A Further Measurement to Test Electron Conversion Theory: $^{116}\text{In}$ Measurement for Detector Calibration

By Sondra N. Miller
Overview

- Internal Conversion
- $^{119m}$Sn Measurement
- Purpose of measuring $^{116}$In
- Data Collection
- Spectral analysis
- Preliminary Results
- Conclusion
- Acknowledgements
Internal Conversion

Nuclear transition

Competition between γ-ray emission or electron emission
Internal Conversion

- Internal Conversion Coefficient (ICC)
  - Number of electrons emitted : Number of γ-rays emitted
  - Can be expressed for each shell

\[ \alpha = \frac{N_{\text{electrons}}}{I_\gamma} \]

\[ \alpha = \sum \alpha_i = \alpha_K + \alpha_L + \alpha_M + \ldots \]
Internal Conversion

We detect x-rays

And γ rays
Internal Conversion

- Internal Conversion Coefficient (ICC)
  - Number of electrons ejected : Number of γ-rays emitted
  - Can be expressed for each shell

\[ \alpha = \frac{N_{\text{electrons}}}{I_{\gamma}} \]

\[ \alpha = \sum_i \alpha_i = \alpha_K + \alpha_L + \alpha_M + \ldots \]

- Fluorescence yield
  - Relates number of x-rays emitted to number of electrons emitted

\[ \alpha_K = \left( \frac{1}{\omega_K} \right) \left( \frac{I_{K\alpha}}{I_{\gamma}} \right) \]
Internal Conversion

- ICC crucial for nuclear decay schemes
  - Transition rates
  - Spin and parity designations
  - Branching Ratios
- Few available precise data
  - ~10 measurements available with error <1%
- Experimental data to test theoretical calculations
  - Determine valid ICC modeling method
Internal Conversion

• Two main theoretical models:
  • 1) Accounts for the hole left behind by the departing electron.
  • 2) Regards the hole left behind by the departing electron as negligible (filled quickly)
## ICC of Interest

**Decay of $^{119m}$Sn**

<table>
<thead>
<tr>
<th>Decay Product</th>
<th>Halflife</th>
<th>Spin</th>
<th>Other Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{119m}$Sn</td>
<td>0.97 d</td>
<td>1/2+</td>
<td>Enriched in Bi-119</td>
</tr>
<tr>
<td>$^{119}$Sn</td>
<td>8.59</td>
<td>1/2+</td>
<td>*</td>
</tr>
</tbody>
</table>

- **Table:**
  - **Elements:** Te114, Te115, Te116, Te117, Te118, Te119, Te120, Te121, Te122, Te123, Te124, Te125, Sb113, Sb114, Sb115, Sb116, Sb117, Sb118, Sb119, Sb120, Sb121, Sb122, Sb123, Sb124, Sn112, Sn113, Sn114, Sn115, Sn116, Sn117, Sn118, Sn119, Sn120, Sn121, Sn122, Sn123, In111, In112, In113, In114, In115, In116, In117, In118, In119, In120, In121, In122, Cd110, Cd111, Cd112, Cd113, Cd114, Cd115, Cd116, Cd117, Cd118, Cd119, Cd120, Cd121.
  - **Columns:** Element, Halflife, Spin, Other Information (EC, β-).
**ICC of Interest**

![Image of isotopic data]

**119m Sn**

- **Half life:** 293.1 d
- **E(level):** 89.531 keV
- **Jp:** 11/2-
- **S_n (keV):** 6485.4
- **S_p (keV):** 10126.8
- **Prod. mode:** Fast neutron activation, Thermal neutron activation

**ENSDF citation:** NDS 67,327 (1992)
**Literature cut-off date:** 1-May-1991
**Author(s):** K. Kitao, M. Kanbe and K. Ogawa
**References since cut-off:** 119Sn decay from 1991-98 (NSR)

**Decay properties:**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Branching (%)</th>
<th>Q-value (keV)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT</td>
<td>100</td>
<td></td>
<td>68Bo09</td>
</tr>
</tbody>
</table>

Source: Lund/LBNL Nuclear Data Search; WWW Table of Radioactive Isotopes
ICC of Interest

\[ \text{\textsuperscript{119}Sn IT Decay 1968Bo09} \]

Decay Scheme

Intensities: I(\(\gamma+ce\)) per 100 parent decays
%IT=100

\[
\begin{align*}
\text{11/2−} & \quad 89.535 & \quad 293 \text{ d} \\
\text{3/2+} & \quad 23.875 & \quad 18.03 \text{ ns} \\
\text{1/2+} & \quad 0.0 & \text{stable}
\end{align*}
\]

Source: National Nuclear Data Center; Evaluated Nuclear Structure Data File
Measuring ICC of Interest

- Hyper pure germanium detector, Cyclotron Institute, Texas A&M University
  - Relative photopeak efficiencies calibrated to 0.15% above 50 [keV] at 151.[mm]
ICC of Interest: $^{116}\text{In}$

Emission of Sn x-rays following the $\beta$ decay of $^{116}\text{In}$

- $^{116}\text{In}$ $\beta$- decays to $^{116}\text{Sn}$
  - 138 [keV] and 418 [keV] $\gamma$ rays
  - Sn x-rays
- Values of $\alpha_k$ are in agreement
- Used to calibrate detector at range of Sn x-rays
ICC of Interest: $^{116}\text{In}$

$^{116}\text{In}$ $\beta^-$ Decay (54.29 min) 2006Kr04

Decay Scheme

Intensities: Iγ per 100 parent decays

Source: National Nuclear Data Center; Evaluated Nuclear Structure Data File
Data Collection

- Adhesive Mylar tape
- $\text{In}_2\text{O}_3 + \text{HNO}_3$

Source ready to be irradiated

Trim excess tape to minimize impurities

γ- and x-rays

151. [mm]

7.0 mm

0.5 in
Spectral Analysis

Source: June 2011 $^{116}$In, spectrum 4
~8 hour measurement

$^{116}$In: Number of Photons Detected with Given Energies

- 138 [keV] and 418 [keV] peaks: $\alpha_x$
- Values well-known to calibrate Sn x-rays
- 24-25 [keV] Sn x-rays

Energy (keV) vs. Counts
Radiation Spectra

• Impurity criteria:
  • Energy and intensity of $\gamma$ rays

• Likely impurities:
  • Activated varieties of other isotopes in the source
  • Elements with nearby Z values
  • Activated nuclei of mounting material

• Additional spectra analyzed
  • $^{119m}$Sn spectrum
  • $^{182}$Ta spectrum
Radiation Spectra

Source: June 2011 $^{116}\text{In}$, spectrum 4
~8 hour measurement
Preliminary Results

• Impurities identified:
  • $^{122}$Sb
  • $^{124}$Sb
  • $^{140}$La
  • $^{24}$Na
  • $^{115}$In (from fast neutrons)

• Using calibration from $^{116}$In:
  • $^{119m}$Sn: $\alpha_k = 1601(40)$ - PRELIMINARY
    • $\alpha_k$ (no hole) = 1544
    • $\alpha_k$ (hole) = 1618
Summary

- Obtained preliminary detector calibration at Sn x-ray range
- Analyzed Sn and Ta spectra for impurities
- Successfully analyzed 4 In spectra for impurities
- Performed impurity subtraction
- Calculated preliminary values for $\alpha_k$ for $^{119m}\text{Sn}$
- More detailed analysis of x-rays needed
  - Analysis is ongoing
- Produce new source without fast neutrons in activation channel
Acknowledgements

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