



International Atomic Energy Agency

INDC(NDS)-196/GE

INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

GAMMA-RAY STANDARDS FOR DETECTOR CALIBRATION

Summary Report of a Research Coordination Meeting
held in Rome, Italy, 11-13 June 1987

*Superseded by
IAEA-TECDOC-619*

Prepared by

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and

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and edited by

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September 1987

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

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Abstract

The first official meeting of the IAEA Coordinated Research Programme on the Measurement and Evaluation of X- and Gamma-ray Standards for Detector Calibration was held in Rome from 11 to 13 June 1987. Work undertaken by the CRP members was reviewed in detail: specific problems in the evaluations were identified and actions placed on the participants to resolve these issues.

Reproduced by the IAEA in Austria
September 1987

87-04189

1. Introduction

An IAEA Consultants' meeting on Gamma-ray Standards for Detector Calibration was held at the Centre d'Etudes Nucléaires de Grenoble in May 1985 (see INDC(NDS)-171/GE, 1985). At that meeting, an internationally coordinated research programme (CRP) was recommended in order to produce a single comprehensive and internationally acceptable file of x-ray and gamma-ray data for the efficiency calibration of detectors. A list of nuclides was prepared at the Grenoble meeting, and participants agreed to evaluate the relevant data. The IAEA Nuclear Data Section established the recommended CRP starting in April 1986, and this meeting at ENEA, Rome, Italy, constituted the first official meeting of the CRP participants. The meeting was organized to review all relevant evaluations and to define needs for further measurements and reassessments. The list of participants is given in Appendix A and the meeting agenda in Appendix B. The List of Actions resulting from this meeting are listed in Appendix C.

2. Progress Reports

Progress reports for 1986/87 had been distributed before the meeting, and brief presentations were made by the participants. The list of reports distributed by the participants is given in Appendix D. These reports (identified by GS/ numbers in the text below) are available on request from A. Lorenz (IAEA).

2.1. Half-life Evaluations (GS/14)

The method of data evaluation elaborated by Christmas (NPL), Debertain (PTB) and Woods (NPL) was discussed by Christmas and problems of inconsistency noted. This work was defined in greater detail as noted in Section 4 below.

2.2. Evaluation of Decay Data for Cr-51, Zn-65, Se-75 and Au-198 (GS/13)

Nichols (AEE, Winfrith) described his evaluation methods in detail. All measured data from reputable publications are listed and considered in the evaluations, and efforts are made to define reasonably precise internal conversion coefficients to assist in the production of a consistent data set for each nuclide. Emission probabilities are then recommended by the evaluator for the most suitable gamma-rays. This procedure was approved, but greater documented detail was requested together with a listing of the chi-squared data in the weighted mean analysis.

2.3. Evaluation of Decay Data for Co-57, Co-58 and Ba-133 (GS/3 and GS/21)

Jedlovsky (OMH) described the status of the decay data in terms of requirements for further work. The emission probability for the 14.41 keV gamma-ray of Co-57 is particularly uncertain, and better internal conversion coefficient data are needed. No difficulties had been experienced during the evaluation of Co-58, but the doublet of Ba-133 (P_{γ} (79 and 81 keV)) posed problems that necessitate further measurements.

2.4. Evaluation of Decay Data for Co-56, Sr-85, In-111, Cs-134 and Eu-154 (GS/17)

In specific instances, Yoshizawa et al (University of Hiroshima) had selected only their own decay data as the recommended data set (e.g. for Co-56 and for many gamma-rays of Eu-154). This procedure was questioned by other participants, and Yoshizawa agreed to reassess the data including other appropriate measurements. The P_{γ} for Sr-85 relies upon a theoretical estimate of the branch to the ground state; this was accepted in the absence of experimental data.

2.5. Evaluation of Decay Data for Y-88, I-125, Sb-125 and Cs-137 (GS/15)

Coursol (LMRI) had not yet specifically undertaken CRP re-evaluations of these nuclides. The recommended decay data had been taken from the LMRI Table de Radionuclides, and these evaluations were undertaken in 1982 (I-125 and Sb-125), 1984 (Cs-137) and 1985 (Y-88). For Cs-137 the most precise value had been adopted. This was questioned, and Coursol agreed to re-evaluate the measurements at the same time as the update of the other radionuclides. Further measurements are clearly required for I-125.

2.6. Evaluation of Decay Data for Eu-152 and Eu-155 (GS/1)

Helmer (INEL) had adopted ICRM-based data for Eu-152; this was viewed as unsatisfactory and he agreed to undertake a more comprehensive evaluation. Whilst the relative gamma-ray emission probabilities for Eu-155 are known to reasonable accuracy, it is extremely difficult to define absolute values. The problem is currently insurmountable, and it was agreed to remove this radionuclide from the P_{γ} list but retain the half-life evaluation. The relative P_{γ} -values for this nuclide remain of practical importance.

2.7. Evaluation of X-Ray Decay Data (GS/16)

Bambynek (CBNM) presented the data of relevance from a previous publication (Nuclear Standard Reference Data, IAEA-TECDOC-335, 412, 1985). No improvements can be made on these data at the present time (apart from possibly Am-241), but efforts are required to achieve consistency between P_x and P_{γ} with respect to internal conversion coefficients (from the other evaluators). It was agreed that the P_{γ} evaluators would state in their evaluations the ICC data which they had used.

2.8. Studies at US the National Bureau of Standards

No written report was available, but Schima (NBS) noted that they were reassessing all of their gamma-emission decay data for detector calibration. These included studies of P_{γ} (380 keV) for Sb-125 and new P_{γ} measurements for Se-75.

3. Discussion on General Principles of Evaluation

Efforts were made to clarify data evaluations by other bodies. The ENSDF file received particular attention in this discussion, and it was noted by Helmer that within the ENSDF system it is quite acceptable for an evaluator to use the data from only one set of measurements; that is, weighted mean evaluations may not be undertaken. Emphasis is placed on nuclear structure evaluation for the physics community rather than evaluating decay data for spectroscopic applications.

It was agreed, with minority dissent, that experimental data from laboratory reports and private communications should be included by the CRP evaluators, although the latter must be viewed with particular caution. A clear and detailed statement of the precise evaluation procedure must be included with each assessment, with details of any changes made in the uncertainties of the reported measurements. The data from one laboratory generally should not be adopted in preference to all other sources. The following statement was approved by the CRP participants:

"All available experimental data should be considered in the evaluation. Preference should be given to data from published papers and official laboratory reports; caution should be exercised in respect of data from unofficial sources such as private communications.

Measurement techniques continue to improve and in normal circumstances the most recent data should be emphasised in the evaluation.

The input data should be examined for consistency. If data are rejected at this stage there must be good reasons for this, and the reasons should be documented. In general the evaluation should aim to include results from more than one laboratory. The evaluator may wish to ensure that no individual measurement contributes more than 50 % to the sum of weights by increasing the uncertainty of the datum in question.

The evaluation procedure should be described. Normally it will involve the determination of a weighted mean for each parameter.

If the set of accepted experimental data proves to be inconsistent at this point, there are several possibilities for proceeding further. One may decide:

- (a) to take the unweighted mean,
- (b) to reject some values on the basis of objective or subjective reasons,
- (c) to change the weight.

An appropriate method of changing weights is to be preferred rather than the outright rejection of data.

At the completion of the evaluation, detailed and specific recommendations should be made in respect of any further measurements which may be required; priorities should be given."

4. Half-Life Evaluations

4.1. Current Status

The method of half-life evaluation adopted by Christmas (NPL), Debertain (PTB) and Woods (NPL) (GS/14) was discussed in detail, and accepted in principle by a majority of participants. Coursol (LMRI) expressed some reservations, and provided detailed comments on specific nuclides for the further consideration of the authors.

4.2. Recommendations for Measurements

On the basis of a comparison of the required and presently realized uncertainties, three groups of nuclides have been identified for which further measurements are required. These are presented in order of decreasing priority:

Priority 1: Fe-55, Co-56, I-125, Eu-155

Priority 2: Mn-54, Se-75, Cd-109

Priority 3: Na-22, Co-58, Zn-65, Ba-133.

In principle Nb-93m should have been included in the priority 2 list, but it was omitted due to the agreed extreme unlikelihood of further improvements in this particularly difficult measurements.

A further category of nuclides was also identified, for which the current uncertainties are adequate but for which inconsistencies exist between the experimental data:

Priority 4: Na-24, Co-57, Cs-137, Eu-152

Members of the CRP reported measurements already in hand, or planned for some of the above nuclides; the information is summarised in Table 1.

5. X- and Gamma-Ray Probability Evaluations

5.1. Current Status

All of the data were reviewed in detail and updated on the basis of a tabulation provided by Lorenz (IAEA) and the various CRP progress reports (Section 2). This exercise produced a number of actions to be undertaken by individual participants:

- (a) all x-ray data to be provided by Bambynek (CBNM) (based on GS/16), to supersede the data in the current table;
- (b) decay data for Na-22, Na-24 and Co-60 to be evaluated by Schima (NBS);
- (c) decay data for Nb-94, Nb-95 and Hg-203 to be evaluated by Helmer (INEL);
- (d) decay data for Cd-109 and Ce-139 to be evaluated by Coursol (LMRI);
- (e) decay data for Am-243/Np-239 to be evaluated by Nichols (AEE, Winfrith);
- (f) re-evaluation of decay data for Cr-51 and Se-75 by Nichols (AEE, Winfrith);
- (g) re-evaluation of decay data for Co-56 and Eu-154 by Yoshizawa (University of Hiroshima);
- (h) re-evaluation of decay data for Cs-137 by Coursol (LMRI)
- (i) re-evaluation of decay data for Eu-152 by Helmer (INEL).

A revised tabulation of provisionally recommended decay data, including all available half-life and x- and gamma-ray probability evaluations, will be issued as a separate IAEA INDC report, and will supersede the April 1983 version of this compilation.

5.2. Recommendations for Measurements

Following the P_x and P_γ decay data evaluations, specific parameters have been identified for further measurements:

| | |
|--------|---|
| Cr-51 | P_γ |
| Co-57 | P_γ (14.4 keV) |
| Zn-65 | P_γ |
| Se-75 | P_γ |
| Cd-109 | P_γ |
| In-111 | ICC |
| Sb-125 | P_γ |
| I-125 | P_γ |
| Ba-133 | P_γ (79 and 81 keV doublet) |
| Eu-154 | P_γ |
| Am-241 | P_γ (26.3 and 59.5 keV), P_{L-x} |

CRP members are undertaking some of the above measurements (see Table 2 and also below). Other laboratories should be encouraged to assist in the resolution of these issues as revealed by these recent evaluations.

- (a) Measurements are underway at OMH to determine P_γ for 14.4 keV of Co-57, P_γ for 79-81 keV doublet of Ba-133 and all P_γ for Se-75. The latter studies are being undertaken as part of an ICRM exercise.
- (b) Measurements at PTB include P_γ studies of Co-57, Zn-65, Se-75 (as ICRM exercise), Cd-109, and I-125 (in connection with BIPM intercomparison of activity measurements) and Am-241. Other unspecified studies are envisaged on the basis of the CRP recommendations.
- (c) Measurements at NBS include P_γ studies of Se-75 (as ICRM exercise), Sb-125 and Eu-154.
- (d) P_γ studies of Zn-65 will be undertaken at NPL.

6. Other Standards

After some consideration it was agreed to withdraw Eu-155 from the P_γ data list and re-introduce Bi-207 (P_γ to be evaluated at the University of Hiroshima).

Helmer noted that an international exercise is underway to re-evaluate gamma-ray energies. He is involved in this work and would inform the CRP of developments.

Discussions of standards beyond 3 MeV ranged widely on the basis of a thesis report provided by C. van der Leun (GS/11). Both (p, γ) and (n, γ) reaction data were involved, but the evaluation of such data fell beyond the general expertise of the CRP members. A summary of the current situation will be prepared by Helmer for the next CRP meeting.

7. CRP Report

The format of the CRP report on Decay Data of the Transactinium Nuclides (IAEA Tech. Report Series No. 261 (1986)) will be adopted. There will be a general introduction (problems, philosophy, current status and recommendations for further work), individual evaluations in agreed tabulations, and detailed data listings.

Summing effects and measurement problems will be considered in the introduction, with suitable references. Further discussions are required after using the agreed format in individual evaluations.

8. Conclusions

An attempt was made to define a suitable evaluation philosophy and procedures in order to achieve the desired quality and consistency in the final set of recommended data. The meeting was partially successful in this respect, and it is to be hoped that the second round of agreed evaluations (Table 3) will produce a data file of the required quality. Further evaluations and re-evaluations will be undertaken during 1987/88 in preparation for a meeting in October 1988. All results will be forwarded to Lorenz (IAEA, Nuclear Data Section) as they become available for distribution to the participants.

Some decay-data parameters are of poor quality because of discrepant measurements; these data have been identified by the CRP members (see Sections 4.2. and 5.2.). Measurements are underway for a reasonable number of these radionuclides, and non-CRP laboratories are encouraged to become involved in these studies in order to assist in the resolution of the current problems.

Efforts will be made to convene an informal meeting in the first or second week of October 1988. The next official CRP meeting will be held in June 1989.

TABLE 1: HALF-LIFE MEASUREMENTS BY CRP PARTICIPANT LABORATORIES

| Nuclide | Hiroshima University | NBS | NPL | PTB | Comments |
|---------|----------------------|-----|-----|-----|--------------------------|
| Fe-55 | | | | | No measurements underway |
| Co-56 | | Yes | Yes | Yes | |
| I-125 | | Yes | | Yes | |
| Eu-155 | | | | Yes | |
| Mn-54 | | Yes | | | |
| Se-75 | | | Yes | | |
| Cd-109 | | Yes | | | |
| Na-22 | | Yes | | | |
| Co-58 | | | Yes | | |
| Zn-65 | | | | | No measurements underway |
| Ba-133 | | | | Yes | |
| Na-24 | Yes | | Yes | | |
| Co-57 | | Yes | | Yes | |
| Cs-137 | | Yes | | | |
| Eu-152 | | Yes | | | |

TABLE 2: P_x AND P_γ MEASUREMENTS BY CRP PARTICIPANT LABORATORIES

| Nuclide | NBS | NPL | OMH | PTB | Comments |
|---------|-----|-----|-----|-----|--------------------------|
| Cr-51 | | | | | No measurements underway |
| Co-57 | | | Yes | Yes | |
| Zn-65 | | Yes | | Yes | |
| Se-75 | Yes | | Yes | Yes | Coordinated by ICRM |
| Cd-109 | | | | Yes | # |
| In-111 | | | | | No measurement underway |
| Sb-125 | Yes | | | | |
| I-125 | | | | Yes | # |
| Ba-133 | | | Yes | | |
| Eu-154 | Yes | | | | |
| Am-241 | | | | Yes | |

In conjunction with BIPM intercomparison; a number of laboratories may participate

TABLE 3: CALIBRATION STANDARDS: LIST OF RADIONUCLIDES

(Update of Table 2, INDC(NDS)-171, Summary Report of May 1985 meeting)

| Nuclide | Half-life | ICC | P _x | P _y |
|-------------------|---------------------|--------------------|---------------------|----------------|
| Na-22 | ↑ Christmas ↓ | Coursol/ Hansen | - | Schima* |
| Na-24 | | | - | Schima* |
| Sc-46 | | | - | Yoshizawa |
| Cr-51 | | | Bambynek+ | Nichols* |
| Mn-54 | | | Bambynek+ | Yoshizawa |
| Fe-55 | | | Bambynek+ | - |
| Co-56 | | | - | Yoshizawa* |
| Co-57 | | | Bambynek+ | Jedlovsky* |
| Co-58 | | | Bambynek+ | Jedlovsky |
| Co-60 | | | - | Schima* |
| Zn-65 | | | Bambynek+ | Nichols |
| Se-75 | | | Bambynek+ | Nichols* |
| Sr-85 | | | Bambynek+ | Yoshizawa |
| Y-88 | | | Bambynek+ | Coursol |
| Nb-93m | | | Bambynek+ | - |
| Nb-94 | | | - | Helmer* |
| Nb-95 | | | - | Helmer* |
| Cd-109 | | | Bambynek+ | Coursol* |
| In-111 | Bambynek+ | Yoshizawa | | |
| Sb-125 | - | Coursol | | |
| I-125 | Bambynek+ | Coursol | | |
| Cs-134 | - | Yoshizawa | | |
| Cs-137 | Bambynek+ | Coursol* | | |
| Ba-133 | Bambynek+ | Jedlovsky* | | |
| Ce-139 | Bambynek+ | Coursol* | | |
| Eu-152 | Bambynek+ | Helmer* | | |
| Eu-154 | Bambynek+ | Yoshizawa* | | |
| Eu-155# | - | - | | |
| Au-198 | Bambynek+ | Nichols | | |
| Hg-203 | Bambynek+ | Helmer* | | |
| Bi-207 | Bambynek+* | Yoshizawa* | | |
| Th-228 | Coursol/Vaninbroukx | - | Coursol/Vaninbroukx | |
| Am-241 | Bambynek | - | Bambynek | |
| Am-243/ Np-239 | Debertin* | - | Nichols* | |

* Re-evaluation underway 1987/88

+ Data from GS/16 or evaluation 1987/88

Half-life evaluation only

RESEARCH COORDINATION MEETING ON THE MEASUREMENT AND
EVALUATION OF GAMMA-RAY STANDARDS FOR DETECTOR CALIBRATION

Rome, Italy, 11-13 June 1987

List of Participants

| | |
|------------------|--|
| Dr. W. Bambynek | CEC-JRC Bureau Central de Mesures Nucléaires Steenweg naar Retie B-2440 Geel, Belgium |
| Dr. P. Christmas | Division of Radiological Science and Acoustics National Physical Laboratory Teddington, Middlesex TW011 OLW United Kingdom |
| Dr. N. Coursol | LMRI Centre d'Etudes Nucléaires de Saclay B.P. No. 2 F-91190 Gif-sur-Yvette, France |
| Dr. K. Debertain | Physikalisch Technische Bundesanstalt Abteilung 6 Bundesallee 100 D-3300 Braunschweig, FRG |
| Dr. R.G. Helmer | Idaho National Engineering Lab. EG&G Idaho Inc. P.O. Box 1625 Idaho Falls, Idaho 83415 U.S.A. |
| Dr. R. Jedlovsky | National Office of Measures (OMH) 126 - PF. 19 H-1531 Budapest, Hungary |
| Dr. A. Lorenz | IAEA/Nuclear Data Section |
| Dr. A.L. Nichols | Chemistry Division Building A50 Atomic Energy Establishment Winfrith, Dorchester Dorset DT2 8DH United Kingdom |
| Dr. F.J. Schima | National Bureau of Standards Gaithersburg, Maryland 20899 U.S.A. |
| Dr. Y. Yoshizawa | Faculty of Science Hiroshima University 1-1-89 Higashi-Senda-Cho Hiroshima-Shi 730 Japan |

RESEARCH COORDINATION MEETING ON THE MEASUREMENT AND
EVALUATION OF GAMMA-RAY STANDARDS FOR DETECTOR CALIBRATION

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ADOPTED AGENDA

1. Introductory Items
2. Progress Reports from CRP Participants
3. Half-Life Evaluations
 - 3.1. Current Status
 - 3.2. Recommendations for measurements
 - 3.3. Activities by CRP
4. X- and Gamma-ray Emission Probability Evaluations
 - 4.1. Current Status
 - 4.2. Recommendations for measurements
 - 4.3. Activities by CRP
5. Other Standards beyond 3 MeV
6. Discussion of Outline of Final Report
7. Next Meeting

ACTIONS

(All CRP participants are referred to here as the "Group")

1. Group Send information on any new x-ray measurements to Bambynek
2. Bambynek Inquire from Behrens about ICC values below $Z=30$, and inform Group
3. Lorenz Inform Group of any other ICC Tables (for $Z < 30$) published in the USSR
4. Helmer Inform Lorenz about the status of the re-evaluation of the "Recommended Standards for Gamma-Ray Energy Calibration", by R.G. Helmer et al, published in ADNDT 24 (1979)39.
5. Schima Draft a few paragraphs summarizing the treatment and assessment of uncertainties, for eventual inclusion in final report, and send to Lorenz for distribution to Group
6. Schima Send reports on the NBS re-assessment of gamma-ray emission decay data to Lorenz for Group distribution
7. Coursol Inquire about R.A. Meyer's report and send it to Lorenz for distribution to the Group. Send ICC Rosel's cubic spline interpolation to Group upon request.

Appendix D

List of GS- Papers

| <u>No.</u> | <u>Author(s)</u> | <u>Date</u> | <u>Title</u> |
|------------|---|-------------|---|
| GS/1 | R.G. Helmer | 1985 | Preliminary Evaluation of P_{γ} Values from the Decay of ^{152}Eu |
| GS/2 | A.L. Nichols | Dec 1985 | Cr-51 - Gamma-Ray Emission Probabilities |
| GS/3 | T. Barta | 1985 | Report on gamma photon emission probabilities ($P_{\gamma i}$) of ^{57}Co , ^{58}Co and ^{133}Ba based on data from the literature |
| GS/4 | K. Debertin | Jan 1986 | Evaluation of half lives |
| GS/5 | R. Vaninbroukx | 1986 | ^{241}Am (from IAEA Technical Report Series # 261) |
| GS/6 | R. Vaninbroukx | 1986 | ^{243}Am (from IAEA Technical Report Series # 261) |
| GS/7 | M.J. Woods | Mar 1986 | Evaluation of half-lives |
| GS/8 | M.J. Woods and S.E.M. Lucas | Sep 1986 | The Half-Lives of ^{152}Eu and ^{154}Eu |
| GS/9 | A. Robert | Aug 1977 | Standard 6.13 MeV gamma-ray Source |
| GS/10 | R. Jedlovsky | Dec 1986 | Progress Report April 1, 1986 to December 10, 1986 |
| GS/11 | C. van der Leun | Feb 1986 | Investigation of Light Nuclei by Particle Capture and Resonant Absorption |
| GS/12 | R. Jedlovsky | May 1986 | Plan of ^{75}Se Action |
| GS/13 | A.L. Nichols | Mar 1987 | X-and Gamma-ray Standards for Detector Calibration: Evaluation of Specific Decay Data |
| GS/14 | P. Christmas K. Debertin and M. Woods | Mar 1987 | Half-Life Data for Calibration Nuclides: Formulation and Application of Evaluation Criteria |
| GS/15 | N. Coursol | April 1987 | Progress Report: Evaluation of E_{γ}/P_{γ} of Y88, I125, Sb125 and Cs137 |
| GS/16 | W. Bambynek | Nov 1984 | Emission Probabilities of Selected X Rays for Radionuclides used as Detector Calibration Standards |
| GS/17 | Y. Yoshizawa | May 1987 | Evaluation of Gamma-ray Emission Probabilities for Co56, Sr85, In111, Cs124 and Eu154 |

| | | | |
|-------|--------------|-----------|--|
| GS/18 | W. Bambynek | Jun 1987 | Progress Report |
| GS/19 | R. Jedlovsky | May 1987 | Progress Report II |
| GS/20 | B. Denecke | May 1987 | Measurement of the 59.5 keV Gamma-ray Emission Probability in the Decay of Am241 |
| GS/21 | R. Jedlovsky | May 1987 | Report to the CRP Meeting |
| GS/22 | N. Coursol | Jun 1987 | Summary on Progress Report from LMRI |
| GS/23 | F.J. Schima | July 1987 | Progress Report from the NBS for the June 11-13 meeting |
| GS/24 | T. Barta | July 1987 | Revised Evaluation of the Gamma Photon Emission Probabilities (P_γ) of Co57, Co58 and Ba133, Based on Data of the Literature and on Experiences of the IAEA CRP Expert's Meeting on 13-15 June 1987, Rome |