International Atomic Energy Agency INDC(NDS)-171/GE

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

GAMMA-RAY STANDARDS

FOR DETECTOR CALIBRATION

Summary Report of a Consultants' Meeting
held at the Centre d'Etudes Nucléaires
de Grenoble, France, 30-31 May 1985

Prepared by A. Lorenz
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Abstract

The proceedings are reported of a Consultants' Meeting on Gamma-ray Standards for Detector Calibration, held at the CEN, Grenoble in France, from 30-31 May 1985. The meeting provided a forum to assess the requirements for a suitable file to be used internationally for the calibration of X- and gamma-ray detectors. A provisional list of nuclides was drawn up, and an initial assessment of the status of the required data was agreed to be performed by the participants before the end of 1985.

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Meeting Summary

A consultants' meeting on Gamma-ray Standards for Detector Calibration was held at the Centre d'Etudes Nucléaires de Grenoble, 30 to 31 May 1985, to assess the current status of decay data for X- and gamma-ray emissions used in detector calibration. This meeting was organized by the Nuclear Data Section on the recommendation of the INDC; it was chaired by Dr. W. Bambynek (CBNM). The primary aims were to recommend suitable nuclides, and to organise the evaluation of their relevant X- and gamma-ray data, with a view to establishing an internationally agreed data file for detector calibration purposes. A list of nuclides was prepared, and the participants agreed to assess the status of the data in order to produce a preliminary file before the end of 1985.

The meeting participants formulated a recommendation to the International Nuclear Data Committee emphasizing the need for an internationally coordinated project to measure and evaluate the necessary data in order to produce a single internationally accepted file of decay data for the calibration of gamma-ray detectors.

The list of participants is given in Appendix A, and the meeting agenda in Appendix B.

1. Background

During the IAEA Coordinated Research Programme on Transactinium Isotope Nuclear Decay Data (1978-1984), there had been problems in selecting and agreeing upon calibration standards for the measurement of the heavy element and actinide gamma decay data. Although a calibration data compilation was made by the IAEA Nuclear Data Section (Ref. 1), it was generally agreed that an internationally-accepted evaluated data file of X- and gamma-ray data for the calibration of gamma-ray detectors should be established. A recommendation to this effect resulted from the IAEA Transactinium Nuclear Data Advisory Group Meeting at Uppsala, May 1984 (see Recommendation 1 in Appendix C) (Ref. 2); this was supported by the INDC who recommended that the IAEA organize a small meeting of experts associated with the International Committee for Radionuclide Metrology (see Recommendation 2 in Appendix C). This need was confirmed again by the 1984 Advisory Group Meeting on Nuclear Standard Reference Data (see Recommendation 3 in Appendix C).

2. Proposed Standards

In the discussion on terminology and definitions, it was generally agreed that the terms "primary standard" and "secondary standard" be avoided in the preparation of a suitable list of nuclides for X- and gamma-ray detector calibration. Participants from NPL and PTB noted that there would be nuclides with decay data derived absolutely, compared with others obtained from previously calibrated detector systems containing inherent uncertainties identified with the calibration. It was decided that efforts would be made to differentiate between nuclides for which emission probabilities P were measured absolutely (Class I) and others for which P was measured on calibrated equipment. For nuclides designated as Class I, it was agreed that the photon emission probabilities per disintegration be determined with adequate precision by methods other than those requiring the use of calibrated detectors. Acceptable methods may

include, where appropriate, the use of theoretically derived internal conversion coefficients used in conjunction with other decay scheme data such as beta branching ratios.

Every effort would be made to cover as wide a photon energy range as possible. Improvements in detector performance over the energy range of 5 keV to 100 keV necessitate the use of both X- and low-energy gamma-ray emitting standard sources, as well as those with gamma-rays of higher energy.

An initial list of calibration nuclides was produced for discussion, based on data available from refs. 3-7. After extensive debate this lengthy compilation, given in Table 1, was reduced to a recommended list of 33 nuclides. The relevant data (half-life, X- and gamma-ray emission probabilities) were considered, and the participants agreed to review the data as indicated in Table 2.

Specific nuclides were viewed as posing no assessment problems, their decay data being of adequate quality for direct insertion into the provisional data file (e.g. Na-22, Na-24, Mn-54, Co-60, Nb-95, Cd-109 and Hg-203). In addition, it was noted that X-ray data would be assessed for a relatively large number of nuclides in order to provide sufficient calibration data at the lower energies: of special note in this respect are Fe-55, Nb-93m, In-111 and Cd-109.

Until such time when a new list of gamma-ray standards is recommended, the IAEA will issue an interim data tabulation consisting of the 1983 IAEA list (Ref. 1) updated by the addition of the recommended values presented by Vaninbroukx and Bambynek (CBNM) at the 1984 IAEA meeting on Nuclear Standard Reference Data (Refs. 4 and 5).

3. Assessment of the current data status

The meeting participants agreed to perform a thorough assessment of the existing data before the end of 1985 in preparation for a possible long-term coordinated effort, based on the list of nuclides given in Table 2. It was also recognized that other nuclides may be added to this provisional list, so as to assure a complete coverage of the desired energy range.

The required work was distributed among the meeting participants in the following manner.

Half-lives

Christmas (NPL) and Debertin (PTB) agreed to review all the half-lives of the proposed standards, excluding Th-228, Am-241 and possibly Am-243/Np-239. These latter nuclides have been evaluated recently for the IAEA Coordinated Research Programme on Transactinium Isotope Nuclear Decay Data, and the resulting values from this source will be adopted for the new file.

Internal Conversion Coefficients

The internal conversion coefficient data of Rösel et al (Ref. 9) will be adopted in preparing the file. Coursol (LMRI) will provide such data on request to the evaluators of the emission probabilities, and Vaninbroukx (CBNM) will compare these data, when appropriate, with a recent unpublished evaluation by Hansen (CBNM). These data will be used

Table 1: Radionuclides Considered as Standards for X- and Gamma-ray Detector Calibration

Nuclide	Accepted/Rejected Standard	Nuclide	Accepted/Rejected Standard
Be-7	-	Cd-109	+
Na-22	+	In-111	+
Na-24	+	Sn-113	-
K-42	-	Sb-120	-
Sc-46	+	Sb-124	-
V-49	-	Sb-125	+
Cr-51	+	I-125	+
Mn-52	-	Xe-133	-
Mn-54	+	Cs-131	-
Mn-56	-	Cs-134	+
Fe-55	+	Cs-137	+
Co-56	+	Ba-133	+
Co-57	+	Ce-139	+
Co-58	+	Ce-141	-
Co-60	+	Eu-152	+
Ni-65	-	Eu-154	+
Zn-65	+	Eu-155	+
Se-75	+	Tb-160	-
Kr-85	-	Tm-168	-
Sr-85	+	Hf-180m	-
Y-88	+	Ta-182	-
Zr-95	-	Ir-192	-
Nb-90	-	Au-198	+
Nb-93m	+	Hg-203	+
Nb-94	+	Bi-207	-
Nb-95	+	Ra-226	-
Tc-99m	-	Th-228	+
Ag-108m	-	Am-241	+
Ag-110m	-	Am-243/Np-239	-

Table 2: Calibration Standards: Provisional List of Nuclides and Assessment Effort

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

to develop the desired decay schemes, and so assist in the evaluation of the gamma-ray emission probabilities.

X-ray Emission Probabilities

These data have been evaluated recently by Bambynek (Ref. 5), and they will be used in the compilation of the new calibration data file.

Gamma-ray Emission Probabilities

Specific nuclides have well characterised gamma-ray emission probabilities, and no extensive evaluation is envisaged as indicated for Na-22, Na-24, Sc-46, Mn-54 and others. Individual participants were assigned to review the emission probability data for the more complex decay schemes; the individual responsibilities are indicated in Table 2.

Gamma-ray Energies

A consistent set of gamma-ray energies for use in the energy calibration of gamma-ray spectra has been recommended by Helmer, van Assche and van der Leun (Ref. 10) in 1979. This set of data, currently being updated by the same authors, will be incorporated in the preliminary gamma-ray standards file.

Data Accuracy

In the representation of uncertainties of the data, the participants agreed to use the methodology prescribed by the BIPM (Ref. 11). The "Statement of Uncertainties", as it appeared in Reference 11 (p.73), is reproduced in Appendix D.

Miscellaneous

Helmer (INEL) agreed to distribute bibliographies of the relevant nuclides as soon as possible to the participants. Lorenz (IAEA) requested listings of the relevant K X- and gamma-ray emissions in order of energy from the INEL und UKCNDC data files to assist in determining whether any serious gaps exist in the proposed data file.

4. Recommendations

The following recommendations were addressed to the International Nuclear Data Committee (INDC):

1. After reviewing the existing decay data used for the calibration of X- and gamma-ray detectors, the consultants recommended that the available data should be systematically re-evaluated. Suitable nuclides were identified and commitments were agreed between the participants to undertake an initial assessment of the data before the end of 1985 (see Table 2).

2. A more thorough programme of data measurements and evaluations should be established under the auspices of an IAEA Coordinated Research Programme. The aim of this effort is to establish a single internationally-accepted set of X- and gamma-ray detector calibration data of improved quality to meet the needs in fields such as safeguards, dosimetry, fuel management, and other applications.

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IAEA Meeting on Gamma-ray Standards for Detector Calibration

Centre d'Etudes Nucléaires de Grenoble
30 - 31 May 1985

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Appendix B

IAEA Consultants' Meeting on Gamma-ray Standards for Detector Calibration

CEN, Grenoble, 30-31 May 1985

Agenda

1. Introduction. Objectives of the meeting.

2. Determination of the radionuclides which should be included as calibration standards.

3. Status Review. Discussion of the status of currently used data, their accuracy and adequacy.

4. Recommendations of appropriate actions to produce an internationally recognized set of X- and gamma-ray standard data.

Recommendation of Advisory Group Meeting on Transactinium Isotope Nuclear Data (May 1984)

Recommendation to establish international gamma-ray calibration measurement standards.

Reference standards are important for the calibration of the detectors used to measure gamma-ray emission probabilities, and it is essential that a common data base be adopted for these reference nuclides. It is recommended that an evaluation be carried out by experienced evaluators to create a data base of the form given in INDC(NDS)-145 for the most commonly used radionuclides and gamma-ray transitions. The participants in the Working Group on the Status and Needs for Nuclear Decay Data of Transactinium Nuclides believe that a suitable mechanism for accomplishing this exists within the framework of the International Committee for Radionuclide Metrology (ICRM).

Recommendation of the INDC (October 1984)

Gamma-ray standards for detector calibration

The Subcommittee discussed the recommendation made by the TND Advisory Group Meeting at Uppsala, May 1984 (INDC/P(84)-24) to select and evaluate gamma-ray standards for detector calibration.

It was recommended that Dr. K. Okamoto (IAEA/NDS) in consultation with Dr. A.J. Deruytter (CBNM/Geel) arrange a discussion at the Geel Meeting with participants representing the International Committee on Radionuclide Metrology (ICRM), the IAEA CRP on Transactinium Isotope Nuclear Decay Data and the INDC Standard Subcommittee.

The possibility to charge ICRM with the task to set up a gamma-ray standard file for detector calibration should be investigated at this occasion. The Subcommittee also recommended that an option should go into the discussion at Geel to have a small meeting of experts arranged by NDS to assess the current status of the data and agree about the content of the file.

Recommendation of the IAEA Meeting on Nuclear Standard Reference Data (November 1984)

Recommendation concerning decay data for gamma-ray detector-efficiency calibration standards

The need for a common base of radionuclide decay data to serve as standards for the efficiency calibration of gamma-ray detectors has become increasingly apparent over the past few years. A number of nuclides are presently being employed in various measurement laboratories for this purpose. The existence of an internationally produced and accepted file of carefully evaluated decay data suitable for detector-efficiency calibration

would be an extremely valuable contribution to the field of quantitative gamma-ray spectrometry.

Accordingly, the participants in the Advisory Group Meeting on Nuclear Standard Reference Data agree that a meeting, convened by the IAEA, of a small number of experts in precision gamma-ray spectrometry could make a major contribution. Those involved in such a meeting should examine the present status of the radionuclide decay data currently used for detector-efficiency calibration, address the adequacy of this information, identify additional nuclides appropriate as either primary or secondary calibration standards and implement appropriate actions to produce a file of decay data to serve as a standard set for gamma-ray detector-efficiency calibration.

Draft Recommendation on the Statement of Uncertainties, BIPM Meeting of Experts on the Subject of Expression of Uncertainties

21-23 October 1980, Sèvres, France

1. The uncertainty in the result of a measurement generally consists of several components which may be grouped into two categories according to the way in which their numerical value is estimated:

   A. those which are evaluated by applying statistical methods to a series of repeated determinations;

   B. those which are evaluated by other means.

   There is not always a simple correspondence between the classification into categories A or B and the previously used classification into "random" and "systematic" uncertainties. The term "systematic uncertainty" can be misleading and should be avoided.

   Any detailed report of the uncertainty should consist of a complete list of the components, specifying for each the method used to obtain its numerical value.

2. The components in category A are characterized by the estimated variances s_i^2 (or the estimated standard deviations s_i) and the number of degrees of freedom v_i. Where appropriate, the covariances should be given.

3. The components in category B should be characterized by quantities u_j^2 which may be considered as approximations to the corresponding variances, the existence of which is assumed. The quantities u_j^2 may be treated like variances and the quantities u_j like standard deviations.

4. The combined uncertainty should be characterized by the numerical value obtained by applying the usual method for the combination of variances. The combined uncertainty and its components should be expressed in the form of "standard deviations".

5. If, for particular applications, it is necessary to multiply the combined uncertainty by a factor to obtain an overall uncertainty, the multiplying factor used must always be stated.