



The Abdus Salam
International Centre for Theoretical Physics



1939-24

**Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data:
Theory and Evaluation**

28 April - 9 May, 2008

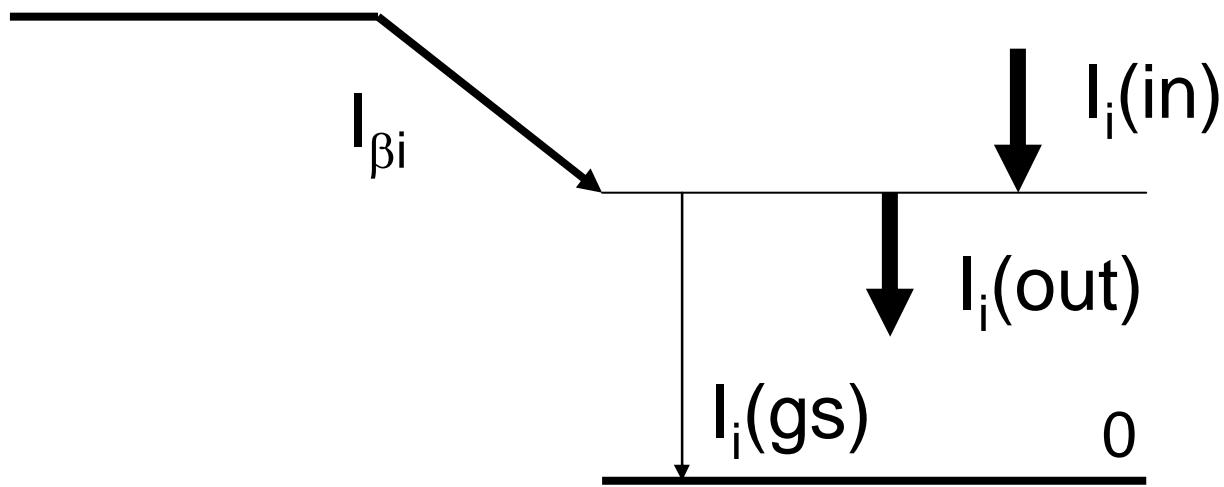
Model Exercises - Decay

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**Workshop on
NUCLEAR STRUCTURE AND DECAY
DATA EVALUATION
Model exercise**

**Trieste, April 28 – May 9, 2008
Edgardo Browne**

γ -ray transition intensity balance



The corresponding normalization factor is

$$\begin{aligned} N &= 100 / \sum [I_i(out) + I_i(gs) - I_i(in)] = \\ &= 100 / \sum [I_i(out) - I_i(in)] + \sum I_i(gs), \text{ but} \\ &\sum [I_i(out) - I_i(in)] = 0, \text{ therefore} \\ N &= 100 / \sum I_i(gs) \end{aligned}$$

^{233}Pa β^- decay

$I_\gamma(312) = 38.6 (5) \%$ (experimental value, Gehrke et al.)
 $\Sigma I(\gamma + ce) (\text{gs}) = 102 (2) \%$

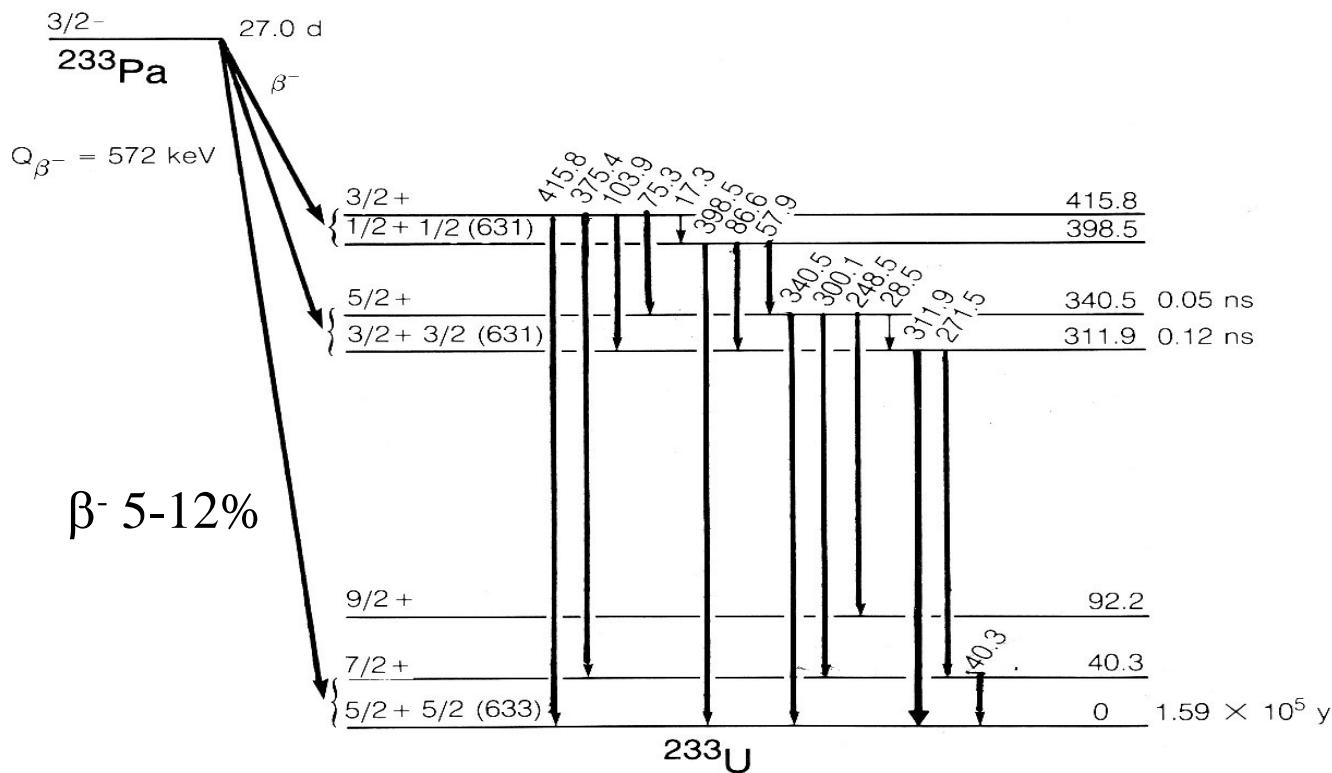


Fig. 1. Simplified ^{233}Pa decay scheme from ref. ¹).

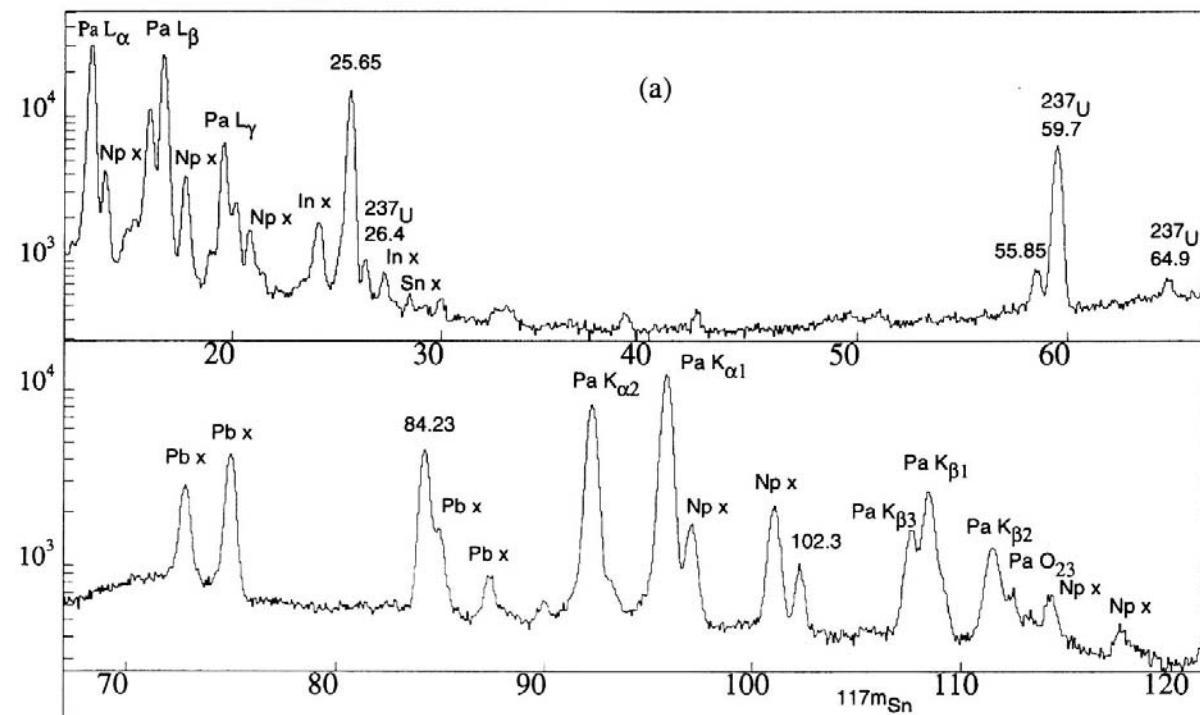
What went wrong?

E_γ (keV)	α_T (exp.)	α_T (theo. M1)
300	0.83 (2)	1.04
312	0.79 (2)	0.96
340	0.61 (2)	0.75

Answer: Nuclear penetration effects

Using X rays to normalize a decay scheme

^{231}U γ -ray spectrum



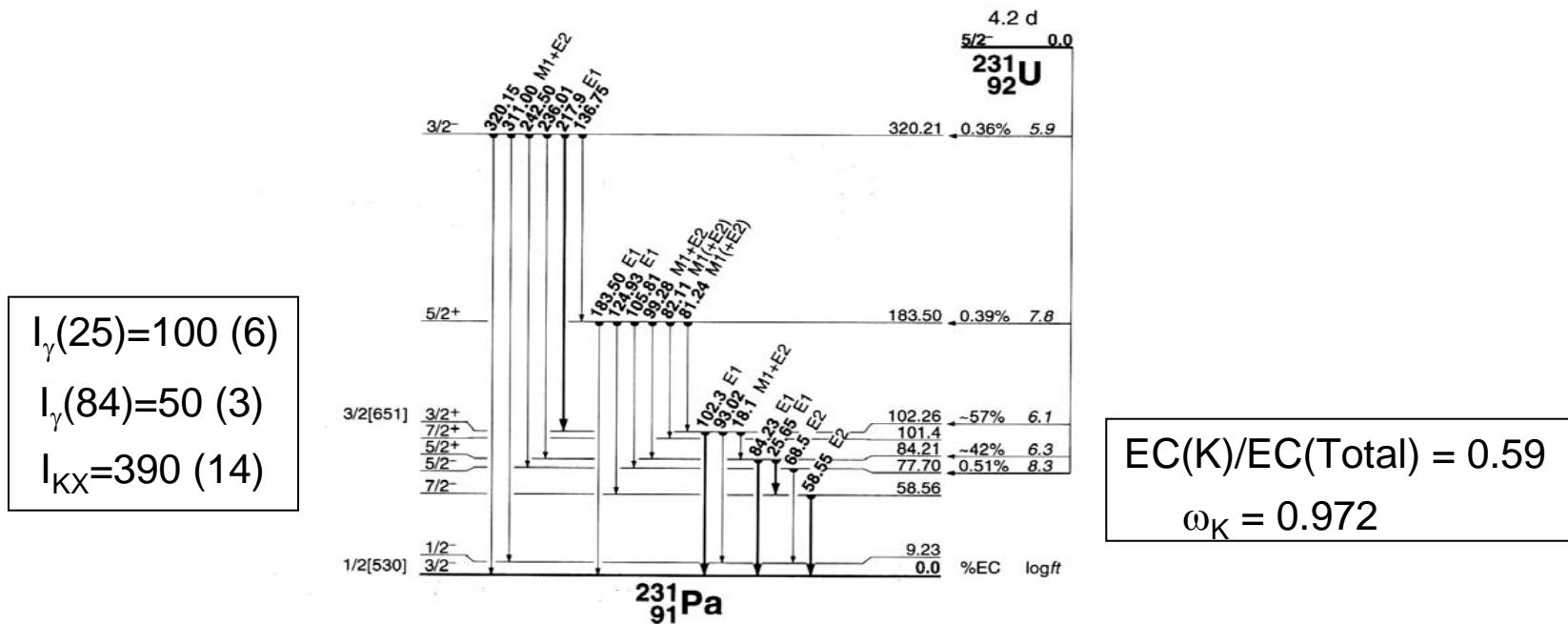


Fig. 4. ^{231}U electron-capture decay scheme. Gamma rays measured in this work are shown with thicker arrows; other data are from refs. [3,11]. Electron-capture branches per 100 decays of ^{231}U and $\log ft$ values are from gamma-ray transition probability balances (see Table 3).

$B_K=115.6 \text{ keV}$, thus most K-x rays originate from vacancies produced by the electron-capture process.

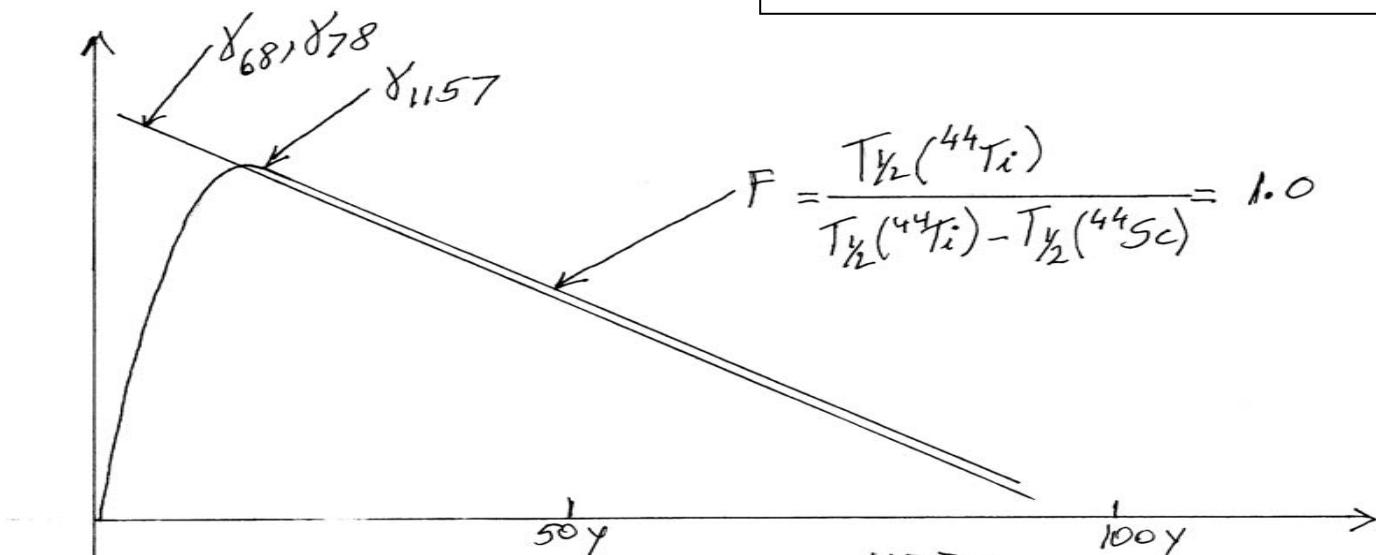
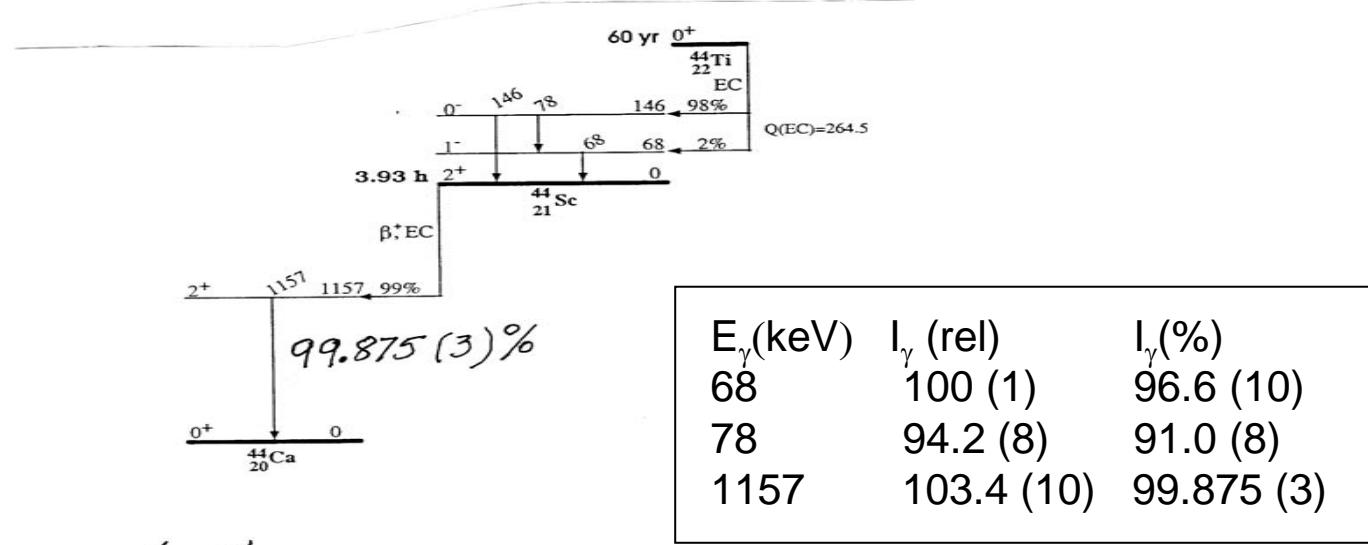
$$\text{Total vacancies} = I_{KX} EC(\text{Total}) / \omega_K EC(K) = 680 \quad (33)$$

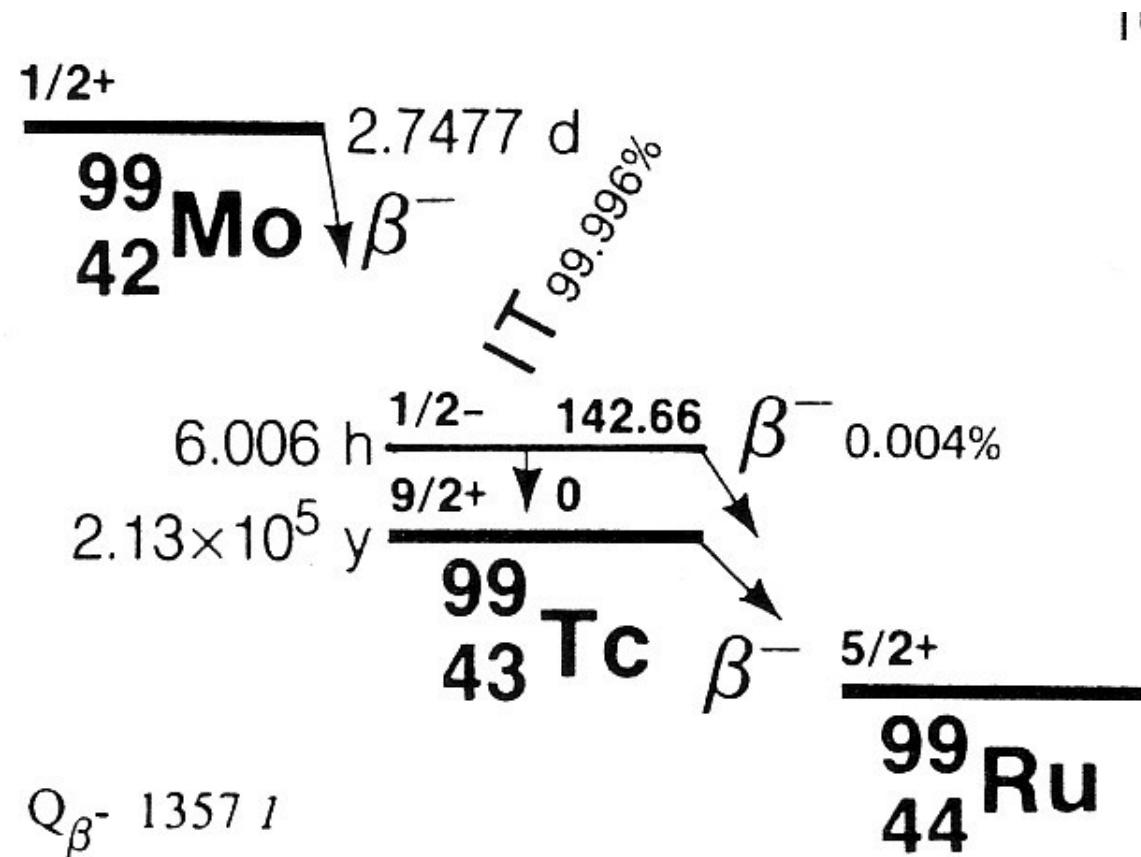
$$\text{Normalization factor } N = 100 / 680 \quad (33) = 0.147 \quad (7)$$

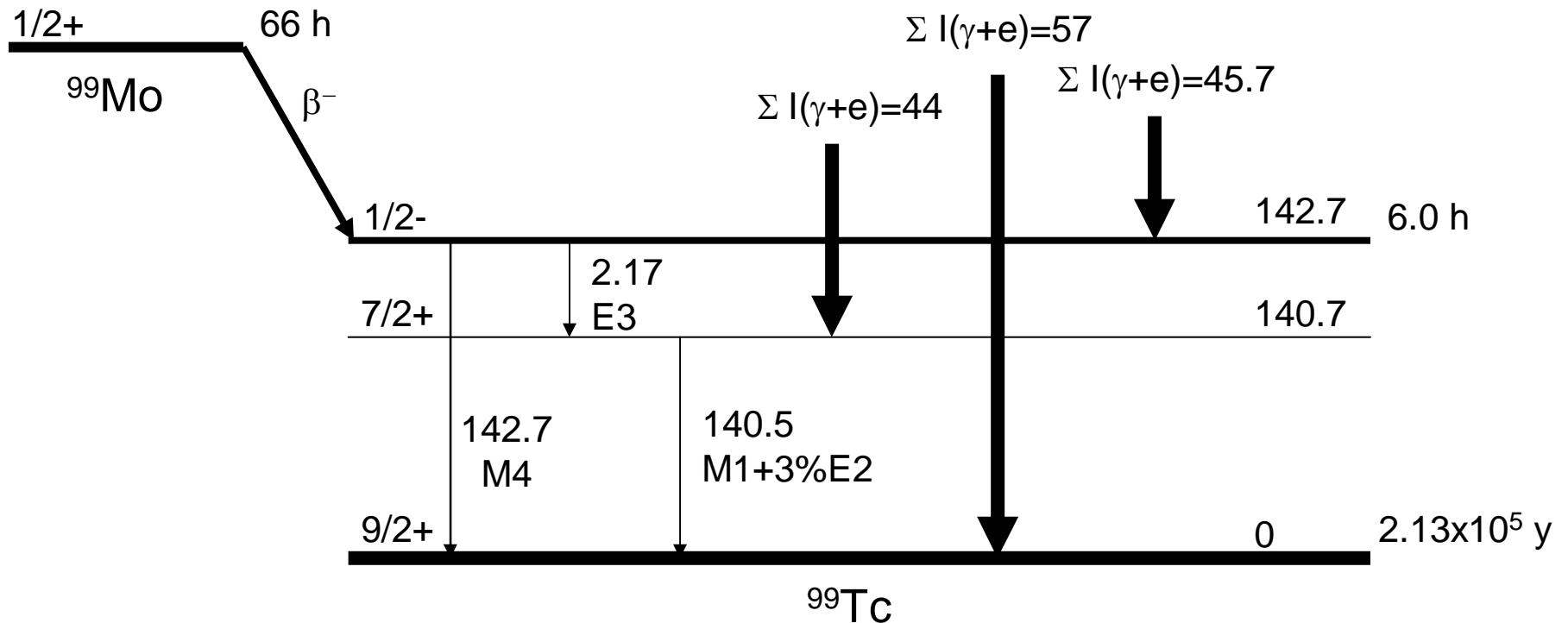
$$I_{\gamma}(25)=100 (6) \times 0.147 (7) = 15 (1)\%$$

$$I_{\gamma}(84)=50 (3) \times 0.147 (7) = 7.5 (6)\%$$

^{44}Ti electron capture decay

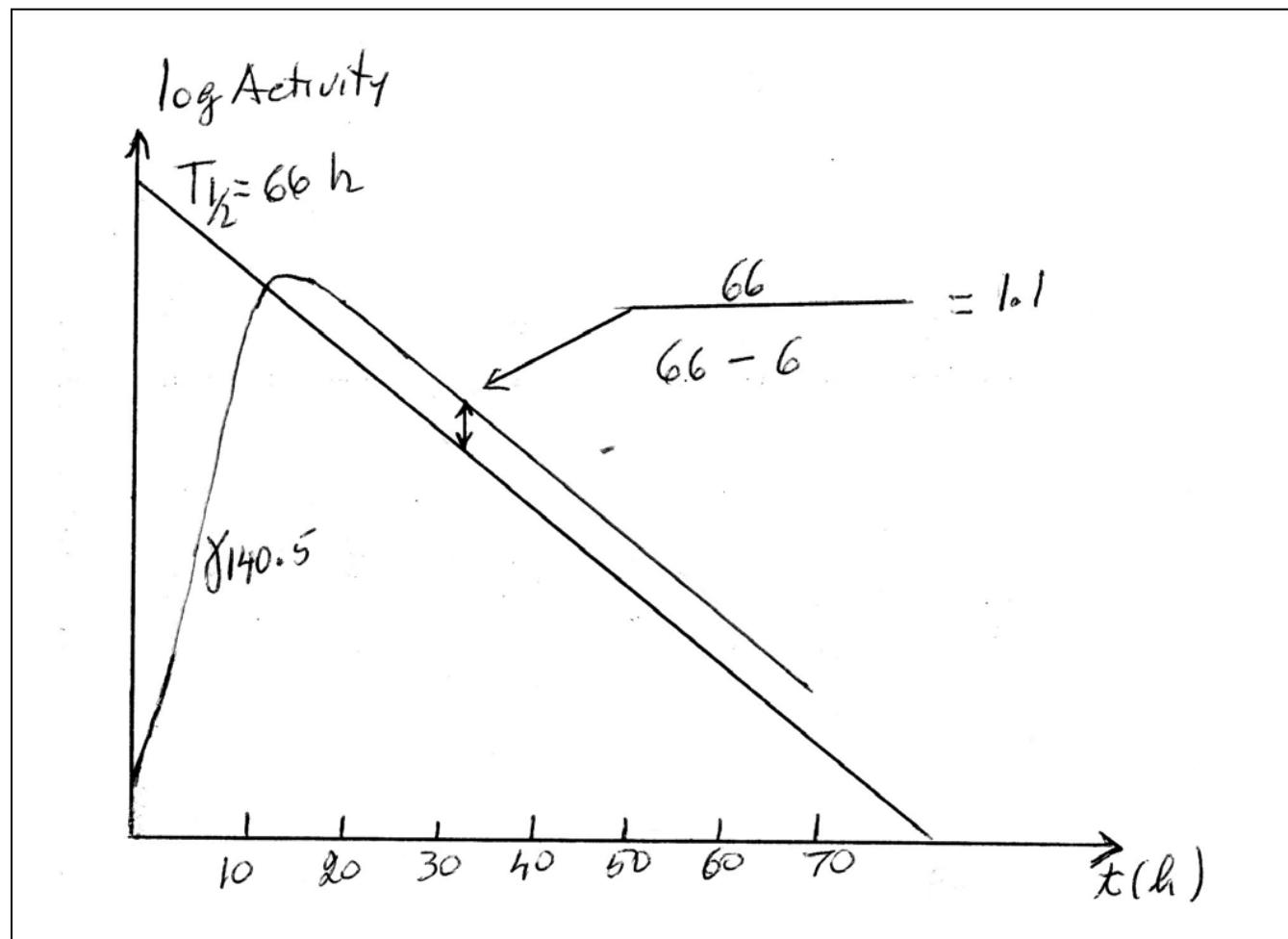


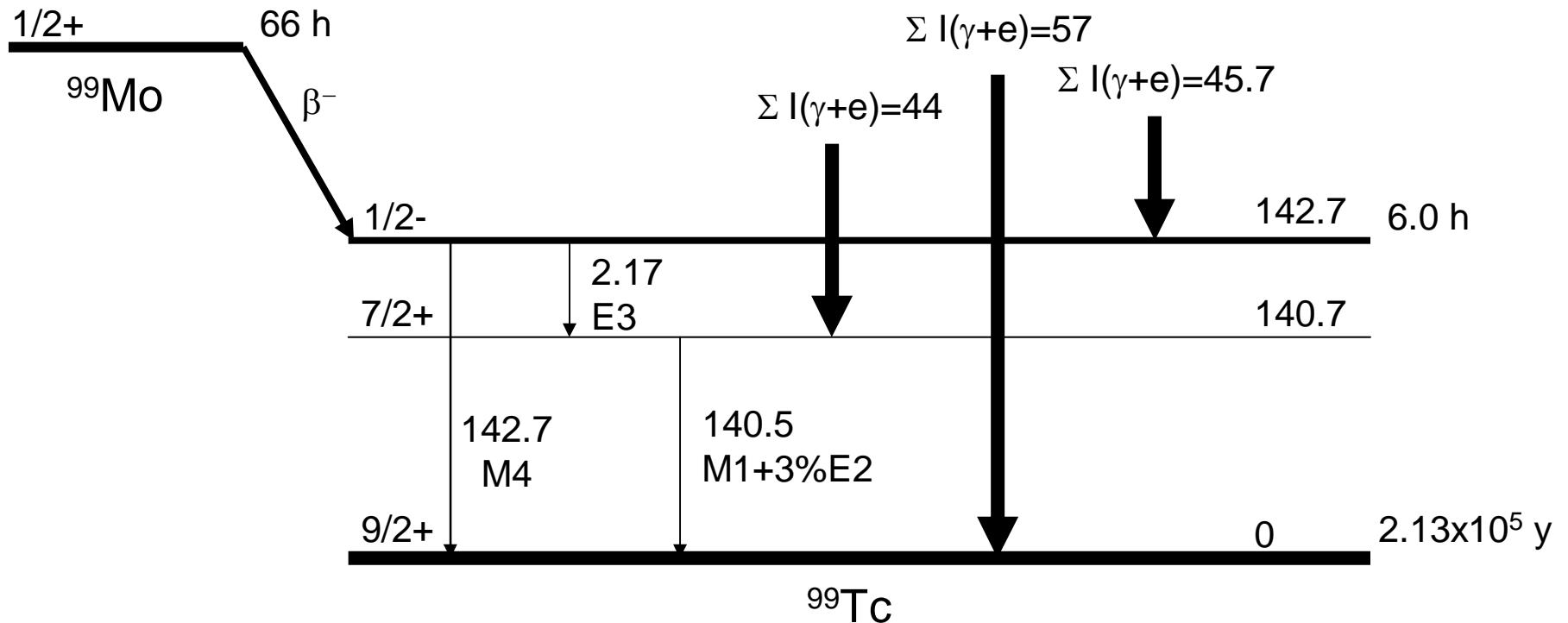




Equilibrium Intensities

$E_\gamma (\text{keV})$	I_γ	α	$I_{\gamma+ce}$
140.5	742 (11)	0.114 (3)	827 (12)
142.7	0.17 (2)	40.9 (12)	7.3 (7)





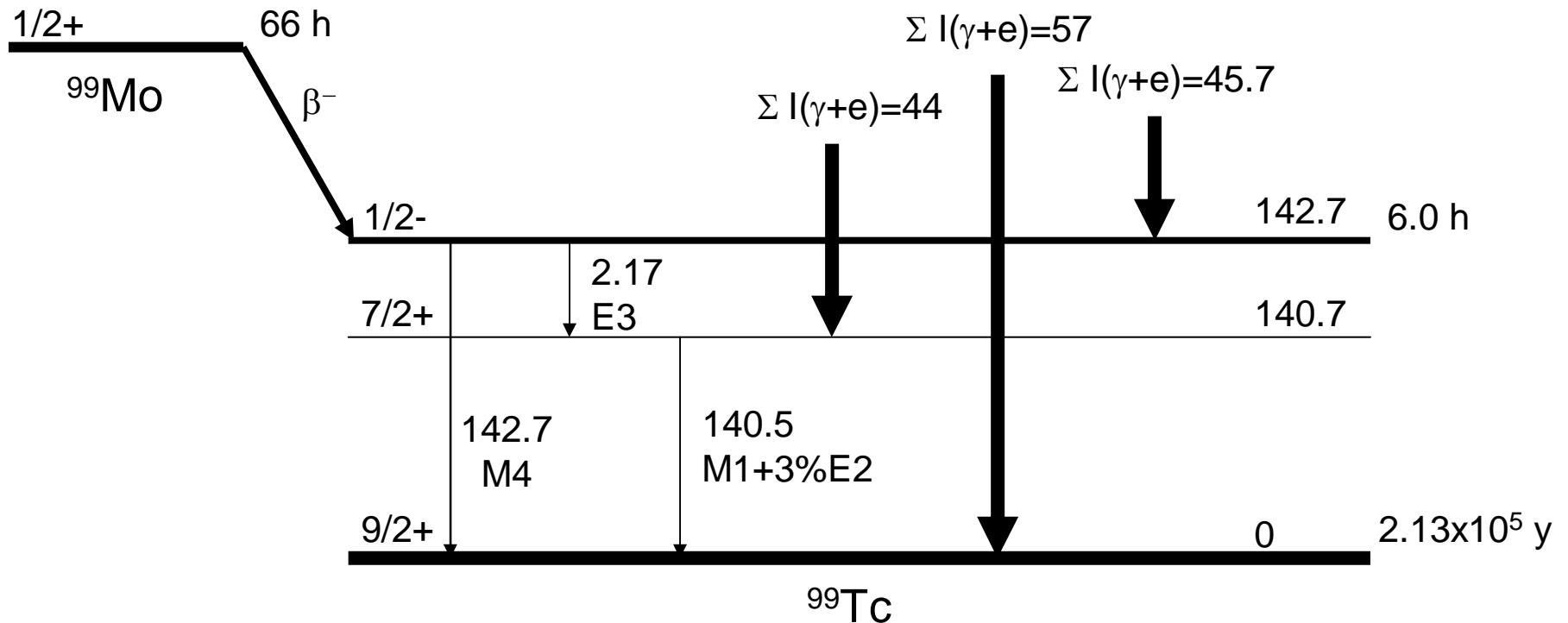
Decay Scheme Normalization

$$[I(\gamma+ce)(142.7)/1.1 + I(\gamma+ce)(140.5)/1.1 + \Sigma I(\gamma+ce)_{gs}] \times N = 100$$

$$[7.3 (7)/1.1 + 827 (12)/1.1 + 57.0 (8)] \times N = 100$$

$$N = 100/816 (11) = 0.1226 (17)$$

$$\text{So, } I_\gamma(\%) (140.5) = 742 (11) \times 0.1226 (7) = 91.0 (3)\%$$



β^- feeding to 142.7-keV level

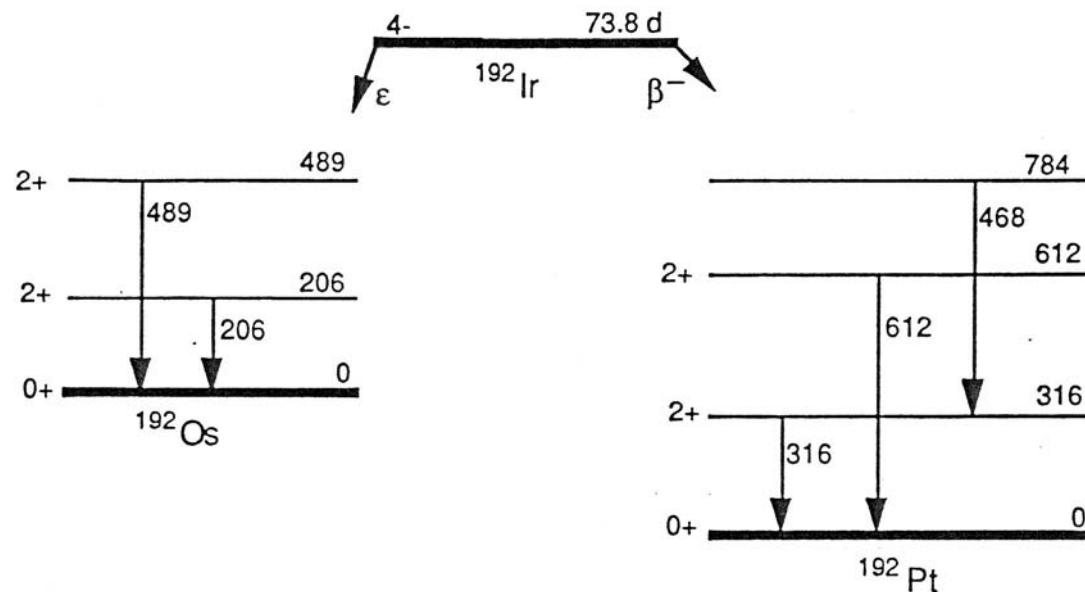
$$I_{\beta^-} = I(\gamma+ce)(142.7)/1.1 + I(\gamma+ce)(2.17)/1.1 - \Sigma I(\gamma+ce)_{142.7}$$

$$I(\gamma+ce)(140.5)/1.1 - I(\gamma+ce)(2.17)/1.1 - \Sigma I(\gamma+ce)_{140.5} = 0$$

$$I_{\beta^-} = 668$$

$$\text{So, } I_{\beta^-} (\%) = 668 \times 0.1226 = 82.0\%$$

^{192}Ir β^- and electron capture decay



$E_\gamma(\text{keV})$	I_γ	α	$I_\gamma(1+\alpha)$	
206	4.01 (6)	0.305 (9)	5.23 (8)	
489	0.527 (9)	0.0242 (7)	0.540 (9)	$\Sigma = 5.77 (8)$
316	100.0 (5)	0.085 (3)	108.5 (6)	
468	57.76 (20)	0.0294 (9)	58.43 (20)	
612	6.365 (25)	0.0155 (5)	6.464 (25)	$\Sigma = 114.9 (6)$

The normalization factor is:

$$N = 100 / [I_\gamma(489) (1+\alpha_{489}) + I_\gamma(206) (1+\alpha_{206}) + I_\gamma(316) (1+\alpha_{316}) + I_\gamma(612) (1+\alpha_{612})]$$
$$= 100 / 120.7 (7) = 0.828 (5)$$

$$N = 0.828 (5)$$

The electron capture (ε) and β^- decay branchings are:

$$\varepsilon = 100 [I_\gamma(489) (1+\alpha_{489}) + I_\gamma(206) (1+\alpha_{206})] / 120.7 (7) =$$
$$100 / [1 + (I_\gamma(316) (1+\alpha_{316}) + I_\gamma(612) (1+\alpha_{612})) / (I_\gamma(489) (1+\alpha_{489}) + I_\gamma(206) (1+\alpha_{206}))] =$$
$$100 / [1 + 114.9 (6) / 5.77 (8)] = 100 / 20.9 (3) = 4.78 (7)\%$$
$$\beta^- = 100 - EC = 100 - 4.78 (7) = 95.22 (7)\%$$

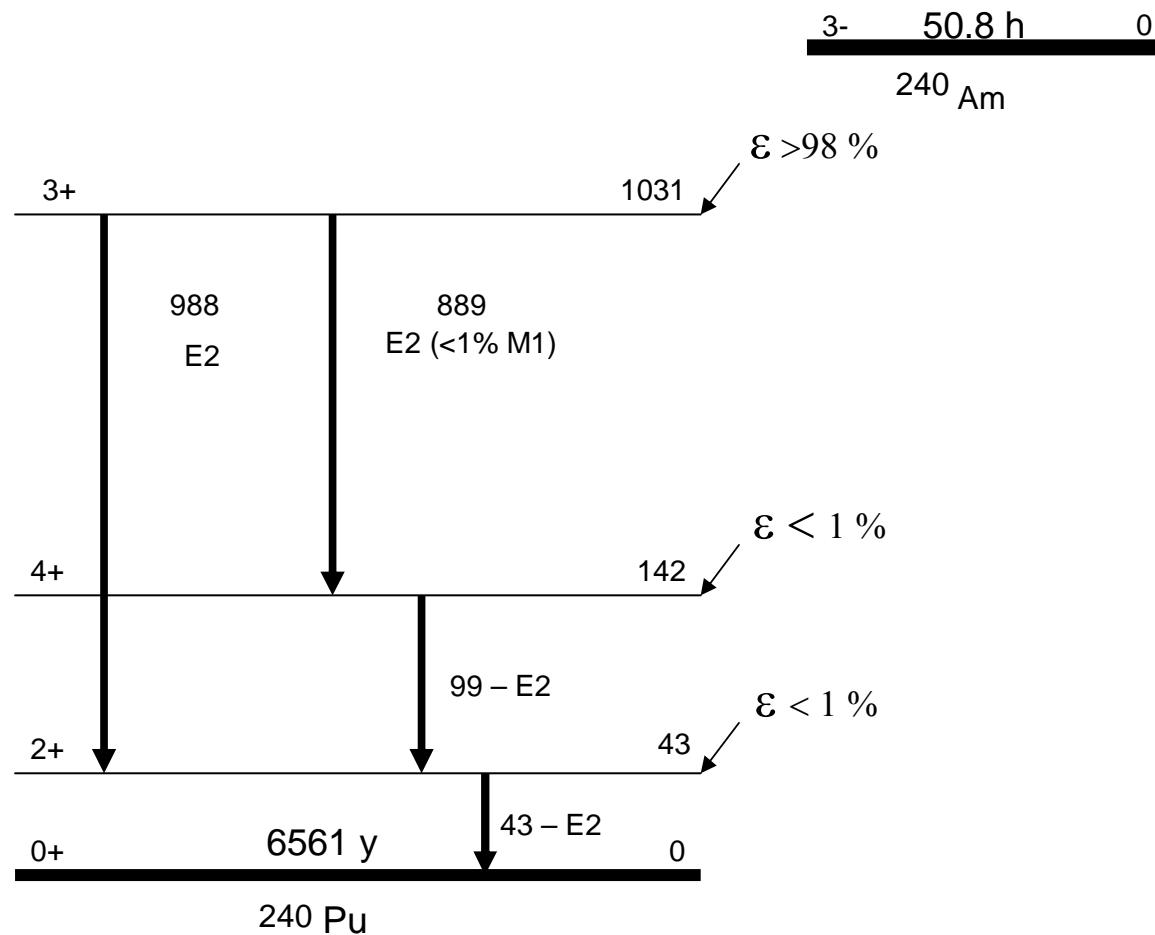
$$\beta^- = 95.22 (7)\%$$

$$\varepsilon = 4.78 (7)\%$$

The 988-keV γ Ray from ^{240}Am Electron-Capture Decay



Simplified ^{240}Am Decay Scheme



^{240}Am Relative γ -Ray Intensities

E _g (keV)	1971LeZO	1972Ah07	Weighted Average
889	25.1 ± 0.4	25.1 ± 0.0	25.1 ± 0.4
988	73.2 ± 1.0	73.3 ± 2.5	73.2 ± 1.0

Decay Scheme Normalization and Absolute γ -Ray Intensity

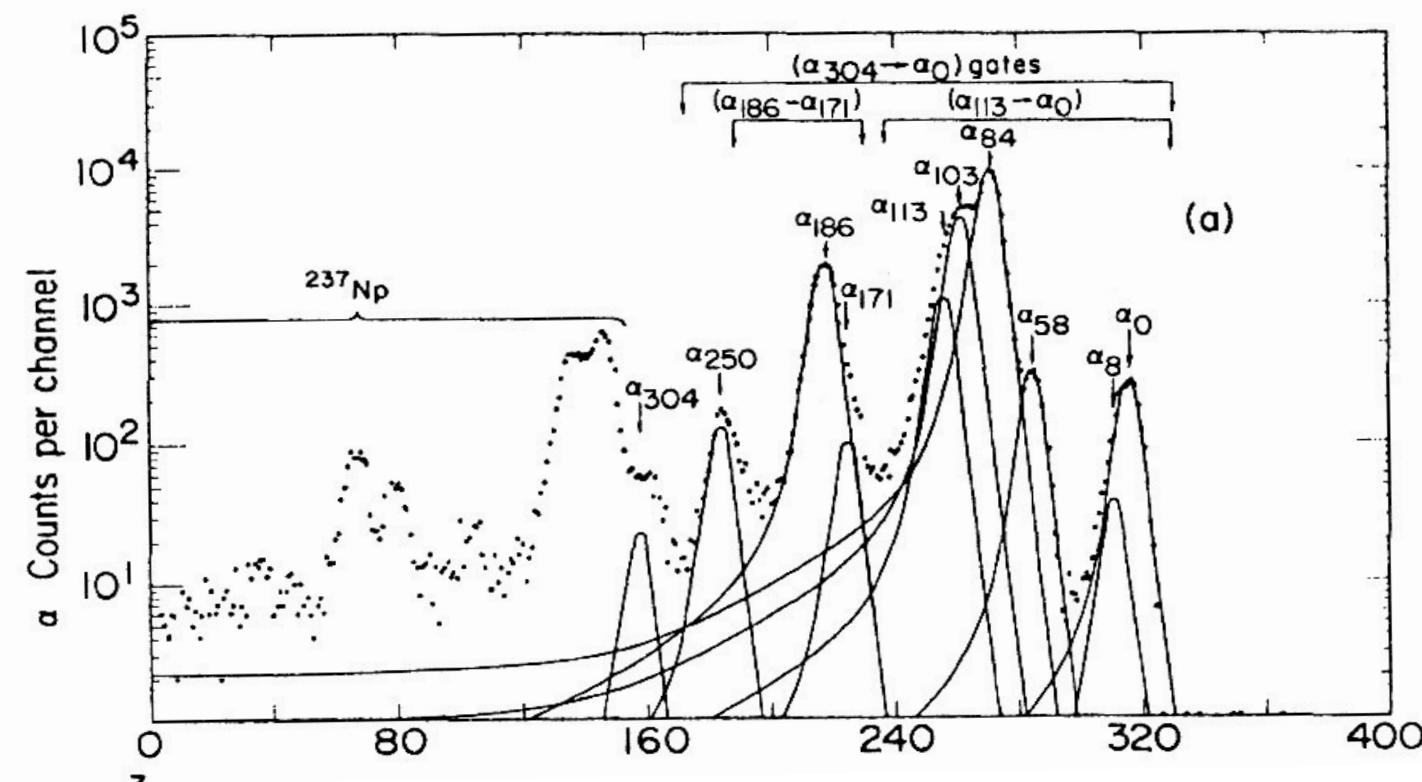
$$\{I\gamma(988) [1 + \alpha_{988}] + I\gamma(889) [1 + \alpha_{889}]\} N = 99 (1) \% \\ N = 0.994 (15)$$

$$I\gamma(988)(\text{abs}) = I\gamma(988) \times N =$$

$$\frac{99 (1) \%}{[1 + \alpha_{988}] + \frac{I\gamma(889) [1 + \alpha_{889}]}{I\gamma(988) [1 + \alpha_{988}]}} =$$

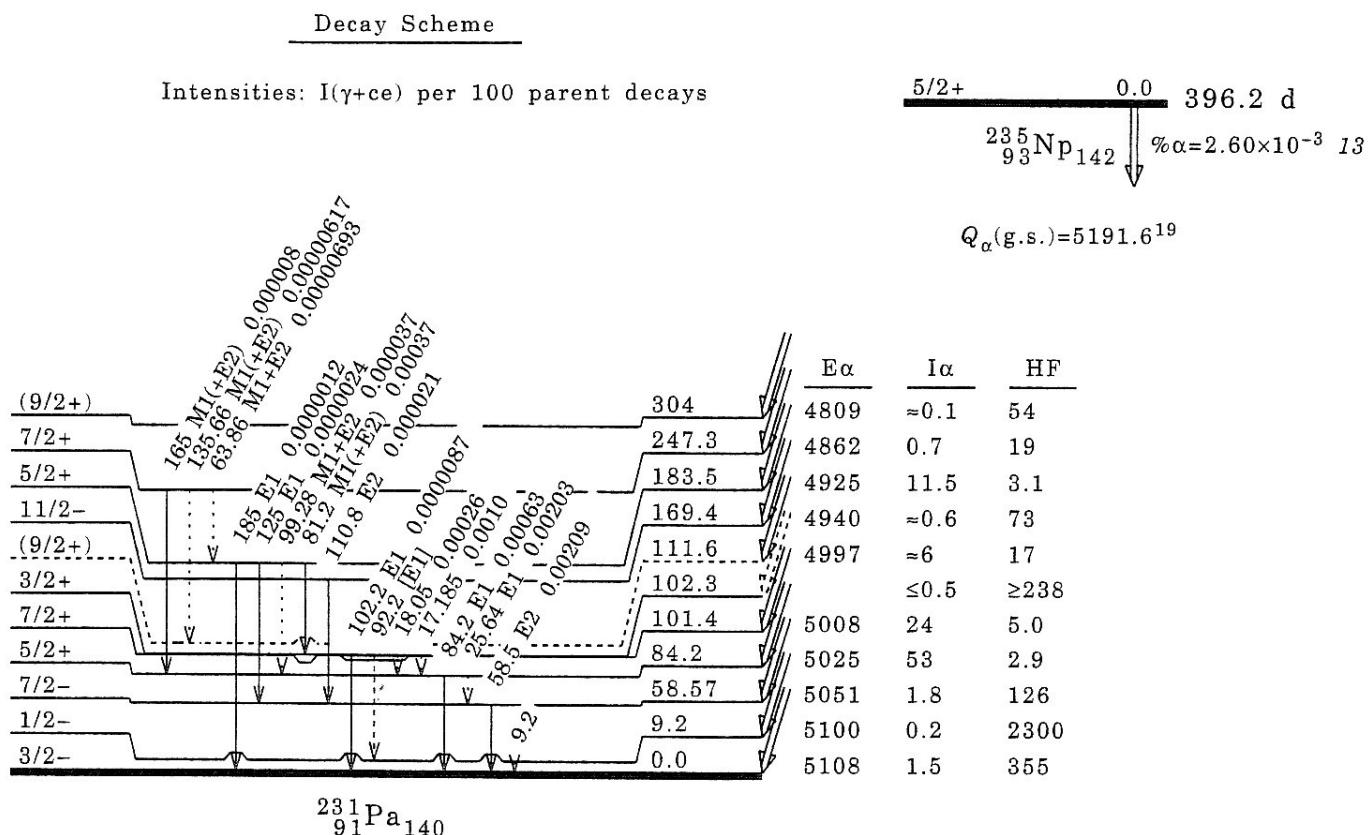
$$\frac{99 (1) \%}{1.0128 (2) + 0.3438 (70)} = 73.0 (7) \%$$

^{235}Np Alpha-Particle Spectrum



^{235}Np Alpha Decay Scheme

^{235}Np α Decay 1973Br12 (continued)



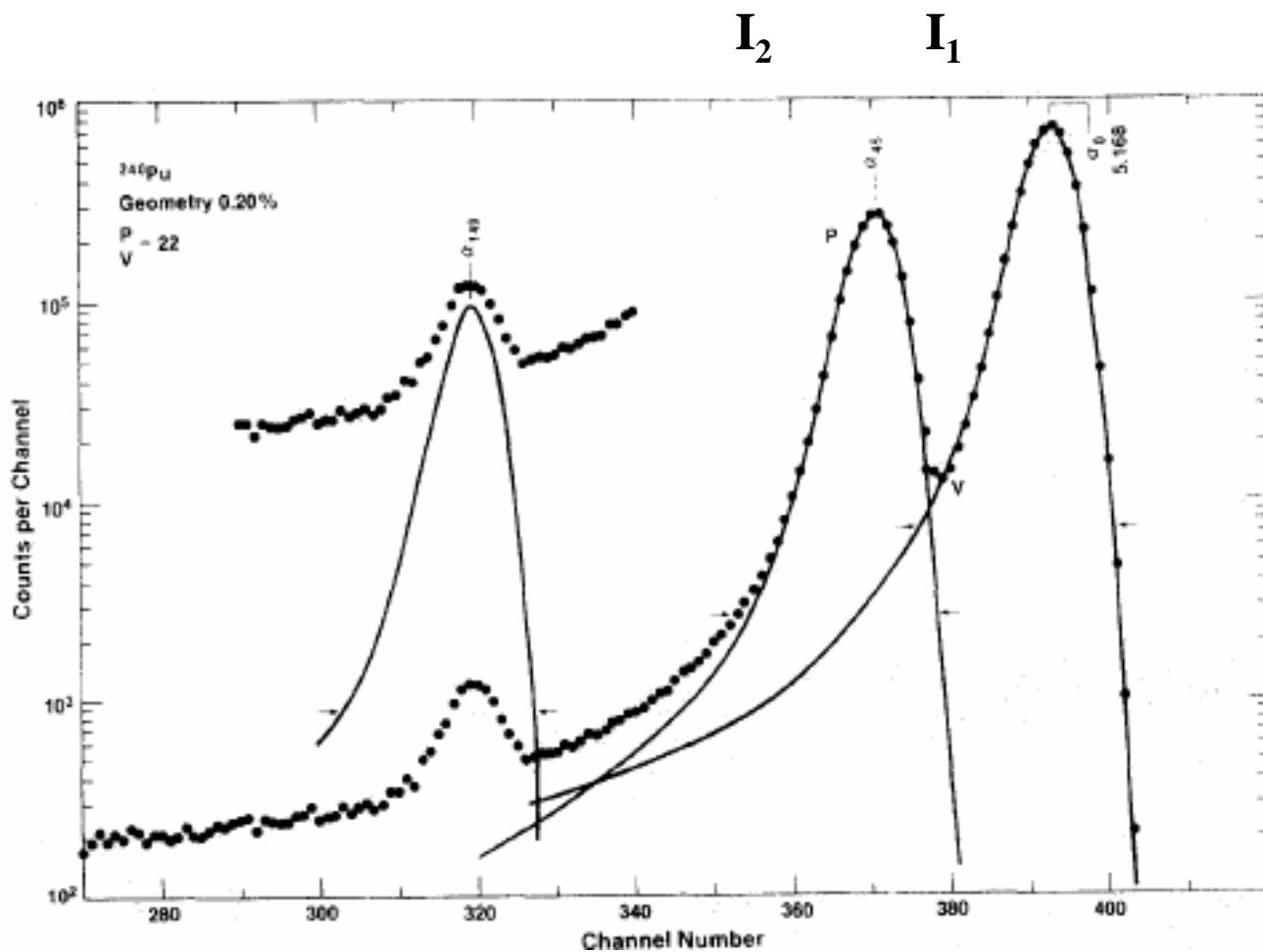
^{235}Np Alpha-particle intensities

$E_\alpha(\text{keV})$	$E_{\text{lev}}(\text{keV})$	$I_\alpha(\text{spec.})$	$I_\alpha(\text{bal.})$
4809	304	~0.1	
4862	247	0.7 (1)	0.8 (2)
4925	183	11.5 (5)	16 (3)
4940	169	~0.6	0.8 (3)
4997	112	~6	
5008	101	24 (8)	33 (10)
5025	84	53 (8)	51 (12)
5051	58	1.8 (3)	~2
5100	9	0.2	
5108	0	1.5 (2)	

Particle Emission Probabilities

- Directly measured
- Deduced from γ -ray intensity balance

^{240}Pu Alpha Spectrum



The α -particle emission probabilities are:

$$p_1(\%) = I_1 \times 100 / (I_1 + I_2), \text{ and}$$

$$p_2(\%) = I_2 \times 100 / (I_1 + I_2)$$

I_1 and I_2 are spectral areas

Uncertainties assuming uncorrelated spectral areas (I_1 , I_2) and small dI_1 and dI_2 values.

$$p_1(\%) = I_1 \times 100 / (I_1 + I_2)$$

$$p_2(\%) = I_2 \times 100 / (I_1 + I_2)$$

$$dp_1^2 = (dp_1/dI_1)^2 dI_1^2 + (dp_1/dI_2)^2 dI_2^2$$

$$dp_2^2 = (dp_2/dI_1)^2 dI_1^2 + (dp_2/dI_2)^2 dI_2^2$$

$$= \frac{100^2}{(I_1 + I_2)} \left[(I_1^2 dI_2^2 + I_2^2 dI_1^2) \right]^2$$

Notice that if $I_1 = I_2 = I$, and $dI_1 = dI_2$, then

$$dp_1/p_1 = dp_2/p_2 = (2)^{1/2}/2 dI/I$$

Surprising??

Of course NOT!

p_1 and p_2 are correlated!

$$p_1 = I_1 \times 100/(I_1 + I_2) = 100 \times 1/(1 + I_2/I_1)$$

$$p_2 = I_2 \times 100/(I_1 + I_2) = 100 \times 1/(1 + I_1/I_2)$$

Back to ^{240}Pu

Table 1
 ^{240}Pu alpha decay

Alpha energy [keV]	Intensity (relative)
5168.17 ± 0.15	73.51 ± 0.36
5123.62 ± 0.25	26.39 ± 0.21
5021.5 ± 0.5	0.071 ± 0.001

a) Present work.

$$dp_1^2 = dp_2^2 = \frac{100^2 x}{(I_1+I_2)^4} [I_1^2 dI_2^2 + I_2^2 dI_1^2], \text{ so}$$

$$dp_1^2 = dp_2^2 = \frac{[73.51^2 \times 0.21^2 + 26.39^2 + 0.36^2]}{100^2} = \frac{328.56}{100^2}$$

$$dp_1 = dp_2 = \frac{(328.56)^{1/2}}{100} = 0.18$$

Finally,

$$p_1 = 73.51 \pm 0.18 \% \quad p_2 = 26.39 \pm 0.18 \%$$

General Case

Nucl. Instr. Meth. In Phys. Res. A265, 541 (1988)

The emission probability of the i th particle group is given by

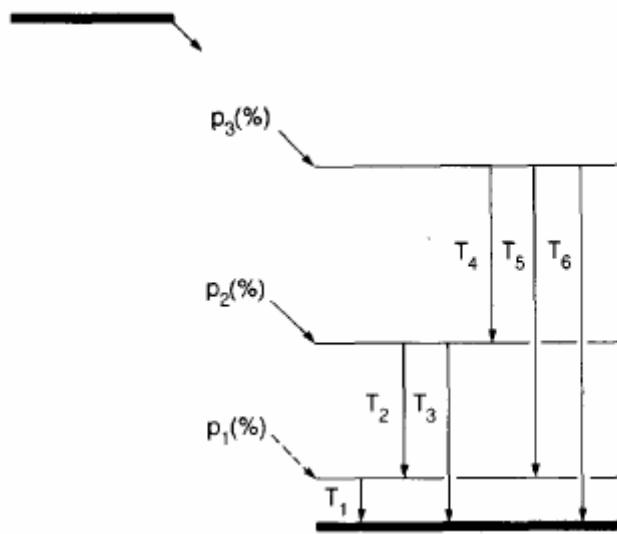
$$p_i(\%) = \frac{BI_i}{\sum_k I_k}, \quad (1)$$

where I_i is the relative spectral intensity of the i th particle group (with statistical uncertainty dI_i), B is the percentage particle branching (with statistical uncertainty dB), and the summation is over all particle groups k .

The fractional uncertainty of $p_i(\%)$, calculated in first order approximation in a Taylor series expansion, as in ref. [1], is

$$\frac{dp_i(\%)}{p_i(\%)} = \left(\left(\frac{dI_i}{I_i} \right)^2 \left(1 - \frac{2I_i}{\sum_k I_k} \right) + \frac{\sum_k dI_k^2}{\left(\sum_k I_k \right)^2} + \left(\frac{dB}{B} \right)^2 \right)^{1/2}. \quad (2)$$

Particle Emission Probabilities Deduced from Decay Scheme



$$p_1(\%) = \frac{T_1 - T_2 - T_5}{T_1 + T_3 + T_6} \times 100, \quad p_2(\%) = \frac{T_2 + T_3 - T_4}{T_1 + T_3 + T_6} \times 100, \quad p_3(\%) = \frac{T_4 + T_5 + T_6}{T_1 + T_3 + T_6} \times 100.$$

$$dp_i^2(\%) = \sum_{k=1}^6 \left(\frac{\partial p_i}{\partial T_k} dT_k \right)^2,$$

The uncertainties become

$$\begin{aligned} dp_1(\%) = & \frac{100}{(T_1 + T_3 + T_6)^2} \left(dT_1^2 (T_2 + T_3 + T_5 + T_6)^2 \right. \\ & \left. + (dT_2^2 + dT_5^2) (T_1 + T_3 + T_6)^2 + (dT_3^2 + dT_6^2) (T_1 - T_2 - T_5)^2 \right)^{1/2}, \end{aligned}$$

$$\begin{aligned} dp_2(\%) = & \frac{100}{(T_1 + T_3 + T_6)^2} \left(dT_3^2 (T_1 - T_2 + T_4 + T_6)^2 \right. \\ & \left. + (dT_2^2 + dT_4^2) (T_1 + T_3 + T_6)^2 + (dT_1^2 + dT_6^2) (T_2 + T_3 - T_4)^2 \right)^{1/2}, \end{aligned}$$

$$\begin{aligned} dp_3(\%) = & \frac{100}{(T_1 + T_3 + T_6)^2} \left(dT_6^2 (T_1 + T_3 - T_4 - T_5)^2 \right. \\ & \left. + (dT_4^2 + dT_5^2) (T_1 + T_3 + T_6)^2 + (dT_1^2 + dT_3^2) (T_4 + T_5 + T_6)^2 \right)^{1/2}. \end{aligned}$$

If $p_1(\%)=0$, then $T_1 = T_2 + T_5$

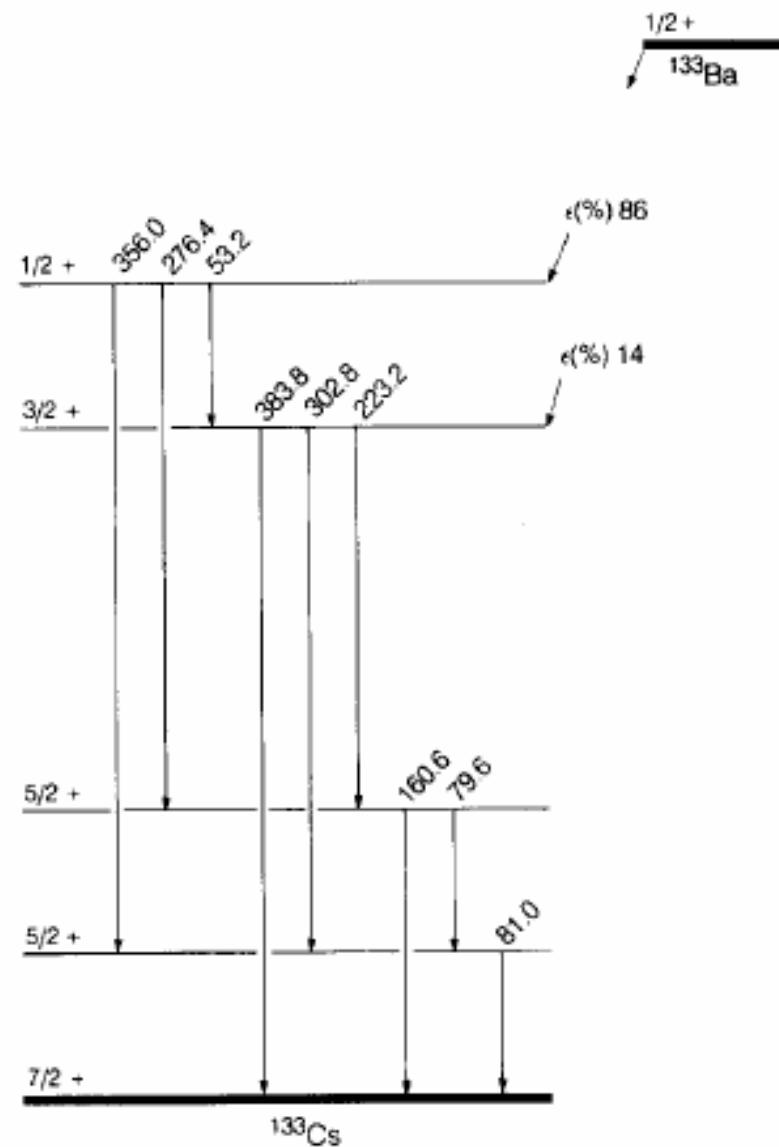
The particle emission probabilities then become

$$p_2(\%) = \frac{T_2 + T_3 - T_4}{T_2 + T_3 + T_5 + T_6} \times 100 \quad \text{and} \quad p_3(\%) = \frac{T_4 + T_5 + T_6}{T_2 + T_3 + T_5 + T_6} \times 100,$$

and their corresponding uncertainties become equal, i.e.,

$$\begin{aligned} dp_2(\%) = dp_3(\%) &= \frac{100}{(T_2 + T_3 + T_5 + T_6)^2} \left(dT_4^2 (T_2 + T_3 + T_5 + T_6)^2 \right. \\ &\quad \left. + (dT_2^2 + dT_3^2)(T_4 + T_5 + T_6)^2 + (dT_5^2 + dT_6^2)(T_2 + T_3 - T_4)^2 \right)^{1/2}. \end{aligned}$$

^{133}Ba EC Decay to ^{133}Cs



^{133}Ba EC Decay to ^{133}Cs

Normalization factor $N=100/(T_{81} + T_{161} + T_{384}) = 1.0044$

The uncertainties become:

$d\varepsilon_{384} = 0.74$, $d\varepsilon_{437} = 2.0$ (Notice that they are not equal).

$\varepsilon_{437} = 86 \pm 2\%$ and $\varepsilon_{384} = 14.00 \pm 0.74\%$

^{133}Ba EC Decay to ^{133}Cs

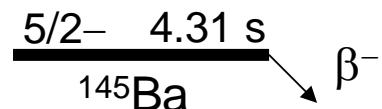
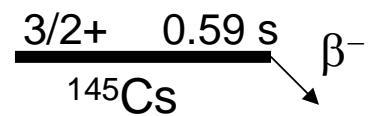
If we assume $\varepsilon_{81} = \varepsilon_{162} = 0\%$, then

$$N = 100/(T_{356} + T_{276} + T_{384} + T_{223}) = 1.00090, \text{ and}$$

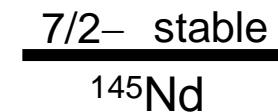
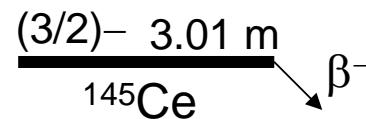
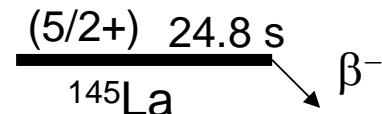
$$\varepsilon_{437} = 86.00 \pm 0.67 \%, \text{ and } \varepsilon_{384} = 14.00 \pm 0.67 \%$$

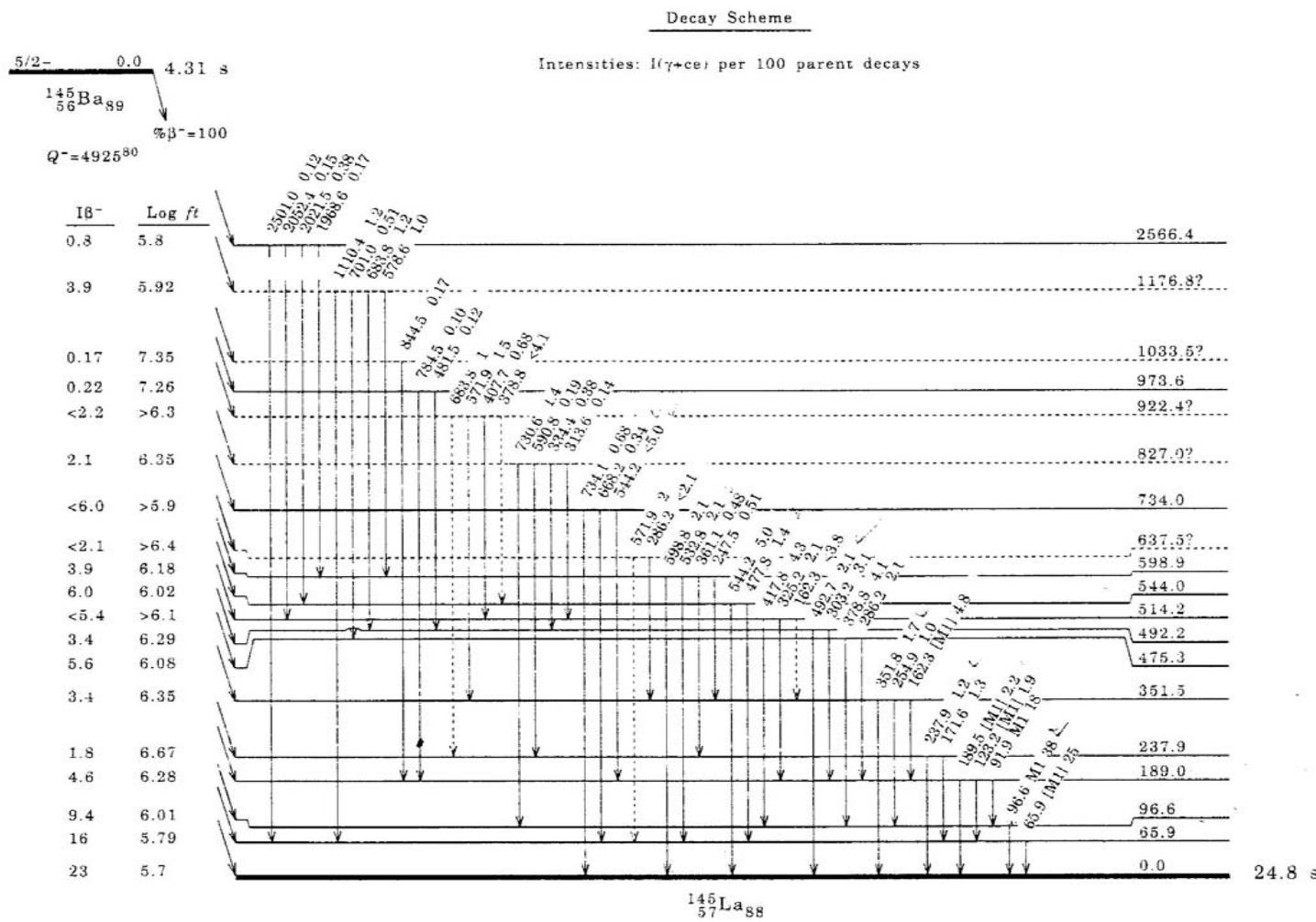
For the general case see

Nucl. Instr. Meth. In Phys. Res. A265, 541 (1988)



$$Q_{\beta^-} = 4923 \pm 65 \text{ keV}$$





Decay scheme is from NDS 68, 997 (1963)

Absolute γ -ray intensities are based on a measured value of $\gamma(96)=17.1 \pm 2.1\%$.
 β^- feeding intensities are from γ -ray intensity balances



Measurement of β^- -decay intensity distributions of several fission-product isotopes using a total absorption γ -ray spectrometer

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Received 6 June 1996

Abstract

A total absorption γ -ray spectrometer coupled to the ^{252}Cf -based INEL ISOL facility has been used in a program of systematic study of the distributions of β^- -decay intensities of fission-product radionuclides. Cascade-summed γ -ray spectra measured with the system have been compared with the spectrum simulated from the corresponding decay schemes, as a test of the completeness and correctness of these schemes. New β^- -decay intensity distributions have been deduced for the decay of these radionuclides. Radionuclides which have been studied in this manner include ^{89}Rb , ^{90g}Rb , ^{90m}Rb , ^{91}Rb , ^{93}Rb , ^{93}Sr , ^{94}Sr , ^{94}Y , ^{95}Sr , ^{95}Y , ^{138g}Cs , ^{138m}Cs , ^{139}Cs , ^{140}Cs , ^{141}Cs , ^{141}Ba , ^{142}Ba , ^{142}La , ^{143}Ba , ^{143}La , ^{144}Ba , ^{144}La , ^{145}Ba , ^{145}La , ^{145}Ce , ^{146}Ce , ^{146}Pr , ^{147}Ce , ^{147}Pr , ^{148}Ce , ^{148}Pr (2.0 min), ^{148}Pr (2.27 min), ^{149}Pr , ^{149}Nd , ^{151}Pr , ^{151}Nd , ^{152}Nd - ^{152}Pm (4.1 min.), ^{153}Nd , ^{153}Pm , ^{154}Nd , ^{154}Pm (1.7 min), ^{155}Nd , ^{155}Pm , ^{156}Pm , ^{157}Pm , ^{157}Sm , ^{158}Sm , and ^{158}Eu .

^{145}Ba Total Absorption γ -Ray Spectrum (1997Gr09)

R.C. Greenwood et al. / Nucl. Instr. and Meth. in Phys. Res. A 390 (1997) 95–154

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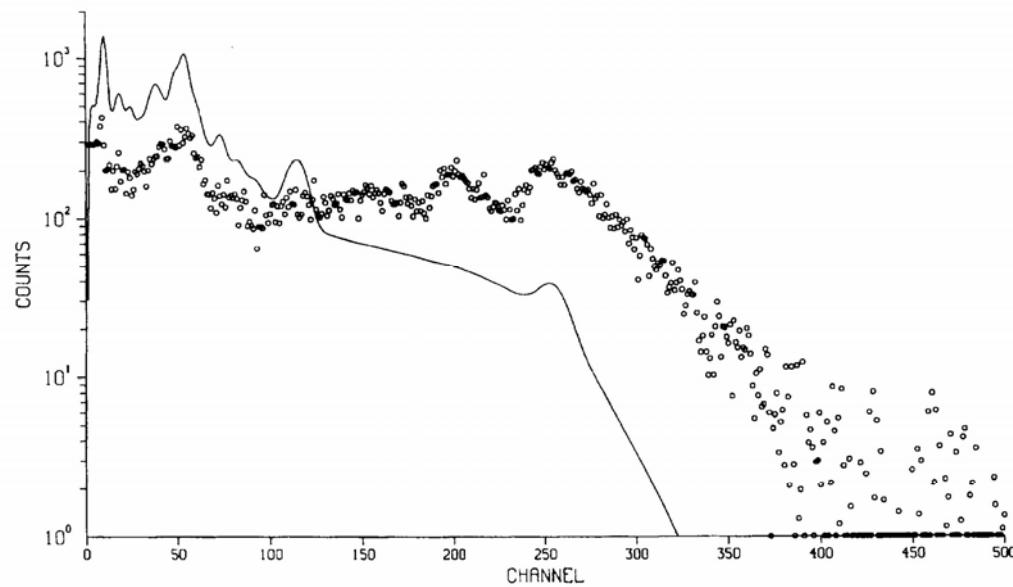
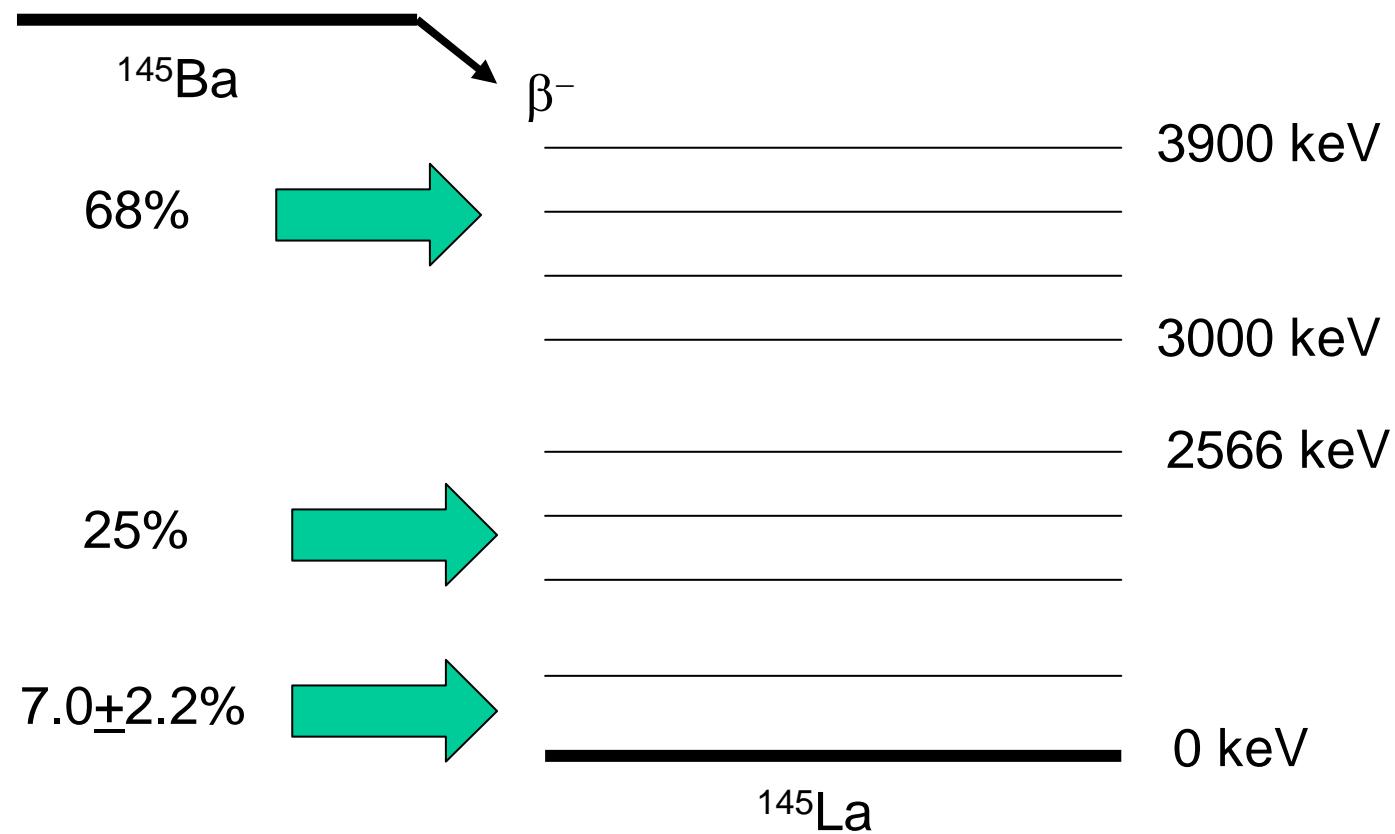


Fig. 25. Comparison of measured singles spectrum for ^{145}Ba with the simulated spectrum for the NDS decay scheme [32].

^{145}Ba Decay Scheme Based on Total Absorption γ -Ray Spectrum
1997Gr09

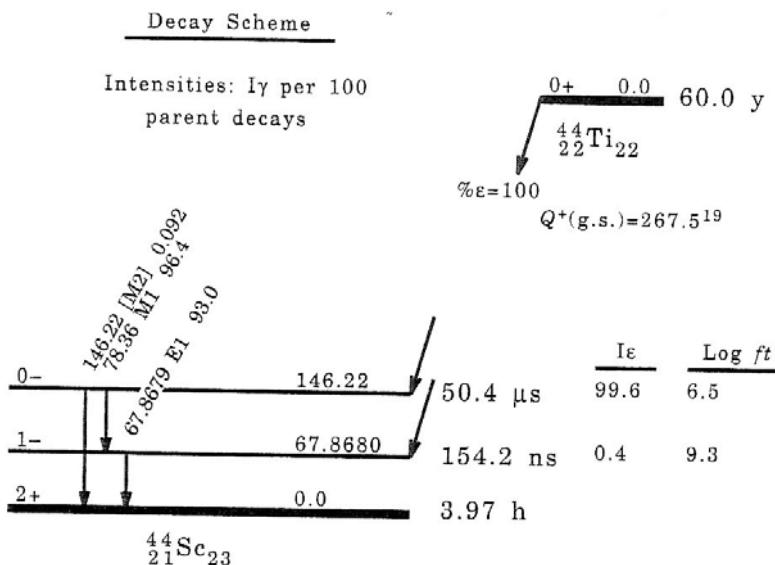


^{145}Ba β^- -decay intensities

Level energy (keV)	I_β (%)		
		NDS [32]	TAGS
0.0	23.0		
65.9	16.0		$\left. \begin{array}{l} \\ \end{array} \right\} 7.0 \pm 2.2$
96.6	9.4		4.39
189.0	4.6		2.15
237.9	1.8		0.65
351.5	3.4		3.4
475.3	5.6		0.84
492.2	3.4		0.51
514.2	< 5.4		4.84
544.0	6.0		1.94
598.9	3.9		1.89
637.5	< 2.1		1.02
734.0	< 6.0		0.54
827.0	2.1		1.02
922.4	< 2.2		0.0
973.6	0.22		0.22
1033.5	0.17		0.17
1176.8	3.9		1.83
1300. P			0.38
1400. P			0.81
1500. P			1.35
1600. P			2.69
1700. P			1.61
1800. P			0.54
2000. P			7.53
2100. P			4.30
2200. P			1.40

Preparing ENSDF Data Sets

⁴⁴Sc ENSDF Data Set



44SC 44TI EC DECAY

44TI	P 0	0+	60.0	Y	11	267.5	19
44SC	N 0.964	13	1.0				
44SC	L 0	2+	3.97	H	4		
44SC	L 67	1-	154.2	NS	8		
44SC	G 67.8679	14	96.5	16	E1	0.0845	
44SCS	G KC= 0.0766	\$LC= 0.00664					
44SC	L 146	0-	50.4	US	7		
44SC	G 78.36	3	100.0	11	M1	0.0302	
44SCS	G KC= 0.0273	\$LC= 0.00243					
44SC	G 146.22	3	0.095	3	[M2]	0.0460	
44SCS	G KC= 0.0414	\$LC= 0.00385					

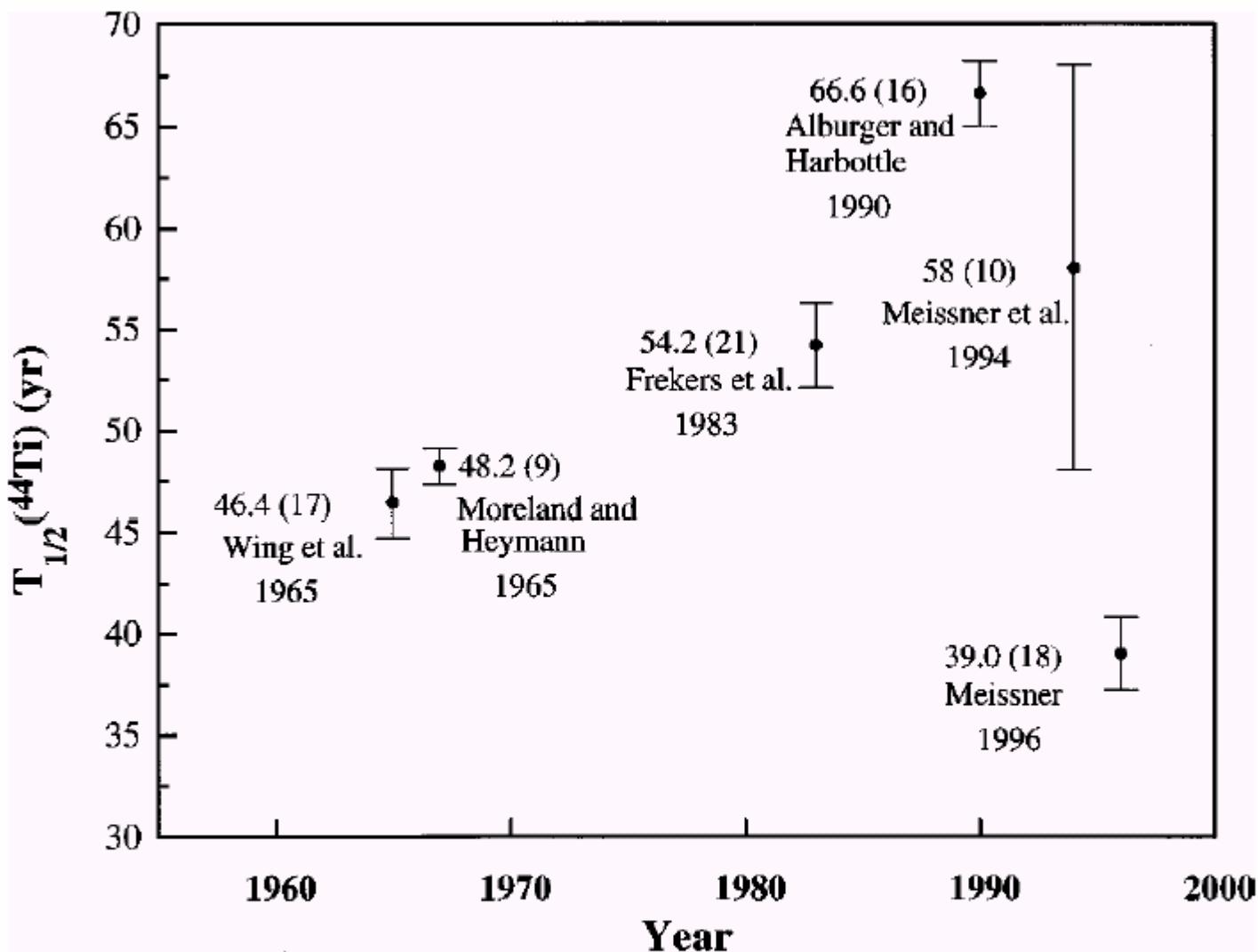


FIG. 2. Summary of previously reported values for the half-life of ^{44}Ti . Numbers in parentheses represent the 1σ uncertainties in the least significant digit(s).

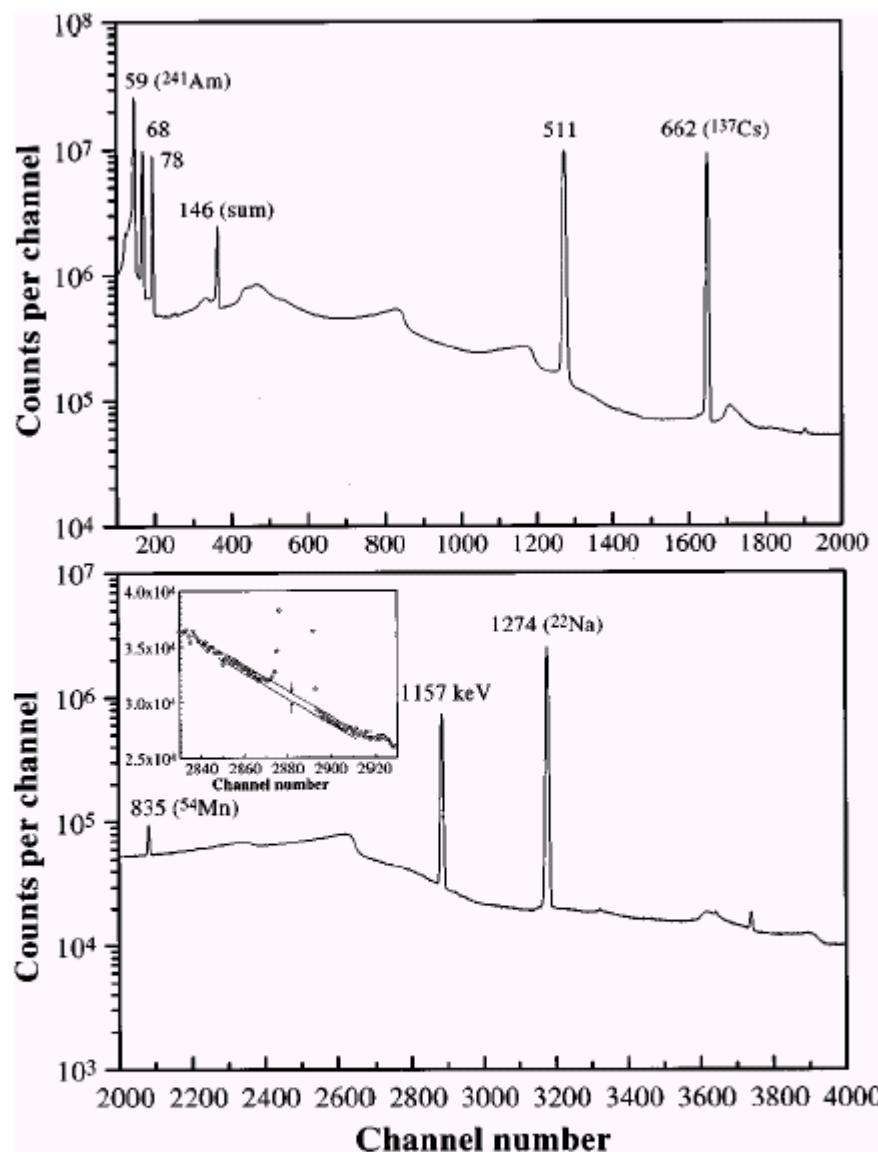


FIG. 4. γ -ray spectrum accumulated in 10 days of counting the mixed source of ^{44}Ti , ^{241}Am , ^{137}Cs , and ^{22}Na . All energies are in keV. Peaks labeled only by energy are from the decay of ^{44}Ti . The inset illustrates the background under the 1157-keV peak. The arrows indicate a $\pm 1\%$ systematic background uncertainty.

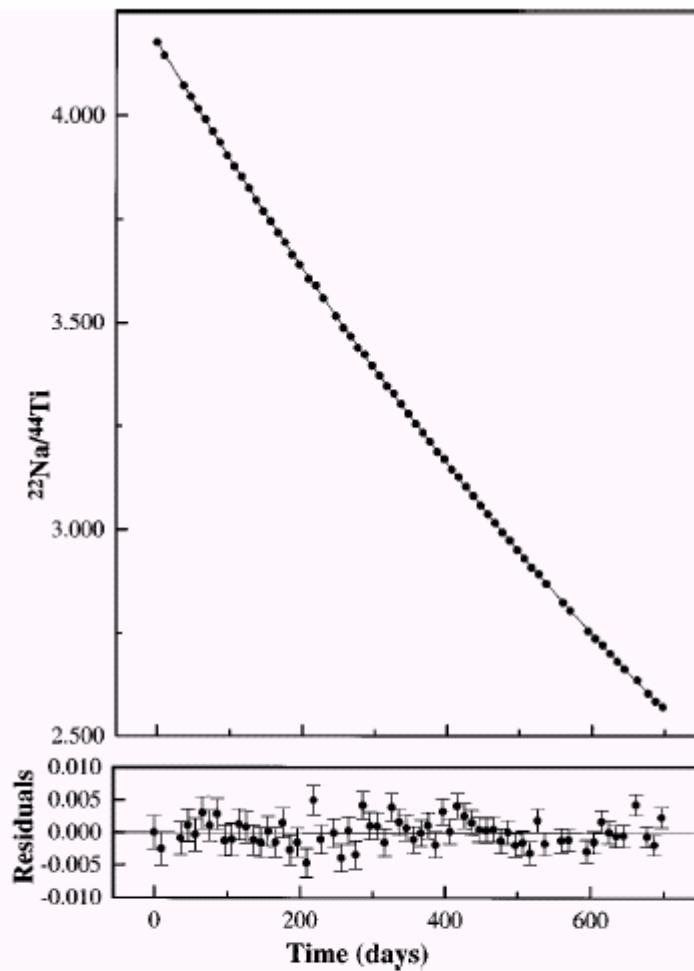


FIG. 5. The upper part of this figure shows the decrease in the ratio between the peak areas of the 1274-keV (^{22}Na) and 1157-keV (^{44}Ti) γ rays as a function of time. The curve going through the data is the result of a least-squares fit of an exponentially decreasing function of time. The ^{44}Ti half-life determined from this fit is 61.5(9) yr and $\chi^2/\nu = 1.1$. The lower panel shows the residuals to this fit.

44Ti Half-life (LWEIGHT)

44Ti Half-life Measurements

INP. VALUE	INP. UNC.	R. WGHT	chi**2/N-1	REFERENCE
.607000E+02	.120E+01	.141E+00	.826E-01	99Wi01
.590000E+02	.600E+00	MIN * .563E+00*	.479E+00	98Ah03
.603000E+02	.130E+01	.120E+00	.163E-01	98Go05
.620000E+02	.200E+01	.507E-01	.214E+00	98No06
.666000E+02	.160E+01	.792E-01	.348E+01	90Al11
.542000E+02	.210E+01	.460E-01	.149E+01	83Fr27

No. of Input Values N= 6 CHI**2/N-1= 5.76 CHI**2/N-1(critical)= 3.00

UWM :.604667E+02 .164796E+01
WM :.599288E+02 .450317E+00(INT.) .108057E+01(EXT.)

INP. VALUE	INP. UNC.	R. WGHT	chi**2/N-1	REFERENCE
.607000E+02	.120E+01	.161E+00	.563E-01	99Wi01
.590000E+02	.681E+00	* .500E+00*	.487E+00	98Ah03
* Input uncertainty increased .114E+01 times *				
.603000E+02	.130E+01	.137E+00	.663E-02	98Go05
.620000E+02	.200E+01	.580E-01	.188E+00	98No06
.666000E+02	.160E+01	.907E-01	.334E+01	90Al11
.542000E+02	.210E+01	.526E-01	.156E+01	83Fr27

No. of Input Values N= 6 CHI**2/N-1= 5.63 CHI**2/N-1(critical)= 3.00

UWM :.604667E+02 .164796E+01
WM :.600634E+02 .481846E+00(INT.) .114378E+01(EXT.)
LWM :.600634E+02 .114378E+01 Min. Inp. Unc.=.600000E+00
LWM has used weighted average and external uncertainty

Recommended value: 60.0 (11) y

44Sc ENSDF Data Set (GTOL)

LEVEL	TI	TI	TI	NET FEEDING	
	(OUT)	(IN)	(NET)	(CALC)	(USE)
0.0	0.000	104.8 18	-104.8 18	-1.0 17	0.0
67.8679 14	104.7 18	103.0 12	1.6 21	1.6 21	0.6 11
146.224 22	103.1 12	0.000	103.1 12	99.4 11	99.4 11

```

44SC      44TI EC DECAY
44TI  P 0          0+           60.0 Y   11        267.5    19
44SC  N 0.964      13          1.0
44SC  L 0          2+           3.97 H   4
44SC  L 67.8679   141-         154.2 NS  8
44SC  E            0.6          11
44SC  G 67.8679   14   96.5 16   E1          0.0845
44SCS G KC= 0.0766 $LC= 0.00664
44SC  L 146.224   220-         50.4 US  7
44SC  E            99.4          11
44SC  G 78.36      3   100.0 11   M1          0.0302
44SCS G KC= 0.0273 $LC= 0.00243
44SC  G 146.22     3   0.095 3    [M2]        0.0460
44SCS G KC= 0.0414 $LC= 0.00385

```

^{44}Sc ENSDF Data Set (LOGFT)

44SC	44TI	EC DECAY						
44TI	P 0	0+	60.0	Y	11	267.5	19	
44SC	N 0.964	13	1.0					
44SC	L 0	2+	3.97	H	4			
44SC	L 67.8679	141-	154.2	NS	8			
44SC	E		0.6	11	9.2	8		
44SCS	E	CK=0.8910 \$CL=0.09309 \$CM+=0.01592						
44SC	G 67.8679	14 96.5 16 E1				0.0845		
44SCS	G KC= 0.0766 \$LC= 0.00664							
44SC	L 146.224	220-	50.4	US	7			
44SC	E		99.4	11	6.509	17		
44SCS	E	CK=0.8883 \$CL=0.09533 \$CM+=0.016352 18						
44SC	G 78.36	3 100.0 11 M1				0.0302		
44SCS	G KC= 0.0273 \$LC= 0.00243							
44SC	G 146.22	3 0.095 3 [M2]				0.0460		
44SCS	G KC= 0.0414 \$LC= 0.00385							

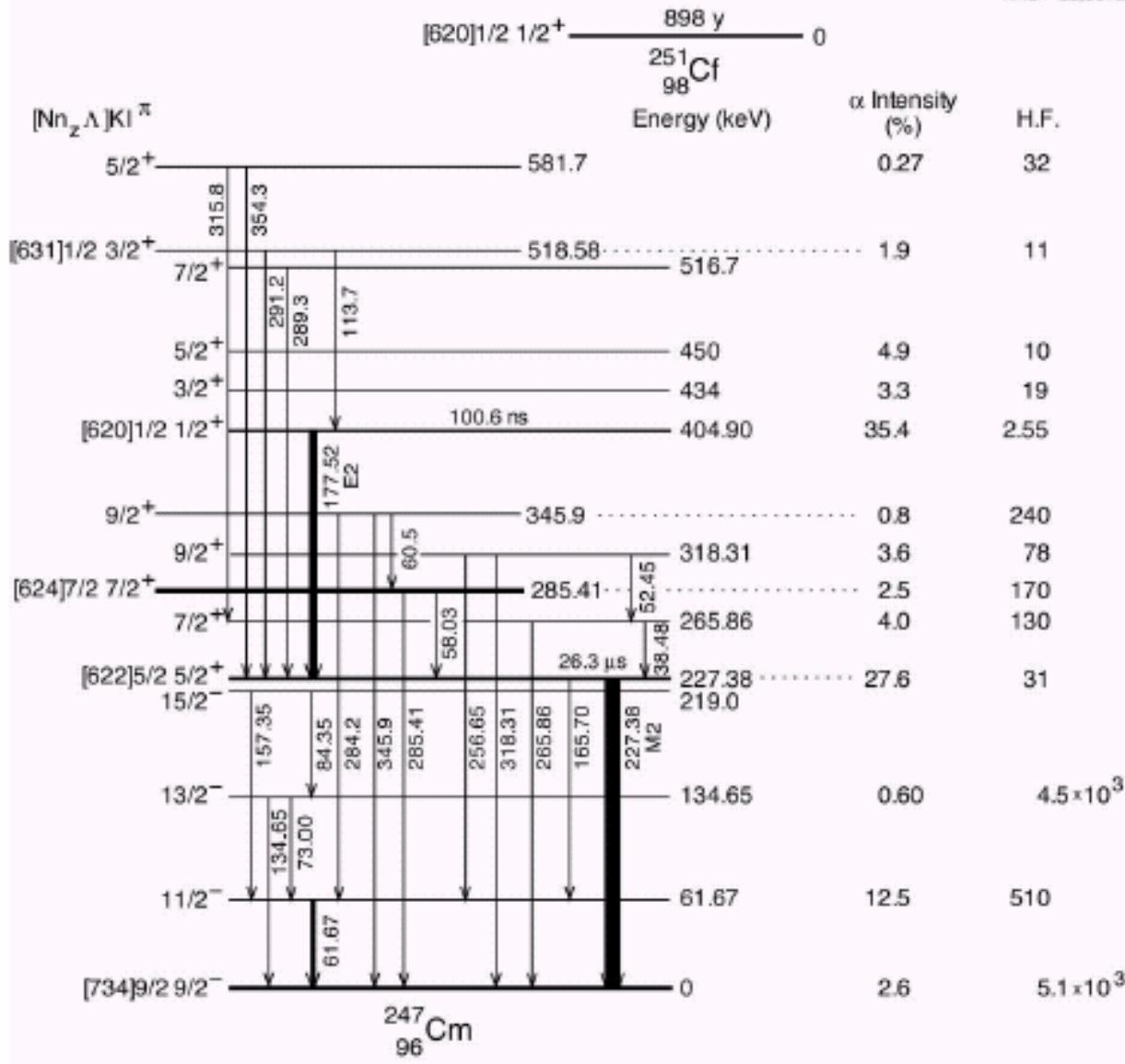
New Exercise

Trieste, April 28 – May 9, 2008

PHYSICAL REVIEW C 68, 044306 (2003)

Energy levels of ^{247}Cm populated in the α decay of $^{251}_{98}\text{Cf}$

ANL-P-22.897a



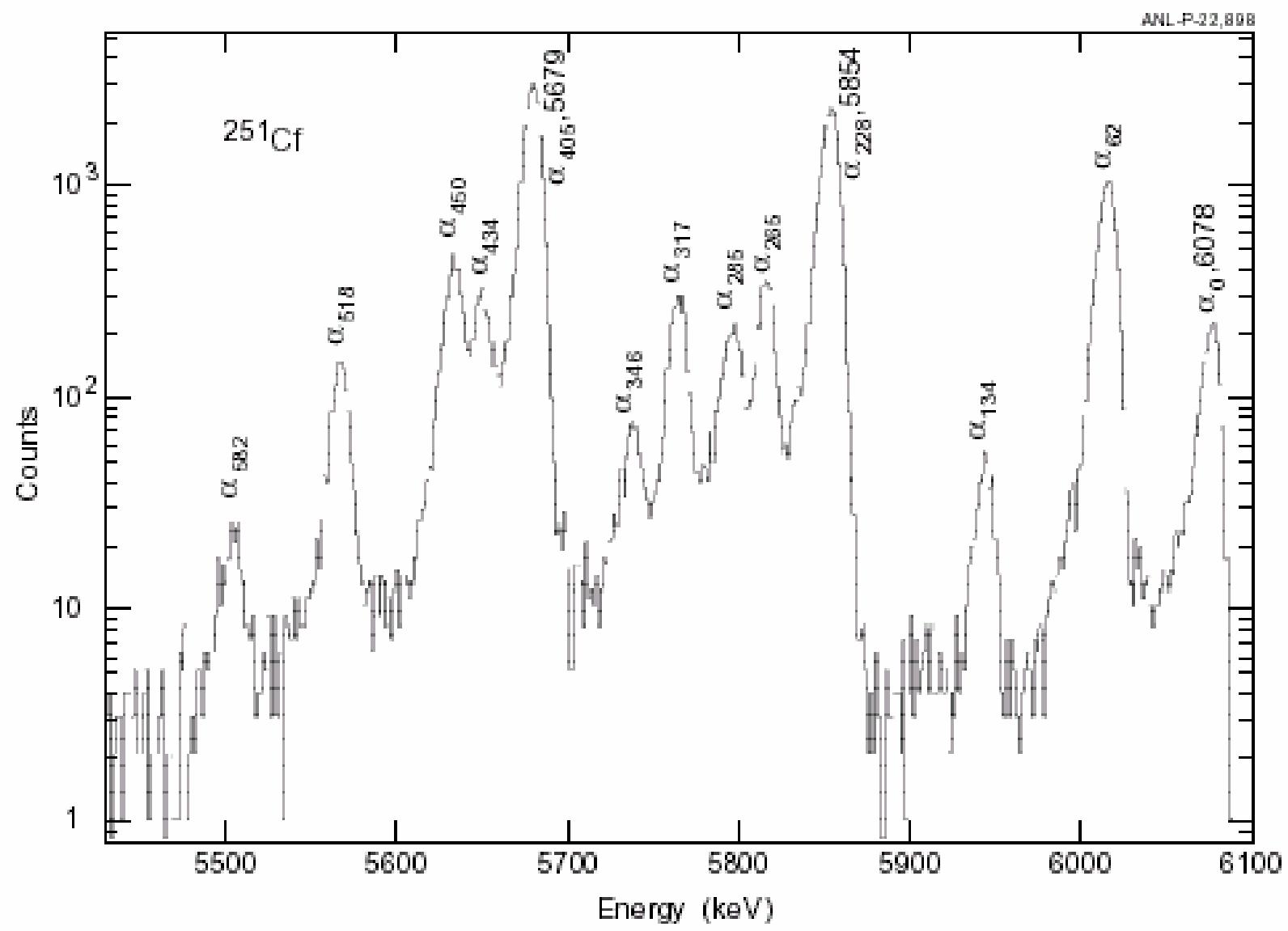


TABLE I. ^{251}Cf α groups.

Energy (MeV)	Excited state energy (keV)	Intensity (%)	Hindrance factor ^a
6.078±0.002	0	2.6±0.1	5.1×10^3
6.017±0.002	62	12.5±0.3	5.1×10^2
5.946±0.002	134	0.60±0.06	4.5×10^3
5.854±0.002	228	27.6±0.5	31
5.817±0.002	265	4.0±0.2	1.3×10^2
5.798±0.002	285	2.5±0.2	1.7×10^2
5.766±0.002	317	3.6±0.2	78
5.738±0.002	346	0.8±0.1	2.4×10^2
5.679±0.002	405	35.4±0.5	2.55
5.651±0.002	434	3.3±0.2	19
5.635±0.002	450	4.9±0.2	10
5.568±0.002	518	1.9±0.1	11
5.505±0.002	582	0.27±0.05	32

ANLP-22,896

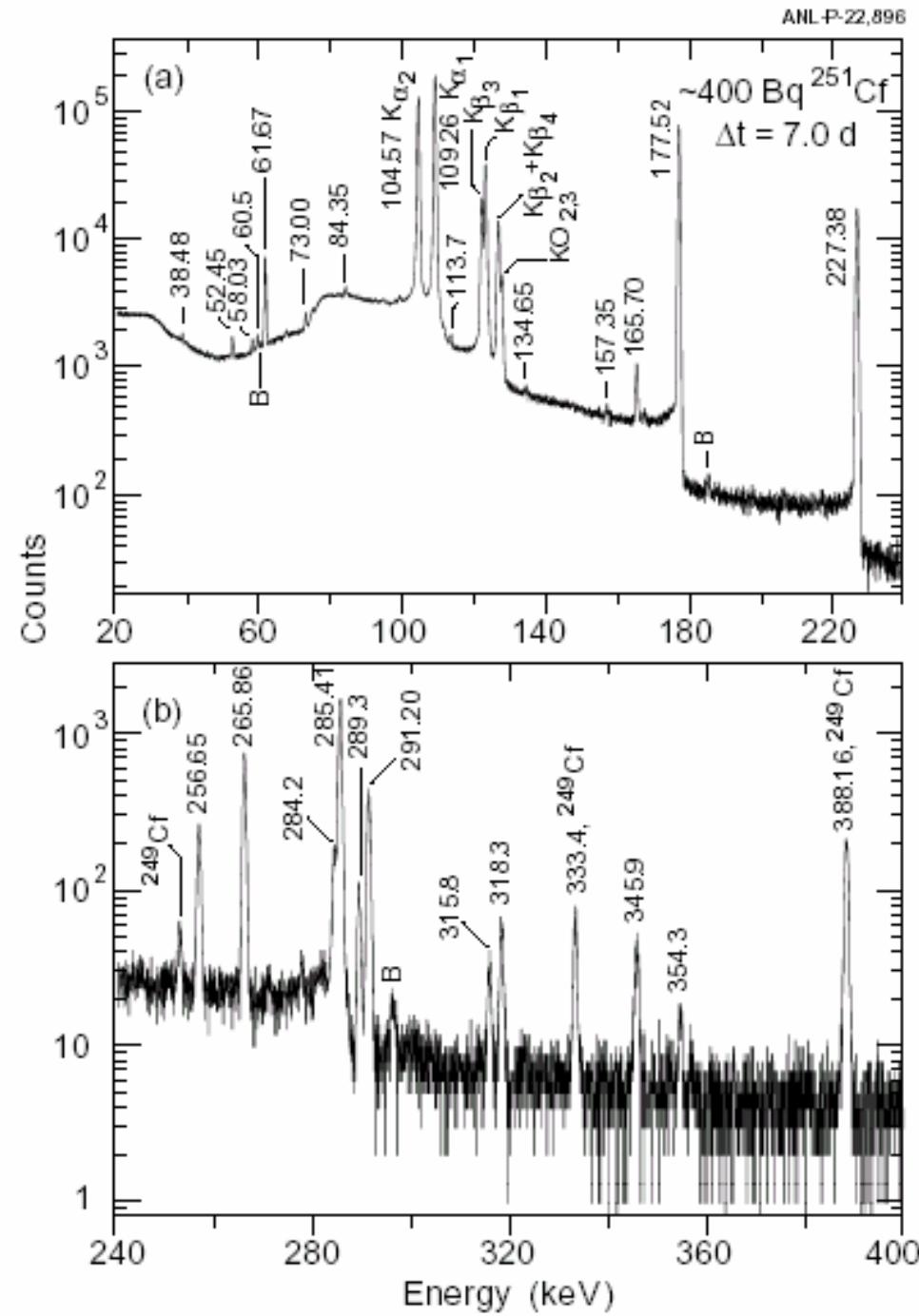


TABLE III. ^{251}Cf γ rays.

Energy (keV)	Intensity (%)	Transitions Initial→Final
38.48±0.05	0.038±0.006	265.86→227.38
52.45±0.05	0.048±0.005	318.31→265.86
58.03±0.05	0.024±0.005	285.41→227.38
60.5±0.1	0.010±0.003	345.9→285.41
61.67±0.05	0.40±0.03	61.67→0
73.00±0.08	0.040±0.005	134.65→61.67
84.35±0.08	0.040±0.005	219.0→134.65
104.57±0.02	12.6±0.7	Cm $K\alpha_2$
109.26±0.02	19.8±1.0	Cm $K\alpha_1$
113.7±0.1	0.024±0.005	518.58→404.90
122.31±0.02+		Cm $K\beta_3$
123.40±0.02	7.7±0.5	Cm $K\beta_1$
127.01±0.04+		Cm $K\beta_2+K\beta_4$
128.00±0.05	2.6±0.2	Cm $KO_{2,3}$
134.65±0.08	0.014±0.003	134.65→0
157.35±0.08	0.020±0.004	219.0→61.67
165.70±0.05	0.12±0.01	227.38→61.67
177.52±0.02	17.3±0.9	404.90→227.38
227.38±0.02	6.8±0.3	227.38→0
256.65±0.08	0.13±0.01	318.31→61.67
265.86±0.08	0.43±0.03	265.86→0
284.2±0.1	0.12±0.01	345.9→61.67
285.41±0.08	1.13±0.09	285.41→0
289.3±0.1	0.070±0.007	516.7→227.38
291.20±0.08	0.30±0.03	518.58→227.38
315.8±0.1	0.024±0.003	581.7→265.86
318.3±0.1	0.050±0.005	318.31→0
345.9±0.1	0.043±0.004	345.9→0
354.3±0.1	0.013±0.002	581.7→227.38

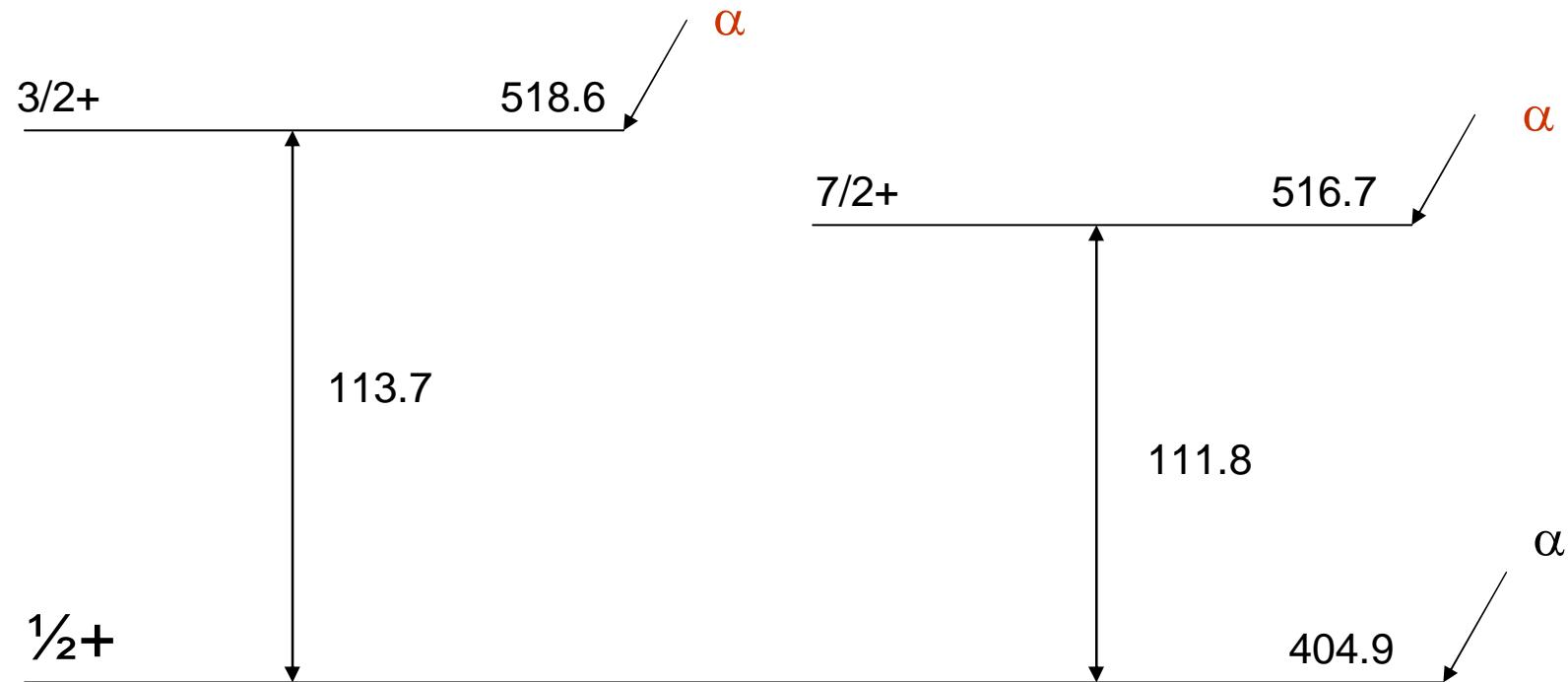
TABLE II. ^{251}Cf conversion electron data.

Transition energy (keV)	Shell	Energy (keV)	Intensity (%)	Conversion coefficient	Theory	Mixing ratio δ	Multipolarity
38.48	$L+M+\dots$			$183\pm31^{\text{a}}$	$122(M1), 1833(E2)$	0.19 ± 0.05	$M1+3.6\%E2$
52.45	$L+M+\dots$			$70\pm10^{\text{a}}$	$49.3(M1), 410(E2)$	0.25 ± 0.06	$M1+5.7\%E2$
58.03	$L+M+\dots$			$80\pm19^{\text{a}}$	$36.7(M1), 256(E2)$	0.50 ± 0.08	$M1+20\%E2$
60.5	$L+M+\dots$			$62\pm21^{\text{a}}$	$32.6(M1), 208(E2)$	0.45 ± 0.12	$M1+17\%E2$
61.67	L_1+L_2	37.4	9.4 ± 1.0	23.5 ± 3.1	$22.8(M1), 78.7(E2)$	0.11 ± 0.025	
	L_3	43.0	1.3 ± 0.3	3.3 ± 0.8	$0.096(M1), 56.7(E2)$	0.24 ± 0.03	
	$M+N$	55.5	4.5 ± 0.6	11.0 ± 1.7	$7.7(M1), 53(E2)$	0.28 ± 0.07	$M1+7\%E2$
73.00	$L+M+\dots$			$40\pm16^{\text{a}}$	$18.7(M1), 84.3(E2)$	0.69 ± 0.14	$M1+32\%E2$
165.7	L_1+L_2	141.7	1.8 ± 0.3	15 ± 3	$15.6(E3)$		$E3$
	L_3	146.6	0.8 ± 0.3	6.7 ± 2.6	$5.6(E3)$		
177.52	K	49.3	3.3 ± 0.5	0.19 ± 0.03	$0.17(E2)$		
	L_1+L_2	153.7	12.3 ± 1.2	0.71 ± 0.08	$0.73(E2)$		$E2$
	L_3	158.6	5.3 ± 0.5	0.31 ± 0.03	$0.31(E2)$		
	$M+N$	171.8	7.1 ± 0.7	0.41 ± 0.05	$0.40(E2)$		
227.38	K	99.1	41 ± 3	6.0 ± 0.5	$7.9(M2), 0.27(E3)$	0.58 ± 0.05	$M2+25\%E3$
	L_1+L_2	202.9	18.4 ± 1.9	2.7 ± 0.3	$2.76(M2), 3.26(E3)$		
	L_3	208.2	2.8 ± 0.3	0.41 ± 0.05	$0.28(M2), 0.91(E3)$		
	$M+N$	221.1	10.4 ± 1.1	1.53 ± 0.17	$1.13(M2), 1.73(E3)$		

^aDeduced from decay scheme γ -ray and α -particle intensity balance.

ENSDF Dataset (1)

247CM	251CF	A	DECAY		2003AH07			
251CF	P	0.0		1/2+		898	Y	44
247CM	N	1.0		1.0				6175.8
247CM	L	0.0		9/2-		1.56E+7	Y	5
247CM	A	6078	2	2.6	1			
247CM	L	62		11/2-				
247CM	A	6017	2	12.5	3			
247CM	G	61.67	5	0.40	3 M1+E2	0.24		3
247CM	L	135		13/2-				
247CM	A	5946	2	0.60	6			
247CM	G	73.00	8	0.040	5 M1+E2	0.69		14
247CM	G	134.65	8	0.014	3 [E2]			
247CM	L	219		15/2-				
247CM	G	84.35	8	0.040	5 [M1+E2]			
247CM	G	157.35	8	0.020	4 [E2]			
247CM	L	227		5/2+		26.3	US	3
247CM	A	5854	2	27.6	5			
247CM	G	165.70	5	0.12	1 E3			
247CM	G	227.38	2	6.8	3 M2+E3	0.58		5
247CM	L	266		(7/2+)				
247CM	A	5817	2	4.0	2			
247CM	G	38.48	5	0.038	6 (M1+E2)	0.19		5
247CM	G	265.86	8	0.43	3 [E1]			
247CM	L	285		(7/2+)				
247CM	A	5798	2	2.5	2			
247CM	G	58.03	5	0.024	5 (M1+E2)	0.50		8
247CM	G	285.41	8	1.13	9 [E1]			
247CM	L	318		9/2+				
247CM	A	5766	2	3.6	2			
247CM	G	52.45	5	0.048	5 (M1+E2)	0.25		6
247CM	G	256.65	8	0.13	1 [E1]			
247CM	G	318.3	1	0.050	5 [E1]			
247CM	L	346		(9/2+)				
247CM	A	5738	2	0.8	1			
247CM	G	60.5	1	0.010	3 (M1+E2)	0.45		12
247CM	G	284.2	1	0.12	1 [E1]			
247CM	G	345.9	1	0.043	4 [E1]			



$$516.7 - 404.9 = 111.8 \text{ keV}$$

$$518.6 - 404.9 = 113.7 \text{ keV}$$

$$E_{\alpha}(516.7 + 518.6) = 5568 \text{ keV}$$

$$E_{\alpha}(404.9) = 5679.3 \text{ keV}$$

$$Q(516.7) = 5679.3 \times 251/247 - 111.8 = 5659.5 \text{ keV}$$

$$E_{\alpha}(516.7) = 5659.5 \times 247/251 = 5569 \text{ keV}$$

$$Q(518.6) = 5679.3 \times 251/247 - 113.7 = 5657.6 \text{ keV}$$

$$E_{\alpha}(518.6) = 5657.6 \times 247/251 = 5567 \text{ keV}$$

ENSDF Dataset (2)

247CM	L	405	1/2+	100.6	NS	6
247CM	A	5679.3	1635.4	5		
247CM	G	177.52	2 17.3	9	E2	
247CM	L	434	(3/2+)			
247CM	A	5651	2 3.3	2		
247CM	G	28	5	[M1+E2]		8.2
247CM	L	450	2 (5/2+)			3
247CM	A	5635	2 4.9	2		
247CM	G	16	5	[M1+E2]		4.9
247CM	G	44				2
247CM	L	517	(7/2+)			S
247CM	A	5569	2 1.9	LE		
247CM	cA	E	from E a(404.9 level)=5679.3 {I16} and the energy difference			
247CM2cA			between 516.7 and 404.9 levels (recoil energy is taken into account).			
247CM3cA			E a=5568 {I2}, measured by 2003Ah07, is assumed by the evaluator to be			
247CM4cA			a doublet, feeding the 516.7- and 518.58-keV levels.			
247CM	cA	IA	1.9 {I1} was measured by 2003Ah07 for the doublet.			
247CM	G	289.3	1 0.070	7 [M1+E2]		
247CM	L	519	(3/2+)			
247CM	A	5567	2 1.9	LE		
247CM	cA	E	from E a(404.9 level)=5679.3 {I16} and the energy difference			
247CM2cA			between 518.6 and 404.9 levels (recoil energy is taken into account).			
247CM	G	113.7	1 0.024	5 [M1+E2]		
247CM	G	291.20	8 0.30	3 [M1+E2]		
247CM	L	582	(5/2+)			
247CM	A	5505	2 0.27	5		
247CM	G	63	5	[M1+E2]		0.21
247CM	G	315.8	1 0.024	3 [M1+E2]		5
247CM	G	354.3	1 0.013	2 [M1+E2]		

Program HSICC (1)

```

247CM   251CF A DECAY          2003AH07
251CF P 0.0      1/2+          898 Y    44           6175.8   10
247CM N 1.0      1.0          1.0
247CM L 0.0      9/2-          1.56E+7 Y 5
247CM A 6078     2  2.6      1
247CM L 62       11/2-
247CM A 6017     2 12.5      3
247CM G 61.67    5  0.40      3 M1+E2      0.24    3      39.2  22
247CMS G LC=29.0 16$MC=7.4 5$NC+=2.82 18
247CM L 135      13/2-
247CM A 5946     2  0.60      6
247CM G 73.00    8  0.040     5 M1+E2      0.69    14     40   6
247CMS G LC=29 5$MC=7.8 13$NC+=3.0 5
247CM G 134.65   8  0.014     3 [E2]           5.06
247CMS G KC=0.156$LC=3.52$MC=0.99$NC+=0.389
247CM L 219      15/2-
247CM G 84.35    8  0.040     5 [M1+E2]         27
247CMS G LC=20 11$MC=5 4$NC+=2.1 13
247CM G 157.35   8  0.020     4 [E2]           2.62
247CMS G KC=0.178$LC=1.76$MC=0.495$NC+=0.193
247CM L 227      5/2+          26.3 US   3
247CM A 5854     2 27.6      5
247CM G 165.70   5  0.12      1 E3           31.2
247CMS G KC=0.243$LC=21.7$MC=6.60$NC+=2.65
247CM G 227.38   2  6.8       3 M2+E3      0.58    5      10.6  2
247CMS G KC=6.0  3$LC=3.35 4$MC=0.93 2$NC+=0.364 6
247CM L 266      (7/2+)
247CM A 5817     2  4.0       2
247CM G 38.48    5  0.038     6 (M1+E2)     0.19    5      1.8E2  4
247CMS G LC=135 25$MC=35 7
247CM G 265.86   8  0.43      3 [E1]           0.0571
247CMS G KC=0.0446$LC=0.0094$MC=0.00229$NC+=0.00084
247CM L 285      (7/2+)
247CM A 5798     2  2.5       2
247CM G 58.03    5  0.024     5 (M1+E2)     0.50    8      80   12
247CMS G LC=58 8$MC=15.6 23$NC+=6.0 9
247CM G 285.41   8  1.13     9 [E1]           0.0489
247CMS G KC=0.0383$LC=0.00795$MC=0.00194$NC+=0.00071
247CM L 318      9/2+
247CM A 5766     2  3.6       2
247CM G 52.45    5  0.048     5 (M1+E2)     0.25    6      71   11
247CMS G LC=52 8$MC=13.4 22$NC+=5.1 9
247CM G 256.65   8  0.13      1 [E1]           0.0617
247CMS G KC=0.0481$LC=0.0102$MC=0.00249$NC+=0.00091
247CM G 318.3    1  0.050     5 [E1]           0.0387
247CMS G KC=0.0304$LC=0.00620$MC=0.00151$NC+=0.00055

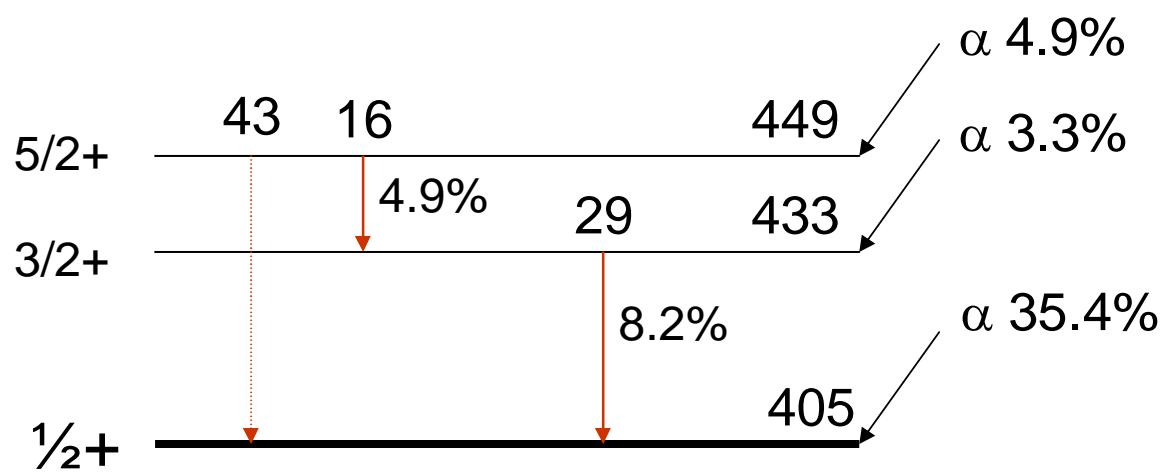
```

Program HSICC (2)

```

247CM L 346          (9/2+)
247CM A 5738          2 0.8    1
247CM G 60.5           1 0.010   3 (M1+E2)   0.45    12      62  14
247CMS G LC=45 10$MC=12 3$NC+=4.6 11
247CM G 284.2           1 0.12    1 [E1]                 0.0494
247CMS G KC=0.0386$LC=0.00803$MC=0.00196$NC+=0.00072
247CM G 345.9           1 0.043    4 [E1]                 0.0324
247CMS G KC=0.0256$LC=0.00515$MC=0.00125$NC+=0.00046
247CM L 405            1/2+          100.6 NS  6
247CM A 5679.3          1635.4   5
247CM G 177.52          2 17.3    9 E2                  1.61
247CMS G KC=0.168$LC=1.04$MC=0.291$NC+=0.113
247CM L 434            (3/2+)
247CM A 5651            2 3.3     2
247CM G 28              5             [M1+E2]                4.E3  58.2      3
247CMS G L/T=0.73 23$M/T=0.20 21
247CM L 450            2 (5/2+)
247CM A 5635            2 4.9     2
247CM G 16              5             [M1+E2]                1.9E4 194.9      2
247CMS G M/T=0.75 19
247CM G 44
247CM L 517            (7/2+)
247CM A 5569            2 1.9     LE
247CM cA E           from E|a(404.9 level)=5679.3 {I16} and the energy difference
247CM2cA between 516.7 and 404.9 levels (recoil energy is taken into account).
247CM3cA E|a=5568 {I2}, measured by 2003Ah07, is assumed by the evaluator to be
247CM4cA a doublet, feeding the 516.7- and 518.58-keV levels.
247CM cA IA           1.9 {I1} was measured by 2003Ah07 for the doublet.
247CM G 289.3           1 0.070   7 [M1+E2]                1.0  8
247CMS G KC=0.7 7$LC=0.21 7$MC=0.052 15$NC+=0.020 6
247CM L 519            (3/2+)
247CM A 5567            2 1.9     LE
247CM cA E           from E|a(404.9 level)=5679.3 {I16} and the energy difference
247CM2cA between 518.6 and 404.9 levels (recoil energy is taken into account).
247CM G 113.7           1 0.024   5 [M1+E2]                8    3
247CMS G LC=5.7 19$MC=1.5 6$NC+=0.60 25
247CM G 291.20          8 0.30    3 [M1+E2]                1.0  7
247CMS G KC=0.7 7$LC=0.20 7$MC=0.051 15$NC+=0.020 6
247CM L 582            (5/2+)
247CM A 5505            2 0.27    5
247CM G 63              5             [M1+E2]                1.0E2 70.21      5
247CMS G L/T=0.72 19$M/T=0.20 16$N/T=0.08 7
247CM G 315.8           1 0.024   3 [M1+E2]                0.8  6
247CMS G KC=0.6 5$LC=0.16 6$MC=0.040 13$NC+=0.015 5
247CM G 354.3           1 0.013   2 [M1+E2]                0.6  5
247CMS G KC=0.4 4$LC=0.11 5$MC=0.028 11$NC+=0.011 4

```



Report from GTOL

LEVEL	RI (OUT)	RI (IN)	RI (NET)	TI (OUT)	TI (IN)	TI (NET)	NET FEEDING (CALC)	NET FEEDING (INPUT)
0.0	0.000	8.9 4	-8.9 4	0.000	97 5	-97 5	3 5	2.6 1
	Upper limit (90% C.L.) estimates:							
	Method 1: 9.80							
	Method 2: 9.10							
61.67 4	0.40 3	0.430 19	-0.03 4	16.1 16	5.8 5	10.2 17	10.2 17	12.5 3
134.66 6	0.054 6	0.040 5	0.014 8	1.7 4	1.1 7	0.6 8	0.6 8	0.60 6
	Upper limit (90% C.L.) estimates:							
	Method 1: 1.63							
	Method 2: 1.54							
219.02 7	0.060 7	0.000	0.060 7	1.2 7	0.000	1.2 7	1.2 7	
	Upper limit (90% C.L.) estimates:							
	Method 1: 2.05							
	Method 2: 2.03							
227.379 19	6.9 3	17.7 9	-10.8 10	83 5	55 4	28 6	28 6	27.6 5
265.86 4	0.47 3	0.072 6	0.40 4	7.3 19	3.5 7	3.8 20	3.8 20	4.0 2
	Upper limit (90% C.L.) estimates:							
	Method 1: 6.40							
	Method 2: 6.38							
285.41 5	1.15 9	0.010 3	1.14 9	3.1 5	0.63 24	2.5 6	2.5 6	2.5 2
318.31 5	0.228 13	0.000	0.228 13	3.6 7	0.000	3.6 7	3.6 7	3.6 2
345.89 6	0.173 12	0.000	0.173 12	0.80 24	0.000	0.80 24	0.80 24	0.8 1
404.90 3	17.3 9	0.024 5	17.3 9	45.2 25	8.4 4	37 3	37 3	35.4 5
433.4	0.000	0.000	0.000	8.2 3	4.90 20	3.3 4	3.3 4	3.3 2
448.9 10	0.000	0.000	0.000	4.90 20	0.000	4.90 20	4.90 20	4.9 2
516.68 11	0.070 7	0.000	0.070 7	0.14 6	0.000	0.14 6	0.14 6	1.9 LE
518.59 7	0.32 3	0.000	0.32 3	0.82 24	0.21 5	0.61 24	0.61 24	1.9 LE
581.67 8	0.037 4	0.000	0.037 4	0.27 6	0.000	0.27 6	0.27 6	0.27 5

Program GTOL (1)

```

247CM   251CF A DECAY          2003AH07
251CF P 0.0      1/2+          898 Y    44           6175.8   10
247CM N 1.0      1.0          1.0
247CM L 0.0      9/2-          1.56E+7 Y  5
247CM A 6078     2  2.6       1 5080
247CM L  61.67 4 11/2-
247CM A 6017     2 12.5       3 512
247CM G 61.67    5  0.40      3 M1+E2      0.24    3      39.2 22
247CMS G LC=29.0 16$MC=7.4 5$NC+=2.82 18
247CM L  134.66 6 13/2-
247CM A 5946     2  0.60      6 4460
247CM G 73.00    8  0.040     5 M1+E2      0.69    14     40    6
247CMS G LC=29 5$MC=7.8 13$NC+=3.0 5
247CM G 134.65   8  0.014     3 [E2]           5.06
247CMS G KC=0.156$LC=3.52$MC=0.99$NC+=0.389
247CM L  219.02 7 15/2-
247CM G 84.35    8  0.040     5 [M1+E2]        27    16
247CMS G LC=20 11$MC=5 4$NC+=2.1 13
247CM G 157.35   8  0.020     4 [E2]           2.62
247CMS G KC=0.178$LC=1.76$MC=0.495$NC+=0.193
247CM L  227.37919 5/2+      26.3 US   3
247CM A 5854     2 27.6       5 31.3
247CM G 165.70   5  0.12      1 E3             31.2
247CMS G KC=0.243$LC=21.7$MC=6.60$NC+=2.65
247CM G 227.38   2  6.8       3 M2+E3      0.58    5      10.6  2
247CMS G KC=6.0 3$LC=3.35 4$MC=0.93 2$NC+=0.364 6
247CM L  265.86 4(7/2+)
247CM A 5817     2  4.0       2 134
247CM G 38.48    5  0.038     6 (M1+E2)    0.19    5      1.8E2  4
247CMS G LC=135 25$MC=35 7
247CM G 265.86   8  0.43      3 [E1]           0.0571
247CMS G KC=0.0446$LC=0.0094$MC=0.00229$NC+=0.00084
247CM L  285.41 5(7/2+)
247CM A 5798     2  2.5       2 168
247CM G 58.03    5  0.024     5 (M1+E2)    0.50    8      80    12
247CMS G LC=58 8$MC=15.6 23$NC+=6.0 9
247CM G 285.41   8  1.13      9 [E1]           0.0489
247CMS G KC=0.0383$LC=0.00795$MC=0.00194$NC+=0.00071
247CM L  318.31 5 9/2+
247CM A 5766     2  3.6       2 77
247CM G 52.45    5  0.048     5 (M1+E2)    0.25    6      71    11
247CMS G LC=52 8$MC=13.4 22$NC+=5.1 9
247CM G 256.65   8  0.13      1 [E1]           0.0617
247CMS G KC=0.0481$LC=0.0102$MC=0.00249$NC+=0.00091
247CM G 318.3    1  0.050     5 [E1]           0.0387
247CMS G KC=0.0304$LC=0.00620$MC=0.00151$NC+=0.00055

```

Program GTOL (2)

```

247CM L 345.89 6(9/2+)
247CM A 5738 2 0.8 1 244
247CM G 60.5 1 0.010 3 (M1+E2) 0.45 12 62 14
247CMS G LC=45 10$MC=12 3$NC+=4.6 11
247CM G 284.2 1 0.12 1 [E1] 0.0494
247CMS G KC=0.0386$LC=0.00803$MC=0.00196$NC+=0.00072
247CM G 345.9 1 0.043 4 [E1] 0.0324
247CMS G KC=0.0256$LC=0.00515$MC=0.00125$NC+=0.00046
247CM L 404.90 3 1/2+ 100.6 NS 6
247CM A 5679.3 1635.4 5 2.6
247CM G 177.52 2 17.3 9 E2 1.61
247CMS G KC=0.168$LC=1.04$MC=0.291$NC+=0.113
247CM L 433 4(3/2+)
247CM A 5651 2 3.3 2 19.2
247CM G 28 5 [M1+E2] 4.E3 58.2 3
247CMS G L/T=0.73 23$M/T=0.20 21
247CM L 448.910(5/2+)
247CM A 5635 2 4.9 2 10.5
247CM G 16 5 [M1+E2] 1.9E4 194.9 2
247CMS G M/T=0.75 19
247CM G 44 S
247CM L 516.6811 (7/2+)
247CM A 5569 2 1.9 LE11 GE
247CM cA E from E|a(404.9 level)=5679.3 {I16} and the energy difference
247CM2cA between 516.7 and 404.9 levels (recoil energy is taken into account).
247CM3cA E|a=5568 {I2}, measured by 2003Ah07, is assumed by the evaluator to be
247CM4cA a doublet, feeding the 516.7- and 518.58-keV levels.
247CM cA IA 1.9 {I1} was measured by 2003Ah07 for the doublet.
247CM G 289.3 1 0.070 7 [M1+E2] 1.0 8
247CMS G KC=0.7 7$LC=0.21 7$MC=0.052 15$NC+=0.020 6
247CM L 518.59 7 (3/2+)
247CM A 5567 2 1.9 LE11 GE
247CM cA E from E|a(404.9 level)=5679.3 {I16} and the energy difference
247CM2cA between 518.6 and 404.9 levels (recoil energy is taken into account).
247CM G 113.7 1 0.024 5 [M1+E2] 8 3
247CMS G LC=5.7 19$MC=1.5 6$NC+=0.60 25
247CM G 291.20 8 0.30 3 [M1+E2] 1.0 7
247CMS G KC=0.7 7$LC=0.20 7$MC=0.051 15$NC+=0.020 6
247CM L 581.67 8(5/2+)
247CM A 5505 2 0.27 5 32
247CM G 63 5 [M1+E2] 1.0E2 70.21 5
247CMS G L/T=0.72 19$M/T=0.20 16$N/T=0.08 7
247CM G 315.8 1 0.024 3 [M1+E2] 0.8 6
247CMS G KC=0.6 5$LC=0.16 6$MC=0.040 13$NC+=0.015 5
247CM G 354.3 1 0.013 2 [M1+E2] 0.6 5
247CMS G KC=0.4 4$LC=0.11 5$MC=0.028 11$NC+=0.011 4

```

Program AlphaD (Alpha Hindrance factors)

Q ALPHA	E TOTAL	ALPHA HALF LIFE	RADIUS	RZERO	TOTAL HALF LIFE	ALPHA BRANCH	DATE RUN
6.1758	6.2154	3.280E+05 D	9.3638E-13	1.4924	8.980E+02 Y	1.000E+00	23-FEB- 5
ENERGY LEVEL	ABUNDANCE	CALC. HALF LIFE	HINDRANCE FACTOR				
0.00	2.60E-02	2.48E+03	5.08E+03				
61.67	1.25E-01	5.13E+03	5.12E+02				
134.66	6.00E-03	1.23E+04	4.46E+03				
227.38	2.76E-01	3.80E+04	3.13E+01				
265.86	4.00E-02	6.13E+04	1.34E+02				
285.41	2.50E-02	7.83E+04	1.68E+02				
318.31	3.60E-02	1.18E+05	7.69E+01				
345.89	8.00E-03	1.68E+05	2.44E+02				
404.90	3.54E-01	3.59E+05	2.58E+00				
433.00	3.30E-02	5.17E+05	1.92E+01				
448.90	4.90E-02	6.36E+05	1.05E+01				
516.68	1.90E-02	1.56E+06	1.11E+01				
518.59	1.90E-02	1.60E+06	1.08E+01				
581.67	2.70E-03	3.74E+06	3.25E+01				