Determining normalization factor for decay involving transient equilibrium

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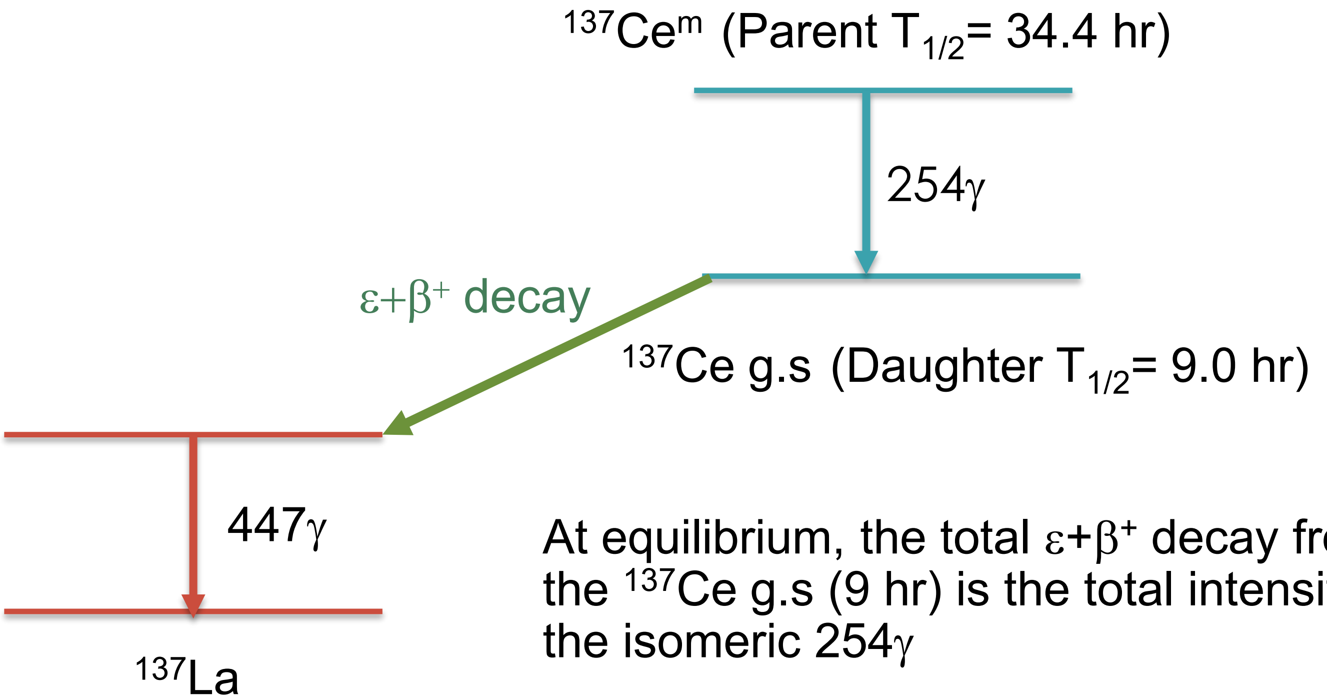
^{137}La: ^{137}Ce ε decay

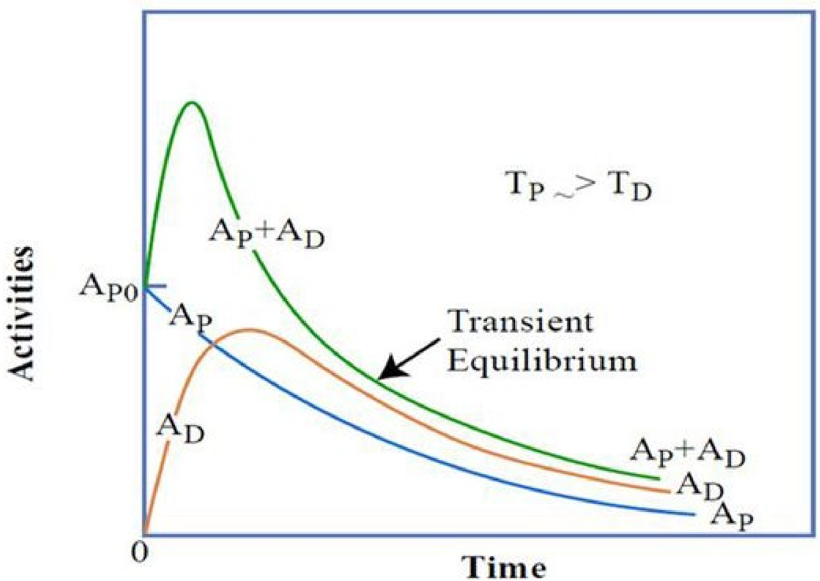
Determine decay scheme normalization involving transient equilibrium intensities

Normalization can be calculated if the relative intensities are known with respect to a transition in a daughter or further down in the decay chain provided that the sample is in transient equilibrium and the absolute intensity is known for some transition in the decay chain



At equilibrium, the total $\varepsilon+\beta^+$ decay from the ^{137}Ce g.s (9 hr) is the total intensity of the isomeric 254γ

Transient equilibrium from Bateman Equation



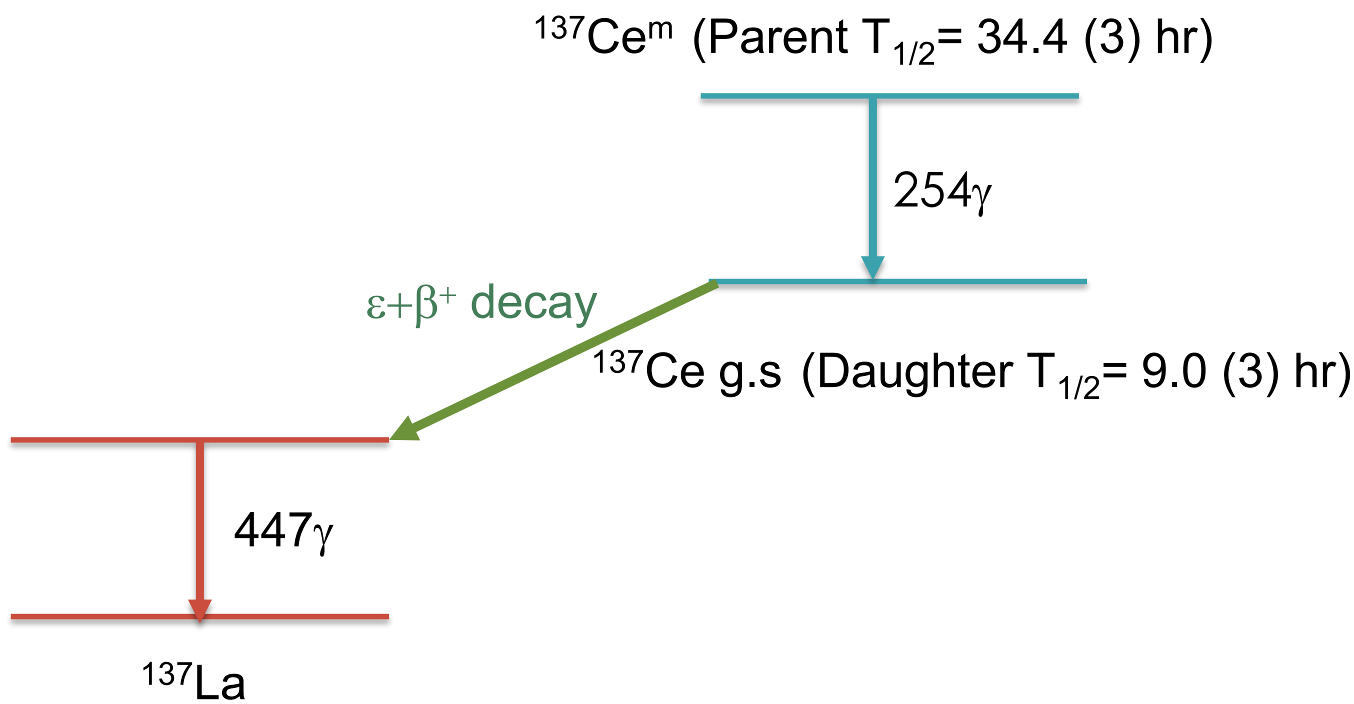
$$A_d(t) = A_p(0)\frac{\lambda_d}{\lambda_d - \lambda_p}\left(e^{-\lambda_p t} - e^{-\lambda_d t}\right)$$

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

$$= \frac{\lambda_d}{\lambda_d - \lambda_p}\left(1 - e^{-(\lambda_d - \lambda_p)t}\right) \rightarrow \frac{T_p}{T_p - T_d}$$

Activity Equilibrium correction factor

^{137}La: ^{137}Ce ε decay



Activity Equilibrium correction factor = $\dfrac{T_p}{T_p - T_d} = \dfrac{34.4}{34.4 - 9.0} = 1.354\ (17)$

It's a bit of a sticky wicket to determine the NR

Experiment: 1975He20

- Henry et.al (1975)
- Measured γ and conversion electron
- HsIcc
- At equilibrium, the total $\varepsilon+\beta+$ decay from the ^{137}Ce g.s (9 hr) is the total intensity of the isomeric 254γ.
- In transient equilibrium spectra

I(254γ)/I(477γ)= 4.91 (15)

- NR= 0.0224 (10)

Evaluation: ENSDF

- Current ENSDF database
- Determined normalization factor NR using activity Equilibrium correction factor
- BrIcc
- NR= 0.0168 (8)

Experiment: 2012To09

- Torrel & Krane (2012)
- Measured γ
- Authors used normalization factor from ENSDF
- NR= 0.0168 (8)

In transient equilibrium:

$I(254\gamma)/I(447\gamma) = 4.91\ (15)$ ——— (1)

At equilibrium, the total $\varepsilon+\beta+$ decay from the ^{137}Ce g.s (9 hr) is the total intensity of the isomeric 254γ.

Hence $TI(254\gamma)$ can be set to 100 decays of the gs

$TI(254\gamma)=I(254\gamma)(1+\alpha)=100$ ——— (2)

Combine equation (1) and (2)

$I(447\gamma)= [100/(1+\alpha)] / 4.91\ (15)$

i) with a (254g) (HsIcc)=8.08 (25)

$I(447\gamma)$= 2.24 (9) per 100 ^{137}Ce g.s (9 hr)

NR=2.24 (9)/1000 =**0.00224 (9)**

ii) with Activity Equilibrium correction factor =1.354 (17)

$I(447\gamma)$= 2.24/1.354 (17)=1.68 (8) per 100 ^{137}Ce g.s (9 hr)

NR=1.68 (8)/1000 =**0.00168 (8)**

1975He20

TABLE I. γ rays which follow $^{137}Ce^{g}$ 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
479.12(10)	6.7 (3)	926–447
482.47(10)	25.7 (9)	493–10
493.03(10)	5.9 (3)	493–0
529.3 (2)?	0.2 (1)	(1171–641)
631.38 (6)	7.5 (4)	641–10
678.26(12)	0.5 (2)	1171–493
698.72(11)	17.5 (9)	709–10
709.72(11)	0.6 (1)	709–0
724.4 (3)	0.4 (2)	1171–447
770.97(10)	3.4 (2)	781–10
781.57(13)	1.7 (2)	781–0
915.80(13)	28.9 (10)	926–10
926.35(13)	19.0 (7)	926–0
1160.85(22)	0.84 (8)	1171–0

[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).

^{137}Ce ε decay (9.0 h) 1975He20 (continued)

γ(^{137}La)

Iγ normalization: from I(254γ)/I(447γ)=4.91 *15* in a transient equilibrium γ-spectrum of 9.0 h and 34.4 h ^{137}Ce. The correction factor for the γ-ray intensities from ^{137}Ce(9.0 h) is 34.4 *3*/[34.4 *3* − 9.0 *3*] = 1.354 *16*, where 34.4 h *3* is the half-life of ^{137m}Ce, and 9.0 h *3* the half-life of ^{137}Ce ground state. Thus the normalization factor becomes Iγ(447)/[Iγ(254)x(1+α)]x 1/1.354 *16* = (1/4.91 *15*)x(1/(1+7.93 *12*))x(1/1.354 *16*) = 0.0168 *6*, where α=7.93 *12* is the M4 conversion coefficient of 254γ. However, since in our scale of relative intensities we use Iγ(447)=1000, then Iγ normalization=0.00168 *6*.

I(447γ)= 100 α= 7.93 (12)(BrIcc) CF=1.354 (16) ENSDF Database: NR= 0.0168 (6)

^{137}Ce ε decay:9.11 h:XUNDL-3 2012To09 (continued)

γ(^{137}La)

Iγ normalization: See detailed comment in 137CE EC DECAY (9.0 H) dataset in ENSDF database.

I(447γ)= 100 α= 7.93 (12)(BrIcc) CF=1.354 (16) XUNDL: NR= 0.0168 (6)

^{137}Ce ε decay (9.11 h) 2012To09,1975He20 (continued)

γ(^{137}La)

Iγ normalization: At transient equilibrium, the total ^{137g}Ce ε+β decay equals to the total intensity of the 254γ with I(254γ)/I(447γ)=4.91 *15* in a transient equilibrium γ-spectrum of 9.11 h and 34.80 h ^{137}Ce given by 1975He20. The evaluator assumes that the correction factor for the γ-ray intensities from ^{137}Ce(9.11 h) which is 34.80 *3*/[34.80 *3* − 9.11 *3*]= 1.354 *16*, where 34.80 h *3* is the half-life of ^{137m}Ce, and 9.11 h *3* the half-life of ^{137}Ce ground state has been already taken into account by the authors in 1975He20. Thus the normalization factor is Iγ(447)/[Iγ(254)x(1+α)]=(1/4.91 *15*)x(1/(1+7.93 *12*)))=0.0228 *8*, where α=7.93 *12* (BrICC) is the M4 conversion coefficient of 254.283γ (Eγ from 2012To09).

I(447γ)= 100 α= 7.93 (12)(BrIcc) Current Evaluation: NR= 0.0228 (8)