GAMMA-RAY CALIBRATION STANDARDS

Leslie J. Jardine

April 1971

AEC Contract No. W-7405-eng-48

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GAMMA-RAY CALIBRATION STANDARDS

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Berkeley, California  94720

April 1971

ABSTRACT

A collection of γ-ray energies and intensities is given that are suitable for use in the calibration of high resolution γ-ray spectrometers. The energy range included in this tabulation is 25 keV < Eγ < 3452 keV. Adopted values are given for gamma-ray energies based on weighted averages of the author's stated uncertainties. Relative γ-ray intensities are also given for 133Ba, 182Ta, and 56Co. No attempt was made to establish weighted averages for the intensity values.
I. INTRODUCTION

With the development of high resolution Ge(Li) detectors coupled with highly stabilized linear electronics and computer photopeak analysis of data, it has become possible to measure gamma-ray energies to a precision of better than 0.1 keV. However, to do this, it is necessary to have available a large number of standards known to tens of eV. Marion\textsuperscript{1} compiled a list of such standards in 1968, but since that time there have been improvements in the measurements of standards, and their number has increased substantially. Because the newer information is scattered in the literature, it is the purpose of this report to collect and tabulate those measurements and references for standards that are routinely being used in our nuclear spectroscopy research. In the recent literature, the most extensive work has been that of Gunnink et al.\textsuperscript{2,13}

Gamma-ray energies are listed by source in Table I. The original data are shown along with the reference. The "adopted values" that are given represent weighted averages (weighted inversely as the square of the author's stated uncertainties). The errors given are the larger of the \( \sigma \) values as defined below. \( E_i \) and \( \sigma_i \) are the author's stated energy and error, respectively.

\[
\sigma^2 = \frac{1}{\sum \frac{1}{\sigma_i^2}} \quad \quad \quad \sigma^2 = \frac{1}{n-1} \sum_{i=1}^{n} (E_m - E_i)^2 \quad \quad \quad E_m = \frac{\sum E_i / \sigma_i^2}{\sum 1 / \sigma_i^2}
\]

Marion's\textsuperscript{1} values, which are also tabulated, often represent weighted averages of several measurements. In these cases the original measurements reported by Ref.\textsuperscript{1} were used in obtaining the new weighted set of adopted values.
Table II lists gamma-ray energy and intensity measurements for $^{133}$Ba, $^{182}$Ta, and $^{56}$Co. No attempt was made to establish a weighted set of intensity values. The energy values of Gunnink et al.$^2$ are used for $^{56}$Co while weighted sets are given for $^{133}$Ba and $^{182}$Ta.

The $^{182}$Ta low energy (84–265 keV) γ-ray intensity measurements$^{18}$ were made using a calibrated 10 cm$^3$ Ge(Li) detector. Details of these measurements are to be published later.
FOOTNOTES AND REFERENCES

*Work performed under the auspices of the U. S. Atomic Energy Commission.

1. J. B. Marion, Nucl. Data A4, 301 (1968).


### Table I. Gamma-ray energies used as calibration standards listed by source.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Half-Life</th>
<th>$\gamma$-Ray Energy</th>
<th>Refs.</th>
<th>Adopted</th>
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<tbody>
<tr>
<td>$^{241}\text{Am}$</td>
<td>432.9 ± 0.8y</td>
<td>26.348 ± 0.010</td>
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<td>26.346 ± 0.007</td>
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<tr>
<td></td>
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<td>26.345 ± 0.010</td>
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<tr>
<td></td>
<td></td>
<td>59.536 ± 0.010</td>
<td>13</td>
<td>59.538 ± 0.008</td>
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<tr>
<td></td>
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<td>59.543 ± 0.015</td>
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<tr>
<td>$^{170}\text{Tm}$</td>
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<td></td>
<td></td>
<td>84.257 ± 0.003</td>
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<td>84.257 ± 0.002</td>
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<td>$^{109}\text{Cd}$</td>
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<td></td>
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<td>88.035 ± 0.006</td>
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<td></td>
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<td>88.036 ± 0.008</td>
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<td>88.035 ± 0.004</td>
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<td>$^{57}\text{Co}$</td>
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<td></td>
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<td>122.055 ± 0.013</td>
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<td>122.061 ± 0.010</td>
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<td>122.04 ± 0.02</td>
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<td>136.465 ± 0.020</td>
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<td>136.471 ± 0.010</td>
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<td>136.47 ± 0.02</td>
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<td>136.470 ± 0.008</td>
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<th>$\gamma$-Ray Energy (keV)</th>
<th>Refs.</th>
<th>Adopted (keV)</th>
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<tbody>
<tr>
<td>$^{203}\text{Hg}$</td>
<td>$46.8 \pm 0.2d$</td>
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<td>$279.186 \pm 0.009$</td>
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<td>$391.71 \pm 0.02$</td>
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<td>$411.792 \pm 0.008$</td>
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<td>$^{137}\text{Cs}$</td>
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<td>$661.615 \pm 0.030$</td>
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<tr>
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<td>$^{88}\text{Y}$</td>
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<td>$898.023 \pm 0.065$</td>
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<td>$898.021 \pm 0.023$</td>
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<td>$898.010 \pm 0.030$</td>
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<td>$1836.127 \pm 0.050$</td>
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<td></td>
<td>$1836.030 \pm 0.030^{b,c}$</td>
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<td>$1836.129 \pm 0.031$</td>
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<thead>
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<th>Isotope</th>
<th>Half-Life</th>
<th>γ-Ray Energy</th>
<th>Refs.</th>
<th>Adopted</th>
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<td>$1332.505 \pm 0.025$</td>
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<td>$1332.505 \pm 0.021$</td>
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<tr>
<td>$^{22}$Na</td>
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<td>$511.0041 \pm 0.0016$</td>
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<td>$511.0041 \pm 0.0016$</td>
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<td>$511.0041 \pm 0.0016$</td>
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<td>$1274.550 \pm 0.040^c$</td>
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<td>$1274.55 \pm 0.04$</td>
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<td>$^{24}$Na</td>
<td>$15\text{h}$</td>
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<td>$1732.130 \pm 0.060^a$</td>
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<td>$2754.142 \pm 0.060$</td>
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(continued)
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<thead>
<tr>
<th>Isotope</th>
<th>Half-Life</th>
<th>γ-Ray Energy</th>
<th>Refs.</th>
<th>Adopted</th>
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<tr>
<td>¹⁴⁶⁰K</td>
<td>1.26 × 10⁹y</td>
<td>1460.75 ± 0.06</td>
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<td>1460.9 ± 0.3</td>
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<td>1460.95 ± 0.07</td>
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<td>1460.836 ± 0.11</td>
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<tr>
<td>²⁰⁷⁷Bi</td>
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<td></td>
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<td>569.62 ± 0.06</td>
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<td>569.650 ± 0.030</td>
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<td>1063.44 ± 0.090</td>
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<td>(1063.611 ± 0.172)</td>
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<td>1769.71 ± 0.13°</td>
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<td>1770.22 ± 0.040°</td>
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<td>1770.06 ± 0.07</td>
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<td>1770.06 ± 0.07</td>
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<td>¹⁹²Ir</td>
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<td>295.938 ± 0.009</td>
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<tr>
<td></td>
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<td>295.938 ± 0.010</td>
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<td>295.938 ± 0.007</td>
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<tr>
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<td>308.429 ± 0.010</td>
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<td>316.486 ± 0.010</td>
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<td>316.490 ± 0.010</td>
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<td>316.488 ± 0.007</td>
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<th>Isotope</th>
<th>Half-Life</th>
<th>γ-Ray Energy</th>
<th>Refs.</th>
<th>Adopted</th>
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<th>$\gamma$-Ray Energy</th>
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<td>677.572 ± 0.017</td>
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<td>884.68 ± 0.04</td>
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<td>937.48 ± 0.04</td>
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Table I. (continued)

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Table I. (continued)

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| a | Since these values are for double-escape pair peaks, care, as warned by Gunnink et al., should be employed if using them. |
| b | The calibration is from the double-escape peak. See Ref. 10. |
| c | This is not included in the adopted value given. |
| d | Th energies listed are from daughters in Th decay chain. |

-228
Table II. Gamma-ray energies and intensities used as calibration standards listed by source.

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(continued)
### Table II. (continued)

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(continued)
### Table II. (continued)

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<th>$\gamma$-Ray Energy</th>
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**Ref.**

- **a**: Since these values are for double-escape pair peaks, care, as warned by Gunnink et al., should be employed if using them.
- **b**: This not a weighted value, but that of Ref. 2.
- **c**: This is an adopted value from previous works. See Ref. 8 for details.
- **d**: These energy values are averaged results of Refs. 17, 24 as calculated in Ref. 3.
- **e**: This not included in the adopted value given.
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