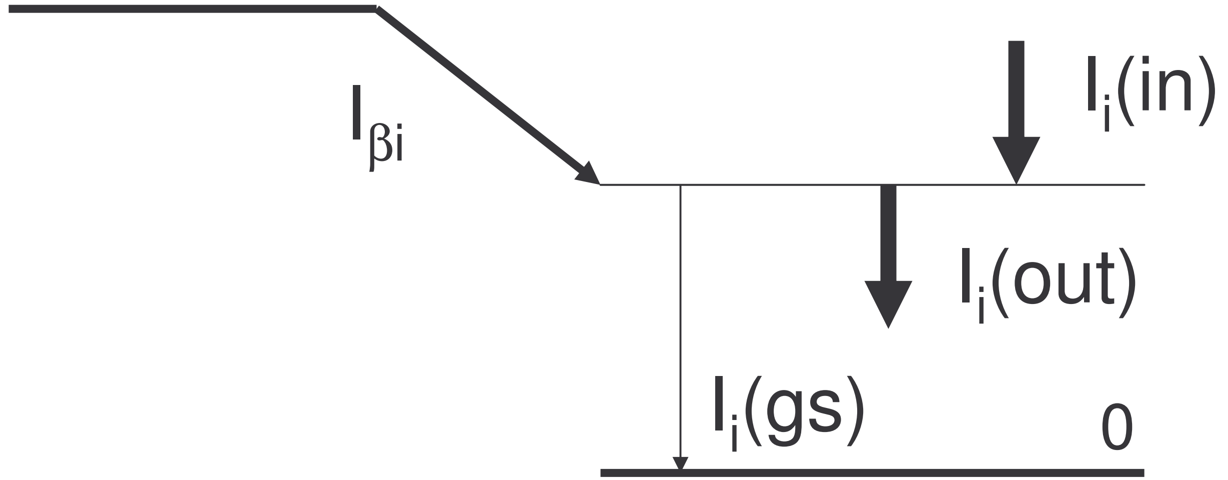
Workshop on
NUCLEAR STRUCTURE AND DECAY DATA EVALUATION
Model exercise

Trieste, February 18 – March 3, 2006

Edgardo Browne

γ-ray transition intensity balance



The corresponding normalization factor is

$N = 100 / \Sigma[\, I_i(out) + I_i(gs) - I_i(in)] =$

$100 / \Sigma[\, I_i(out) - I_i(in)] + \Sigma\, I_i(gs)$, but

$\Sigma[\, I_i(out) - I_i(in)] = 0$, therefore

$N = 100 / \Sigma\, I_i(gs)$

^{233}Pa β^- decay

$I_\gamma(312)$ = 38.6 (5) % (experimental value, Gehrke et al.)

$\Sigma I(\gamma+ce)$ (gs) = 102 (2) %

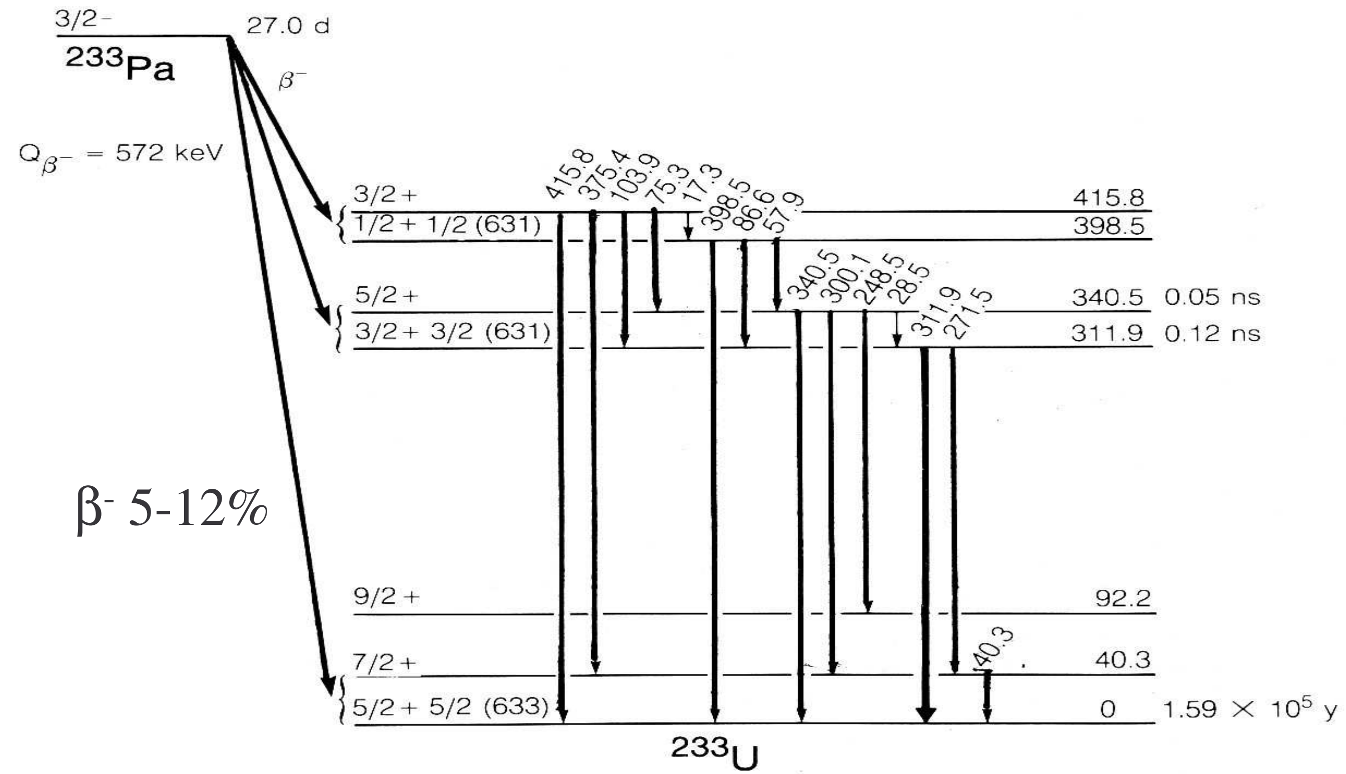


Fig. 1. Simplified ^{233}Pa decay scheme from ref. [1]).

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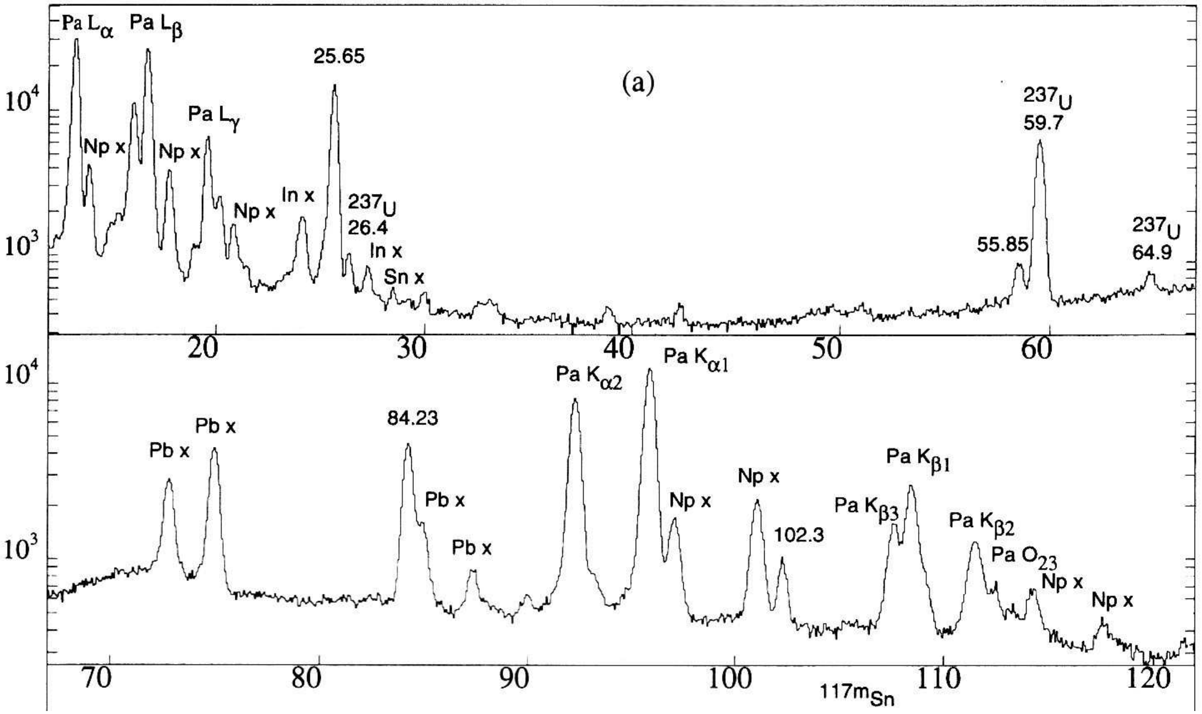
What went wrong?

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



$I_\gamma(25)=100\ (6)$

$I_\gamma(84)=50\ (3)$

$I_{KX}=390\ (14)$

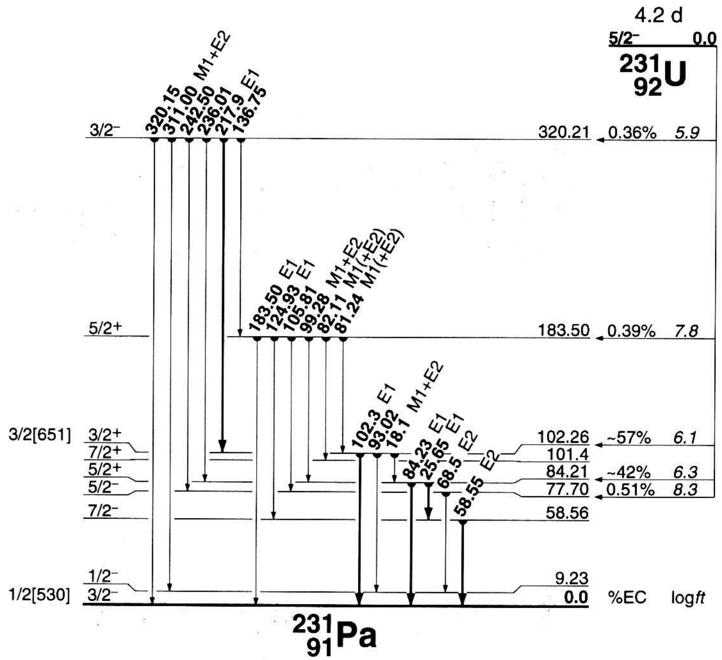


Fig. 4. [231]U electron-capture decay scheme. Gamma rays measured in this work are shown with thicker arrows; other data are from refs. [3,11]. Electron-capture branches per 100 decays of [231]U and log *ft* values are from gamma-ray transition probability balances (see Table 3).

EC(K)/EC(Total) = 0.59

$\omega_K = 0.972$

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

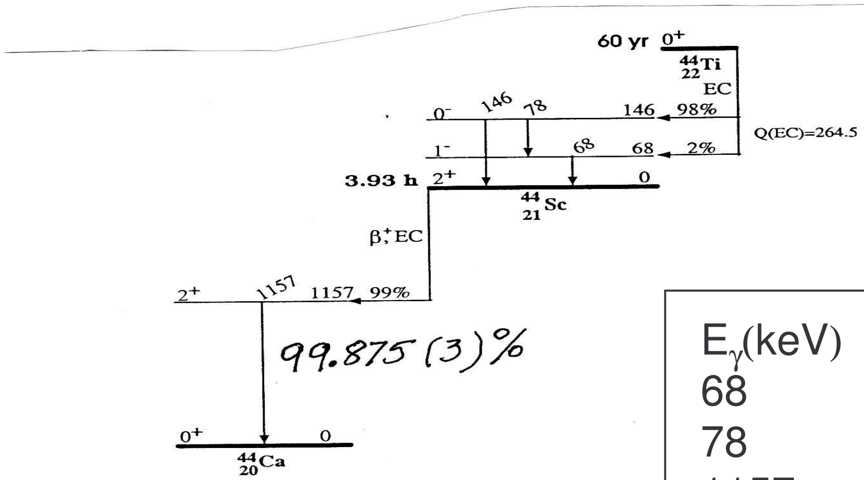
Total vacancies = I_{KX} EC(Total) / ω_K EC(K) = 680 (33)

Normalization factor N = 100 / 680 (33) = 0.147 (7)

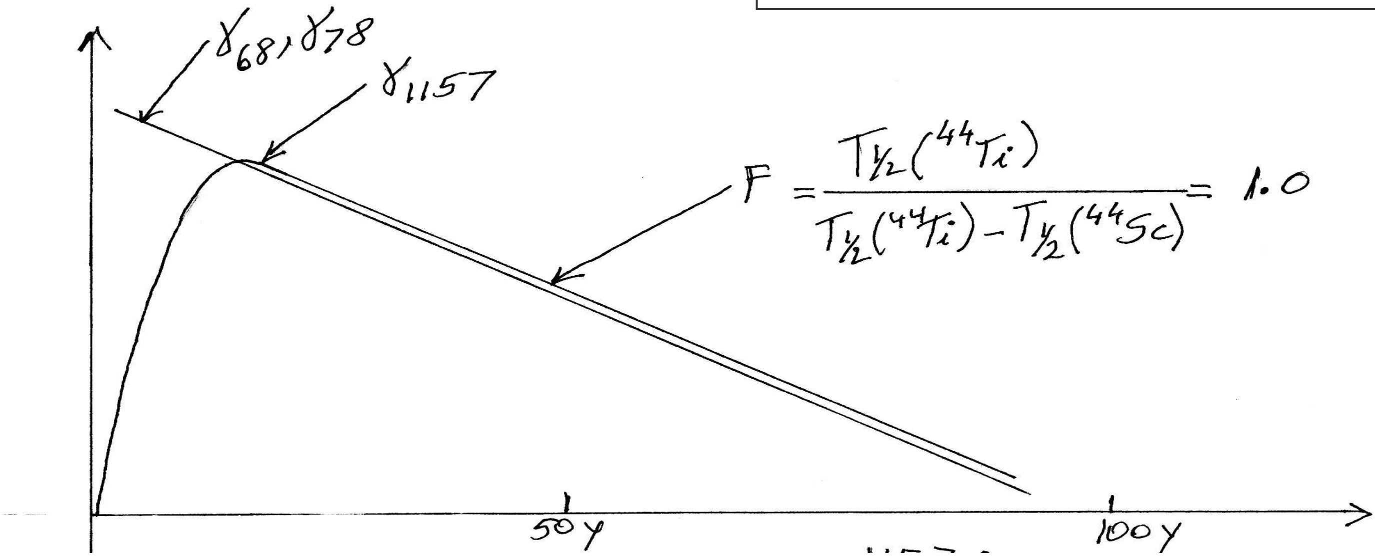
$I_\gamma(25)=100\ (6) \times 0.147\ (7) = 15\ (1)\%$

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

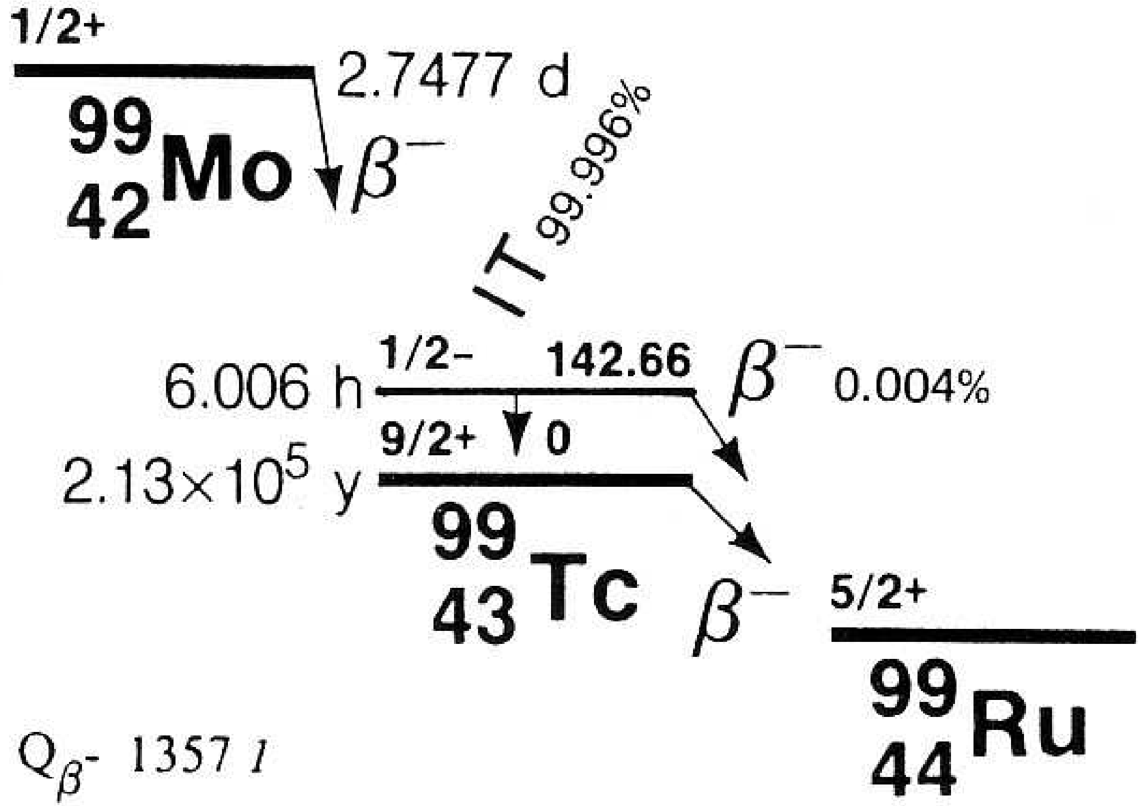
^{44}Ti electron capture decay

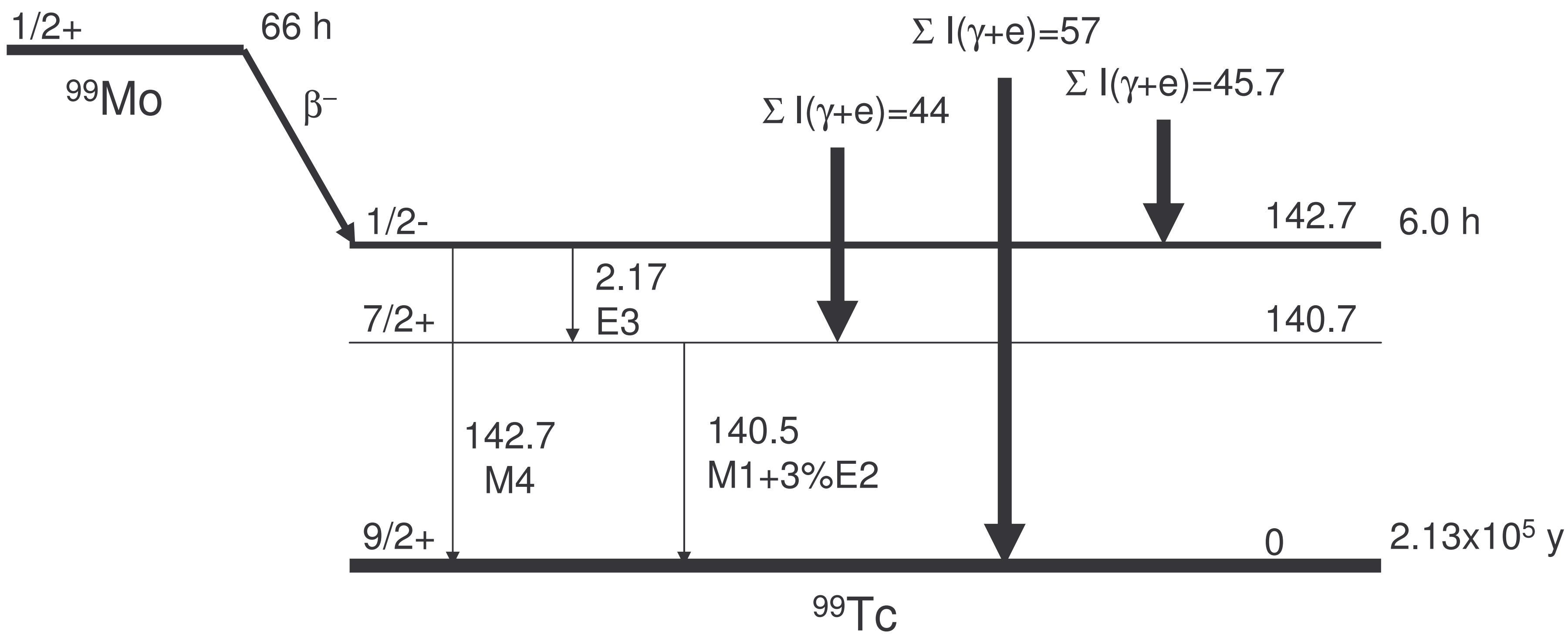


E_γ(keV)	I_γ (rel)	I_γ(%)
68	100 (1)	96.6 (10)
78	94.2 (8)	91.0 (8)
1157	103.4 (10)	99.875 (3)



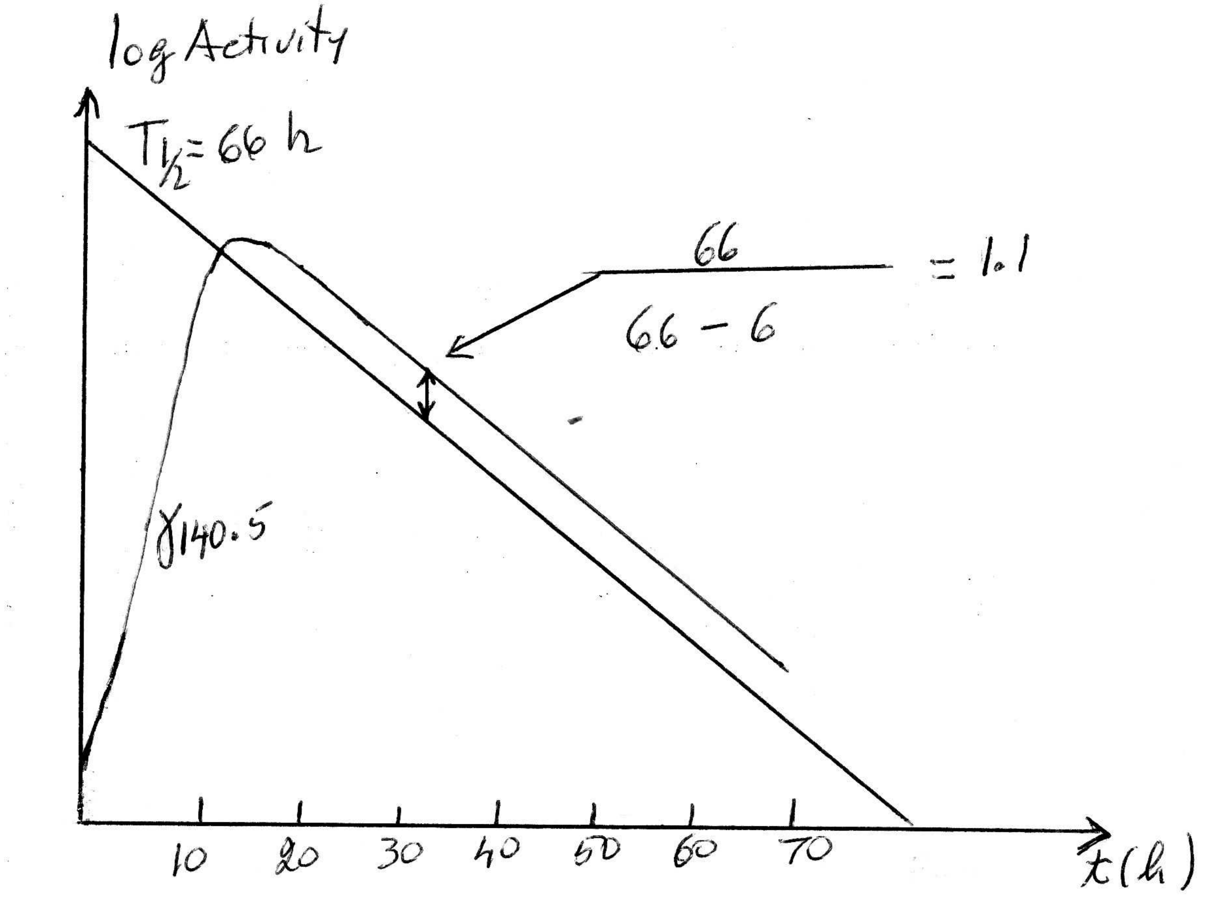
$$^{99}\text{Mo}(2.75\text{ d}) \xrightarrow{\beta^-} {}^{99m}\text{Tc}(6.0\text{ h}) \xrightarrow{\text{IT}} {}^{99}\text{Tc}(2.1\text{x}10^5\text{ y})$$

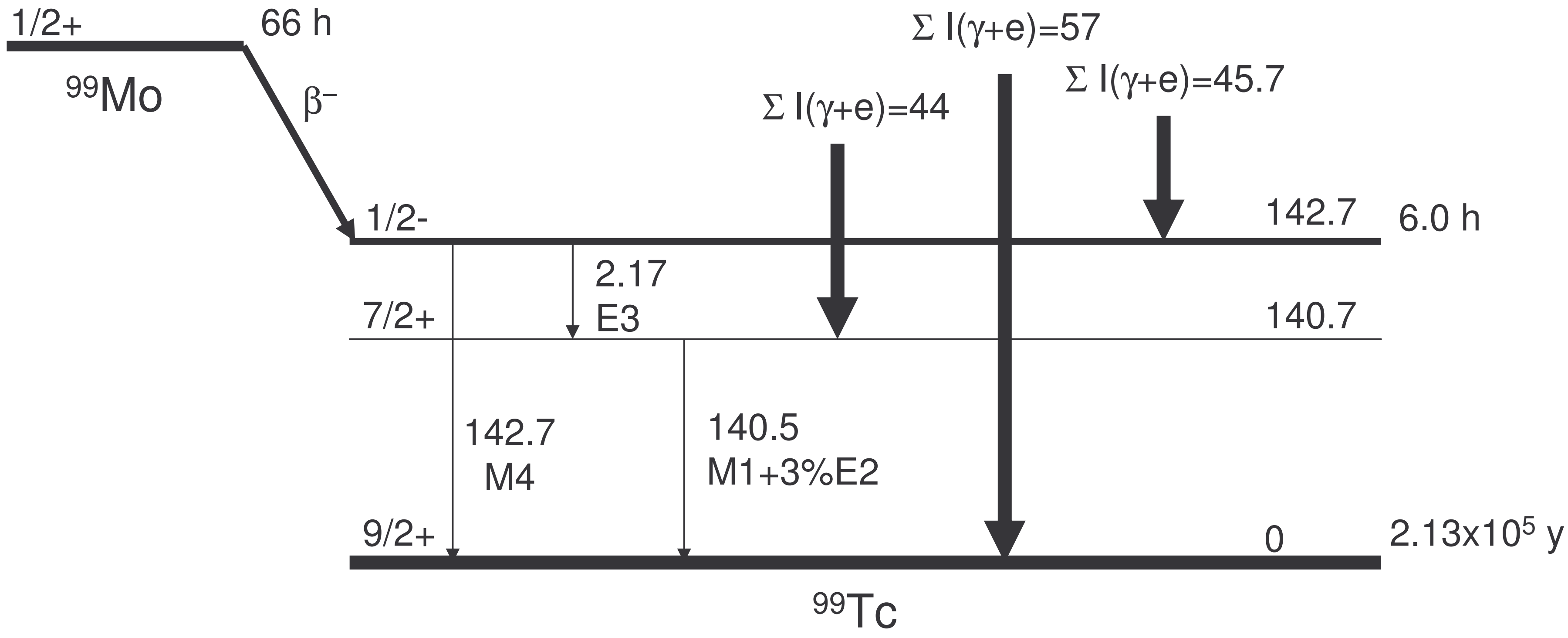




Equilibrium Intensities

E_γ(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)


log Activity
T1/2 = 66 h
66 / 66 − 6 = 1.1
γ140.5
10
20
30
40
50
60
70
t (h)



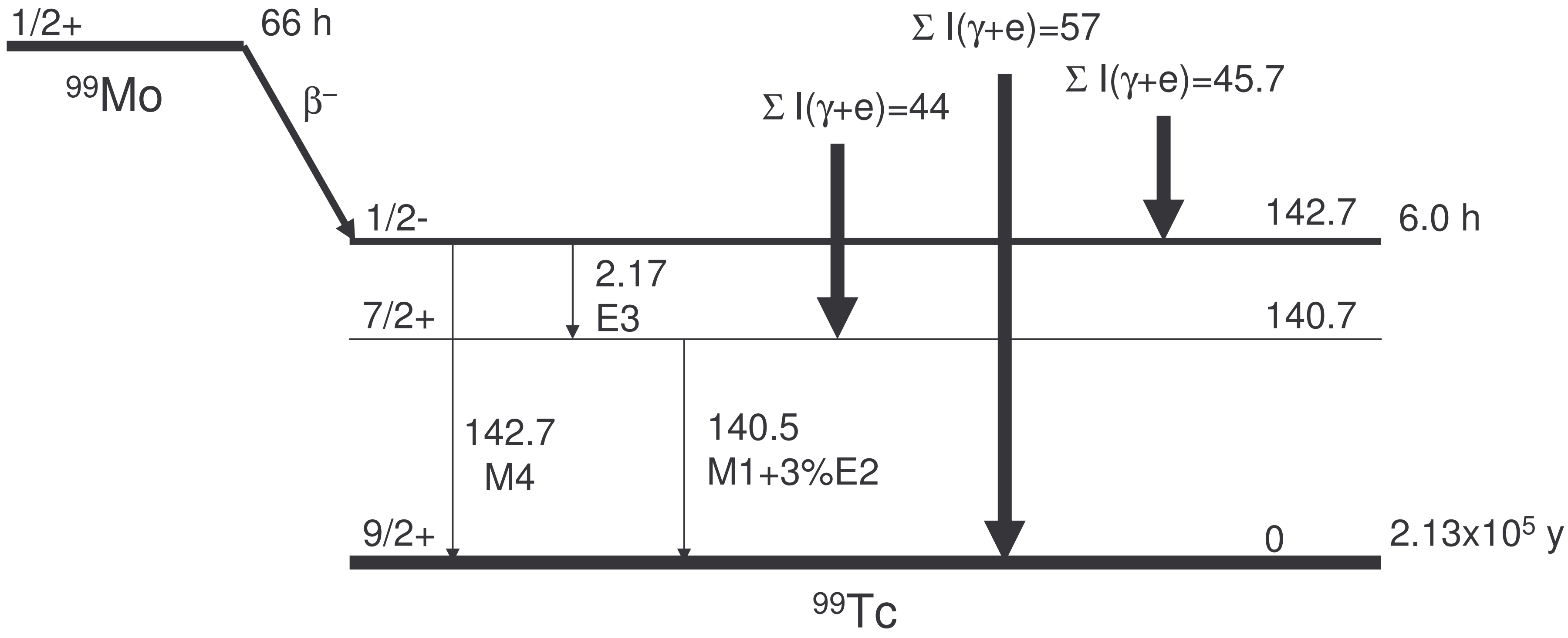
Decay Scheme Normalization

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

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

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

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



β^- feeding to 142.7-keV level

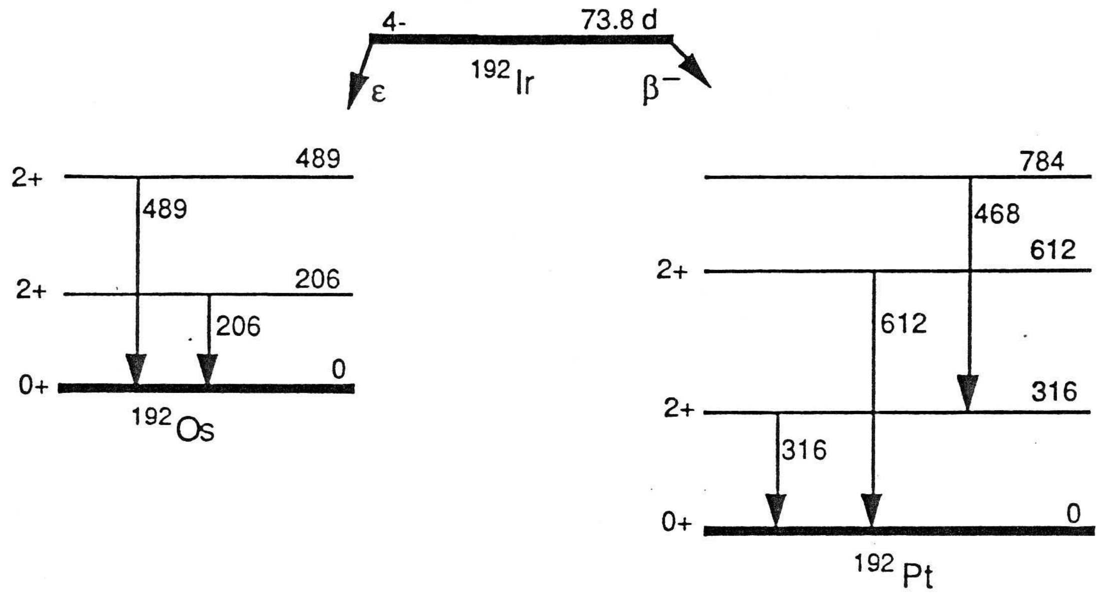
$$I_{\beta-} = I(\gamma+ce)(142.7)/1.1 + I(\gamma+ce)(2.17)/1.1 - \Sigma I(\gamma+ce)_{142.7}$$

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

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

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

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



E_γ(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)	Σ= 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)	Σ= 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:

$$\varepsilon = 100\ [I_\gamma(489)\ (1+\alpha_{489}) + I_\gamma(206)\ (1+\alpha_{206})]\ /120.7\ (7) =$$

$$100 / [1 + (I_\gamma(316)\ (1+\alpha_{316}) + I_\gamma(612)\ (1+\alpha_{612})/(I_\gamma(489)\ (1+\alpha_{489}) + I_\gamma(206)\ (1+\alpha_{206})) =$$

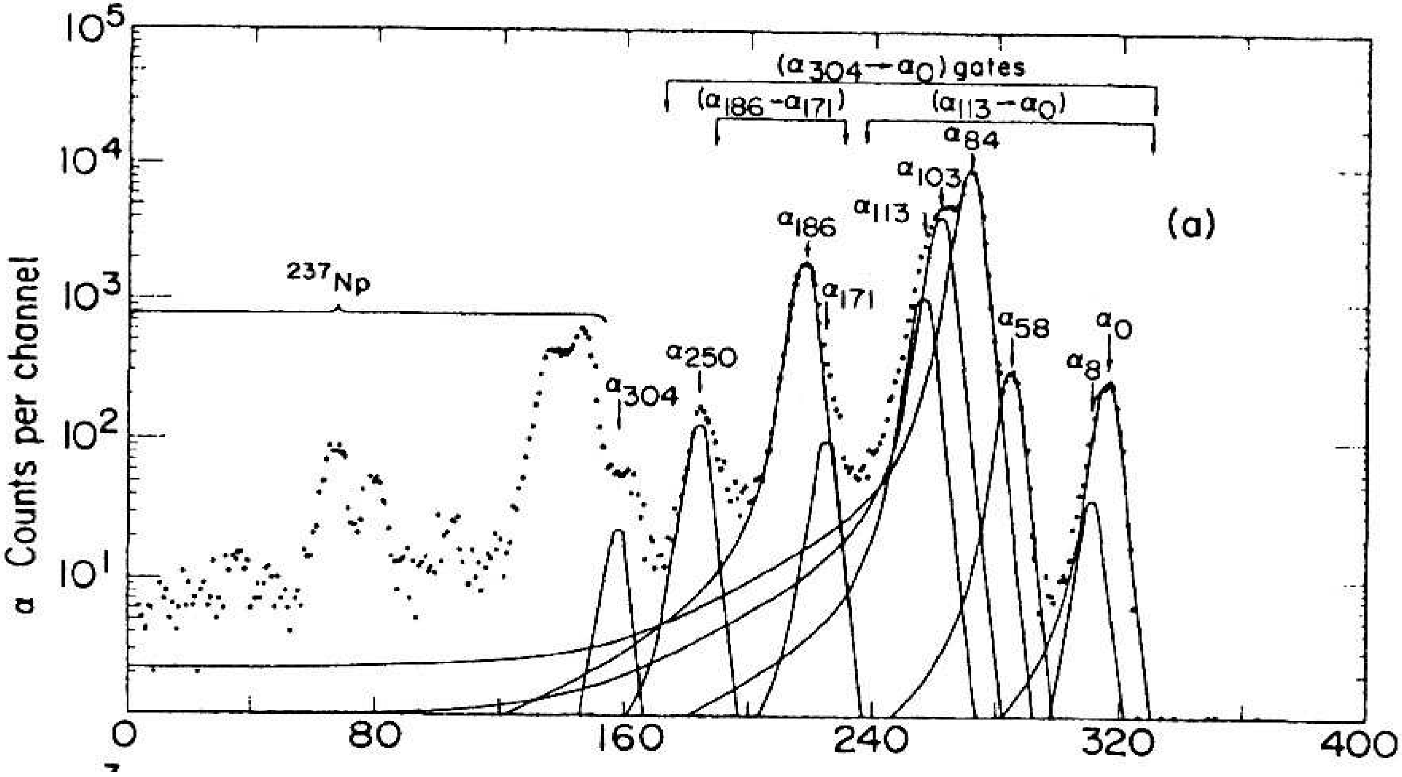
$$100 / [1 + 114.9\ (6)/5.77\ (8)] = 100 / 20.9\ (3) = 4.78\ (7)\%$$

$$\beta^- = 100 - EC = 100 - 4.78\ (7) = 95.22\ (7)\%$$

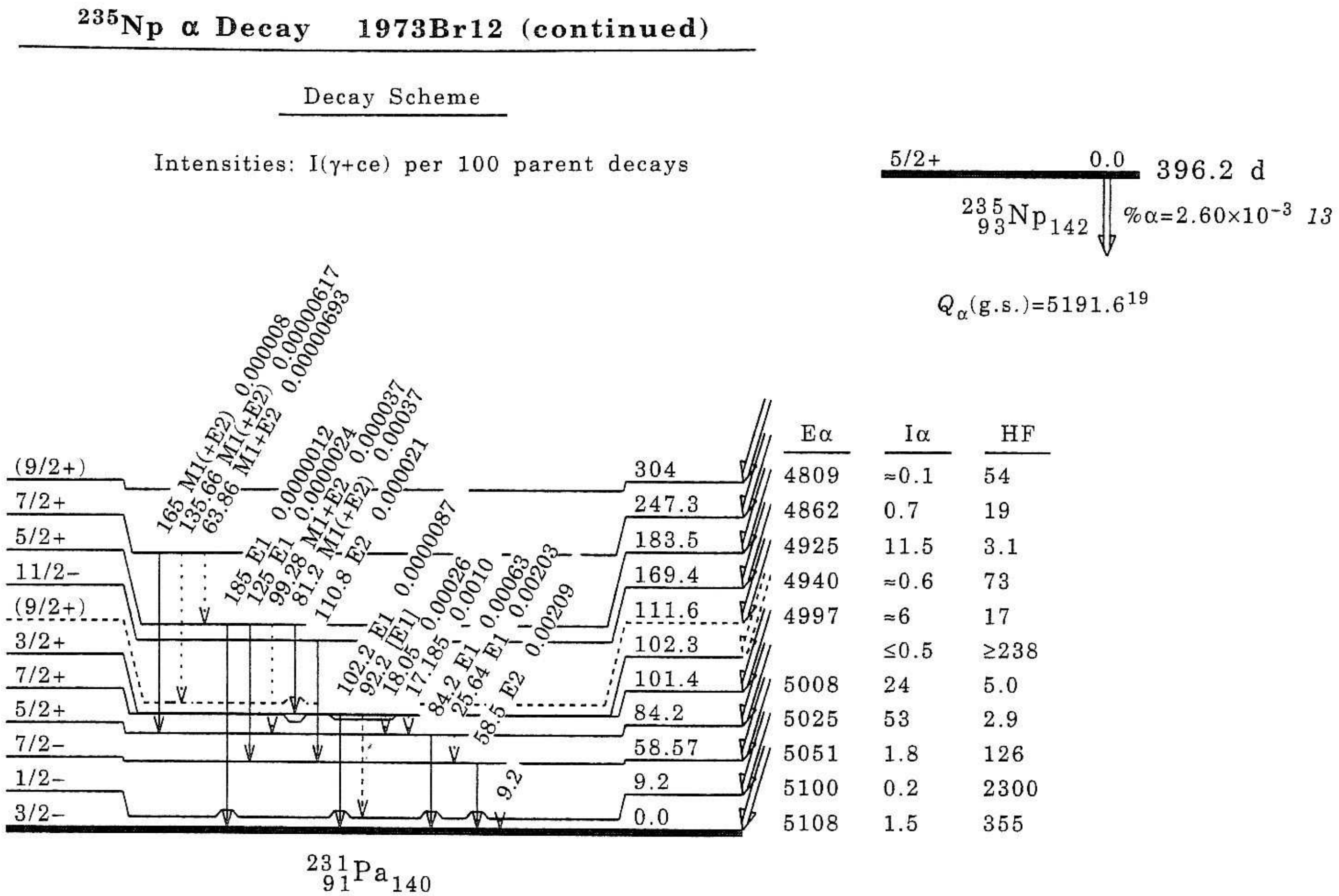
$$\beta^- = 95.22\ (7)\%$$

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

^{235}Np Alpha-Particle Spectrum



^{235}Np Alpha Decay Scheme

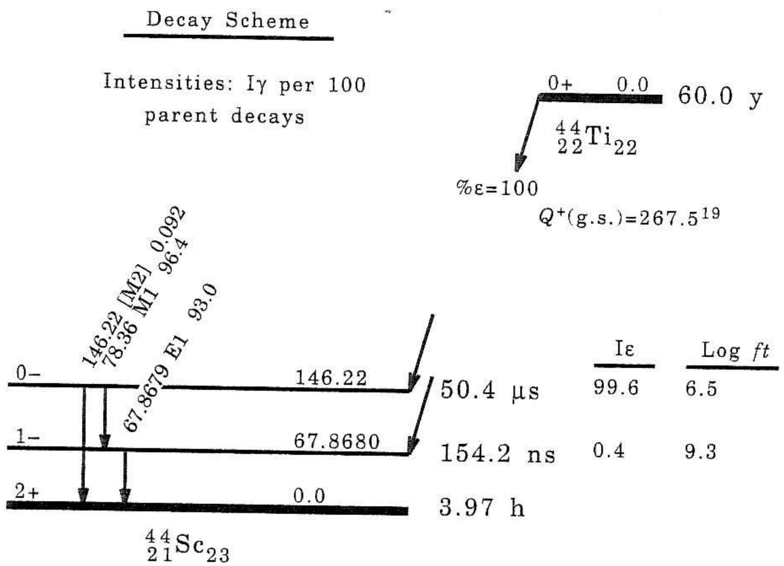


^{235}Np Alpha-particle intensities

E_{α}(keV)	E_{lev}(keV)	I_{α}(spec.)	I_{α}(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)	

Preparing ENSDF Data Sets

^{44}Sc 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
```

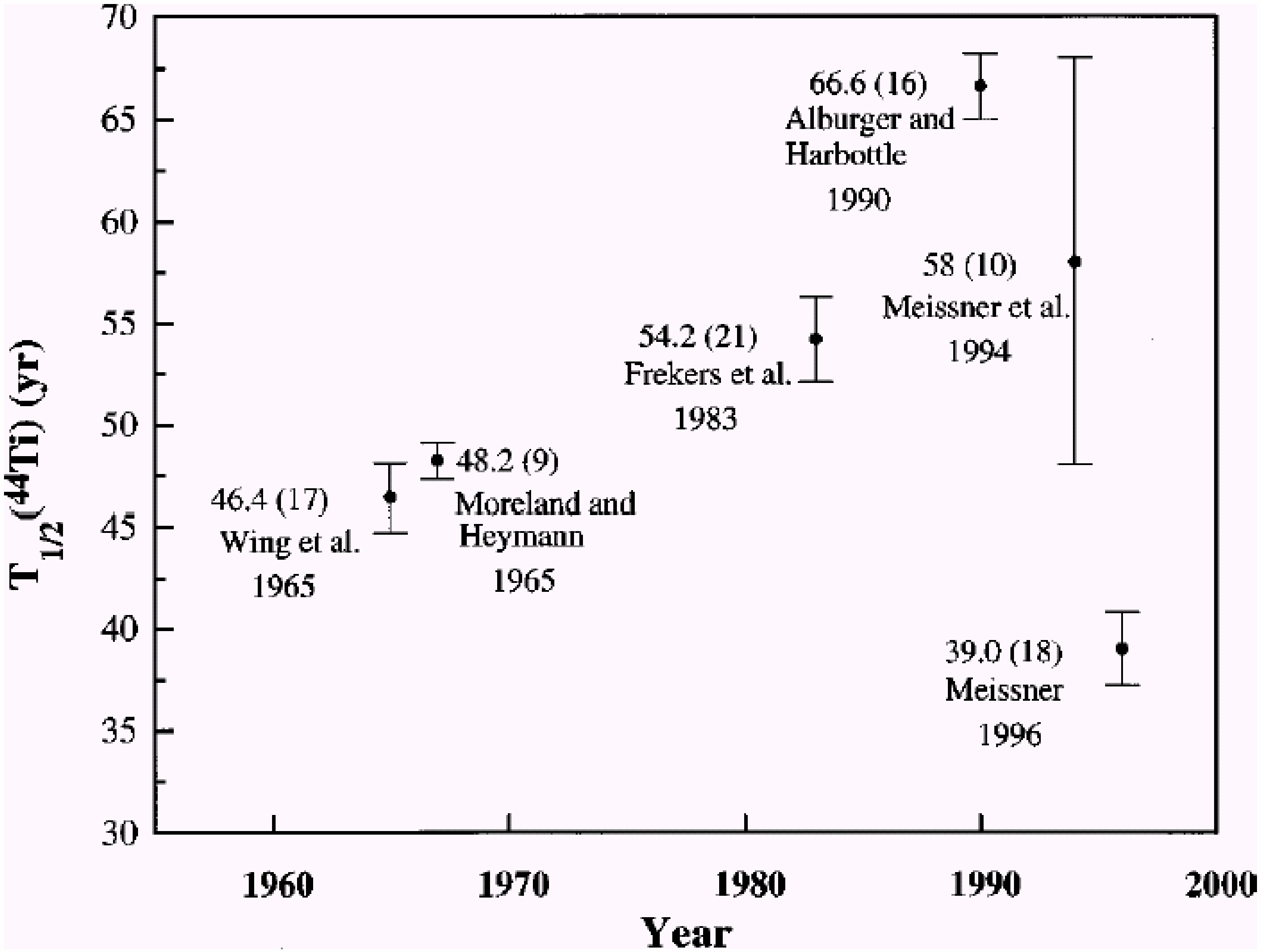


FIG. 2. Summary of previously reported values for the half-life of ^{44}Ti. Numbers in parentheses represent the 1σ uncertainties in the least significant digit(s).

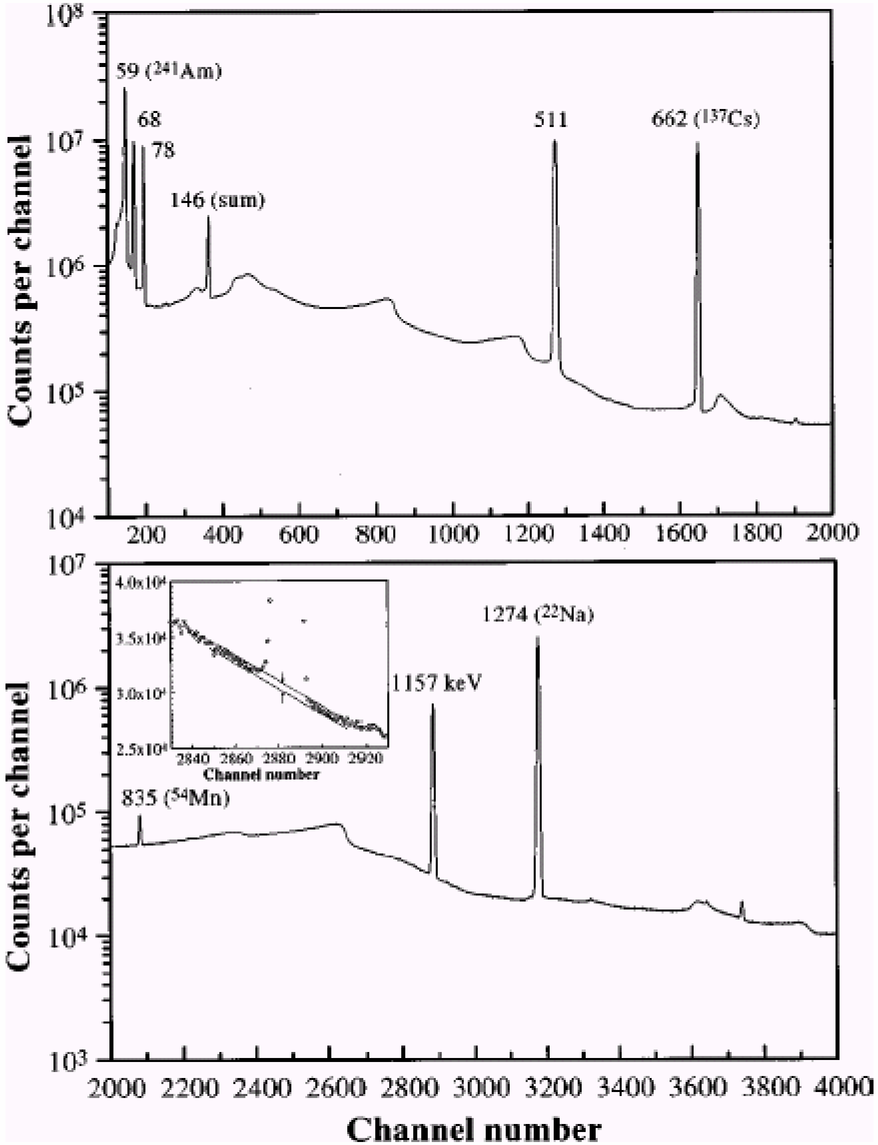


FIG. 4. γ-ray spectrum accumulated in 10 days of counting the mixed source of ^{44}Ti, ^{241}Am, ^{137}Cs, and ^{22}Na. All energies are in keV. Peaks labeled only by energy are from the decay of ^{44}Ti. The inset illustrates the background under the 1157-keV peak. The arrows indicate a $\pm 1\%$ systematic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

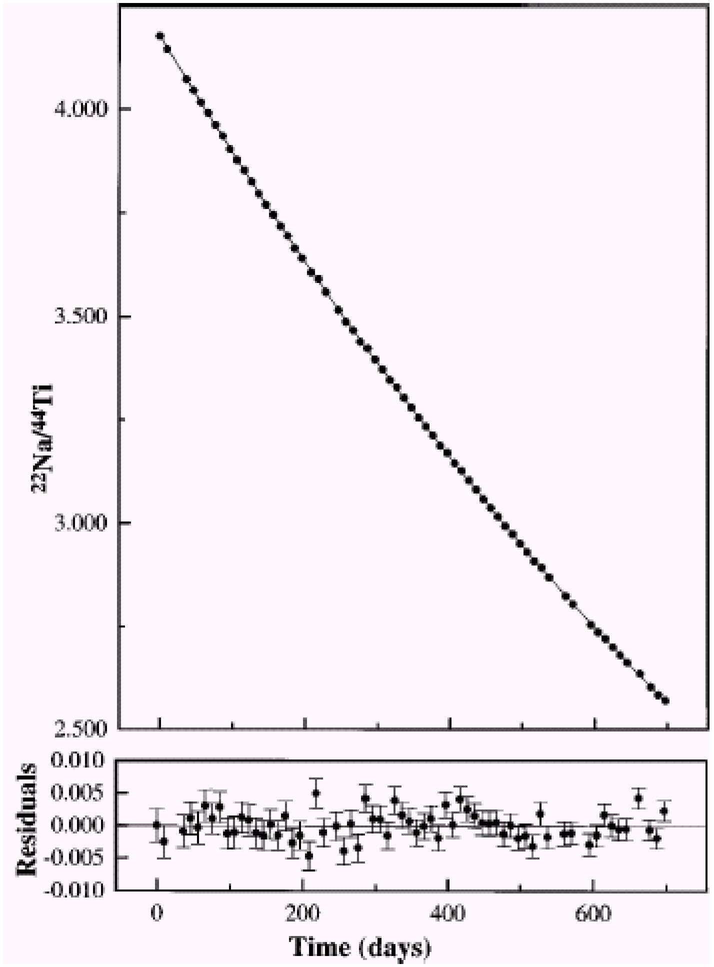


FIG. 5. The upper part of this figure shows the decrease in the ratio between the peak areas of the 1274-keV (^{22}Na) and 1157-keV (^{44}Ti) γ rays as a function of time. The curve going through the data is the result of a least-squares fit of an exponentially decreasing function of time. The ^{44}Ti 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.

^{44}Ti 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

^{44}Sc ENSDF Data Set (GTOL)

LEVEL	TI (OUT)	TI (IN)	TI (NET)	NET FEEDING (CALC)	NET FEEDING (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
```

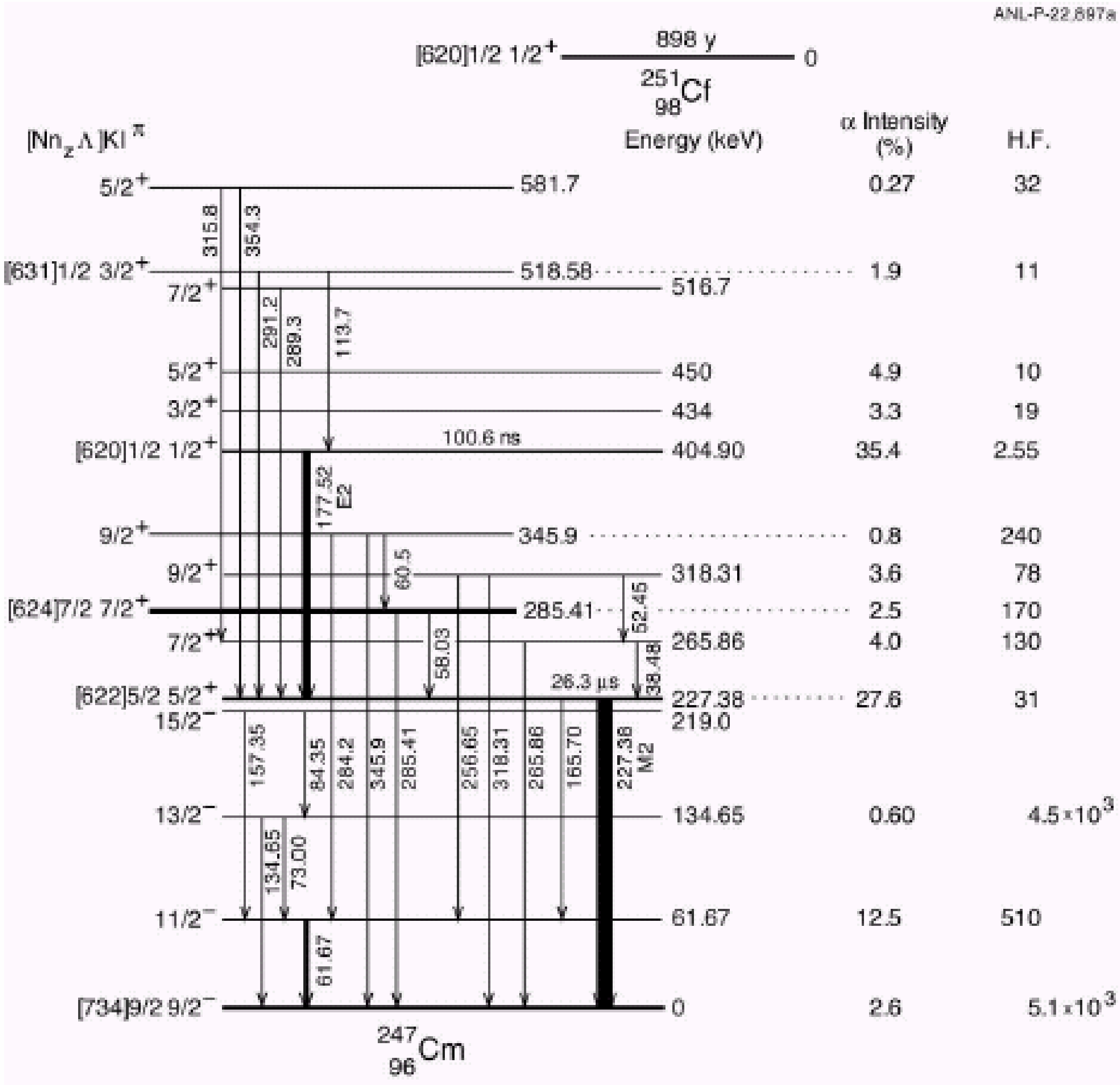
^{44}Sc ENSDF Data Set (LOGFT)

```
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 4 – 15, 2005

PHYSICAL REVIEW C **68**, 044306 (2003)

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


ANL-P-22,897a
[620]1/2 1/2+
898 y
0
251 98 Cf
[Nnz Λ]KI π
Energy (keV)
α Intensity (%)
H.F.
5/2+ 581.7 0.27 32
[631]1/2 3/2+ 518.58 1.9 11
7/2+ 516.7
5/2+ 450 4.9 10
3/2+ 434 3.3 19
[620]1/2 1/2+ 100.6 ns 404.90 35.4 2.55
9/2+ 345.9 0.8 240
9/2+ 318.31 3.6 78
[624]7/2 7/2+ 285.41 2.5 170
7/2+ 265.86 4.0 130
[622]5/2 5/2+ 26.3 µs 227.38 27.6 31
15/2− 219.0
13/2− 134.65 0.60 4.5×10^3
11/2− 61.67 12.5 510
[734]9/2 9/2− 0 2.6 5.1×10^3
315.8
354.3
291.2
289.3
113.7
177.52 E2
60.5
52.45
58.03
38.48
157.35
84.35
284.2
345.9
285.41
256.65
318.31
265.86
165.70
227.38 M2
134.65
73.00
61.67
247 96 Cm

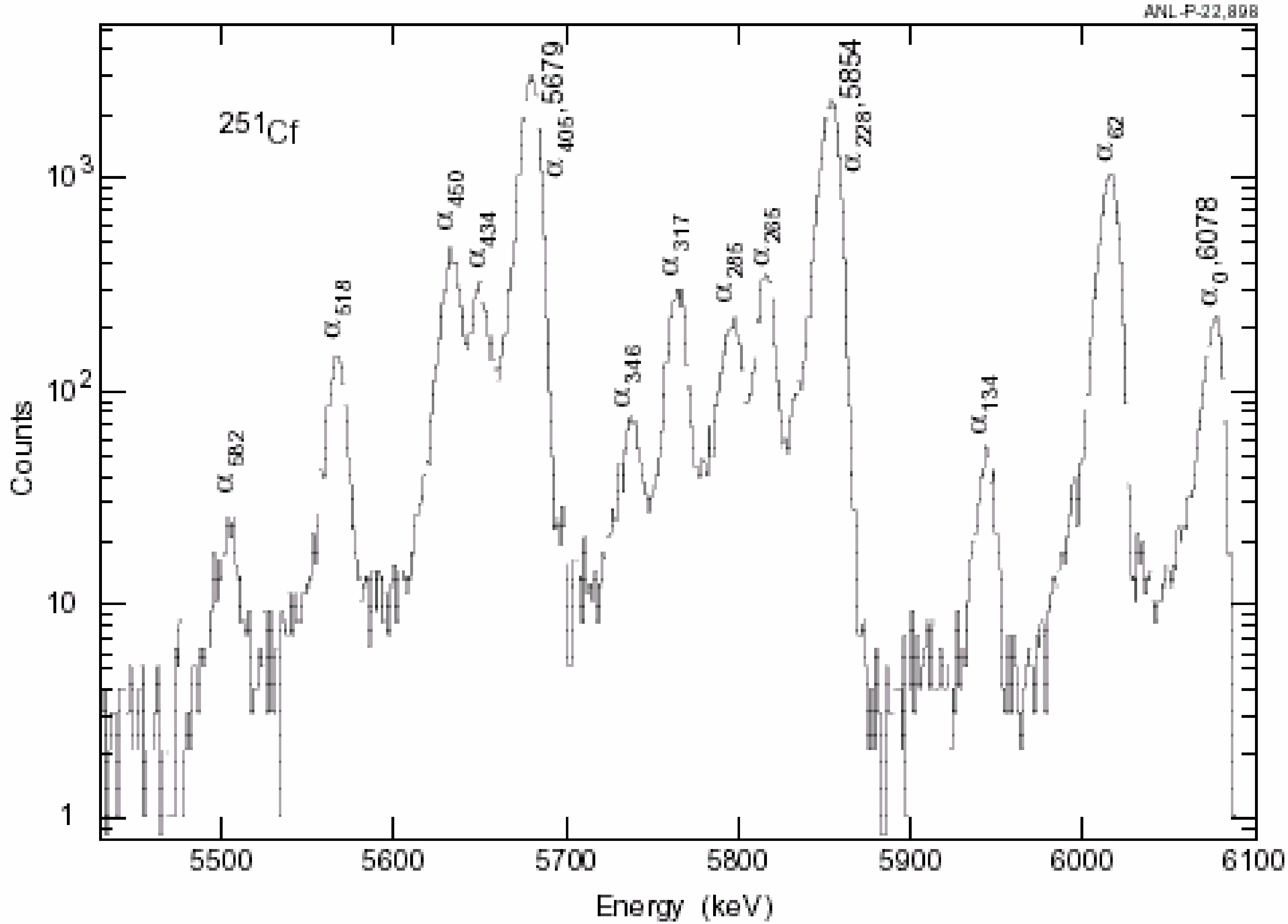

ANL-P-22,898
^{251}Cf
α_{582}
α_{518}
α_{450}
α_{434}
α_{405}, 5679
α_{346}
α_{317}
α_{285}
α_{265}
α_{228}, 5854
α_{134}
α_{62}
α_{0}, 6078
Counts
Energy (keV)

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

ANL-P-22,896

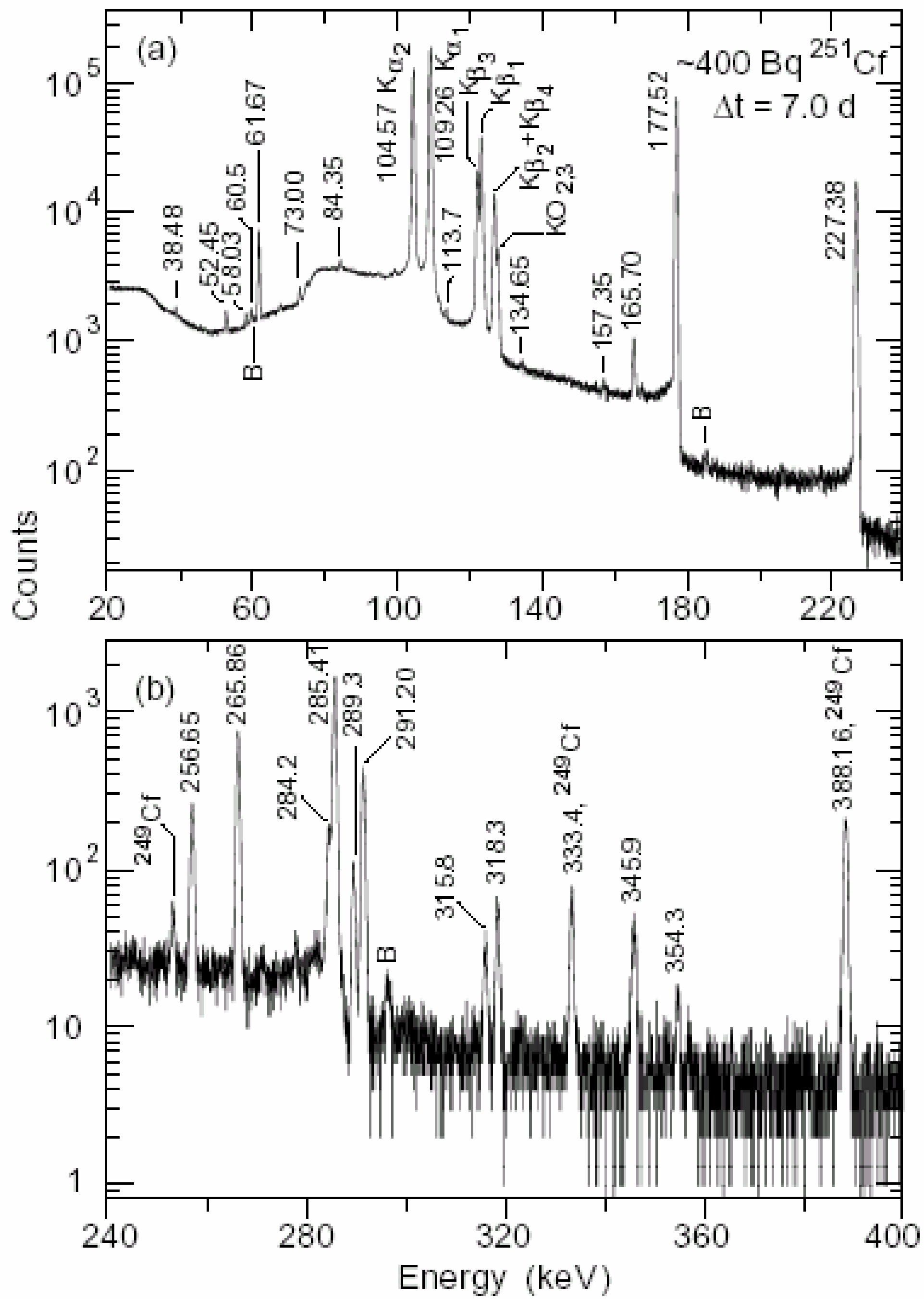

(a)
~400 Bq 251Cf
Δt = 7.0 d
38.48
52.45
58.03
60.5
61.67
73.00
84.35
104.57 Kα2
109.26 Kα1
Kβ3
Kβ1
Kβ2+Kβ4
KO2,3
113.7
134.65
157.35
165.70
177.52
227.38
B
B
(b)
249Cf
256.65
265.86
284.2
285.41
289.3
291.20
B
315.8
318.3
333.4, 249Cf
345.9
354.3
388.16, 249Cf
Counts
Energy (keV)

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

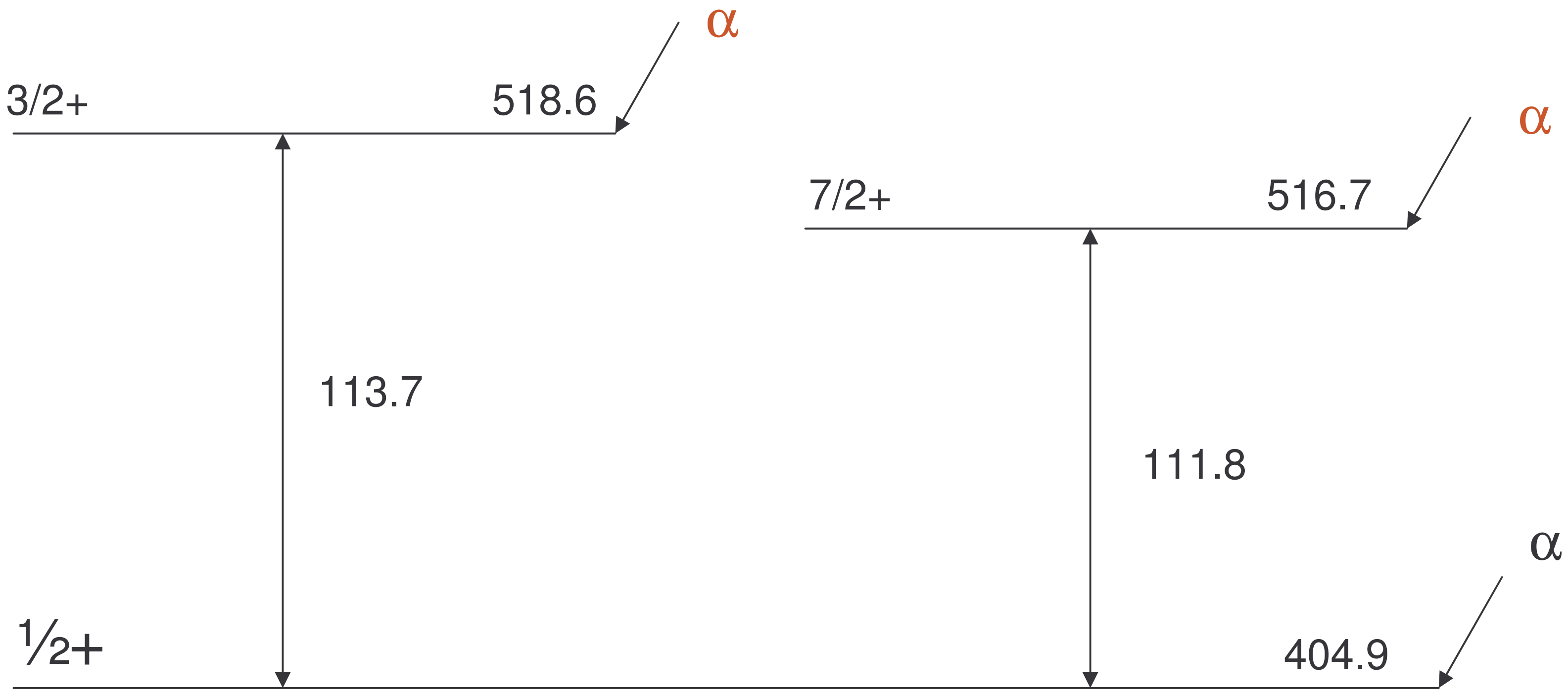
TABLE II. ^{251}Cf conversion electron data.

Transition energy (keV)	Shell	Energy (keV)	Intensity (%)	Conversion coefficient	Theory	Mixing ratio δ	Multipolarity
38.48	$L+M+\cdots$			183±31[a]	122($M1$), 1833($E2$)	0.19±0.05	$M1$+3.6%$E2$
52.45	$L+M+\cdots$			70±10[a]	49.3($M1$), 410($E2$)	0.25±0.06	$M1$+5.7%$E2$
58.03	$L+M+\cdots$			80±19[a]	36.7($M1$), 256($E2$)	0.50±0.08	$M1$+20%$E2$
60.5	$L+M+\cdots$			62±21[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	$L+M+\cdots$			40±16[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($E3$)		

[a]Deduced 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             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
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 keV
518.6 - 404.9 = 113.7 keV
E_α(516.7 + 518.6) = 5568 keV

E_α(404.9) = 5679.3 keV

Q(516.7) = 5679.3 x 251/247 – 111.8 = 5659.5 keV
E_α(516.7) = 5659.5 x 247/251 = 5569 keV

Q(518.6) = 5679.3 x 251/247 – 113.7 = 5657.6 keV
E_α(518.6) = 5657.6 x 247/251 = 5567 keV

ENSDF Dataset (2)

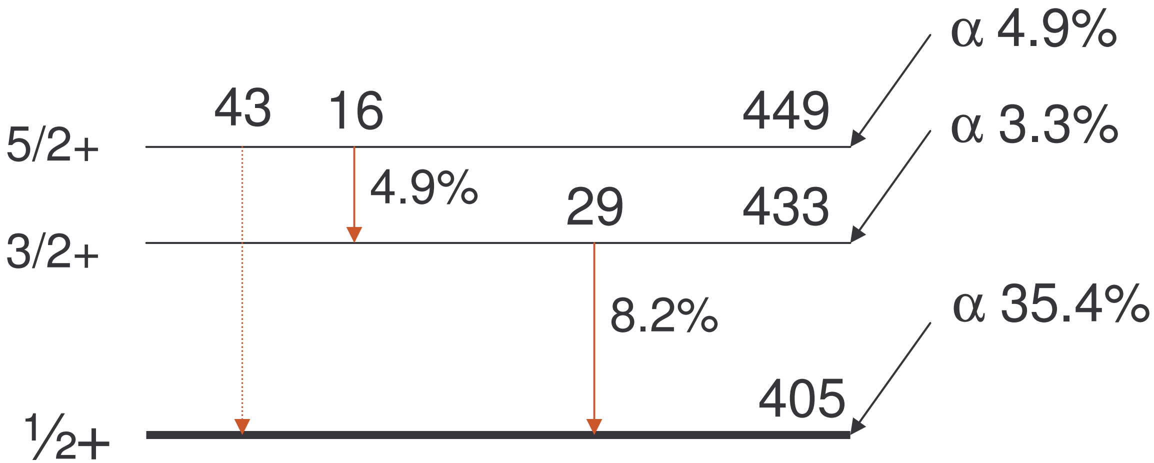
```
247CM  L 405          1/2+             100.6 NS  6
247CM  A 5679.3    1635.4    5
247CM  G 177.52    2  17.3   9  E2
247CM  L 434         (3/2+)
247CM  A 5651      2   3.3   2
247CM  G 28        5           [M1+E2]                          8.2       3
247CM  L 450       2 (5/2+)
247CM  A 5635      2   4.9   2
247CM  G 16        5           [M1+E2]                          4.9       2
247CM  G 44                                                                    S
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]
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      5
247CM  G 315.8     1 0.024   3 [M1+E2]
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
```

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                                                                        S
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
```


α 4.9%
43
16
449
5/2+
4.9%
α 3.3%
29
433
3/2+
8.2%
α 35.4%
405
½+

Report from GTOL

```
                RI            RI            RI            TI            TI            TI               NET FEEDING
LEVEL          (OUT)         (IN)          (NET)         (OUT)         (IN)           (NET)           (CALC)         (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
```

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
```

Program AlphaD (Alpha Hindrance factors)

	98 251.					DATE RUN 23-FEB- 5
Q ALPHA	E TOTAL	ALPHA HALF LIFE	RADIUS	RZERO	TOTAL HALF LIFE	ALPHA BRANCH
6.1758	6.2154	3.280E+05 D	9.3638E-13	1.4924	8.980E+02 Y	1.000E+00

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