

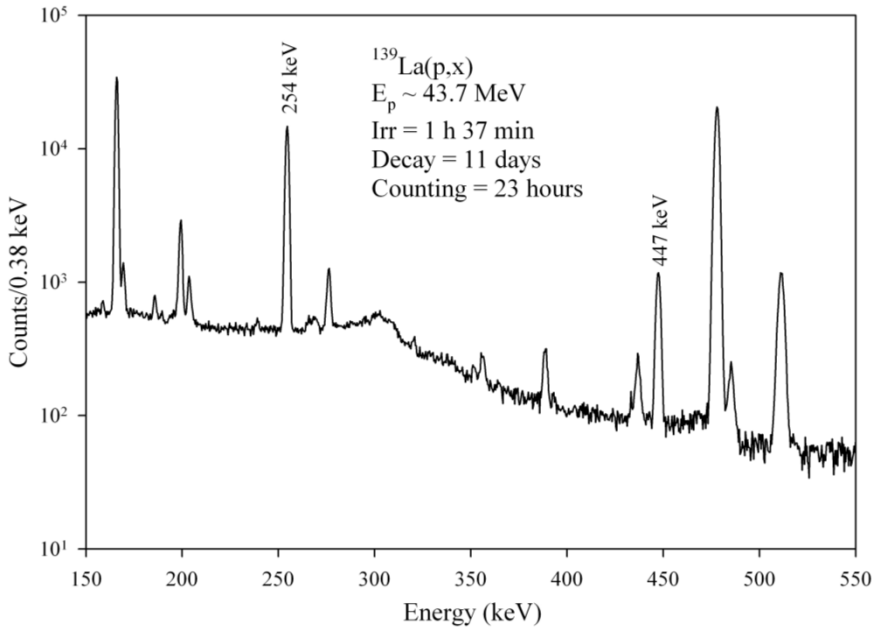
Time-dependent factor

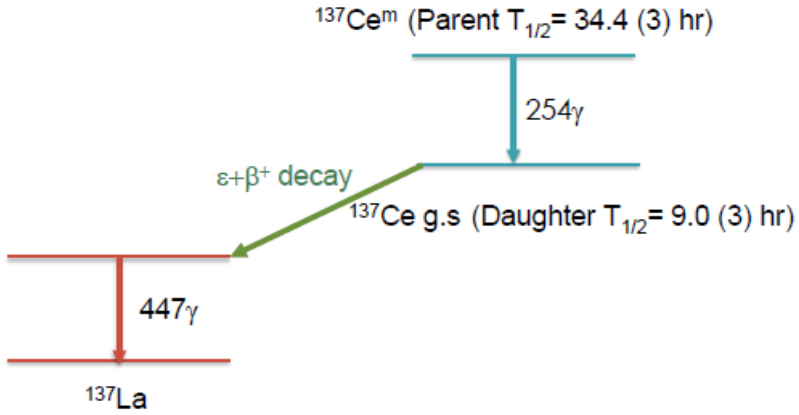




Measurements:

- At 88-Inch cyclotron, LBNL - proton beam, E=57 MeV
- $^{139}La(p,3n)^{137}Ce^{m,g}$





$$\frac{P_{\gamma p}}{P_{\gamma d}} = \frac{I_{\gamma p}}{I_{\gamma d}} \times \frac{T_p}{T_p - T_d} = \frac{I_{\gamma p}}{I_{\gamma d}} \times F$$

- We identify the incorrect use of the time-dependent factor in 1975He20

Results: γ-ray emission probability in $^{137}Ce^{g}$ decay

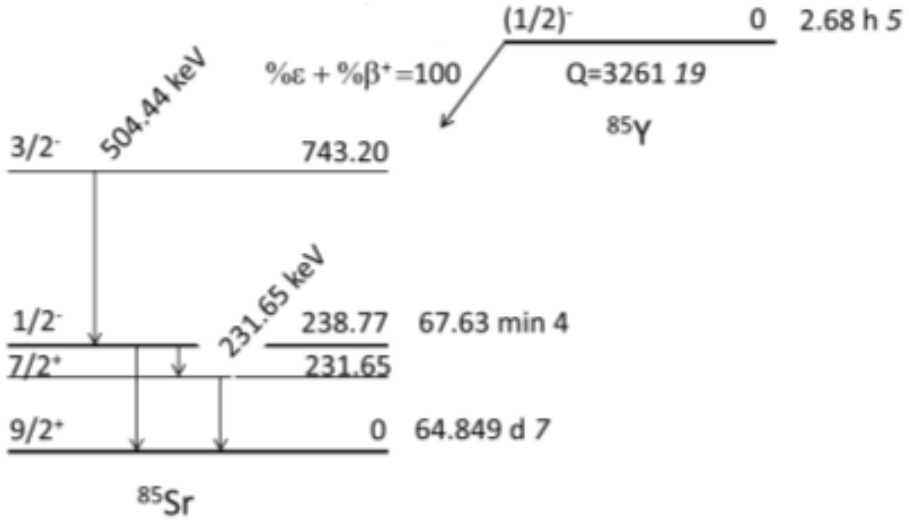
F=1.354 (17)

Sample #/ [Ref.]	$I_{\gamma p}/I_{\gamma d}$	$I_{\gamma p}/I_{\gamma d} \times F$	$\%P_{\gamma}$ (447)
This work	6.78 (9)	9.18 (17)	**1.21 (3)**
1969 Thesis data	6.0 (6)	8.1 (13)	**1.4 (2)**
1975He20	4.91 (15)		**2.24 (10)**
1975He20 (Revised)		9.00 (32)g	**1.23 (5)**

γ-ray emission probability in $^{85}Y^{g}$ decay

- Normalized in transient equilibrium – $^{85}Sr^{m}$ with $^{85}Y^{g}$
- Assumed time-dependent correction was done by authors

2014Si05 - NDS



^{85}Y ε decay (2.68 h) 1976Li02,1975Ba49 (continued)

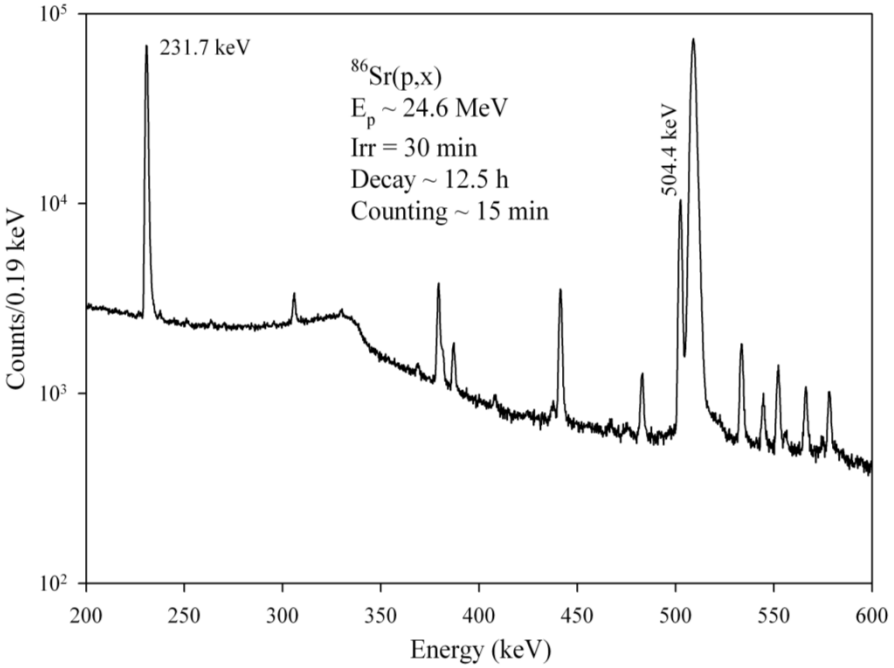
γ(^{85}Sr)

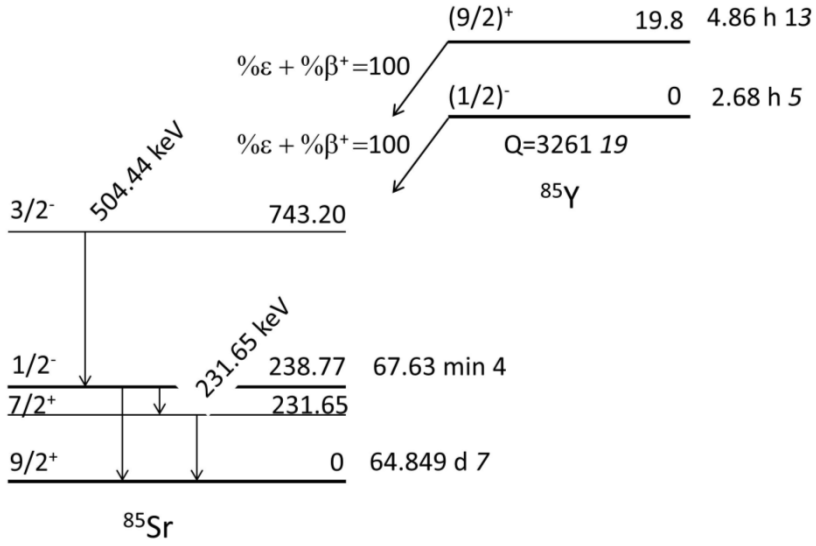
Iγ normalization: From Iγ(504γ)/Iγ(231γ)=0.71 *5* and %Iγ(231γ)=83.9% *4* (see ^{85}Sr IT decay dataset).

E_γ[†]	I_γ[‡&]	E_i(level)	J_i^π	E_f	J_f^π	Mult.[§]	δ[§]	α[@]	$I_{(\gamma+ce)}$[&]	Comments
(7.12 *25*)		238.77	1/2⁻	231.65	7/2⁺	[E3]		2.02×10^{7} *12*	143 *10*	α(L)=1.66×10^{7} *10*; α(M)=3.31×10^{6} *19*; α(N)=3.17×10^{5} *18*; α(O)=63 *4* E_γ: from level-energy difference. $I_{(\gamma+ce)}$: I(γ+ce)(7γ)=I(γ+ce)(231γ)=143 *10*.
215.9 *4*	0.32 *3*	1152.67	3/2⁻	936.8	5/2⁻					
231.65 *7*	140 *10*	231.65	7/2⁺	0.0	9/2⁺	M1+E2	−0.45 *6*	0.0224 *12*		α(K)=0.0196 *11*; α(L)=0.00228 *14*; α(M)=0.000383 *23*; α(N)=4.7×10^{-5} *3* I_γ: it is assumed that Iγ=140 *10* in 1976Li02 is corrected for time dependence.

Measurements:

- At 88-Inch cyclotron, LBNL - proton beam, E=27 MeV
- Enriched $^{86}SrCO_3$ target, $^{86}Sr(p,2n)^{85}Y^{m,g}$





$$I_{\gamma dc} = I_{\gamma d}/F$$

Results: γ-ray emission probability in $^{85}Y^{g}$ decay

Ref.	$I_{\gamma p}$(504)	$I_{\gamma dc}$(232)	%P_{γ}(504)
This work	100	139 (4)	60 (2)
1976Li02 (NP_A)	100	140 (10)	
2014Si05 (NDS)			60 (5)

We have confirmed the reported Iγ(232) in 1976Li02 was corrected for time dependency. Which is assumed to normalize the $^{85}Y^{g}$ decay scheme in NDS

Conclusions:

- Solved the discrepancy in the γ-ray emission probability in $^{137}Ce^{g}$ decay
- Our value 1.21 (3)% is in excellent agreement with the revised value of 1.23 (5)% (1975He20) for the 447-keV γ-ray emission probability
- Confirmed that the reported Iγ(232) in 1976Li02 was corrected for time dependency in $^{85}Y^{g}$ decay

- In cases where the literature data are ambiguous on this issue, new experiments are needed to verify the accuracy of the γ-ray emission probabilities

Resolution of a discrepancy in the γ-ray emission probability from the beta decay of $^{137}Ce^{g}$

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Thank you