Absolute and Relative γ-Ray Intensities in ENSDF

*E. Browne[#] and J.K. Tuli**

National Nuclear Data Center
Brookhaven National Laboratory
#Guest appointment at Lawrence Berkeley National Laboratory. Email: EBrowne@lbl.gov
**Email: Tuli@bnl.gov*

The Need for Both Types of Intensities

Relative Intensities

Usually are known more precisely.

Absolute Intensities

Usually are known less precisely.

The Use of Absolute Intensities

Absolute γ-ray intensities are used in:

Nuclear structure, mainly for normalizing emitted radiations to a scale per nuclear transformation.

Applied research, mainly for estimating amounts of radionuclides of known specific activities. For example: ^{238}U in uranium ore.

Also, for determining reaction cross-sections. For example: $^{241}Am(n,2n)^{240}Am$.

How to Obtain them

We determine absolute γ-ray intensities:

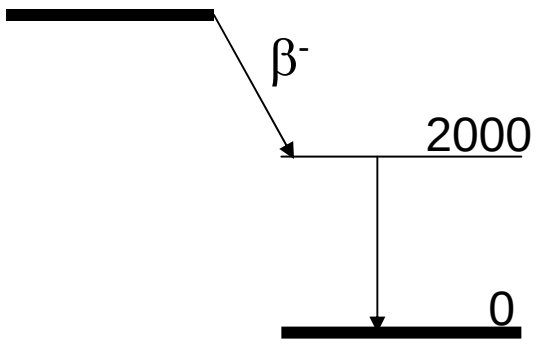
- Experimentally
- Using the decay scheme

Uncertainties in Absolute γ-Ray Intensities

Measurement of an absolute intensity and *its uncertainty* for a single γ ray. Propagating linearly this uncertainty to other γ rays.
This is a trivial procedure.

Deducing absolute intensities and *their uncertainties* from relative intensities using the decay scheme.
This is not a trivial procedure.

A Simple Decay Scheme



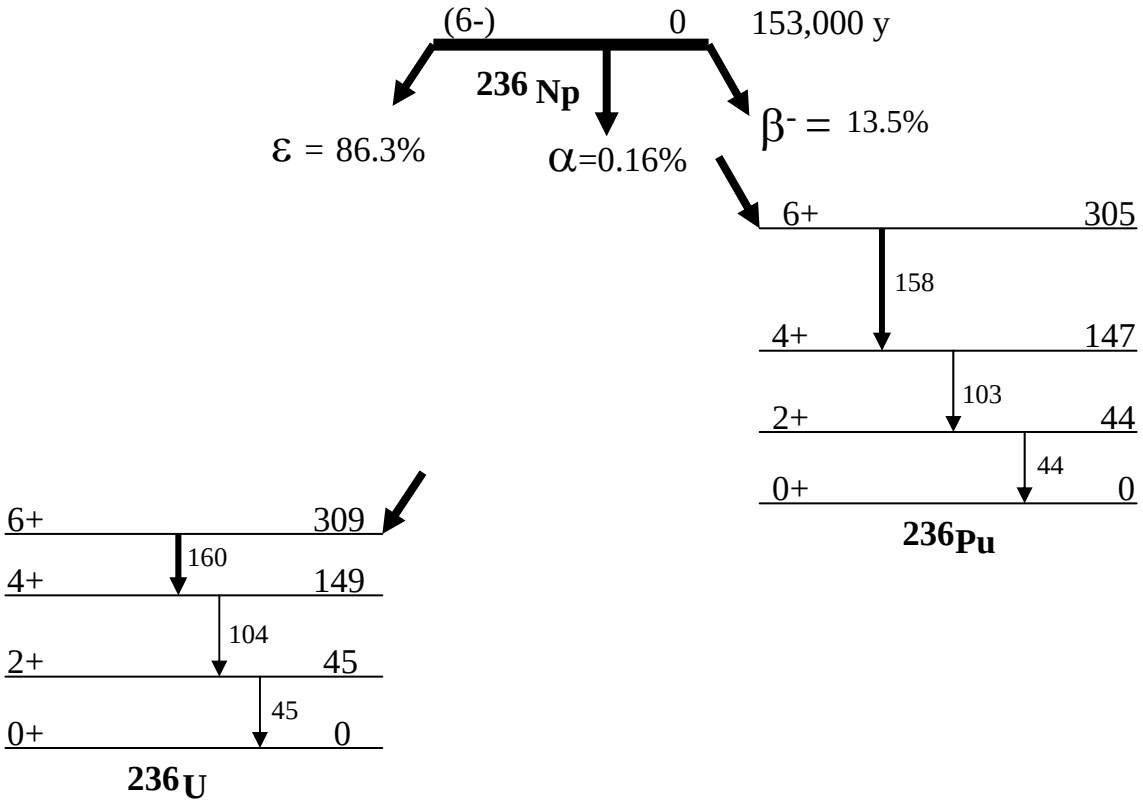
I_γ = 235 (5) photons/sec

Internal conversion coefficient α= 0

Normalization factor *N* = 100 / 235 (5)

Absolute intensity I_γ(%) = (235 (5)) 100 / (235 (5)) = 100

A Real Example



Decay-Scheme Normalization

$[I\gamma_{160}\ (1 + \alpha_{160}) + I\gamma_{158}(1 + \alpha_{158})]\ N$=100 - %$\alpha$ =99.84 6
N=0.313 *12*

Incorrect calculation

$I\gamma_{160}(\%) = I\gamma_{160}$ x *N* = 100 *4* x 0.313 *12* = 31.3 *18*
5.8% fractional uncertainty

Correct calculation

$I\gamma_{160}(\%) = 99.84\ 6 / [(1+ \alpha_{160})+ I\gamma_{158}\ (1 + \alpha_{158})/ I\gamma_{160}] = 31.3\ 4$
1.3% fractional uncertainty

CONCLUSION

The knowledge of relative γ-ray intensities and a normalization factor *N* may not be sufficient for deducing uncertainties in absolute γ-ray intensities.

Proposal

- To include both *relative and absolute* γ-ray intensities (2G records) in ***ENSDF***.

- To include a choice for presenting just *relative* γ-ray intensities, *absolute* γ-ray intensities, or both in ***Nuclear Data Sheets***.

GABS Version 10 [October – 2007]

GABS:\> Enter input file name: 236Np.ENS

GABS:\> Enter REPORT file name <def – GABS.RPT>: 236Np.RPT

GABS:\> Do you want to create a new ENSDF data set? (Y/N): Y

GABS:\> Enter File name for new ENSDF data set: 236Np.OUT

GABS:\> Do you want to include new absolute-intensity 2G records? (Y/N): Y

Input File [236Np.ENS]

```
236U    236NP EC DECAY (154E+3 Y)
236NP  P 0          (6-)          154E+3 Y  6            930      50
236U   N                          0.9984  3
236U   L 0          0+
236U   L 45.242      2+
236U   G 45.23    3  0.4    1 E2                589
236U   L 149.477     4+
236U   G 104.23    2  23     1 E2                10.99
236U   L 309.784     6+
236U   G 160.33    2  100    4  E2               1.76              X

236PU   236NP B- DECAY (154E+3 Y)
236NP  P 0          (6-)          154E+3 Y  6            480      50
236U   N                          0.9984  3
236PU  L 0          0+
236PU  L 44.6        2+
236PU  G 44.6      1 0.058   4 E2                743
236PU  L 147.4       4+
236PU  G 102.82    2 2.9     2 [E2]              13.87
236PU  L 305.8       6+
236PU  G 158.35    2  13.5   7  [E2]             2.19              X
```

Output File [236Np.OUT]

```
236U    236NP EC DECAY (154E+3 Y)
236NP  P 0          (6-)          154E+3 Y  6            930      50
236U    N    0.363              0.863 8
236U    L 0          0+
236U    L 45.242       2+
236U    G 45.23    3  0.4    1 E2                589
236U 2 G %IG=0.13 4
236U    L 149.477      4+
236U    G 104.23    2  23     1 E2                10.99
236U 2 G %IG=7.2  4
236U    L 309.784      6+
236U    G 160.33    2  100    4  E2               1.76
236U 2 G %IG=31.3 4

236PU   236NP B- DECAY (154E+3 Y)
236NP   P 0          (6-)          154E+3 Y  6            480      50
236PU   N     2.32             0.135 8
236PU   L 0          0+
236PU   L 44.6        2+
236PU   G 44.6      1 0.058   4 E2                743
236PU2 G %IG=0.0182 15
236PU   L 147.4        4+
236PU   G 102.82    2 2.9     2 [E2]              13.87
236PU2 G %IG=0.91 7
236PU   L 305.8        6+
236PU   G 158.35    2  13.5   7  [E2]             2.19
236PU2 G %IG=4.23 25
```

Report File [236Np.RPT]

- Current date: 10/05/2007
- 236NP EC DECAY (154E+3 Y)
- NR= 0.363 BR= 0.863 8
- FOR INTENSITY UNCERTAINTIES OF GAMMA RAYS NOT USED IN CALCULATING NR,
- COMBINE THE UNCERTAINTY IN THE RELATIVE INTENSITY IN QUADRATURE
- WITH THE UNCERTAINTY IN THE NORMALIZING FACTOR (NR x BR).
- FOR THE FOLLOWING GAMMA RAYS:
- E= 45.23 3 %IG=0.13 4 PER 100 DECAYS.
- E= 104.23 2 %IG=7.2 4 PER 100 DECAYS.
- E= 160.33 2 %IG=31.3 4 PER 100 DECAYS.(Compare with 31.3 18)
-
- 236NP B- DECAY (154E+3 Y)
- NR= 2.32 BR= 0.135 8
- FOR INTENSITY UNCERTAINTIES OF GAMMA RAYS NOT USED IN CALCULATING NR,
- COMBINE THE UNCERTAINTY IN THE RELATIVE INTENSITY IN QUADRATURE
- WITH THE UNCERTAINTY IN THE NORMALIZING FACTOR (NR x BR).
- FOR THE FOLLOWING GAMMA RAYS:
- E= 44.6 1 %IG=0.0182 15 PER 100 DECAYS.
- E= 102.82 2 %IG=0.91 7 PER 100 DECAYS.
- E= 158.35 2 %IG=4.23 25 PER 100 DECAYS.(Compare with 4.2 4)

Nuclear Data Sheets

$\gamma(^{236}U)$

Eγ	E(level)	Iγ(rel)	Iγ(%)	Mult.	α	Comments
45.23 *3*	45.23	0.4 *1*	0.13 *4*	E2	589	
104.23 *2*	149.48	23 *1*	7.2 *4*	E2	10.99	
160.33 *2*	309.78	100 *4*	31.3 *4*	E2	1.76	

$\gamma(^{236}Pu)$

Eγ	E(level)	Iγ(rel)	Iγ(%)	Mult.	α	Comments
44.6 *1*	44.6	0.058 *4*	0.0182 *15*	E2	743	
102.82 *2*	147.4	2.9 *2*	0.91 *7*	[E2]	13.87	
158.35 *2*	305.8	13.5 *7*	4.23 *25*	[E2]	2.19	

Thank you